The effect of intra-organisational data sharing during the tender phase on risk awareness in multi-national construction companies

A multiple-case design

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The effect of intra-organisational data sharing during the tender phase on risk awareness in multinational construction companies

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by

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Preface

This MSc thesis represents the end of my journey at the TU Delft. I can definitely say that it has been an incredible ride that challenged me, made my head hurt, taught me many lessons, and in the end, has been very fulfilling.

First of all, I would like to thank BAM for giving me the opportunity to perform my thesis research in collaboration with their company. In particular, I would like to thank Ruud Verstegen, who always made time for me when I needed it and helped me wherever necessary, creating a very welcoming environment at the company. I enjoyed our weekly meetings, in which we could spar about everything, your mix of scientific and practical knowledge has been very interesting and insightful. Additionally, I would like to thank all my colleagues at BAM for providing me with a great workspace and welcoming me into the organisation with open arms.

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On a personal note, I would like to thank all my friends and family for their support during this period and especially my roommates, who at times had to listen to my complaining at the dinner table. I would like to give special thanks to my parents and brothers, who always supported me and cheered me on. Without their unwavering support and encouragement, my time in Delft would not have been as successful and enjoyable.

Lastly, thank *you*, the reader. I hope you enjoy the work as much as I did producing it.

Skip de Metz
Delft, January 2022

Executive summary

Introduction

Due to the dynamic and complex nature of the construction industry, it is evident that the integration of processes and groups is more challenging to attain in comparison to other industries (Demirkesen & Ozorhon, 2017). Therefore, there is a call for better integration of project participants and processes in construction projects (Franz et al., 2017). Consequently, organisational collaboration and integration are often considered inefficient and dependent on individuals. This inefficiency can be caused by individuals not making the right connections to gain access or obtain relevant data for the decision making process. This can be explained by the fact that the industry is renowned for its fragmentation and temporary project teams (Whitley, 2006). Due to this fragmentation, it is not uncommon for parties to have their own internal silos. These internal silos contain different sorts of data and have limited connections within their own or with other project teams, resulting in bad data sharing and communication. The presence of data silos and limited data sharing affects risk awareness as this can cause unavailability of data or subjective biases in the decision-making process. As a result, the employees that make the decisions are not (completely) aware of the involved risks, which can give the impression of soundly under-supported choices (van der Meer, 2021). By utilising data sharing and ensuring the proper coordination and communication, one could take on the silo's created by this fragmentation between and in project teams, and by doing so, one could expect to reduce the detrimental effects on risk awareness. Especially when firms are active in a multinational environment, research has shown that connections between people that cross physical boundaries can enhance opportunities to improve performance and improve entry to information (DeSanctis & Monge, 1999). That is why, one could argue that data sharing could contribute significantly to risk awareness among team members. To investigate this, the following research question has been formulated:

How does data sharing in intra-organisational project networks contribute to risk awareness in the tender phase?

Methodology

This research is performed in three distinctive parts to answer the main research question. Firstly, a literature review is performed to explore the concepts of data sharing and risk awareness in the construction industry. In addition, factors are gathered from literature that contribute to increasing risk awareness in practice. Secondly, two different rail infrastructure tenders are analysed in a multiple-case study. Here a mixed method research is performed, which consists out of a quantitative Social Network Analysis (SNA) and a qualitative expert panel. Through the use of a survey, data is collected which enabled the researcher to map the data sharing network of the two different case studies. This gives insights into the structures and patterns of both networks and allows for identification of the key players in both projects. Thirdly, an expert panel is performed. Based on the observations and insights from literature and the case study a set of recommendations is formulated. These recommendations will be validated with the help of four experts from the industry. After validation, the set of recommendations will be revised, and a risk awareness framework will be created, which can be used by the construction industry as a strategy to raise the risk awareness of project team members in the tender phase.

Research results

The literature review resulted in a set of 18 factors that contribute to risk awareness in practice, and these can be divided into three different factor focused themes. Namely, 1) factors that contribute to risk awareness by enhancing data sharing within the company, 2) factors that contribute to risk awareness by directly improving risk awareness and 3) factors that contribute indirectly to risk awareness by stimulating a risk culture in the company. This research focuses mainly on the factors that contribute to risk awareness by enhancing data sharing in the company. Therefore, the literature review also dived deeper into the concept of data sharing and established intra-organisational barriers that limit the effectiveness of data sharing. This research argues that by breaking down intra-organisational barriers and influencing data sharing behaviour of project team members positively, the ability of project team members to obtain decision-influencing data can be

improved. As a result, the perspective of the decision-makers regarding risks can be broadened, attaining a higher risk awareness.

Social network analysis

With the help of a social network analysis, the data sharing networks of the two case studies are visualised. By analysing the networks, it can be determined who is sharing data with whom and awareness of the data flow routes, patterns, structures and centrality metrics can be obtained. Both networks show a similar structure with a high clustering of the basic tender team and a high amount of single connection nodes at the network's periphery. Such a structure allows for potential points of failure and multiple gatekeepers, potentially leading to the creation of data silo's in the network. A consistent gatekeeper was found in the role of design manager in both projects. This led to the recommendation to include other design managers and the Drafting/Modelling/BIM group more in the project networks to prevent data silos and reduce the potential of subjective biases. Moreover, based on the data sharing networks and tool use in both tenders it can be concluded that a uniform approach with respect to data sharing is lacking. In addition, both projects mainly used conventional data sharing tools. This can lead to inconsistency in the process and limits transparency, which can lead to loss of data and overview.

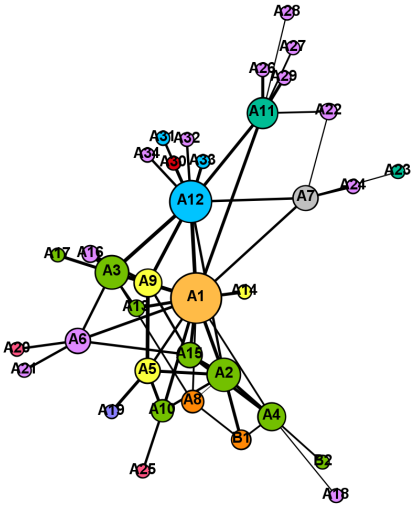

Figure 1: Data sharing network project A.

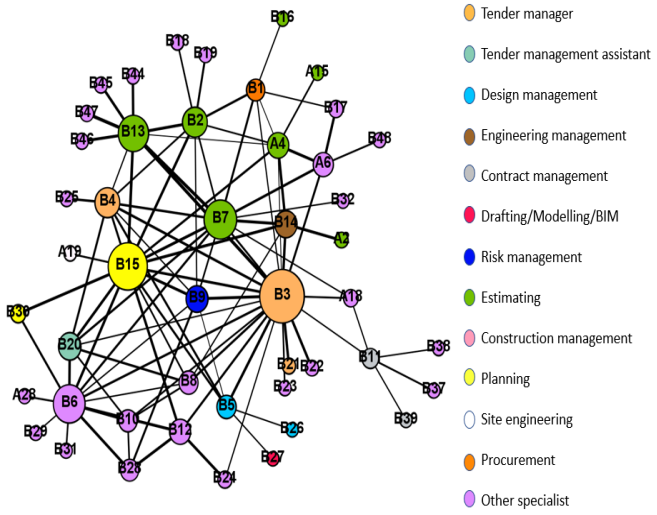

Figure 2: Data sharing network project B.

The key players in the network were found to be the tender managers and senior planners. During the analysis, these nodes have shown to be part of the influential nodes in the network in terms of data control and dissemination. The key players have a significant impact on how data is shared. This is because when roles are undefined towards data sharing, which is shown by the lack of a uniform approach, team members are inclined to depend on their managers instead of taking the initiative. Lastly, no country transcending data sharing connections were determined. Only one lessons learned connection has been found that transcends country borders. This shows that the firm does not fully use its multinational potential in utilising company-wide data and organisational learning. While at the same time, there is a need to utilise best practices and lessons learned from other projects, as others most likely have been coping with similar problems and risks.

Expert panel

In the final phase of the research, an expert panel was performed. Here, based on observations and findings from literature and the case study, a set of recommendations was given to be validated by an expert panel. After validation, the recommendations are combined into a risk awareness framework which can be seen in Figure 3. The goal of the framework is to raise risk awareness of project team members within the organisation during the tender phase. The risk awareness framework is intended to guide construction and engineering companies to improve the risk awareness of project team members during the tender phase. This framework shows that enhancing risk awareness can be done through two ways: (i) By stimulating risk awareness on a project level, and (ii) by stimulating risk awareness on an organisational level.

Overall, when looking at the recommendations, it can be deduced that almost all of them are related to facilitating the data sharing process and thus enabling the team members to share, retrieve, search and find data more easily. Consequently, the risk awareness framework is divided into a part A and B, in which part A encompasses recommendations that enhance risk awareness by improving data sharing, and part B encompasses recommendations that directly influence risk awareness or indirectly through an improved risk culture. As this research mainly focused on factors belonging to part A, this part is logically more extensive. Furthermore, these recommendations prevent organisations from wasting large amounts of money, time and resources in pursuit of data or by making decisions based on incomplete data. This is especially important in the tender phase as this is a phase that is often characterised by enormous time pressure.

The project level recommendations all together mainly contribute to the control and overview of data. Having control and overview of data can offer companies many advantages in terms of preventing data loss, redundancy and data silo's. Moreover, the project level recommendations can be seen as quick wins as these do not take much effort to implement. In addition, the costs of incorporating these recommendations are considered little to none. While at the same time, the organisation level recommendations are more focused on providing training and enhancing the ability to use and obtain data throughout the company. Lastly, it can be concluded that the interventions regarding data sharing on an organisational level contribute more to risk awareness than interventions on a project level.

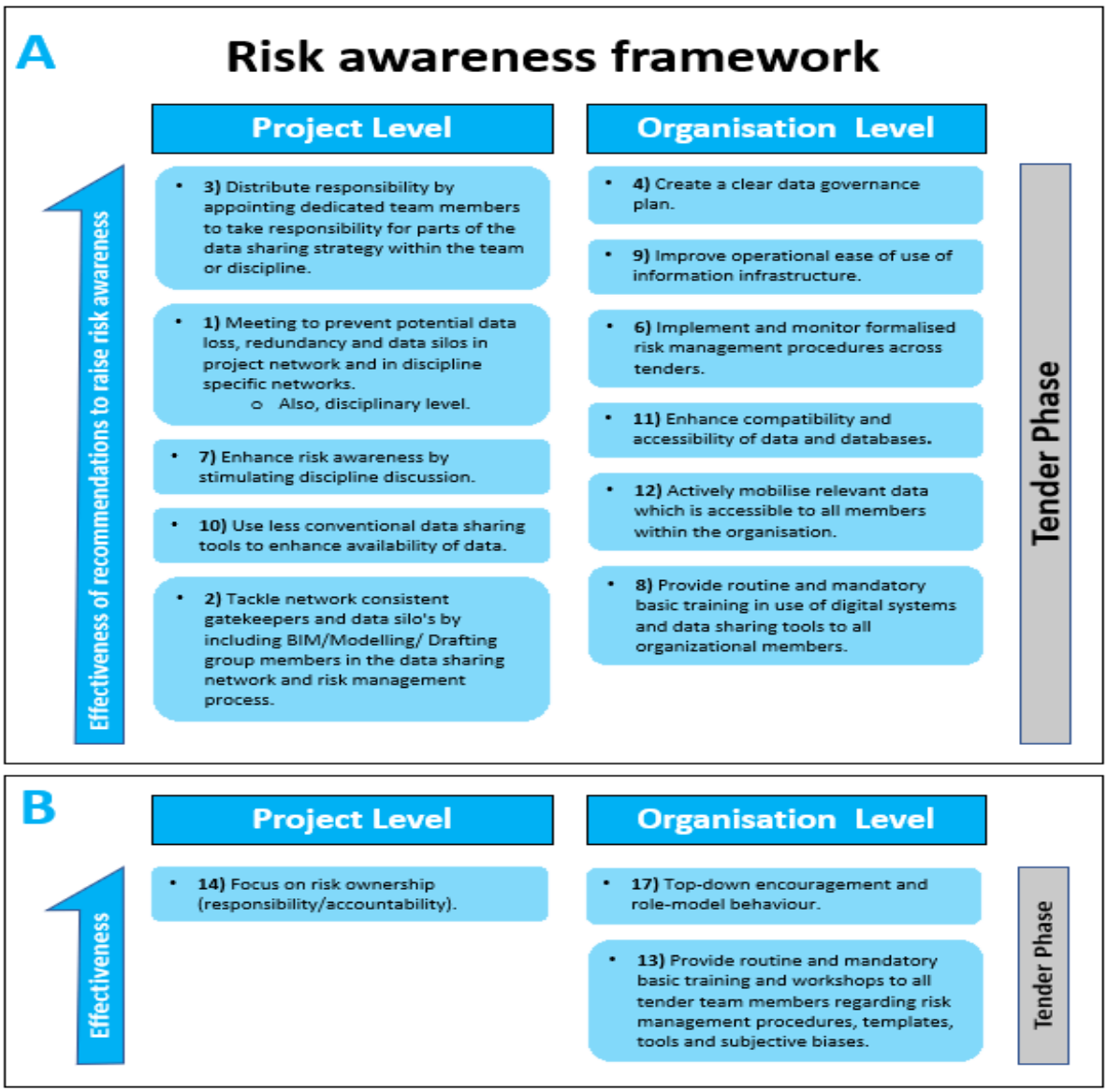

Figure 3: Risk awareness framework.

Discussion and conclusion

Next to confirming the added benefit of factors retrieved from literature, also contradictions have arisen during the research. Literature (Posch, 2020; Zainudin et al., 2019) has often emphasized the use of an incentive system to raise risk awareness. However, although such systems work good in theory and do well in literature, this research rejects the applicability of such systems in practice based on the outcome of the expert panel. Moreover, a factor that was determined through this research that was not established beforehand was role-model behaviour. This research found that role-model behaviour is important in stimulating and motivating employees to show the desired behaviour. In addition, it is also concluded that proper role-model behaviour discards the factor of being able to escalate risk-related problems to higher management.

Furthermore, it is essential to underline that this report used assumptions on which this research is built. These assumptions have been validated with the help of an expert panel and resulted in basically three fundamental findings this research uses to link data sharing and risk awareness together. The first is that all data is potentially important to the risk management process and risk awareness. The second is that the establishment of data sharing and lessons learned connections leads to a greater variety of decision-influencing data and stimulates discussion between organisational members leading to an increased risk awareness. The third is that obtaining a higher availability and variety of decision-influencing data broadens the perspective of project team members and leads to an increased risk awareness. In summary, obtaining a higher availability and variety of decision-influencing data leads to an increased risk awareness.

To achieve a higher availability and variety of decision-influencing data, companies must change the way they approach data sharing in their projects and throughout the company. Here it is essential that all project team members are handed the tools and ability to retrieve the relevant data and effectively share it. However, a pivotal barrier that has been identified in achieving successful data sharing and obtaining desired outcomes appears to be of human nature. This is because organisations are dependent on the human factor as their success factor. As in the end, it are the people who decide how to retrieve and share data, and it are the people who decide what data is relevant. Therefore, it is not about obtaining particular data, as there is no winning formula as to what data is needed to be effective or risk-aware, especially since people have different opinions about which data is relevant. It is more about establishing the right connections and having the possibility of obtaining the data you need. By breaking down intra-organisational barriers and positively influencing the data sharing behaviour of project team members, we can improve the ability of project team members to obtain the for them right and relevant data. As a result, the perspective of the decision-makers can be broadened regarding risks, attaining a higher risk awareness.

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1 Introduction

This research is about data sharing in intra-organisational project networks of multinational construction companies and its impact on the risk awareness of employees inside the firm. This chapter introduces the performed research and starts with explaining the context of the research and the problem analysis in section 1.1. These insights led to the formulation of the research questions in section 1.2. After which, the inter-dependencies of the research concepts are illustrated in section 1.3 together with the research assumptions. Thereafter, the associated scope and limitations will be discussed in section 1.4. Then, the scientific and practical relevance of this research will be elaborated upon in section 1.5. Lastly, the outline of the thesis will be explained in section 1.6.

1.1. Research context and problem analysis

The construction industry is one of the largest industries in the world and accounts for approximately 13% of the global GDP (Mckinsey&Company, n.d.). Even though it accounts for such a significant percentage of the global GDP, the industry's productivity has trailed that of other sectors for decades. A sign of this negative trend is that the industry is shown to underperform in many big infrastructure projects. The associated projects exceed the budgets set for the projects, take longer to finish than planned or do not fit the initial scope anymore. Numerous tools and techniques have been developed to enhance the productivity of the construction sector and minimise the associated project exceedances like Building Information Modelling (BIM), meticulous plannings and risk management.

When observing what drives project success, Teller (2013) has pointed out that there is much research that has found supporting evidence for a positive relationship between project success and project risk management. As a proactive process with respect to risk management can enable project managers to work out potential problems before they occur and, by doing so, contribute to project success (Dey et al., 2007). Hillson and Murray-Webster (2004) state that research has shown that the effectiveness of risk management is dependent on the individuals inside organisations. Because firms can possess and apply the most vigorous risk management structure and framework, but ultimately, it shall always be conditional on the human factor as its success factor (Zainudin et al., 2019; Goto, 2004). As it are the people working the risk management process, and it are the people who determine what are acceptable risks. However, the people involved frequently have different backgrounds in terms of disciplines and/or interests in the project (Baiden & Price, 2011). In the case of risks, this can be disadvantageous due to the fact that risk analysis and management in the construction industry are mainly dependent on the intuition, judgement and experience of involved people (Jen, 2012; Akintoye and MacLeod, 1997). Thus, even though risk management processes are in place, employees appear to still depend to a large degree on their implicit knowledge and experience when interpreting the available risk-related information (van der Meer, 2021). This can be detrimental, especially in the case of subjective biases, when past knowledge and experiences are not compatible with current situations. Therefore, individuals can act without being aware of potential risks and, as a consequence, can make the wrong decisions with respect to risk-related events. That is why, it is of the essence to raise risk awareness among employees within the firm.

Some scholars even argue that as *risk management* today is a prerequisite in a firm, *risk awareness* within the firm will determine the effectiveness of that process (Gorzeń-Mitka, 2011). This is due to the fact that risk-aware employees pro-actively identify risks for their firm and think deeply about the impact and response of the identified risks (van der Meer, 2021). Furthermore, when risk awareness is high within the firm, decision-makers in the company can use the understanding of risks to be more reactive to changes in the environment. This is because risk awareness has the ability to influence decision outcomes as it enables the examination of disappointing and significant results in the decision-making process (van der Meer, 2021). Therefore, risk awareness of employees is essential in future construction projects because project complexity will continue to grow, and the significance of multidisciplinary project teams will persist. Especially, when all the project team members have different experiences and knowledge with respect to risks. By engaging in discussions or risk-based dialogues with organisational members of your project network, underlying perceptions and reasoning based on employees their respective disciplinary expertise emerge such that risk awareness is enhanced (van der Meer, 2021). In the context of this research, this mainly applies to members within their own project network that possess specific data or knowledge that lies outside one's own field of expertise. As risk awareness broadens the view of people making the decisions regarding risk-related problems.

Still, when we compare the construction industry to other sectors, it is evident that integration of people and processes is more challenging to attain due to its dynamic and complex nature where different groups and processes need to be aligned (Demirkesen & Ozorhon, 2017). Therefore, there is a call for better integration of project participants and processes in construction projects (Franz et al., 2017). Consequently, organisational collaboration and integration are often considered inefficient and dependent on individuals. This inefficiency can be caused by individuals not making the right connections to gain access or obtain relevant data for the decision making process. This can be explained by the fact that the industry is renowned for its fragmentation and temporary project teams (Whitley, 2006). Due to this fragmentation, it is not uncommon for parties to have their own internal silos. These internal silos contain different sorts of data and have limited connections within their own or with other project teams, which results in bad data sharing and communication. The presence of data silos and limited data sharing affects risk awareness as this can cause unavailability of data or subjective biases in the decision-making process. As a result, the employees that make the decisions are not (completely) aware of the involved risks, which can give the impression of soundly under-supported choices (van der Meer, 2021). By utilising data sharing and ensuring the proper coordination and communication, one could take on the silo's created by this fragmentation between and in project teams, and by doing so, one could expect to reduce the detrimental effects on risk awareness. Especially when firms are active in a multinational environment, research has shown that connections between people that cross physical boundaries can enhance opportunities to improve performance and improve entry to information (DeSanctis & Monge, 1999). That is why, one could argue that data sharing could contribute significantly to risk awareness among team members. Therefore, this research will aim to map and understand the current data sharing networks of the organisation.

By mapping the data sharing network, one can reveal who controls, facilitates, or inhibits the data flow and which actors have comparable information needs or uses (Hatala and Lutta, 2009; Johanson, 2000). Thus a social network analysis can enable the finding of bottlenecks and data silos and can be used to identify key players in information provision (Hatala & Lutta, 2009). In larger teams the exchange of data is hard due to the fact that a team member may possess an important piece of data but does not know which member needs that data, since it is impossible to know what every other team member is doing or needs. Thus, the main reason as to why communication decision making is challenging is not that it is inherently hard, but that not a single member has all the needed information to decide where to send the data to or whom to send it to (Xu et al., 2004). Through obtaining awareness of current data flow routes, the providers of data can identify opportunities and act upon this by creating alterations to existing data routes, enhancing the delivery of data services. In addition, this research will focus specifically on the tender phase in the project life-cycle. The effectiveness of data sharing, especially in this phase of the project life-cycle is imperative. This is due to the fact that project managers are often forced to make decisions based on incomplete information, while simultaneously project engineers have to make calculations based on premature data until the correct and complete data is finally available (Westin, 2014). This can lead to unanticipated and excessive costs in the later stages of the project. This is due to the fact that alterations and redoing of work become more expensive as the project progresses with time. The possibility to influence the impact and costs of the project are highest in the early stages of the project. Thus, if the data is accurate and available at the beginning of the project life-cycle, the

chance of design changes and potential rework later on in the project's life-cycle becomes smaller. Although utilising data sharing is easier said than done. In every organisation, there are barriers opposing effective data sharing, and businesses can benefit tremendously from removing barriers that negatively influence data sharing. Most of the identified barriers are related to the use of organisational systems, the attitude of the organisation towards data sharing, relationships between members within an organisation and how data is treated as an asset (Barua et al., 2007; Li and Lin, 2006; Drake et al., 2004). A pivotal barrier that has been identified in achieving successful data sharing and obtaining desired outcomes appears to be more of a human nature (Alreshidi et al., 2018). Taking this into account, together with the fact that risk awareness is more related to the human-side instead of specific content, it substantiates the decision of the researcher to focus more on the human side of the process around data sharing rather than on the content. Thus, it is more about the organisation, what sort of processes occur, what sort of behaviour takes place, and how data is exchanged verbally and non-verbally.

Therefore, this research will determine what sort of data sharing behaviour occurs and look into how a firm can positively influence the behaviour of employees by coordinating and facilitating data sharing between members within the company, to broaden the perspective of the people involved regarding risks. When teams are able to effectively share data and communicate lessons learned with their colleagues within and between project teams, this will enhance efficiency and provide opportunities for organisational learning and enrich the understanding of involved individuals. As a result, enhancing risk awareness within the project teams during the tender phase. Consequently, this research proposes adaptations to the organisational structure of the data sharing network and suggests additional activities if needed to enhance risk awareness. Thus, not facilitating the natural data sharing behaviour perhaps, but actually directing the data sharing behaviour of employees by the organisation.

1.2. Research questions

This is an exploratory research, with the main objective being to determine how data sharing in intra-organisational project networks contributes to risk awareness in the tender phase. In order to solve the problem as described in section 1.1 the following main research question has been formulated:

How does data sharing in intra-organisational project networks contribute to risk awareness in the tender phase?

Based on this, four sub-questions have been formulated that aid in answering the main research question of the research:

1. What does risk awareness in the construction industry entail based on literature and what are factors that contribute to this?
2. What does data sharing in the construction industry entail based on literature?
3. How does a data sharing network of a construction project look like in practice?
4. What are the key roles in a project network of data sharing?

In order to research the effects of data sharing on risk awareness the concept of risk awareness is explored in question 1. So what does risk awareness entail exactly? what are the benefits of increased risk awareness? and what factors have advantageous or disadvantageous effects on risk awareness? By identifying these factors, it can be determined what role data sharing can play in enabling these factors later on.

Question 2 dives into the concept of data sharing. Here, the focus will be on collecting available literature about the definition of data and data sharing. This is needed because many definitions of the concept of data exist in literature and among practitioners. Therefore, it is essential to determine and formulate a clear meaning of the concept within this research. Furthermore, to create an understanding of the field of data sharing, general concepts are explored. This is because scholars might have interesting findings of the role of data sharing within companies. Moreover, to perform a social network analysis and model the data sharing network properly, one should be able to recognise elements of such a network.

Furthermore, question 3 is the main deliverable of the research. Here the data sharing network of various cases will be mapped and analysed with the help of a social network analysis tool. Applying a social analysis will help find data sharing patterns, structures, and data silos in the network. In addition, the actors can

be identified together with their roles, responsibilities, position in the network, and relationships with other actors. Analysing the data streams between the actors will reveal structures and the inter-connectivity of the network. Moreover, the social network analysis tool provides additional metrics that expose more insights into the workings of the network. Surveys will be used as a data collection method that aids in mapping the network. Knowledge obtained in the first two sub-questions will be utilised to answer this question.

Lastly, question 4 is used to determine the key roles in a network. Thus, the data sharing network can help reveal who controls, facilitates, or inhibits the data flow and which actors have comparable information needs or uses. Moreover, this research makes a distinction and dives deeper into the node types and determines who has the most significant influence on the data flow in the network and ultimately on risk awareness. As well as trying to find the (underlying) reason why these roles have the most significant influence and see if organisational adaptions need to occur to enhance risk awareness. In addition, it can be determined if specific roles are not 'overloaded' in the process and a paradigm in responsibilities per role needs to occur. By determining this, this research can make significant steps in the process of optimally facilitating and steering the data sharing among team members such that the risk awareness can be enhanced throughout the company.

Sub-questions 1 till 4 together will help answer the main research question. They will uncover what factors contribute to risk awareness, what data sharing patterns and structures there exist, how connected the networks are, who has control over the data, who has access to crucial outside data and knowledge, where the bottlenecks are located, and finally how this can be used to an advantage to increase risk awareness among employees in the company.

1.3. Research assumptions and concept interdependence

The main focus of this research is to determine how data sharing in project networks contributes to risk awareness. To research this, the main concepts of data sharing and risk awareness have been extensively researched during the literature review. In addition, factors are gathered from literature that contribute to increasing risk awareness in practice. To illustrate the interdependence and interrelatedness of the concepts a mind-map has been created. This mind-map can be seen in Figure 1.1 and includes the numbering of the sections in which each respective (sub)concept is discussed.

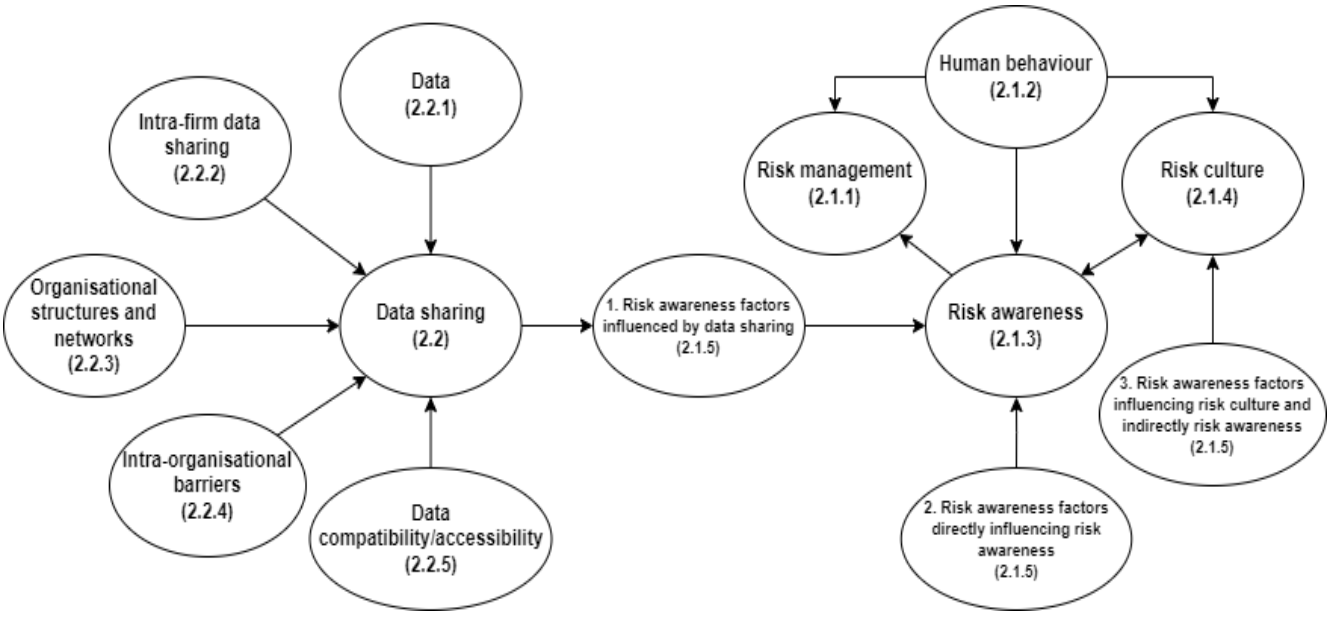


Figure 1.1: Interdependence of research concepts

This established interdependence has resulted in the formulation of multiple research assumptions that are used to link the concepts of data sharing and risk awareness together. It is important to note that these assumptions have been validated with the use of an expert panel. The research assumptions are stated below:

1. All kinds of data can be potentially important to risk management and risk awareness.
2. Establishment of data sharing and lessons learned connections leads to a higher variety of decision-influencing data and stimulates discussion between organisational members leading to an increased risk awareness.
3. Reducing occurrence of missing data leads to a higher availability and variety of decision-influencing data, leading to an increased risk awareness.
4. Minimising compatibility/accessibility issues with data files and systems leads to a higher availability and variety of decision-influencing data, leading to an increased risk awareness.
5. Breaking down intra-organisational data sharing barriers leads to a higher availability and variety of decision-influencing data, leading to an increased risk awareness.

1.4. Research scope

This research has been conducted for the TU Delft in collaboration with BAM. BAM is an independent, listed, international engineering and construction company that has been operating in the field for 152 years and is active throughout all stages of the project life-cycle.

Establishing the scope of the research is essential since it clarifies the boundaries in which the research operates; the scope can be seen in Figure 1.2. As stated above, this research is conducted in collaboration with BAM and has a planned duration of 6 months. This limited time puts some restrictions on the scope of the research, therefore, only a limited selection of elements can be incorporated. Within construction, data is generated in all project life-cycles. However, in consultation with BAM it was decided that the focus of the research will be on the tender phase. More specifically, from the moment the company receives an invite to tender or decides to apply for a tender until the moment the company submits their tender offer to the potential client. The point of departure in this research will be the team that creates and prepares the tender and then, in particular, its data sharing project network. This data sharing network will be limited to data sharing within the company, including cross-boundary data sharing within the firm. Therefore, this research will not consider project members that have an active function outside the company. However, the connections in the network analysis will still visualise these connections with inter-firm project members if and when they are made.

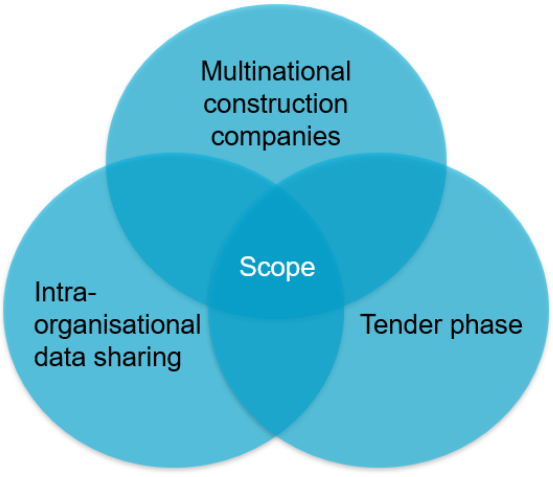


Figure 1.2: Scope of the master thesis research domain

1.5. Relevance

The main purpose of a master thesis research is to contribute something meaningful to existing literature and preferably do something 'new' in the process. This research has two fields to which the findings can contribute, namely to the scientific literature and to practice. The latter is mainly due to the fact that the research has been performed at a multinational construction company in The Netherlands, and the findings are from multiple cases that occurred in real life. How this actually contributes to both fields is described below.

1.5.1. Scientific relevance

There are scientific articles that expand on the use of data sharing on an organisational level, however, these are still limited and often very specific. Most of these contributions relate to the inter-organisational connections made between companies both in and outside the construction industry. These contain issues such as an incomplete data integration among collaborative enterprises due to the fragmented nature of the construction industry (Jiao et al., 2013). The misinterpretation of data and the need for effective and efficient communication (channels) (Cheng et al., 2001) or the lack of trust between project teams (Buvik & Rolfsen, 2015). However, it begs the question if the same issues arise in networks that are active within one single company. As one could argue that the inter-dependencies and relations between and in project teams are different as well as the available data facilities. As for example Zhang et al. (2005) argue that within organisations, there actually is a trend to encourage groups to share data and knowledge. However, often members within an organisation still do not share data if it is dispersed among groups in the organisation (Cress et al., 2006; Yang and Maxwell, 2011), again emphasising the fragmentation problems in the construction industry. While the benefits of effective data sharing inside the company can be great, only a few studies have researched intra-organisational data sharing within multinational construction companies, and these mainly focused on the relationship between data sharing and collaboration (Javernick-Will, 2011).

On the other hand, risk awareness in the construction industry is a concept that has not received much attention in literature in recent years. When scholars discuss risk awareness in the construction industry, it is mostly related to risk awareness with respect to local natural disasters in disaster-prone countries (Chmutina et al., 2018; Ivčević et al., 2020). Therefore, existing literature about risk awareness and its use in risk management is mostly found in other sectors such as accounting and insurance (Roeschmann, 2014; Braumann et al., 2020; Posch, 2020; Collier et al., 2006). Moreover, risk awareness is a concept that is often used within literature that elaborates on the use of Enterprise Risk Management (ERM). Risk awareness is essential in today's risk management practices. This is due to the fact that risk-aware employees pro-actively identify risks for their firm and think deeply about the impact and response of the identified risks (van der Meer, 2021). Furthermore, when risk awareness is high within the firm, decision-makers in the company can use the understanding of risks to be more reactive to changes in the environment. This is because risk awareness has the ability to influence decision outcomes as it enables the examination of disappointing and significant results in the decision-making process (van der Meer, 2021). According to literature, factors that contribute to risk awareness are factors such as but not limited to communication, available and compatible data, formalisation of risk management procedures, and risk-focused information sharing. However, during an exploratory research and extensive literature review, no article has been found that investigates specifically how data sharing in intra-organisational project networks contributes to risk awareness in the tender phase. Hence, this research aims to fill this gap and add to scientific literature in a meaningful way. In addition, this research uses a social network analysis in combination with an expert panel to validate findings. A social network analysis has not been applied before to achieve the equivalent research objective as in this research, according to own literature review, and as a consequence, will also expose new knowledge to the scientific field.

1.5.2. Practical relevance

On a practical level, the findings of this research will contribute to the data sharing practices and risk awareness within multinational construction companies. This particularly applies to BAM as the research has been conducted at the company and is based on real life cases within the company. BAM is an independent, listed, international engineering and construction company that has been operating in the field for 152 years. Their work in the tender phase often consists of unique and temporary project teams that are prone to data silos and exist out of individuals with different backgrounds in terms of disciplines and/or interests in the project. In the case of risks, this can be disadvantageous due to the fact that risk analysis and management in the

construction industry is mainly dependent on the intuition, judgement and experience of involved people (Jen, 2012; Akintoye and MacLeod, 1997). Therefore, on a practical level, this research aims to enhance risk awareness during the tender phase through data sharing, leading to better identification, assessment, and mitigation of risks. As risk management directly affects the project success, the chance of project exceedances gets smaller, and as a consequence, the chance of project success should be enlarged.

1.6. Thesis outline

This report can be divided into three main phases: The first phase is the theoretical background, the second phase is the case study, and the third phase synthesises the research results. In Figure 1.3 an oversight of the thesis is shown, including where the sub and main research questions are analysed. It should be noted though, that the precise formulation of the answers to the specific sub-questions and main research question will be given in the conclusion.

Phase I elaborates upon the theoretical background and encompasses chapter 2 and chapter 3. In chapter 2 the literature review is performed, and information is retrieved about what risk awareness and data sharing in the construction industry entail according to literature. In addition, factors that contribute to risk awareness, according to literature, are determined. After that, in chapter 3 the methodology is presented, which elaborates upon the research design and the methods used to gather and analyse the data.

Subsequently, in phase II, the case study is performed and exists out of chapter 4 and chapter 5. In chapter 4 the social network analysis is performed on both cases, and here the data sharing networks are mapped and visualised. In addition, the key players will be determined, and a cross-case comparison will be performed. In chapter 5 the expert panel is explained, and there, the recommendations that followed from the analysis are validated and combined into a framework.

Lastly, in phase III, the discussion and conclusion of the report are presented in chapter 6 and chapter 7, respectively.

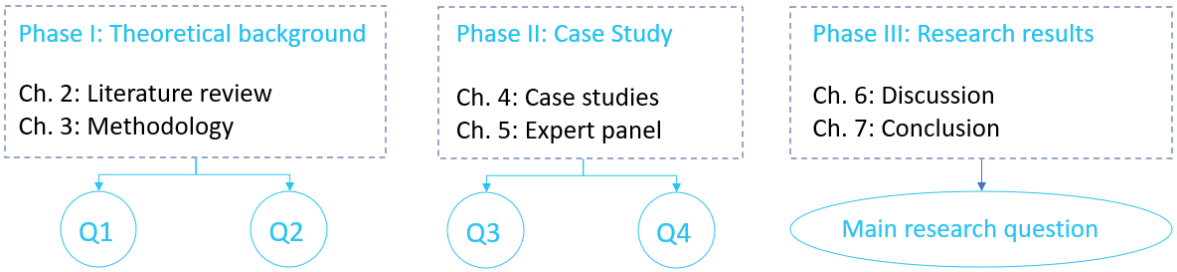


Figure 1.3: Thesis outline.

2

Literature review

In this chapter, the literature review is elaborated upon. The literature review explores the theoretical concepts used in this research and is essential in setting up a scientific research (Verschuren et al., 2010). In appendix A the methodical steps taken to perform the literature review, including search steps, used keywords and used databases, can be seen.

In section 2.1 the concept of risk awareness is explored with the use of multiple subsections. Firstly, a short introduction is given with respect to risk management in section 2.1.1 after which the effects of human behaviour on risk management are discussed. These are elaborated upon to show later how risk awareness comes into play and affects the process of risk management. Then in section 2.1.3 the importance of risk awareness is emphasised and how it can help raise the understanding of what risks exist, their potential impacts and how they are managed. In section 2.1.4 the concept of a risk culture is explained and how this in combination with direct measures can affect the risk awareness among employees. Finally, in section 2.1.5 the factors that contribute directly to risk awareness or indirectly through a risk culture are determined and summarised.

In section 2.2 the concept of data sharing is explored. To start off the data sharing section, section 2.2.1 elaborates upon how data is defined and used in this research. Thereafter, in section 2.2.2 the benefits and workings of intra-organisational data sharing are elaborated upon. Followed-up by the involved organisational structures and networks in section 2.2.3. After which, the barriers involved with intra-organisational data sharing are discussed in section 2.2.4. Lastly, attention is given to the types of data and the compatibility and accessibility of data in section 2.2.5.

2.1. Risk awareness

Risk awareness in the construction industry is a concept that has not received much attention in literature in recent years. When scholars discuss risk awareness in the construction industry, it is mostly related to risk awareness with respect to local natural disasters in disaster-prone countries (Chmutina et al., 2018; Ivčević et al., 2020). Therefore, existing literature about risk awareness and its use in risk management is mostly found in other sectors such as accounting and insurance (Roeschmann, 2014; Braumann et al., 2020; Posch, 2020; Collier et al., 2006). Moreover, risk awareness is a concept that is often used within literature that elaborates on the use of Enterprise Risk Management (ERM). ERM is an integrated framework that can be applied to any industry and addresses the need for organisations to improve their approach to managing risks. Enterprise Risk Management according to the integrated framework of COSO (2004) is defined as "a process, effected by an entity's board of directors, management and other personnel, applied in strategy setting and across the enterprise, designed to identify potential events that may affect the entity, and manage risk to be within its risk appetite, to provide reasonable assurance regarding the achievement of entity objectives."

This definition is defined very broadly. According to the framework, this is done because it captures the key concepts to how entities manage their risks, providing a clear foundation for application throughout industries, sectors, and organisations. Moreover, the definition emphasises the fact that ERM is a process that takes place throughout the whole entity and is executed by personnel at each level of the organisation and that it is included in the strategy (Gorzeń-Mitka, 2011). One of the keys to achieving this is raising the firm's risk awareness of involved stakeholders. This research will follow the definition as proposed by Jen

(2012) who defines risk awareness as the raising of understanding within the population of what risks exist, their potential impacts, and how they are managed. However, before we dive deeper into the meaning of the concept of risk awareness, it is important to elaborate on the meaning of risk and risk management in the context of this research.

Firstly, in the context of this research, risk is an ingrained characteristic of decisions in projects and defined as the extent to which there is uncertainty about whether potentially significant and/or disappointing outcomes of decisions will be realised (Sitkin & Pablo, 1992). Generally, risk is a result of uncertainty, which can drift a company from its path in attaining its planned objectives and goals. Nevertheless, divergence does not necessarily have to be bad for a firm, as apart from having a negative effect, it can also have positive consequences for the company (Zainudin et al., 2019). Traditional wisdom recognises that firms need to participate in risk-taking to create returns (Fiegenbaum & Thomas, 1988). As firms generally want to avoid risks that only have a negative potential, they deliberately take strategic risks to generate higher returns (Kaplan & Mikes, 2012). To generate these returns, firms, among other things, make use of risk management in their daily practices.

2.1.1. Risk management

According to Collier et al. (2006) risk management is the process where firms methodically address the risks bound to their activities in pursuit of the companies objectives and across the portfolio of all their activities. Generally, (effective) risk management consists out of:

- Risk identification
- Risk analysis
- Risk response
- Risk monitoring
- Risk reporting

Risk management facilitates decision-making in response to uncertainty. It can be characterised as a continual process of refinement into existing practices or business processes of risk-aware firms (Gorzeń-Mitka, 2011). The objective of risk management is not to eliminate all risks. As explained before, risks are also needed to generate value, but to ensure that strategic risks are governed to be accordant to the firm's risk appetite. A firm's risk appetite is defined as the amount of risk a firm is willing to take on in pursuit of value (Rittenberg and Martens, 2012; Posch, 2020). Moreover, it requires the interactive participation of involved members (Dey et al., 2007; Kutsch and Hall, 2005). According to Teller (2013) there is much previous research that found supporting evidence of a positive relationship between project success and project risk management. As a proactive process with respect to risk management can enable project managers to work out potential problems before they occur and, by doing so, contribute to project success (Dey et al., 2007). Nevertheless, to ensure effective risk management processes and tools, a strong risk management culture is needed (Teller, 2013; Collier et al., 2006; Roeschmann, 2014; Zainudin et al., 2019; Posch, 2020; Braumann et al., 2020; Gorzeń-Mitka, 2011). As a strong risk management culture encompasses the general awareness of risks and their management (Ropponen & Lyytinen, 2000).

Awareness of risks empowers involved players to modify their behaviour and expectations appropriately (De Bakker et al., 2011). From this angle, the existing risks awareness of involved stakeholders may contribute to risk management quality. This is amplified by the fact that it has been suggested that the awareness of stakeholders regarding risks in the portfolio as well as their involvement are required to manage risks properly (De Bakker et al., 2011; Dey et al., 2007). Therefore, as risk management is a necessity in present-day firms, risk awareness within the firm will determine the effectiveness of this process (Gorzeń-Mitka, 2011).

2.1.2. Human behaviour at the centre of risk management

Since firms, especially in the construction industry where innovation and digitisation have been low, have quite similar systems, technologies and structures, some scholars reason that the distinction in performance is mainly in the behaviour of their employees. Therefore, firms in the industry increasingly acknowledge the significance of human and cultural aspects of risk management (Gorzeń-Mitka, 2011). As stated by Hillson and Murray-Webster (2004), experience and research have shown that the effectiveness of risk management is dependent on the individuals inside organisations. As firms can possess and apply the most vigorous risk management structure and framework but ultimately, it shall always be conditional on the human factor as

its success factor (Zainudin et al., 2019; Goto, 2004). As it are the people that are working the risk management process, and it are the people who determine what are acceptable risks.

Thus, it are the human features that play a significant role in the way forward to achieving effective risk management (Goto, 2004). Emerging from this, firms have begun to look into the 'soft' factors such as incentive structures that reward business success, together with awareness and management of risk (Zainudin et al., 2019; Posch, 2020). This has brought about companies to examine the human component and culture inside the firm that supports risk-aware development. Therefore, a risk-aware culture can be seen as a culture that is supported by a management structure that supports human aspects. This has led to literature that deduced a risk(-aware) culture as one of the fundamental factors in a companies risk management structure, and this is elaborated upon in subsection 2.1.4.

Nevertheless, when humans make decisions, it needs to be taken into account that this can involve subjective biases in the decision-making process. As decisions that are taken under uncertainty can be heavily influenced by a person's subjective bias. As subjective biases hinder the willingness and/or ability of individuals in the decision making process to evaluate even objective probabilities. When this makes individuals under-evaluate risks, they are taking part in overly risky behaviour without even being aware of it, which can result in considerable losses for the firm (Goto, 2007).

An example of subjective bias can be taken from the dissertation of van der Meer (2021) who executed an experiment in which he had employees of a large Dutch construction firm choose between two alternatives. These alternatives were completely filled in trade-off matrices, including box scores but with a different visual representation. The results suggested that the participants used their tacit knowledge to interpret the presented information in the trade-off matrix and based their decision on their personal interpretation of important information in the given background information and not on the given scores in the trade-off matrix. In other words, their decisions were not exclusively based on what was presented, but the employees still based their final decisions on their own knowledge and experience. Similar situations have been illustrated before in literature as Nikou and Klotz (2014) state that decision-makers often tend to take time-saving methods during the process in which decisions are made. In which they may primarily depend on their experiences instead of a complete analysis of alternatives to justify a choice. This can also be seen in practice, where risk analysis and management in the construction industry mainly depend on intuition, judgement and experience of involved stakeholders (Jen, 2012; Akintoye and MacLeod, 1997). However, in a world where complexity and uncertainty are inherent to construction projects and are only increasing with the years as the size of projects increase and risks become more complex, this can cause problems when experiences obtained in the past are not compatible with situations in the present.

Using obtained experiences, employees will have different viewpoints about risks involved in the project, which can lead to different expected values of alternatives (van der Meer, 2021). If the outcome of a situation is unknown, but we can accurately determine the odds, management should instil into employees the significance of objective data. As heuristic methods and depending on experience are not acceptable when probabilities are known (Goto, 2007). On the other hand, where data is insufficient, constant effort should be exerted into collecting meaningful data and accumulating experience within the organisation. Moreover, van der Meer (2021) states that providing a choice architecture can help decision-makers to enhance their own awareness with respect to their own cognitive bias that can lead to irrational choices. Moreover, Goto (2007) suggests that on an individual level, biases can be diminished by educating staff on how to recognise and make up for them. On an organisational level, risk evaluation models can help to make the reasoning of employees more explicit (van der Meer, 2021; Goto, 2007).

Since risks associated with subjective biases are embedded in the way that individuals identify and assess risk, it is suggested that a behavioural approach is very well befitting to mitigating risks. Thus by giving more attention to the behavioural aspects, the decision-makers are able to enhance the quality of risk management inside their enterprise. Practices that facilitate this are employees sharing insights, by doing this bringing together different points of views, knowledge and experiences to decision making and risk evaluation (Goto, 2007). Thus to be successful, risk management must address the behaviour of the people that make decisions connected to risks. If management chooses to neglect this, the minimum outcome is an ineffective allotment of resources, resulting in losing opportunities to enhance firm value. At the most, ignoring behaviour can lead to large losses and insolvency.

To illustrate, some examples of the most relevant subjective biases in practice are given below and are retrieved from internal documentation within BAM (BAM, personal communication, August 4, 2021):

- Anchoring: Propensity to rely on the first piece of information encountered when making decisions.

- Confirmation: Tendency to search for, interpret, favour, and recall information in a way that confirms one's beliefs or hypotheses.
- Complacency: Tendency to accept risks/not explicitly acknowledge risks which are very common.
- Framing: Tendency of people to respond differently on risk information based on how you present it.
- Myopia/Near-sightedness: Risks that recently occurred are unequally estimated with a very high probability of occurrence.
- Self-overestimation (Lake Wobegon effect): Natural tendency to overestimate one's capabilities and see oneself as better than others. Being convinced that your risk estimation is accurate.
- Similarity heuristic: How people make judgments based on similarity. More specifically, the similarity heuristic is used to account for how people make judgments based on the similarity between current situations and other situations or prototypes of those situations.

Thus to conclude, even though risk management processes are in place, employees appear to still depend to a large degree on their implicit knowledge and experience when interpreting the available risk-related information. This can be a bad thing in case of subjective biases, as people can make big mistakes without being aware of them. Especially when past knowledge and experience are not compatible with current situations. Therefore, individuals can act without being aware of potential risks and, as a consequence, can make the wrong decisions with respect to risk-related events. This illustrates the certitude that the world is complex, and there is a limit to human capabilities in aspects such as processing information and evaluating risks. Therefore, in a world where complexity and uncertainty in projects are increasing, it is of the essence to reduce the effects of subjective biases regarding risks by raising the risk awareness of involved employees.

2.1.3. The importance of risk awareness

Some has already been said about the application of risk awareness in effective risk management. However, the concept itself and its general importance and use have not been elaborated upon extensively yet. Up till now, there has not been a formal definition of risk awareness, and some literature assumes that risk awareness is the knowledge of risk management. Although knowledge of risk management is important, risk awareness is not the same as risk management knowledge. This research will follow the definition as proposed by Jen (2012) who defines risk awareness as "the raising of understanding within the population of what risks exist, their potential impacts, and how they are managed".

This means that the risk management processes of risk identification, analysis, response, monitoring and control are all contained within this statement. As risk management today is a prerequisite in a firm, scholars argue that risk awareness within the firm will determine the effectiveness of the process (Gorzeń-Mitka, 2011). In addition, a requirement for assessing risks is that the decision-makers are aware of involved risks and are able to perceive a situation as high-risk (van der Meer, 2021). Moreover, in the context of the definition as proposed by Jen (2012) raising the understanding incorporates accountability, communication and cultural change. As a result, this is more than mere knowledge; these are behavioural characteristics required of project stakeholders in addition to the management of project-related risks. (Jen, 2012).

In literature scholars, practitioner's and regulators increasingly highlight the importance of creating risk awareness among employees (Collier et al., 2006; Zainudin et al., 2019; Mikes, 2009; van der Meer, 2021; COSO, 2004; Gorzeń-Mitka, 2011). As risk-aware employees pro-actively identify risks for their firm and think deeply about the impact and response of the identified risks (van der Meer, 2021). Therefore, risk awareness can be seen as the outcome of all employees sharing and reflecting on how their behaviour and activity are related to results and causes of possible risks to the firm. However, while literature on risk management emphasises the significance of risk awareness, empirical evidence that provides insights into the drivers of risk awareness and its implications is limited (van der Meer, 2021; Braumann, 2018). Nevertheless, when risk awareness is high within the firm, decision-makers in the company can use the understanding of risks to be more reactive to changes in the environment. As a result, risk awareness is an essential cultural component of proper risk management and can be seen as the foundation of ERM success (Lam, 2014; Braumann et al., 2020). By having this, all employees within the firm accept individual responsibility for risk management and motivate others to engage in this risk-aware approach (COSO, 2004). This embedded way of thinking involving risks ensures that workers within the firm have a clear comprehension of what top management expects from employees with respect to addressing risks in their activities, which can span from daily operations to strategic planning (Collier et al., 2006). Furthermore, risk awareness has the ability to influence decision outcomes as it enables the examination of disappointing and significant results in the decision-making process.

Nonetheless, if employees that make the decisions are not (completely) aware of the involved risks, it can give the impression of soundly under-supported choices (van der Meer, 2021). Therefore, risk awareness of employees is essential in future construction projects as project complexity will continue to grow, and the significance of multidisciplinary project teams will persist. Especially, when all the project team members have different experiences and knowledge with respect to risks. Moreover, in the case of high risk awareness, risk management becomes so embedded that it is basically invisible due to the fact that all the employees within the firm are already implicitly managing risks. Due to this intangibility, risk awareness itself can often not be applied directly through management decisions. However, management can take actions to raise risk awareness by creating a suitable control environment (Braumann et al., 2020). Therefore, what literature agrees on is that if we want to increase risk awareness within the firm a cultural change in the organisation is needed with respect to risks which results into the need for a risk(-aware) culture (Jen, 2012; Gorzeń-Mitka, 2011; Zainudin et al., 2019; Braumann et al., 2020; Collier et al., 2006; Posch, 2020).

While other literature emphasises the need for a strong risk culture as risk awareness follows naturally when a strong risk culture is in place (see next subsection). Other literature discusses factors that directly influence risk awareness without focusing on the cultural components. For example Jen (2012) states that risk awareness can be directly increased by one or more of the following methods in which you raise the level of experience, increase the technical skill, increase the knowledge of risk management, normalise risk tolerances and enhance the communication skills. In figure 2.1 it is illustrated which tactics can be used to enhance risk awareness in involved stakeholders per method.

	Simulations/ Case Studies/ Examples	Lessons Learned	Mentorship/Supervision/ Feedback/ Coaching	Training (Technical/ Communications/ Risk Management)	Risk Identification Meetings/ Status Meetings	Checklists/ Questionnaire/ Dictionary/ Definitions	Probability-Impact Matrix
Raise Level of Experience	X	X	X				
Increase Technical Skill			X	X			
Increase Knowledge of Risk Management				X	X	X	
Normalise Risk Tolerance	X					X	X
Enhance Communication Skill	X		X	X	X		

Figure 2.1: Specific approaches to increase risk awareness among stakeholders (Jen, 2012).

Moreover, van der Meer (2021) states that in his research, three validated design rules were determined that help increase awareness of risks involved in design alternatives during the tender stage, such as:

1. Defining the criteria together so that the common understanding and application of relevant information is increased.
2. Highlight or visualise the uncertainty in scoring criteria to trigger discussion about risks.
3. Reflect on the decision-making process by evaluating the quality of the decision process.

van der Meer (2021) states that the application of these rules enables a more transparent understanding of the problem and more rational choices, even though that engineers still base their decision on their own knowledge and experience. Due to this, discussions within tender teams are encouraged, and through these risk-based dialogues, underlying perceptions and reasoning based on their respective disciplinary expertise emerge such that risk awareness is enhanced.

However, on the other hand, Akinci (2015) states that the following components have an adverse effect on awareness within the population. As the situational awareness of engineers can be challenged because of missing data and the data that is available not having it in a format that is easily accessible and actionable. Thus this lack mostly originates from information bottlenecks and not having the correct information at the right time and in compatible formats. Consequently, management and engineers waste large amounts of money and time in pursuit of information or by making decisions based on incomplete information. Therefore, one should look at possible advancements in information and communication technologies that can

help alleviate information bottlenecks and the associated waste, increasing the situational awareness of management and involved engineers.

2.1.4. Risk(-aware) culture

In the context of this research, a risk culture and a risk-aware culture are seen as one and the same. This is due to the fact that in literature, a clear distinction between the two concepts has not been found, and both organisational cultures have the same goal in attaining the optimal execution of risk management by embedding risk awareness in employee behaviour. Therefore, it is assumed that when literature discusses these concepts, they mean the same thing. This can partially come due to the fact that the concept of a risk culture today still remains blurry (Roeschmann, 2014). Hence, when referring to this concept, the term risk culture shall be used from this point forward. A risk culture emphasises the need for risk awareness among employees, and agreement has arisen that risk awareness is one of the elemental components of a risk culture (Collier et al., 2006). This is because a sound risk culture embeds risk awareness in employee behaviour. Therefore, it is assumed that a certain level of reciprocity is present between the two concepts and that risk awareness follows naturally from having a sound risk culture. This is due to the fact that based on determinants such as information overload, bounded rationality, and increasing complexity of projects and consequently risks, literature illustrates weaknesses of risk management tools and highlights the significance of creating a suitable risk culture that embeds risk awareness into employee behaviours (Roeschmann, 2014; Collier et al., 2006; Posch, 2020; Gorzeń-Mitka, 2011; Zainudin et al., 2019; Braumann et al., 2020). Nevertheless, for the sake of this research, risk culture is not seen as an end but as a means to increase risk awareness among the population. This is due to the fact that during this research, it is argued that risk awareness determines the effectiveness of risk management and that a sound risk culture increases risk awareness and embeds this into employee behaviour.

Some literature argues that risk culture is the result of group and organisational learning about what has or has not worked in the past (Roeschmann, 2014). Others agree but state that it's also a product of individual values and of attitudes and behaviour patterns (Gorzeń-Mitka, 2011), which leads to a commitment to the risk management goals of the firm. Organisations with such a culture are distinguished by communication built on reciprocal trust and shared perception of the significance of risk management. Roeschmann (2014) has done extensive research across literature regarding the meaning/definition of a risk culture and has shown that a risk culture is connected with:

- Psychological aspects: general awareness and attitude towards risks and integrity
- behavioural aspects: Tone from the top, senior management actions
- Organisational aspects: C-level placements of risk managers or HR policies

The reasoning is that the formal and informal constituents of a firm's risk management structure interact. On the one hand, the formal procedures of a firm determine which processes to use, what values to pursue and which restrictions to obey. It is principally its risk culture that determines how risk management is executed and which norms and regulations are perceived to be significant and rational. Thus, risk culture's purpose is to implant procedures and policies regarding risk management and to build up the sense of awareness and responsibility as well as to enhance information sharing (Roeschmann, 2014). Therefore, a risk culture acts as a guide on how relevant information regarding risks is provided, used, and understood and how general rules are put in place.

However, the question emerges as to how risk culture can be managed appropriately, acknowledging the inherent difficulties in managing culture in organisations (Ogbonna & Harris, 2002). Generally, companies use internal risk-focused control systems to include risk in performance measures. Here one could think about aspects such as dashboarding, setting rules, creating risk procedures and systems and more. However, on the one hand, risk-focused controls tend to prompt rule-based compliance, which leads to a tick the box mentality and obstructs the flexibility of employees to handle strategic risks (Collier et al., 2006). By acknowledging these weaknesses, literature has searched for methods in which the benefits of risk-focused controls can be maintained while the weaknesses are tackled.

In this manner, based on earlier work Posch (2020) has investigated the role of risk-focused information sharing, which according to Lam (2014) is a significant aspect of risk culture that is controllable by operative management. By using risk-focused information sharing, firms can bypass the shortcomings of conventional risk management procedures as risk-focused information sharing supports the creation of a risk culture that

embeds risk awareness in organisations (Kaplan & Mikes, 2016). Firms have multiple options to engage in risk-focused information sharing stated in the article of Collier et al. (2006): Next to firm guidelines about the character of risk and its interaction with performance, firms can encourage conversations about risks, involving employees in deviation analysis(non-conformance reports) regarding performance, organise risk review meetings, risk workshops, and create risk task-forces. Tools like these assist companies in sharing risk-related information from a top-down approach, which provides a decision facilitating motive, and bottom-up through the access of local information of workers (Posch, 2020). Moreover, Casas-Arce et al. (2017) illustrates that adding decision facilitating information to employees can positively influence their behaviour regarding decisions. Similarly, sharing such information can clarify the expectations of the firm on employees in terms of risk appetite and helps in creating a better comprehension and awareness of risks, and be more pro-active and help to best position employee behaviour with respect to the firm's risk appetite (Casas-Arce et al., 2017). Thereby, these tools encourage risk-aware behaviour in employees and thus nurture a strong risk culture (Lam, 2014).

In addition, literature highlights the role of tone from the top as a key driver of risk awareness (Braumann et al., 2020; Collier et al., 2006; COSO, 2004). Tone from the top can be seen as a strong form of cultural control whose strength arises from its potential to steer the behaviour of employees in (un)expected and ambiguous circumstances (Braumann et al., 2020). Thus, through explicating this form of control as a control practice which centres the attention of an organisation to risk (Henri, 2006), with the goal of strengthening risk awareness (Braumann et al., 2020).

In the context of risk management, tone from the top has two dimensions (Braumann et al., 2020):

1. A top-down approach in which top management communicates its expectations about commitment and behaviour with respect to risk management.
2. Support of bottom-up communication and escalation of risk issues.

To produce a satisfying level of risk awareness within the firm, the CEO must dedicate his attention to issues involving risk, extensively support the risk management process, and transfer expectations regarding risk management behaviour, and encourage communication and escalation regarding issues involving risks to all levels without punishing people who are open about occurring risks and bring this to light (COSO, 2004; Lam, 2014). Doing this portrays that risk management matters because when upper management believes in risk awareness and dedicates their resources, effort, and time to issues involving risks, then others will follow. With respect to the second dimension, proper tone from the top incorporates a bottom-up perspective in which management is able to motivate communication and escalation of issues involving risks from the lower levels to the upper ones. By giving employees a voice in risk-related issues, upper management can take apart hierarchical barriers and support engagement of employees, which results in a higher motivation among firm employees to continuously contemplate about risk-related issues (Adler & Chen, 2011). Consequently, management fabricates a climate of trust and transparency, and signals that it is approachable and focused on open communication, and also inspires and encourages openness to challenge (Braumann et al., 2020).

Research has suggested that this form of control most likely works best in a system with more formal control practices to raise risk awareness (Grabner & Moers, 2013). A more formal control practice is interactive control which uses the discussion and interpretation of budget data and performance measures during face to face meetings between upper management and employees(Braumann et al., 2020). The use of such a control practice strengthens tone from the top due to the fact that these meetings enable management to display their tone from the top by walking the talk and communicating their attitude towards risk and encourage employees to do the same such that risk awareness is increased (Braumann et al., 2020).

In their articles Zainudin et al. (2019) and Gorzeń-Mitka (2011) discuss components that have a direct effect on creating a risk culture. Gorzeń-Mitka (2011) states that a risk-aware culture can be achieved by creating an environment that shows leadership from upper management, entails the involvement of staff positioned at all levels, emphasis is put on training staff in risk management procedures and on learning from the past, suitable accountability for action without creating a blame culture, and communication and openness on lessons learned and any risk management issues.

Zainudin et al. (2019) states that culture fundamentally relates to the behaviour of humans and therefore identified the human related factors that are needed to develop a risk culture:

1. Top Management support

   (a) Involvement of top management:
   (b) Reward/incentive system that rewards proper risk management
2. Culture
   (a) Accountability
   (b) Communication
   (c) Employee involvement
   (d) Common risk language
3. Training
   (a) Knowledge on risk management procedures and system
   (b) Talent management

Important to emphasise is that this research takes place in the context of a multinational engineering and construction company. This means that there are multiple subsidiaries and thus also multiple subgroups. This can mean that there is a formal risk management framework for the whole firm or that there is a separate framework per subsidiary. In either case, due to the fragmented work environment, subgroups are likely to have recognisably different risk cultures, which can be a consequence of different educational backgrounds or other shared experiences. Roeschmann (2014) argues that an approach that dictates full uniformity is culturally impossible but in addition is also blind to the advantages that surface from different perspectives. Therefore, it is important in this context to take a look per subsidiary and find out if risk management uniformity is needed per subgroup.

2.1.5. Risk awareness factors

In the previous sections, literature was consulted to determine what risk awareness entails. Here the importance of risk awareness has been underlined, and one of the main goals of this literature review was to determine which factors contribute to risk awareness. During the literature review, a set of 18 factors have been identified and will be used as starting point for the rest of this research. The aim is to eventually determine which of these factors can be utilised in practice with the help of data sharing such that risk awareness can be increased among employees. This will be examined in two different finished tender projects, and in this manner, the theoretical findings are analysed based on practice. In table 2.1 all factors that contribute to raising risk awareness are presented with a short description and the corresponding literature from which the respective factors are retrieved. Furthermore, in appendix B a detailed description of the factors can be found, with in some cases specific ways to improve the utilisation of the factors such that risk awareness can be improved. In table 2.1 are also taken into account factors that help create a sound risk culture, as during this research, and according to literature, it is assumed that risk awareness is a fundamental component of risk culture. As a strong risk management culture encompasses the general awareness of risks and its management (Ropponen & Lyytinen, 2000) and embeds this into employee behaviour.

Furthermore, if we take a look at the concept interdependence in Figure 1.1 then it is evident that the risk awareness factors can be divided into three distinctive groups:

1. Risk awareness factors influenced by data sharing: 2, 3, 5, 10, 11, 13 and 14
2. Risk awareness factors directly influencing risk awareness: 1, 2, 3, 5, 6, 7, 9 and 12
3. Risk awareness factors that directly influence a risk culture and thus indirectly risk awareness: 4, 15, 16, 17 and 18

These factor focused groups also include the numbers of the risk awareness factors in table 2.1 that belong to that specific group. It has to be noted that both factor 2, 'Role clarity' and factor 3, 'Accountability (responsibility)' are allocated to the first and second factor focused groups. This is because role clarity and accountability can be expressed in terms of data sharing and in terms of risk management.

Factors contributing to risk awareness	Source
1. Formalisation of risk management procedures	Teller, 2013; Roeschmann, 2014; Kumar, 2003; Zainudin et al., 2019
2. Role clarity	Teller, 2013; De Bakker et al., 2011; Beasley et al., 2005
3. Accountability (responsibility)	Jen, 2012; COSO, 2004; Zainudin et al., 2019; Posch, 2020; Gorzeń-Mitka, 2011
4. Reward/incentive system	Zainudin et al., 2019; Posch, 2020; Gorzeń-Mitka, 2011
5. Lessons learned	Goto, 2007; Gorzeń-Mitka, 2011; Zainudin et al., 2019; Jen, 2012; Posch, 2020; COSO, 2004; Roeschmann, 2014
6. Raising level of experience	Jen, 2012
7. Increasing technical skill(s)	Jen, 2012
8. Raising knowledge of risk management	Jen, 2012; Roeschmann, 2014; Zainudin et al., 2019; Gorzeń-Mitka, 2011
9. Normalising risk tolerances	Jen, 2012; Goto, 2007
10. Enhancing communication	Jen, 2012; Gorzeń-Mitka, 2011; Braumann et al., 2020; Zainudin et al., 2019; Hatala and Lutta, 2009; van der Meer, 2021
11. Risk-focused information sharing	Posch, 2020; Jen, 2012; van der Meer, 2021; Roeschmann, 2014; Braumann et al., 2020; Kaplan and Mikes, 2016; Lam, 2014
12. Educating staff on subjective biases	van der Meer, 2021; Goto, 2007
13. Missing data	Akinci, 2015; van der Meer, 2021
14. Data compatibility and accessibility	Akinci, 2015; Casas-Arce et al., 2017; van der Meer, 2021; Roeschmann, 2014
15. Top down management support	Zainudin et al., 2019; Braumann et al., 2020; Collier et al., 2006; Roeschmann, 2014; Gorzeń-Mitka, 2011; COSO, 2004; Posch, 2020
16. Bottom-up communication and escalation of risk issues	Braumann et al., 2020; van der Meer, 2021; Adler and Chen, 2011; COSO, 2004; Gorzeń-Mitka, 2011; Zainudin et al., 2019
17. Employee involvement	Gorzeń-Mitka, 2011; Zainudin et al., 2019
18. Common risk language	Zainudin et al., 2019; Jen, 2012

Table 2.1: Factors that contribute to risk awareness according to literature.

2.2. Data sharing

To repeat, in this section, the concept of data sharing is explored. To start off the data sharing section, section 2.2.1 elaborates upon how data is defined and used in this research. Thereafter, in section 2.2.2 the benefits and workings of intra-organisational data sharing are elaborated upon. Followed-up by the involved organisational structures and networks in section 2.2.3. After which, the barriers involved with intra-organisational data sharing are discussed in section 2.2.4. Lastly, attention is given to the types of data and the compatibility and accessibility of data in section 2.2.5.

2.2.1. Defining data

Information science is a field that is continuously changing. That is why information scientists need to frequently review, and if needed, redefine its fundamental building blocks. The fundamental building blocks in the context of information science are the concepts of data, information and knowledge (Zins, 2007). In addition, the academic field of information science literature supports different meanings for the distinct concepts. Seemingly, the three concepts are interrelated; nevertheless, the nature of inter-relatedness between the concepts is still debatable as well as their meanings (Zins, 2007). This research will follow the way to define data as proposed in the master thesis of Berck (2020). This is due to the fact that in the context of this research and for its purpose, this definition is an excellent fit. Therefore, this research defines data as: "all sorts of quantitative and qualitative retrieved sets of (un)structured numbers, facts, statistics and documents which can be interpreted and used for decision-making".

One of the first to describe the relationship between the concepts of data, information and knowledge was Ackoff (1989), who created a model called the Data-Information-Knowledge-Wisdom (DIKW) hierarchy. This model can be seen in Figure 2.2 and describes a hierarchical pyramid that transforms data into information, information into knowledge, and knowledge into wisdom.

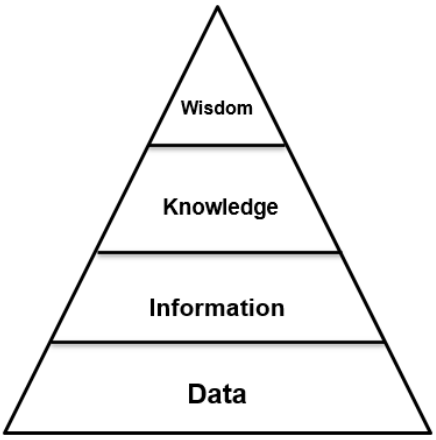


Figure 2.2: DIKW Hierarchy (Ackoff, 1989)

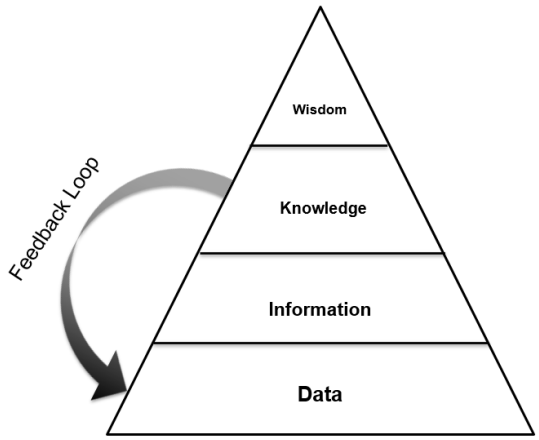


Figure 2.3: DIKW Hierarchy with feedback loop (own illustration)

In the time after Ackoff (1989) many alterations were proposed to the DIKW hierarchy, due to the fact that among scholars still a lot of disagreement existed about the definition of the used concepts and the inter-relatedness between them. One of them was Rowley (2007) who in her paper revisited the DIKW hierarchy by examining articulations of the hierarchy in a number of books in information systems and knowledge management. Rowley (2007) came to the conclusion that still, typically, information is defined in terms of data, knowledge in terms of information, and wisdom in terms of knowledge. However, there is less agreement in terms of the nature of the processes that transform data into information, and information into knowledge, to the degree that it is not clear whether there are, in fact, three distinct concepts, which can be traced back to the presence of a consequent lack of definitional clarity (Rowley, 2007). This comes not as a surprise as Zins (2007) in his article documents over 130 definitions of data, information and knowledge, which are formulated by 45 leading scholars in the field. All definitions of the concepts contained within this article are defined differently, as well as the corresponding relationship between the three different concepts. This illustrates that the definitional clarity of the concepts and the inter-relatedness between them is a topic of discussion as literature has a wide variety of opinions on the matter.

Fisher et al. (2012) define data as isolated facts devoid of meaning and define information as processed data that has meaning because of relationships established with other data. As meaning is enhanced by establishing relationships with other data. While Frické (2018) states that information is relevant, usable, or processed data, and thus information can be seen as a subset of data. This shows that there is still a fine line between the difference of data and information. Moreover, this has been displayed by Fisher et al. (2012, p. 4) in their book "Introduction to information quality" where they shortly discuss data versus information. They used the following manufacturing problem to illustrate the problem: A manager needs to know the number of parts that are in stock, and this is a critical piece of information that has to be accurate. This is due to the fact that the manager needs to know that detail exactly to determine if he can build a product before the day starts. However, the manager's information is simply data to an executive because an executive needs to combine the data with numerous other indicators to deduce how well the plant is running overall compared to the company's objectives and the performance of competitors.

Thus, depending on the users and their purpose, the manufacturing problem is indicative of either information or data. This often leads to literature and scholars using data and information interchangeably at any given moment, especially in information management and data management (Boisot and Canals, 2004; Chen et al., 2008). Due to the fact that there are numerous levels and interpretations of the distinctions between information and data, Fisher et al. (2012) and Westin (2014) treat data and information interchangeably in their research as the context will make the difference between the concepts clear. Hence, this research will follow their lead and use the terms data and information interchangeably. Where the difference between the concepts could potentially matter, the circumstances of the situation will make it clear.

Therefore, this research will focus on data sharing, in which both the sharing of data and information inside the firm will be covered. Principally, knowledge sharing will not be treated as this is outside the scope of this research. Nevertheless, also in the case of knowledge, it is important to understand the relationship with the other concepts. Information, as stated earlier, is often seen as data processed to be meaningful and valuable for a specific purpose. While at the same time, knowledge is described as information combined with understanding and capability (Laudon et al., 2007). Another common view is that knowledge is the product of a synthesis in the mind of the knowing person and exists only in his or her mind (Zins, 2007). Therefore, if knowledge is a property of people and includes foregoing understanding, experience and learning (Boddy et al., 2005), it is hard to argue that explicit knowledge, recorded in documents and information systems, is anything less or more than information (Rowley, 2007). This is also argued by Stenmark (2002) who states that explicit knowledge that can be expressed and made tangible outside of the human mind is information. In this trend, components such as lessons learned that involve explicit knowledge recorded in documents and information systems will be taken into account in this research as part of data sharing. By storing explicit knowledge in enterprise information systems or by sharing it between employees, a feedback loop is created from knowledge to data (see Figure 2.3). In this way, it is possible to capture knowledge and wisdom within the company into data, from which the interpretation can lead to new knowledge.

2.2.2. Intra-organisational data sharing

In this research, data sharing is defined as the operation of sending and/or receiving data from one person to another. Moreover, intra-organisational data sharing occurs among individuals, groups and/or organisational departments and can be seen as the beginning of open communication. This is of importance as the effectiveness and efficiency of processes within the construction industry are strongly dependent on the quality of communication (Hoezen et al., 2006).

Information sharing is crucial to the competitiveness of an organisation and requires a free flow of information among employees in and between work-groups that is up to date and undistorted (Moberg et al., 2002; Li and Lin, 2006). The free flow of information refers to the movement of data and/or information between members within the organisation. With the advances made in information and communications technology (ICT), the feasibility of sharing information across the firm has significantly increased. Nevertheless, extensive sharing of information within firms still seems to be the exception rather than the rule (Bock et al., 2005; Li and Lin, 2006). A lack of sharing across the firm has the potential to cost time and resources spent on replicating the same mistakes, leading to reinventing the wheel every time (Javernick-Will, 2011). Especially the construction industry that is renowned for its fragmentation and teams that are project-based and temporary (Whitley, 2006), faces additional obstacles to share information. The autonomous nature of

construction projects can lead to project teams becoming siloed, making organisational information sharing across projects challenging (Javernick-Will, 2011). This is even further emphasised for global firms that have to deal with the additional obstacle of geographical distribution. As a consequence, multinational firms spent many resources creating an information sharing network and communities of practice that are able to connect employees aligned in interest or tasks across geographical boundaries and try to gather and make information accessible across the firm (Javernick-Will, 2011). Such connections can enable new chances for information sharing by having entry to a larger variety of task-related information, which can lead to increased performance (DeSanctis & Monge, 1999).

The needs and behaviours of organisations in terms of information sharing have been found to be driven by the characteristics of the organisational culture and its appurtenant subcultures (Drake et al., 2004). To facilitate timely response activities, the sharing of information in the organisation and between and among the employees needs to be supported and encouraged by the organisational culture itself (Haythornthwaite, 1996; Hatala and Lutta, 2009). Moreover, Li and Lin (2006) observed that information sharing is stimulated through top management support and trust between work-groups or individuals.

Drake et al. (2004) state that one way to think about information sharing is as a value chain within organisational subcultures. In doing so, it is important to realise that each subculture tends to:

1. require different data, information, and knowledge to do its work.
2. have different abilities and propensities to collect and acquire its own data.
3. gather data about the world in different categories, using different metrics that have specific and not always easily translated meanings.
4. have different requirements for and uses of the outputs of its information.

In this way, they observed that each subculture sees itself with different roles in, contributions to, and purposes for the value chain. These differences can lead to potential challenges in coordinated and productive information sharing. For example, Huang et al. (2003) have determined that inconsistencies between subcultures and any possible subsequent clashing of values can have a negative effect on information sharing. The constant distribution of new information to important members within the firm is expected to lead to increased performance since quality and timely information aid top management in decision-making (Li & Lin, 2006).

Developing a positive behaviour towards information sharing will lead to an increased productivity of workers (Hatala & Lutta, 2009). By speeding up the information flow, an organisation can increase the efficiency and effectiveness and reply to clients' changing needs more quickly when information sharing is enhanced. Therefore, the organisations that stimulate information sharing have been observed to obtain a competitive advantage in the long run (Barua et al., 2007). The context in which information is shared may influence the quality of the information; think about factors such as the type of industry, the size of the firm, and the type of organisational structures (Li & Lin, 2006). To illustrate, hierarchical structures can lead to information overload due to the limitations on acquiring new information and regulations that result in bureaucratic red tape giving rise to delays in decision-making (Hatala & Lutta, 2009). Wheatley (2011) indicates that in the bureaucratic model, organisations are strictly controlling information flows. With the appurtenant limitations on access to and sharing of information, employees within the firm lack the ability to develop integrated solutions to problems. Due to a potential multitude of reasons, employees within a firm often do not share information if it is dispersed among groups within the organisation (Yang & Maxwell, 2011). The movement of information that crosses organisational and individual boundaries is conditional on the information sharing behaviour of members within the organisation. Limited information sharing among individuals and groups inside the firm is most likely to result in information gaps or information silos (Hatala & Lutta, 2009).

2.2.3. Organisational (social) structure and networks

In today's society, there is agreement that a multinational firm can be viewed as an international network that creates, accesses, integrates and applies knowledge in multiple locations (Almeida et al., 2002, p. 148). Though challenging, integration of information and knowledge held by members within the firm that span geographical boundaries enable the firm to add value (Kogut, 1989). More specifically, when firms are active in a multinational environment, research has shown that connections between people that cross physical boundaries can enhance opportunities to improve performance and improve entry to information (DeSanctis & Monge, 1999). The exchange of information within companies normally requires networks of organisational members (Barua et al., 2007; Hatala, 2006). Employees that are active within high-intensity networks

have a larger chance of accessing information of a higher quality in comparison with employees that are active in lower-intensity networks (Sinkula, 1994).

The support of top management and ICT enablers are regarded as facilitators for sharing information and quality information within the company (Hatala & Lutta, 2009). In the exchange of information, both formal and informal social network structures play a significant role (Hatala, 2006). Members within a firm often share essential information with people within their social network. If information is not considered essential, it is often given to people outside of their own networks (Haythornthwaite, 1996). Hansen et al. (2005) define a social network as subsets of established informal relations that exist within teams and across subunits in a firm. The information relationships show what sort of information is traded, between whom, and to what degree. The pattern of relationships between employees can increase exposure to specific sorts of information and also the probability of that information to be original and reliable (Haythornthwaite, 1996). Moreover, Haythornthwaite (1996) states that patterns of sending and acquiring information describe networks that exhibit how information is moved around and how individuals are positioned to facilitate or influence the information flow. In addition, she concluded that sharing of information inside firms depends to a large degree on relationships and the structure of the organisation itself. The relationship between actors is frequently used to determine what sort of information is exchanged and between which actors. Such data is also utilised in determining characteristics of positions held within a network and the characteristics of the network structure within the firm. The positions held in a network can reveal who controls, facilitates, or inhibits the information flow and which actors have comparable information needs or uses (Hatala and Lutta, 2009; Johanson, 2000). Thus a social network can be used to identify key players in information provision (Hatala & Lutta, 2009). Apprehending the social network and the specific relationships within the firm is therefore crucial in successfully implementing any organisational change (Haythornthwaite, 1996).

Actors can dynamically form their social networks by creating new network ties to other actors, taking part in the mobilisation of resources, and by utilising social establishments to facilitate their actions (Rosenkopf et al., 2001). Firms generally facilitate the creation of formal network structures. Informal networks are created when information exchange occurs based on local needs. Haythornthwaite (1996) states that the rapid increase of new options in accessing information such as the internet, email, online journals and others, and the way in which information needs cross organisational roles indicates the significance of informal networks in an information-dependent economy. Moreover, social networks are important in promoting the sharing of information and knowledge between members within the firm (Yang & Maxwell, 2011). Wheatley (2011) holds the opinion that information and knowledge can grow from connections in social networks where continuous reciprocal exchanges of information occur, and information and knowledge is not accumulated by individuals but actually shared with others. In that manner, information exchange also needs the support of the firm in terms of the requisite social structure (Hatala & Lutta, 2009). Information at the personal level is harder to access, particularly in firms that have very stiff social structures. Firms that support both the formal and informal exchange of information encourage information exchange. For firms that don't and are still very traditional and silo-like, the opposite applies (Hatala & Lutta, 2009).

The types of networks relevant for this research are found in the social network of individuals. The options are threefold. The first network can be seen in Figure 2.4 and is a network that often follows from a more traditional information sharing structure, in which all members of the network share data directly with each other, which leads up to information overload, redundancy and irregularities in the process (Heras, 2019). The second network can be seen in Figure 2.5 and is a network where project team members store data into a single environment and in which the data is accurate and available for all organisational members. Advantages in comparison with other firms and in terms of productivity can be attained if firms strive for such an environment (Alreshidi et al., 2018). The common data environment (CDE) would act as a central archive in which the relevant construction project information is stored. By using a single information source, cooperation between individuals should be enhanced, the possible mistakes reduced, and replication avoided. The third option is a network that is a combination of both the first and second networks. Here data and information are shared between employees in addition to having a common data environment (with potential limitations to the access of data by certain positions held).

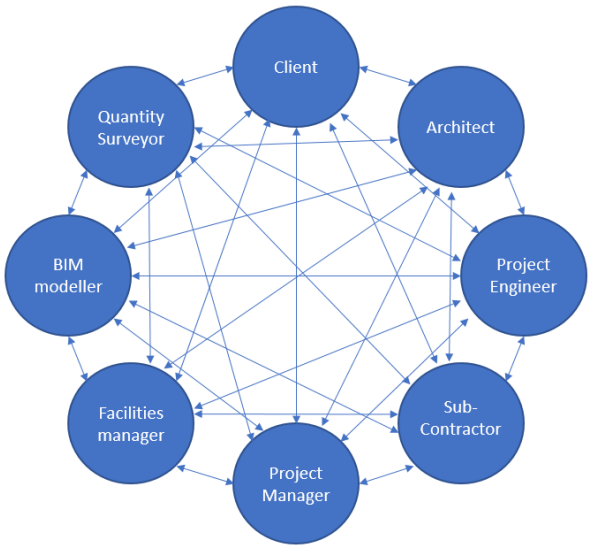


Figure 2.4: Traditional data sharing environment (own elaboration based on Alreshidi et al. (2018))

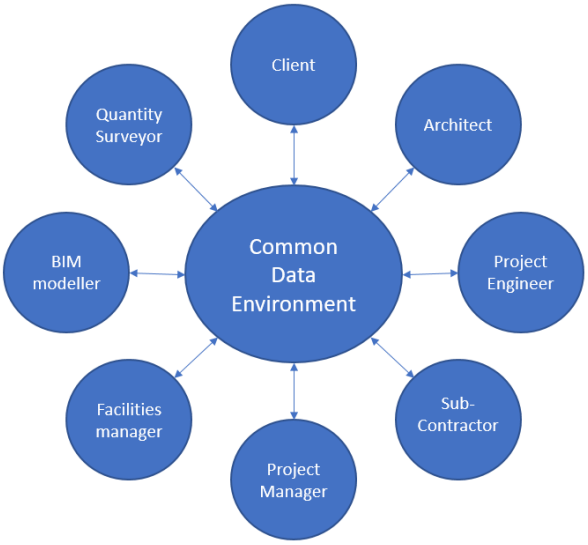


Figure 2.5: Common data sharing environment (own elaboration based on Alreshidi et al. (2018))

In larger teams, the exchange of information is hard due to the fact that a team member may possess an important piece of information but does not know which member needs that information since it is impossible to know what every other team member is doing or needs. Thus the main reason as to why communication decision making is tough is not that it is inherently hard, but that not a single member has all the needed information to decide where to send the information to or whom to send it to (Xu et al., 2004). Through obtaining awareness of current information flow routes, the providers of information can identify opportunities and act upon this by creating alterations to existing information routes, enhancing the delivery of information services.

2.2.4. Intra-organisational barriers

Businesses and society can benefit tremendously from removing barriers that negatively influence information exchange. Most of the identified barriers are related to the use of organisational systems, the attitude of the organisation towards information sharing, relationships between members within an organisation and how information is treated as an asset (Barua et al., 2007; Li and Lin, 2006; Drake et al., 2004). The sharing of information can be seen as a three-step procedure, namely information acquisition, information dissemination and information interpretation (Drake et al., 2004; Sinkula, 1994).

Scholars have determined a large number of determinants that may be considered by employees of a firm as barriers to their sharing of information (Goodman & Darr, 1998). For example, when an employee wants to share tacit information and knowledge, he or she may spend a lot of time and effort to articulate, prepare and arrange the information. Moreover, the employee might also expect that the sharing of information elicits requests for further clarification and help (Yang & Maxwell, 2011). This extra work could interfere with the employee's own work time and resources. In addition, there may exist a sense of fear for becoming subjected to criticism due to the potential of the information being inaccurate and irrelevant. Therefore, without obtaining clear recognition and benefit for the employee's contribution, an employee could be hesitant to share information (Goodman & Darr, 1998). In addition, factors related to behaviour such as leadership, reciprocity, responsibility, communication and commitment have been determined to have an influence on data exchange as well (Ibrahim et al., 2019; Constant et al., 1994).

Willem and Buelens (2007) state that people only tend to share information when they have the feeling that they are protected against opportunistic people. Thus, trust between the individuals that are sharing information is crucial (Zhang et al., 2005). As trust can improve communication and stimulate efficient information sharing (Willem & Buelens, 2007). Therefore, the lack of trust between individuals can create barriers in organisations with respect to information sharing. There are also firms out there that purposefully limit the sharing of information due to the threats of industrial espionage and/or concerns about deflecting or overloading the work-related attention of members within the organisation (Drake et al., 2004). Individuals are

also prone to retaining information if they perceive that the act of sharing such information can lead up to the loss of power, their influence or possible promotion (Bock et al., 2005). Demographics can also act as barriers within firms, for example, the diversity in the background of the people sharing information. These factors have been shown to add to the perception of ownership and inclination to share information (Drake et al., 2004). Furthermore, sharing information also comes with costs, such as the loss of exclusivity to information and the time and effort coupled with sharing information. Therefore, it is essential for members within an organisation to be provided with positive motivation that transcends the reductions placed by the barriers, to partake in information exchange (Barua et al., 2007).

In Figure 2.5 the sharing of information that uses databases can be seen. This is also called mediated sharing, as the database acts like a medium from which other members can retrieve information or store information. Nevertheless, this requires employees to show responsible behaviour in all communication such that they can contribute to the information sharing process. Here the organisational social structure is very significant in the information sharing process. Because the information users need to be prompted to start a search in the database (Barua et al., 2007; Li and Lin, 2006). The type of medium utilised in the information exchange may also be a root of problems instead of the willingness of employees to share information. This is due to the fact that Barua et al. (2007) determined that individuals may actually be willing to share information. However, the endeavour of using the existing technology might be too great. Though in recent years, many advances have been made in information and communications technology, which led to firms developing information systems that aid in sharing data and information among employees within a company (Barua et al., 2007). In conformity with the Technology Acceptance Model (TAM) of Davis (1989), perceived ease of use and perceived usefulness are two fundamental factors for employees of a firm to decide on the acceptance of a new information system. Moreover, Goodman and Darr (1998) state that for members of an organisation, it takes time and effort to master new information technology systems to contribute to information sharing. In addition, Li and Lin (2006) have discovered that information sharing can be improved by user-friendly IT applications and by a high level of use of IT applications by employees. Thus, inside a firm, when the used information technology is hard and inefficient to use, the IT usage of employees will be lower, and activities related to information sharing could be negatively influenced.

2.2.5. Data compatibility and accessibility

In the current construction industry, activities are often data-driven (Sarkar & Thakkar, 2018). Tremendous amounts of data sets are created during the different stages of a construction project. Just to pick a few out of the vast number of possibilities are data sets originating from specifications, BOQ, spatial data, user behaviour, location data, cost data, risk data, design variables and many more (Ayodele & Kajimo-Shakantu, 2021). All these data sets should be easily available and accessible to employees that might need them. Nevertheless, organisational members are having a growing difficulty in accessing such data (Ayodele & Kajimo-Shakantu, 2021). Failure of project members to gather and share data correctly during a project will result in loss of that data (Zhang & Ng, 2012). This can come due to the fact that data sets generated during the project life-cycle are often not maximally utilised because of the inconsistent ways in which the data was produced and shared. Data collected and combined across companies are frequently not compatible with existing databases due to the unstandardised ways of data assemblage during project execution (Ayodele & Kajimo-Shakantu, 2021).

In general, businesses can distinguish between structured and unstructured data. These types of data exist in all the different stages of a construction project and in tasks such as risk management, quality management, cost control, safety, planning, design, etcetera (Martınez-Rojas et al., 2016). Both types have their own attributes and are perpetually produced throughout the project life-cycle. Structured data is of a quantitative nature and exists out of arranged classified values. Examples of structured data can be the bill of quantities, staffing hours, costs and any other numerical value (Soibelman et al., 2008). Furthermore, structured data is generally found in spreadsheets or relational databases that organise the data into rows and columns (Blumberg & Atre, 2003). When stored in databases and organised, properly structured query language (SQL) can be used to analyse the data, which enables filtering, measuring and comparison of the data contained in the database (Bilal et al., 2019). On the other hand, unstructured data is often qualitative data, which does not have any pre-established format, making it more difficult to compare, analyse and process. Examples of unstructured data can be videos, memos, emails, images, reports, surveys, white papers, textual documents, etcetera (Blumberg & Atre, 2003). This sort of data needs more storage space than structured

data and is more descriptive and unstandardised, which makes it harder to analyse. Therefore, unstructured data is likely to result in data manageability issues which can obstruct the use of the generated data (Vo-Tran & Kanjanabootra, 2013). Moreover, the struggle of storing unstructured data often results in rising difficulty of data recovery, below par integration of data management systems and increasing problems with re-using information (Martınez-Rojas et al., 2016). In table 2.2 an oversight of the characteristics of structured and unstructured data can be seen. Other challenges connected to unstructured data are inconsistency in content and difficulty in comprehending the data set (Ruddock, 2002). At the moment, the largest part of the data produced during projects and stored in firm's databases is unstructured data. Merrill Lynch has estimated that around 85% of all business information is present in the form of unstructured data (Blumberg & Atre, 2003). Therefore, the interoperability and compatibility of data are established as barriers that affect the usefulness of data for members of the firm.

Structured data	**Unstructured data**
Quantitative data	Qualitative data
Can be organised in columns, rows and databases	Cannot be organised in columns and rows, and has limited organisational capabilities in databases (classifications/taxonomy)
Numerical or organised categorical values	Video's, figures, images and texts (unstandardised formats)
Uses SQL	SQL and other database communication languages
Approximately 15% of the data	Approximately 85% of the data
Needs less storage space	Needs more storage space
Better data manageability	Inferior data manageability

Table 2.2: Characteristics of structured and unstructured data based on Blumberg and Atre (2003) and Bilal et al. (2019).

The challenges with these barriers are tremendous because there are no universally accepted standards when it comes to the generation, storing, gathering, and assemblage of data in the construction industry. This lack of standardisation associated with data gathering and storage in the construction industry is often magnified by the silo operations in the construction industry (Ayodele & Kajimo-Shakantu, 2021). The problem with the presence of unstructured data and the associated effects in terms of compatibility and interoperability is that it can have disadvantageous effects on the competitiveness of firms with respect to how they manage costs and handle investment decisions, just to name a couple (Vo-Tran and Kanjanabootra, 2013; Ayodele and Kajimo-Shakantu, 2021). This is due to the fact that data is frequently used as a strategic tool in minimising costs or ensuring timely delivery of the project. Martınez-Rojas et al. (2016) have observed that the successful fulfilment of a firms' investment goals is dependent on the extent to which data is available. Thus if data is unavailable, it will expose the investment to risk, which as a result will have a direct influence on both the client and the firm. This is also shown by Bilal et al. (2016), who determined that project decisions are delayed, and incorrect judgements are made due to the absence of robust data. Therefore, if the quality of the investment decisions are strengthened by the quality of the actual data, it is then logical that the availability of accurate data would enhance an individuals ability with respect to identifying problems, coming up with solutions and aiding in decision-making (Ayodele & Kajimo-Shakantu, 2021).

In the current work environment of the construction industry, projects frequently have tight deadlines which they need to fulfil. As a result, project managers are often forced to make decisions based on incomplete data, while simultaneously project engineers have to make calculations based on premature data until the correct and complete data is finally available (Westin, 2014). However, the problem with that is that this can lead to unanticipated and excessive costs in the later stages of the project. This is due to the fact that alterations and redoing of work become more expensive as the project progresses with time. Moreover, the possibility to influence the impact and costs of the project are highest in the stages before construction commences; this is all illustrated in Figure 2.6. Thus, if the information is accurate and available at the beginning of the project life-cycle, the chance of design alterations and potential corrections later on in the life-cycle of the project becomes smaller. Moreover, Casas-Arce et al. (2017) established in their research that adding decision-facilitating information to the information set of organisational members has positive influences on the individuals' decision-making behaviour. Therefore it is of the essence to have the right data available at

the beginning of the project and enhance the estimations made.

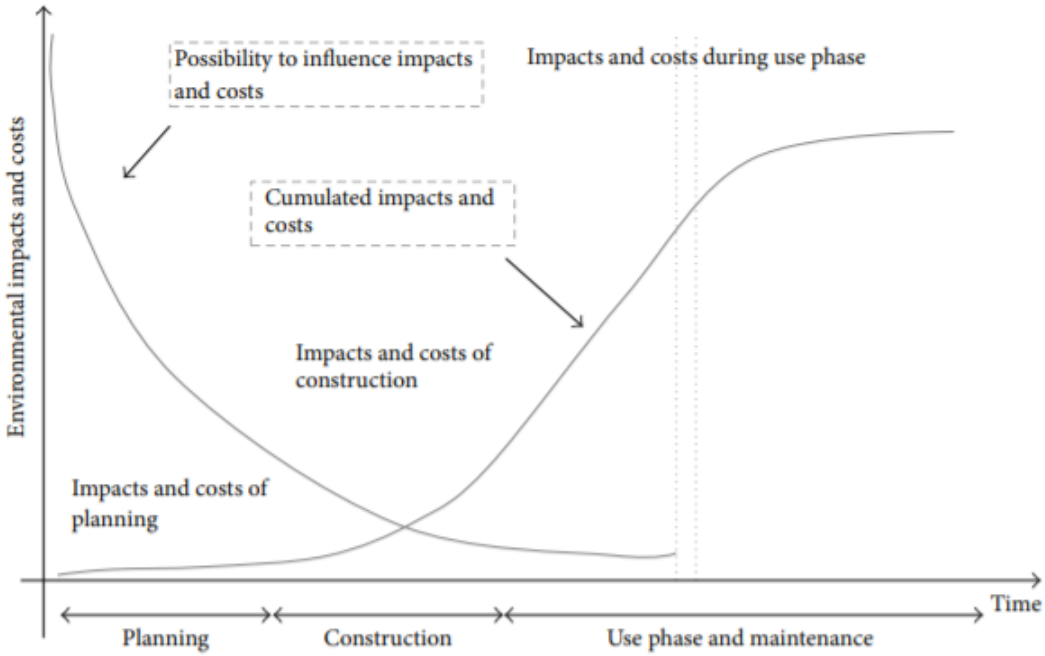


Figure 2.6: Influence of design decisions on life cycle impacts and costs (Bragança et al., 2014)

Data produced at a personal or company level could be valuable to other organisational members when it is assembled correctly and turned into intelligence. In such a case, it is anticipated that data is valid, reliable, transparent and similar to international standards (Ruddock, 2002). Nevertheless, it has been observed that the main roots of budget and time overruns are substandard and untrustworthy data (Ahiaga-Dagbui & Smith, 2014). Westin and Sein (2014) have researched in their article when data is presumed to be suitable and up to standard. They ascertained that data quality could be assessed through a set of dimensions. In their review of data quality methodologies, they determined that the four dimensions that were emphasised most were timeliness, accuracy, completeness and consistency. Dimensions such as these are the elements on which data and information quality assessment frameworks are built (Westin & Sein, 2014). Moreover, the dimensions of accessibility, logical coherence, security and relevancy have been determined as additional dimensions that are relevant to an engineering organisation in terms of data and information quality, next to the previously mentioned dimensions. If existing data or information is shared and does not comply with these dimensions, only meagre value can be extracted.

3

Methodology

In this chapter, the research methodology is explained, following from the literature review. At first, the mixed method research is explained together with the case selection in section 3.1. Then in section 3.2 the workings of the social network analysis are elaborated upon, including the data collection and analysis. Thereafter, the results from the social network analysis will be used as input for the expert session in section 3.3, where the findings will be validated with the use of an expert panel. Furthermore, this research will be conducted using an inductive research approach. This approach does not involve the formulation of a hypothesis. It starts with research questions, aims and objectives that need to be achieved during the research process (Dudovskiy, n.d.). With an inductive approach, one generalises from the specific to the general. Moreover, here the researcher collects specific data, which is used to explore a certain phenomenon, and after collection, analyses this data to come to a generic conclusion (Dudovskiy, n.d.). Therefore, by applying an inductive approach, this research aims to generate a theory based on patterns and observations obtained in the case study.

3.1. Mixed research method

This research makes use of a mixed research method, which means it will make use of both qualitative and quantitative analysis and data collection. The main research will be performed through the use of a case study, analysing organisational decision-making and the data sharing behaviour of organisational members within finished BAM tenders. Case studies are befitted for this part of the research because they respond to the questions 'why' and 'how' (Yin, 1981), which suits this research with the main research question being of a 'how' nature. In addition, case studies are typically used in topics that include organisational decision-making (Yin, 1981)) and focus on behaviour and perceptions (Yin, 2009b) of involved stakeholders. These are all reasons that advocate that the chosen research approach of a case study is a suitable one. In the case study, multiple techniques are used to retrieve, organise, and finally analyse information. Unique in comparison to other qualitative approaches within case study research is that investigators can collect and integrate quantitative survey data, which facilitates reaching a holistic understanding of the phenomenon being studied (Baxter & Jack, 2008).

This research will investigate the intra-organisational data network of multiple tenders within BAM. Here use is made of a holistic multiple-case design, which is illustrated in Figure 3.1. This is done to create a holistic understanding of a phenomenon by observing two different single units of analysis as shown in Figure 3.2.

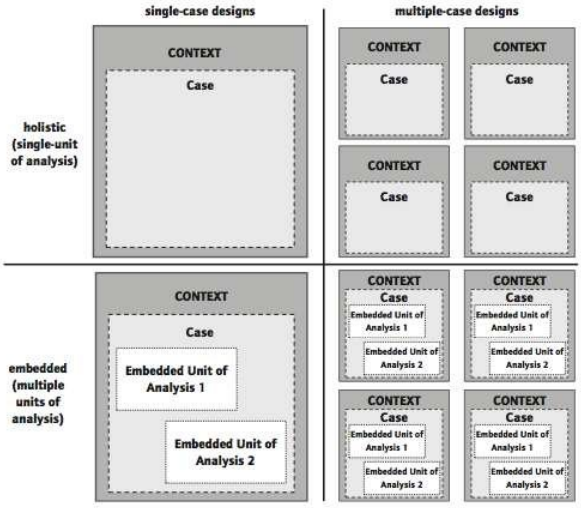


Figure 3.1: Basic types of case study designs (Yin, 2009a).

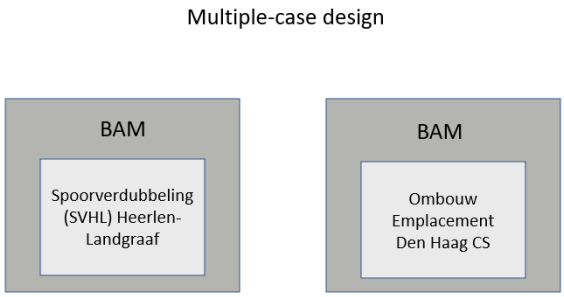


Figure 3.2: Multiple-case design including different tenders within BAM.

Studying multiple cases enables the researcher to understand the differences and similarities between the cases (Baxter and Jack, 2008; Gustafsson, 2017). In addition, the researcher will be able to analyse the data both within each situation and across each situation (Yin, 2009a). According to Yin (2009a), multiple cases can be used to (a) either predict similar results or (b) predict contrasting results but for predictable reasons. This type of study comes with its advantages and disadvantages, but in any case, the evidence created from a multiple-case study is considered robust and reliable (Baxter & Jack, 2008). The data gathering will predominately occur sequentially, in which the output of the data analysis in the previous stage will serve as input for the data analyses executed in later stages. This is illustrated in the research design, which is shown in Figure 3.3.

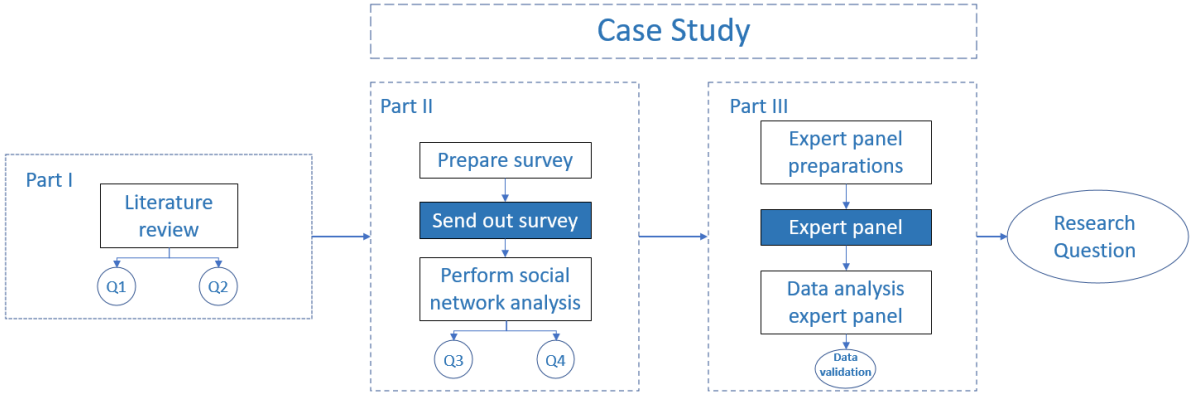


Figure 3.3: Schematic overview of the research design.

Different research methods have been used for the different parts of the case study. For Part II, the research method was a social network analysis, and here quantitative data is collected through the use of a survey. With the help of this method, an oversight can be created of the phenomenon over time and space (Verschuren et al., 2010). Results will help visualise and analyse the data sharing network and simultaneously create a more extensive understanding of the research components and the underlying relationships. Moreover, due to the fact that data is gathered from a larger sample size, it will support the generalisability of the findings.

In the third part, use was made of an expert panel, which is of a qualitative nature. By applying a qualitative research in the case study, a more in-depth understanding can be attained due to the more detailed nature of the research. Overall this research uses more qualitative methods than only expert panels such as

a literature review, informal interviews, and document/system investigations. These are all combined in the end to obtain a greater variety of sources used for verification (Yin, 2009a). Lastly, qualitative data gathering can be mustered with a smaller sample size, thus fewer respondents, but also takes more time (Verschuren et al., 2010).

3.1.1. Case selection

This research focuses on analysing data sharing networks of different tenders within the Dutch branch of BAM. As stated in the previous section, selecting the right cases has to be done carefully, as this will greatly influence the results and the conclusions one can draw from them. That is why before the commencement of the case study, requirements are set to which the tenders should adhere before they are deemed eligible. These requirements are presented in table 3.1. When the tenders are deemed eligible, interviews are performed with the tender managers to confirm that the cases adhere to the requirements and are suitable for use. Lastly, it has to be noted that the selected cases were both cases that took place in The Netherlands. This was not a requirement of the research, but unfortunately, only cases performed in The Netherlands will be researched due to the inability to collect data on foreign projects. Therefore, the multinational context will not be considered, and the focus will be on the Dutch branch of the researched multinational.

Project condition	Explanation
Project phase	All the case projects should be finished tender projects, finished in the past 18 months at the latest, as the scope of this research is set during the tender phase.
Data network	All case projects should have had a properly functioning and presentable data sharing network.
Project team size	All case projects should have a minimum of 10 people in the tender team.
Project scope	All case projects should be similar in terms of project scope (e.g. rail project, bridge project, highway project etc.).
Project size	All case projects should be medium to large projects and similar in size.
Contract scope	All case projects should have the same contract scope (e.g. DB, DB(F)MO, etc.).
Project location	All case projects should have different locations. Overall, the specific location is not relevant, but country borders should separate at least two tenders to examine the multinational context of this research properly.
Project risk level	All case projects should at minimum be classified with a level c risk category by BAM.

Table 3.1: Eligibility requirements BAM tenders.

3.2. Part II: Social network analysis

After case selection, a social network analysis is performed. The social network analysis is used mainly to expose different patterns and structures in the information sharing networks of the distinctive cases. In order to perform a social network analysis properly, different measures need to be taken. These measures are all contained in the following sections. In section 3.2.1 the principle of the social network is explained and what can be achieved with the use of such a research method. In section 3.2.2 the data collection is elaborated upon. Lastly, the data analysis with the help of a Gephi environment is explained in section 3.2.3.

3.2.1. The principle of the social network analysis

The Social Network Analysis (SNA) is a research method that uses qualitative and quantitative analyses to investigate the social structures within networks with the help of network theory. Recently, the method has enjoyed prolific success in construction engineering and management research to study projects, intra-organisational networks, and analysing intra-organisational relations in a multinational context (Javernick-Will, 2011). The social network theory helps describe the social structure and mechanisms between persons that exist within organisations (Wasserman, Faust, et al., 1994). More concrete, it is the study of how the relationships of a person, group or organisation can affect behaviours (Hatala & Lutta, 2009). While the term 'network' generally refers to a set of nodes (people) and the mapping of the interactions or relationships between them (Wasserman, Faust, et al., 1994). By understanding the mapping of a network that links individuals to other individuals, it is possible to learn a great deal about how individuals use their connections to achieve desired outcomes (Coleman, 1988). From an organisational perspective, individuals within the network are able to boost performance or move upward depending on the connections they have with other individuals.

In this research, social network analysis is a research method that uses different techniques to examine the exchange of resources among individuals, with that resource being data. The regular patterns of data exchange between people illustrate social networks (see Figure 3.4), in which the individuals are nodes in the network and the data exchange relationships are the connections (edges) between the nodes. By using a social network analysis, one can evaluate the information opportunities for nodes in terms of their control of data or exposure to data. In this manner, awareness can be gained of existing data exchange routes, and possible interventions can be determined such that data providers are able to act on data opportunities and are able to make alterations to existing data routes that will improve the delivery of data services (Haythornthwaite, 1996).

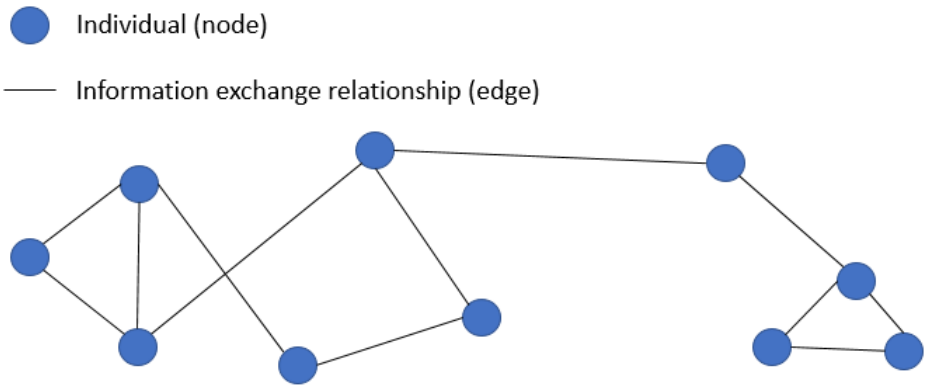


Figure 3.4: A simplified example of a social network (Own illustration).

A social network analysis has demonstrated to be a reliable and suitable instrument to inspect project networks and to map the (in)formal relationships between the individuals active in the projects (Javernick-Will, 2011; Hatala and Lutta, 2009; Wasserman, Faust, et al., 1994; Haythornthwaite, 1996). Organisational network analysis has also shown its potential in identifying data silos and influential/key players in a network (Farshchi & Brown, 2011). Identifying key roles is a popular reason for researchers to use a social network analysis. This is due to the fact that key roles can be seen as influencers in a network that, among other things, can be utilised to spread the information more quickly through the network (Zhu et al., 2014). In addition, key roles are used in evaluating and predicting future data flows. A few of the various formal theoretical attributes in the network analysis include centrality (degree, betweenness, and closeness), the strength of ties (strong or weak and weighted), cohesion (groups, clustering), and division (structural holes, partition) (Wasserman, Faust, et al., 1994; Hatala and Lutta, 2009). These attributes represent the fundamentals for developing and conceptualising network theory and are used, for example, to determine the key players in the network. The network theories involved in social structures are concerned not only with quantitative studies of social networks but are also concerned with the process in how theory is formed and the identification of relationships and contextual effects (Hatala & Lutta, 2009). In literature, most social network analysis studies are quantitative and are focused on the analysis between organisations. However, this research will particularly focus on the data sharing networks within the firm.

3.2.2. Data collection

Most studies that perform a social network analysis make use of a case study (Hatala and Lutta, 2009; Javernick-Will, 2011; Haythornthwaite, 1996). The similarity between the studies is that they make use of a survey to retrieve relevant data. Similarly, this research also uses a survey to retrieve information from the respondents such that data can be collected about the case projects and the corresponding data sharing network. The data collection aims to retrieve information about the data users, data creators, and data routes such that the data sharing network can be mapped. This will help analyse the network and find potential barriers that distort the utilisation of data. Cases are selected based upon the eligibility criteria set in section 3.1.1, and after consultation with the tender managers of the respective projects, team members have been approached to participate in the survey.

In addition, the survey contained statements and questions related to the identified risk awareness factors from literature (see table 2.1). This enables the researcher to say something about the identified factors in practice. To summarise, the survey consists of three parts: The first part relates to the risk awareness details, the second part relates to the social network analysis and is used to map the data sharing network, and the last part is used to retrieve some demographic information details from the respondents. For the creation of the survey and data collection, use was made of survey software Qualtrics, through a paid license of the TU Delft. This software helps in the ease of use for respondents and for the retrieval and reporting of the obtained data. The survey has been sent out in Dutch and English due to some participants' insufficient control of the English language. The English version of the survey is included in this report and can be seen in appendix C. Furthermore, to help map the existing data sharing network, Gephi, an open-source SNA application, was used. Lastly, due to privacy reasons, the names of the participants will be anonymised and replaced by numerical codes.

3.2.3. Data analysis

When the data collection is wrapped up, the next step will be to visualise the results with the help of a social network application and analyse the data to complete this part of the research. The first step in the data analysis is to perform a social network analysis for each respective case project. After this, the cases will be compared and examined on similarities and differences, which enables the researcher to analyse the data both within and across each situation (Yin, 2009a). If enough links exist between people that are active in the different tenders with respect to the existing social networks, a network will be created in which the two networks will be integrated into one, and an additional social network analysis will be performed on the entire network. For the data analysis, use will be made of Gephi, this is a free and open-source software created to aid in network data analysis (Bastian et al., 2009). It helps researchers to reveal patterns and trends, highlight outliers and visualise their data, as it uses a 3D render engine to display large social networks (graphs). For the use of Gephi, no prior programming experience is needed. In addition, Gephi contains pre-coded metrics and codes that automatically help the researcher draw graphs and analyse the networks. Each to be produced network will contain multiple visual graph elements. In table 3.2 a description is given of all the visual elements that will be present in the to be created social networks, including their meaning and sometimes reasoning behind them.

Elements	Element descriptions
Nodes	The nodes represent the people involved in the project. Each of these nodes has a distinctive work role which can be categorised in the visualisation by color. In some cases the colours can look similar due to the wide variety of work roles and limited distinguishable colours. Therefore, if one can't distinguish between the nodes due to similarities in colours, one can look up the nodes with their respective labels and work roles in appendix D. The different roles and corresponding colours can be seen below: • Tender manager: Light orange • Tender management assistant (tenderstrateeg): Mint green • Design management: Light Blue • Engineering management: Brown • Contract management: Grey • Drafting/ Modelling/ BIM: Red • Risk management: Dark Blue • Estimating: Green • Construction management: Pink • Planning: Yellow • Site engineering: White • Procurement: Dark orange • Other specialist (HSE/Sustainability/Geotechnical/etc.): Purple

Edges	The edges represent the data streams between different nodes, and in this research, the edges are weighted. In the visualisation of the network, the weights will be reflected in the thickness of the lines representing the edge, with a higher weight indicating a stronger connection and thus a thicker line. The elements used for determining the weights are the following: • Frequency - Each actor in the network has a frequency in which the node exchanges data with other nodes. The frequencies are defined as followed: – Daily data exchange: 7.0 – Weekly data exchange: 5.0 – Monthly data exchange: 3.0 – Occasional data exchange: 1.0 • Value - Each edge is assigned a value based upon the perceived value of data by the data receiver. The values are defined as followed: – Very high: 7.0 – High: 5.0 – Average: 3.0 – Low: 1.0 The tie strength is a measure of the strength of a relationship between two nodes and can be expressed in terms of weight. Therefore, as said previously, the edges are assigned weights. In this research, the weight assigned to the edges will encompass the frequency of data exchange and the value of the obtained data. More specifically, this is done by taking the sum of these two elements and then assigning that as weight to the edges between the nodes.
Graph layout	The graph is visualised using the ForceAtlas layout. This lay-out is specifically used to spatialise small-world networks. It pushes the nodes with a high number of output links to the periphery and the nodes with a high number of input links in the centre. Moreover, the node size is in proportion with the weighted degree of the nodes. Therefore, the most central and highly connected nodes are bigger than the less connected nodes. Direction - The choice was made to represent the graph as an undirected graph. This entails that the edges between the nodes are undirected, and no distinction is made between sender and receiver. This has been done due to the following reasons: • Such that there is no distinction between the people who filled in the survey and the people identified by the respondents. • Thus, the assumption is made that the data streams between two connected nodes are reciprocal instead of a one-way street.

Table 3.2: Description of the visual elements in the social network application.

During the social network analysis, network theory is applied to analyse the visualisation of the social network and the relationships between different members within the organisation. Identifying patterns and structures will help attain a comprehensive understanding of the network, which will first be done by analysing the visualisation of the network qualitatively. Thereafter, the qualitative analysis will be enriched by the quantitative functions embedded in Gephi. The quantitative analyses will mainly exist out of centrality measures, which can be used to identify structures, weaknesses and key/central nodes in the network. Furthermore, the following techniques will be used to analyse the social networks of the case studies (Chinowsky et al., 2010; Haythornthwaite, 1996; Lee et al., 2018; Hatala and Lutta, 2009; Du, 2020; Krnc et al., 2018):

- **Network density** - The density of a network indicates the degree to which members are connected to all other members in that same network. It is estimated by dividing the number of actual links of a node by the number of possible links in the network. In low-density networks, the information can travel

through fewer routes, while the information in high-density networks can travel from and to a number of different actors. Therefore, information can be expected to flow more freely among members in a high-density network than in a low-density network.

- **Degree centrality** - Degree centrality is the most simple form of centrality and simply measures the number of direct connections a node has to other nodes. Generally, nodes with a high degree are the local connectors.
- **Closeness centrality** - Closeness centrality measures the average distance of a specific node to all the other nodes in the network. Generally, nodes with a high closeness can more easily spread information to the rest of the network and often have a good oversight of what is happening in the network.
- **Betweenness centrality** - The betweenness centrality measures the number of times a node is present on the shortest path between two other nodes. Therefore, it identifies all the shortest paths in the network and counts how many times the node is present on these paths. Nodes with a high betweenness act as bridges between nodes in a network and have more control over the flow of information. However, they can also be potential single points of failure.
- **Eigenvector centrality** - Similarly to the degree centrality, the eigenvector centrality measures the influence of a node based on the number of connections it has to other nodes in the network. However, the eigenvector centrality goes beyond this by also considering how well connected a node is, how many links the connected nodes have to other nodes, and so on. Generally, eigenvector centrality can identify nodes that strongly influence the whole network, but they may not have the most substantial local influence.
- **Clustering coefficient (Network clustering)** - The clustering coefficient can be seen as a form of centrality, although one that takes on small values for influential individuals and is a measure of the degree to which nodes in a graph cluster together (Du, 2020). A node's clustering coefficient is calculated by dividing the number of closed triplets in the node's neighbourhood by the total number of triplets in the neighbourhood. It is also known as transitivity. Evidence indicates that in most real-life networks, the nodes have the tendency to create tightly knit groups that are characterised by a relatively high density of ties (Du, 2020).
- **Eccentricity** - The eccentricity of a node in a network is the maximum distance from that node to any other node in the network. Thus it is the distance from the starting node to the farthest node in the network. Thus a higher eccentricity number indicates that the furthest away node in the network is a long way away. This says something about the connectivity of a node in the network. It shows how 'quickly' a node can transfer information to the furthest away node and says something about the node proximity of that particular node with respect to other nodes in the network.

These are all techniques that can be used to analyse a social network to come to meaningful conclusions. It has to be pointed out that there is no single 'right' measure. Each measure gives a different perspective of the network, and through combining different techniques, a more comprehensive understanding of the network can be created. By providing more insight into the patterns and characteristics of the network, the researcher will also be able to analyse the different node types and how they function within the network (Figure 3.5). The outcome of this research method will be the basis of the recommendations given to enhance risk awareness in the tender phase. In addition, informal interviews will be used to clarify potential weaknesses or data sharing behaviour. Lastly, an expert panel will be used to validate the recommendations determined through the social network analysis and literature.

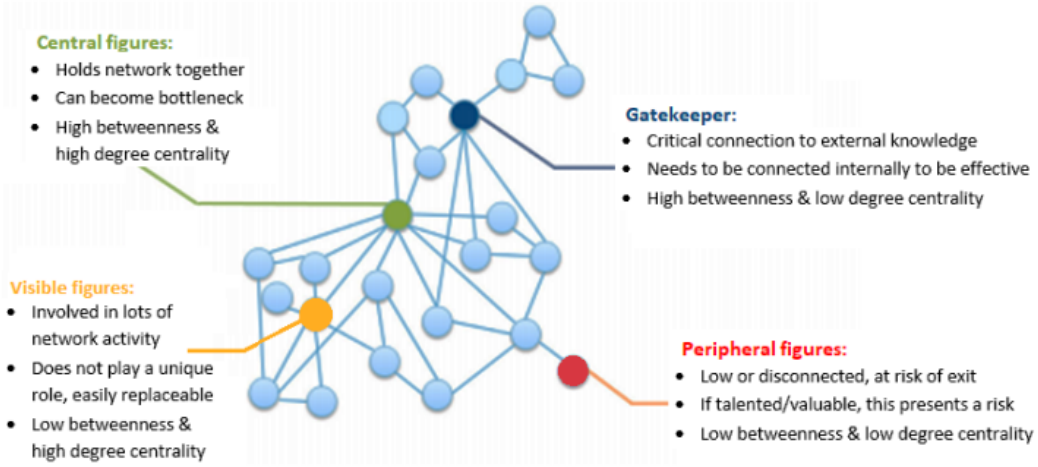


Figure 3.5: Node types in a network (Berck, 2020).

3.3. Part III: Expert panel

The last part of the research consists out of an expert panel, which is of a qualitative nature. Based on the observations and analysis of literature, a set of recommendations will be determined. These recommendations all have as end-goal to raise risk awareness among the tender team members within the organisation. After validation of the recommendations, a framework will be designed which can be used by construction companies as a strategy to improve risk awareness among the tender team members. So, first, the foundation of the recommendations will be laid. This entails a more elaborate explanation of why certain recommendations are made and which observations have led to this. Next to this, certain assumptions are made in the report based on the literature study and case study. The recommendations for interventions are given based on the presumption that these research assumptions are true. Therefore, the main goal of the expert panel is to validate the research assumptions and the given recommendations. This will be done through an expert panel with experts from the industry currently active within BAM. With the expert panel results, only the validated recommendations will remain, and a framework can be designed that works as a guide for construction companies on how risk awareness can be improved across tenders, with the main focus being on data sharing interventions.

To structure the expert session, a PowerPoint presentation has been made and can be seen in appendix E, here also a more detailed approach to the expert session is described. The recommendations in this presentation are all based upon the foundations stated in chapter 5. Furthermore, four days before the expert session, the experts received a document that contained the research assumptions and main concepts. Here the experts were asked prior to the expert session to indicate if they agreed or disagreed with the research assumptions. As a result, limited time is needed to be allocated during the expert session for validating the assumptions. This was done to save time during the expert panel as there were many recommendations to be validated and to make sure the experts were informed prior to the session. Moreover, a semi-structured approach was taken. This has been done as structure was needed to validate all the recommendations. However, on the other hand, it was also valuable to be able to ask follow-up questions to really get to the bottom as to why yes or why not and to be responsive and open to new insights.

Due to COVID-19, the expert session was performed online through Microsoft teams. The session started with an introduction round and an explanation of the research subject and objectives. After that, the main results of literature and the case studies were presented and elaborated upon. During the validation of the recommendations, there was ample opportunity to request extra information about the recommendations and ask for additional clarification when something was unclear. After presenting the main findings, the validation of the recommendations could commence. After asking the opinion of the experts regarding the recommendations, an open dialogue was held between members of the expert panel to discuss the added benefit of the recommendations and come to a consensus. During the session, the place of the researcher was more to moderate the discussion and give clarifications about the recommendations when needed. As a result, the researcher validated the recommendations, and a framework could be created.

4

Case Study

In this chapter, the social network analysis is performed. Here data is collected and used to analyse the data streams between actors in the network and to give insights into the structure and patterns of the data sharing network. In addition, data is collected and analysed that specifically focuses on addressing the identified risk awareness factors from literature. The chapter is divided into three sections. First, project A is discussed in section 4.1, which is subdivided into four different subsections. In section 4.1.1 the data sharing network of project A is visualised, and some general information about the network is given. After which, the network is analysed in more detail in section 4.1.2. Then in section 4.1.3, a more extensive analysis is performed that looks specifically into the different node types and which roles are associated with which node type. Lastly, the section is concluded in section 4.1.4, where statistics are retrieved from the survey that particularly focuses on the identified risk awareness factors in practice.

Project B is analysed in section 4.2 and follows the same build-up as section 4.1. Lastly, to conclude this chapter, a cross-case comparison between the two different cases is performed in section 4.3.

4.1. Project A: Spoorverdubbeling (SVHL), Heerlen-Landgraaf

Project A is located in The Netherlands, with the main deliverable being a heavy rail project. The works exist out of doubling the track between Heerlen-Landgraaf in combination with enabling works, modifications to the catenary system, train security system in accordance with the RVTO and various civil engineering works surrounding the project that were needed to enable the doubling of the track. The tender was executed in 2020 and included a Build and Detailed Design/Engineering contract scope. The basic BAM tender team consisted of 17 employees, making it the smallest of the selected cases up till now. Furthermore, out of the 17 approached employees, a total of 13 employees filled out the survey. This resulted in a response rate of 76.5%, which is far above average for surveys (Baruch & Holtom, 2008). However, more than the initial 17 employees have worked on the tender during the project. However, it has to be noted that these people have not been invited to participate in the survey due to their limited contribution. The whole tender has been executed in The Netherlands. Furthermore, it has to be noted that the team members worked mainly from home due to COVID-19. Therefore, it is very interesting to see the effect of that on the data sharing behaviour and network of the tender.

4.1.1. Results: Visualising the data sharing network

After the data collection, all data is mapped with the use of Gephi, resulting in the data sharing network of project A (see Figure 4.1). At first glance, the network seems to have highly connected regions linking the basic tender team together but also a high number of data streams going out to single connection nodes at the periphery with little to no inter-connectivity to the network. The network in total contains 36 nodes and is connected by 58 edges resulting in an average degree of 3.2 per node. This is quite a small number of connections which indicates that it is a network with many identified actors that do not have any mutual connections with one another. The network in total has potentially 595 connections while in reality, there are just 58 connections, resulting in a network density of 9,2%. Furthermore, the average clustering coefficient is determined to be 0.383, thus 38.3%. This entails that the neighbours of each node are on average 38%

interconnected.

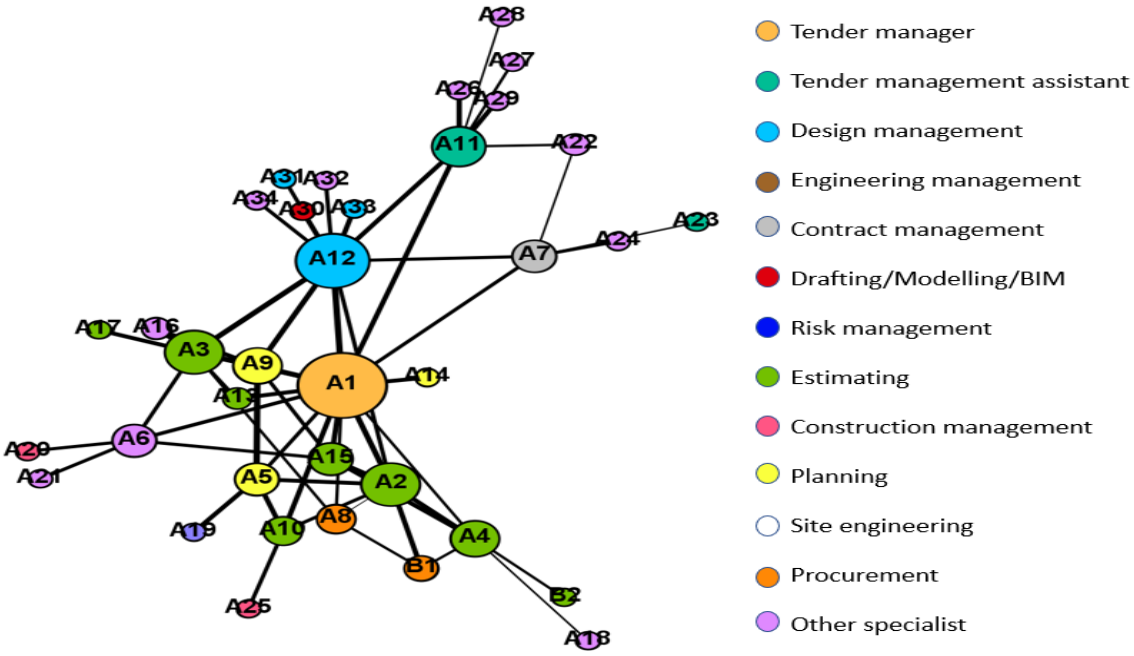


Figure 4.1: Data sharing network of project A.

The average frequency of project A is 4.2, which indicates on average for each node data exchange with its connections on a monthly and weekly basis. Furthermore, the average perceived value of the data is 4.6, which indicates that the average perceived value is a little below high value. Moreover, from the 13 survey respondents, 8 of them indicated that data exchange is most preferably done through email. In Figure D.1 it can be seen what the actual use of tools was for the data exchange during the execution of the tender. Here it can be seen that email is indeed the most used tool with close after that online collaboration platforms and chat applications.

Components	Statistic
Nodes	36
Edges	58
Graph density	0.092 (9.2%)
Average clustering coefficient	0.383 (38.3%)
Average degree	3.2
Average frequency of data exchange	4.2(/7.0)
Average indicated value of data	4.6(/7.0)
Most used tool in practice	E-mail
Most preferred tool	E-mail

Table 4.1: General network information project A

Moreover, the role division of all the actors in the network can be seen in Figure D.2, thus not only the respondents. Furthermore, for this particular aspect, it has to be noted that use was made of BAM's organogram to identify the work roles of identified actors due to the wrong identification of the associated work roles by respondents. As observed in Figure D.2, not all role types are present in the chart of project A, the engineering management roles and risk manager are missing. The absence of a risk manager is not surprising, as for the smaller projects (in terms of budget), the tender manager takes on this role, which often occurs at BAM. In addition, the project occurred during the tender phase and presumably, if all other project phases were included in the research, more or even all work roles could be ticked. The group that is most prominently present in the network of project A are the estimators, with eight people. The other specialist group is even more present, but because this group exists out of a wide variety that is often unrelated, this will not be taken into account. In addition, the wide variety of work roles in the network is a good indicator that it is a tender project as at this point, a wide variety of information is needed to create a correct tender.

The lay-out used is the force atlas lay-out. This lay-out is specifically used to spatialise small-world networks. It pushes the nodes with a high number of output links to the periphery and the nodes with a high number of input links in the centre. Moreover, the node size is in proportion with the weighted degree of the

nodes. Therefore, the most central and highly connected nodes are bigger than the less connected nodes. The nodes with the most connections and the biggest influence in the network are A1 and A12. The network and the nodes and edges will be analysed in more detail in the following subsections to verify if these nodes are the most connected. Here use will be made of the following metrics: degree, closeness centrality, betweenness centrality, eigenvector centrality, eccentricity and the clustering coefficient as explained in the methodology. In table D.1 a full table with all the labels, roles and their associated metric values can be seen. Metrics like these can provide the researcher with more insight on the importance of the actor or connections, thus what are the key roles, who have the most influence, who have the strongest connections, and who are the weakest connections. In the next subsection, some of these metrics, the most connected and least connected nodes, will be discussed.

4.1.2. Analysis: Nodes, edges and metrics

In this subsection, the most and least influential nodes will be discussed together with their metrics. The to be discussed nodes, together with their metrics, can be seen in table 4.2. The node A1 tender manager and the node A12 design management are identified as the most connected nodes in the network with regard to data sharing. A1 has the highest eigenvector centrality of 1.0, which means he is the most connected node and, in this case, is actually connected to all other nodes in the network that are highly connected in the network. This entails that A1 has a strong influence on the network but does not necessarily have the strongest local influence. In addition, A1 also has the highest closeness centrality, which indicates that this node is the most efficient in data sharing. This can also be seen by his low eccentricity of 2, which means it takes him just a maximum of 2 hops to reach any other node in the network.

The clustering coefficient is lower for A12, which means that the nodes he is connected with rely on him more, indicating a strong local influence as well as being privileged to more unique sources of data if we examine the graph. Nevertheless, A1 has a higher clustering coefficient than A12 but is still one of the lower ones in the network, indicating a local influence as well. Moreover, A1 has the highest betweenness value, indicating that he has the highest control over the flow of data in the network. A12 has the second-highest betweenness number, indicating a high control over the flow data as well. However, if we study the graph, we can see that when we remove A1 from the network, all his connections are still connected through the network. This does not apply when we remove A12 from the network. That is why A12 can also be identified as a single point of failure.

A large amount of the identified nodes in the network have low centrality values for project A. More than half of the identified nodes have a betweenness centrality of 0 (21 nodes), and of those identified nodes, 19 have a degree of just one connection, while they all have an eccentricity of 4 hops. Consequently, the level of inter-connectivity in the network is very low, which is also expressed in the density value of the graph. However, it is surprising that the eccentricity of the least connected nodes does not differ that much from the highest connected nodes. This indicates a small-world effect and that this network exists out of short connections between all members with regard to data sharing. The weakest actors identified in the network are nodes A25, A21 and A20. These are all nodes that are present on the periphery of the social network with just one connection in the network, indicating little to no influence on the data exchange in the network.

A25 has the lowest centrality values for all metrics, while A21 and A20 have exactly the same and second-lowest centrality values. It has to be noted that many of the low connected nodes score quite similar on the centrality measures but that these three by a little have shown the worst values. A25 and A20 are construction managers, and A21 is a sustainability specialist. As A25 and A20 are both the only construction managers in this network, it begs the question about the value of the input given by the construction managers at this point in the project life-cycle. This is something that should be compared with the other networks to verify the assertion. The low importance of A21, for now, is not surprising as he is connected with a sustainability specialist that is part of the basic tender team and probably has been consulted on sustainability issues relevant for project A.

Label	Work role	Degree	Degree centrality	Eccentricity	Closeness centrality	Betweenness centrality	Eigenvector centrality	Clustering coefficient
A1	Tender manager	14	0,4000	2	0,6250	286,24	1,0000	0,2088
A12	Design management	11	0,3143	3	0,5385	191,08	0,6751	0,1091
...	...	...	...	...	...	...	...	...
A20	Construction management	1	0,0286	4	0,3017	0	0,0606	0,0000
A21	Other specialist (sustainability)	1	0,0286	4	0,3017	0	0,0606	0,0000
A25	Construction management	1	0,0286	4	0,2966	0	0,0582	0,0000

Table 4.2: Most and least influential nodes inside project A.

The mapping of the data sharing network and analysing the employees and data streams involved has resulted in a multitude of discoveries. Through the use of this quantitative method, we can retrieve accurate observations, structures and patterns from the network. After which, we can analyse them stand-alone and/or compare them with existing phenomena in literature. When the analysis is deemed insufficient, use is made of further qualitative research to enhance understanding of the subject. The general findings with respect to the network have been elaborated upon below:

- **Network density**: The density of the network is only 9.2%. This is very low as we can go up to a 100%. However, Pryke (2017) also states in his book that a network density of 100% is highly unusual as then all nodes in the network would be exchanging information with each other. This would mean a network with a traditional data sharing structure, in which all members of the network share data directly with each other, which leads up to information overload, redundancy and irregularities in the process (Heras, 2019). However, in this tender, the low density most likely indicates the use of a common data environment as illustrated in Figure 2.5, which is beneficial for the operational efficiency (Alreshidi et al., 2018). In addition, this can be substantiated by the fact that online collaboration platforms (e.g. SharePoint) came in second as the most used tool during the tender.

- **The clustering coefficient:** The clustering coefficient is equal to 0.383 (38.3%). When observing the graph, it is visible that most nodes gather around a central hub in the middle around the tender manager A1 and a smaller one around A12. Clusters are usually formed more easily between people who work at the same location. The tender was executed in the Netherlands, but most team members at this point worked together at the same "location" online in teams due to COVID-19. Therefore, because there was no distinction in the working place between parts of the team, we can see a high degree of clustering between the basic tender team in the middle. Most team members that are not located at the periphery of the network seem to be interconnected to the whole network. Therefore, deducing that the high amount of peripheral players has a big influence on the density and clustering coefficient, it substantiates the assumption that there is a high degree of clustering among the basic tender team. Moreover, a slight presence of role cohesion can be found among the design managers, but still, data exchange seems to occur between all roles in the main network. However, analysing the network does show the possibility of data silos due to the presence of isolated nodes at the periphery of the network (more about this in the next subsection).

- **Estimator network:** In the estimator network, a discipline specific data silo was detected. In Figure 4.2 you can see that not all estimators are connected directly to one another within the network. They are, however, connected in the end through other actors in the network. The presence of these data silos can cause the unavailability of data and limit efficiency, productivity and quality of projects (Wanberg et al., 2015). As a result, data sharing is obstructed, and the employees that make the decisions are not (completely) aware of the involved data and risks, which can give the impression of soundly under-supported choices (van der Meer, 2021). Attention needs to be given to this by the firm to prevent its occurrence.

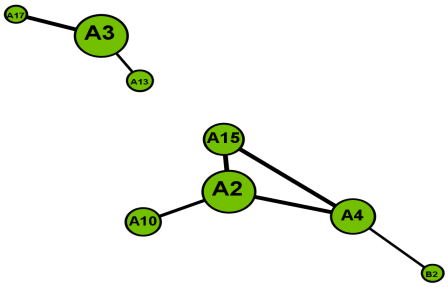


Figure 4.2: Data silo in the estimator network.

- **Tool use:** Respondents indicated that the most preferred tool to exchange data is email. Emails are seen as a fast and direct way to contact other nodes in the network, but it is not transparent. Data exchange through email is susceptible to inefficiency in the process. This is due to the fact that it is more likely that double data goes around, useful and available data is lost, an overview of data is lost, data silos can be created, and team members use outdated data. However, the low network density indicates the use of a common data environment. This assertion is strengthened by the fact that the second most used tool was online collaboration platforms (e.g. SharePoint). This reduces the chance of data silos as everything is saved into a single accessible environment. The use of this type of sharing also improves the competitive advantage and operational efficiency (Alreshidi et al., 2018) as well as improving cooperation between individuals and reducing possible mistakes and duplication. Following from the fact that online collaboration platforms are also used, it makes the loss of information and creation of data silos less likely than in a purely conventional data sharing environment.
- **Lessons learned:** The lessons learned connections are not taken into account in the visualisation of the data sharing network. This is because this network is visualised based on the question, whom the actors share data with most within the tender team. Lessons learned connections are often contacted just once or a few times to learn from their experiences, and due to the fact that including these connections in the network will have consequences for the involved centrality values, it has been decided not to take them into account. Nevertheless, it was still asked if the respondents connected with people of similar projects to learn from their experiences. The results showed that the use of lessons learned connections in this project were very limited. Only A12 has indicated to have contacted a design manager to make use of lessons learned. This limited use of lessons learned connections has a disadvantageous effect on involved employees' risk awareness as lessons learned have been identified as a major factor contributing to risk awareness.

4.1.3. Node type analysis

If we take a look at Figure 3.5, which illustrates the different types of nodes applicable to the network. We can do a general analysis based on the roles associated with the data sharing network of project A. To repeat, the attributes of the nodes, including their centrality measures, can be found in table D.1. In addition, if applicable, we can also qualitatively take into account some of the roles and their position in the network to determine what the effect is on risk awareness.

We start the analysis by looking at the specific node types:

- Gatekeepers
- Central figures
- Visible figures
- Peripheral figures

Gatekeepers

In this project network, there are two clear gatekeepers, nodes A11 and A12. Both nodes act as bridges to multiple single connection nodes that have no connections to others. Therefore, they have critical connections

to external knowledge and data. Some other nodes in the network have connections with one or a maximum of two single connected nodes with low centrality scores as well. However, their roles and data capacity are not deemed unique or beneficial enough to classify the bridge between them and the rest of the network as gatekeepers. In this tender, especially node A12 is privileged to important design data that only flows through him. In the case of risk awareness, attention needs be given to the fact that the relay of data from these nodes only flows through A12 and can be subjected to subjective biases when the data is used in risk management. The same reasoning applies to the specific data relayed through node A11.

Moreover, the vulnerability of a gatekeeper is that they can act as single points of failure. This is visualised in Figure 4.3 and Figure 4.4 where you can see the network when nodes A11 and A12 are removed from the network, respectively. Here you can also see the presence of potential data silos and that failure of A11 or A12 will result in the loss of valuable data, which of course, affects the risk awareness of the tender team. This also relates to the fact that when the gatekeepers do not adequately communicate all the data to the rest of the network.

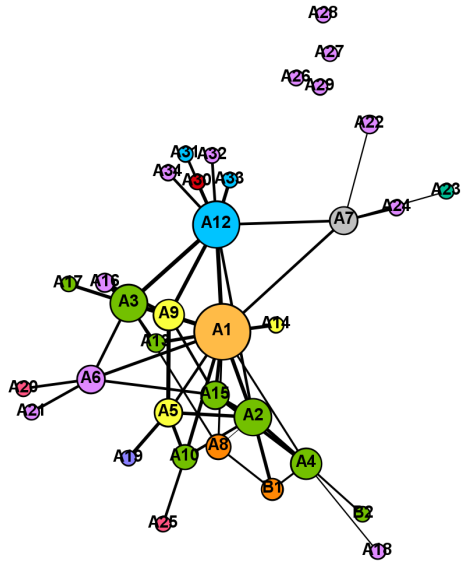


Figure 4.3: Project A network with node A11 removed

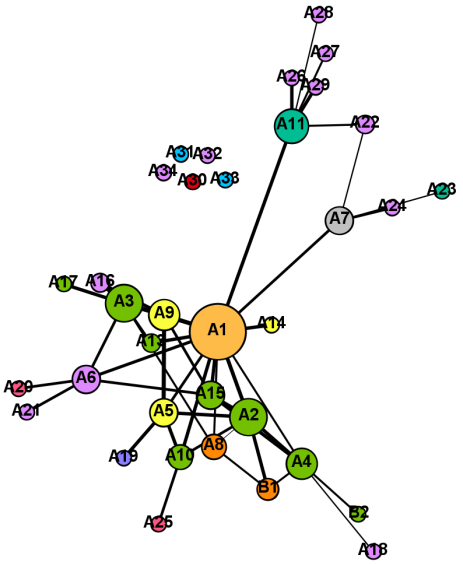


Figure 4.4: Project A network with node A12 removed

Central figures

There are two nodes in the network that can be classified as central figures, nodes A1 and A12. A12 has also been classified as a gatekeeper, but in this research, he fits the criteria for both node types. Both nodes play important roles in the network and have high scores on all centrality measures. Due to their high interconnectivity, careful attention needs to be given to ensure both nodes do not become bottlenecks or overloaded by the amount of data that flows through them.

Nevertheless, it has to be noted that A1 is mainly a connector between nodes that, through one way or another, are linked to the rest of the network (see Figure 4.5). Thus falling away, or bad performance, of the tender manager, will not necessarily lead to data loss as all of his connections are still tied to the network. This is interesting to see as his position indicates a strong influence on the network as information controller and connector but not necessarily a big local influence on the creation or provision of new data.

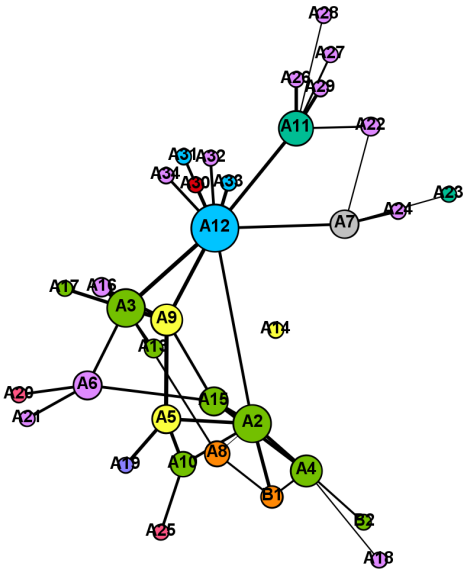


Figure 4.5: Project A network with node A1 removed

Visible figures

The estimators (indicated in Figure 4.1 with the green colour) are with many and do not play a unique role in the project and are therefore easily replaceable. In comparison with the rest of the network, the estimators in the basic team actually have quite a high degree centrality and a medium betweenness centrality. However, due to the high amount of estimators present, it should not be too hard to replace them easily, and therefore they are classified as visible figures.

The planners (indicated in Figure 4.1 with the yellow colour) are also very visible and play a somewhat unique role as there are only two players, which makes it harder to replace these actors. They score very high on the eigenvector centrality, high on the closeness centrality, but low on betweenness. Both their frequency of data exchange and the value of data are classified as high. Thus, as they score well on the centrality measures and especially on the eigenvector centrality, their role and input might be quite important to the network. This might entail that they belong to the central figures in the network, but comparison with other cases should be able to clarify more.

The procurement roles (indicated in Figure 4.1 with the darker orange colour) have a low degree and weak ties. However, they are positioned well in the network and are ranking higher on the eigenvector centrality, which means they are connected with central figures, and their input has some importance. Nevertheless, due to their low frequency of interaction and low value of information, they are classified as visible figures.

Peripheral figures

These are the low central or disconnected nodes in the network that are mainly present in the network's periphery. If talented or valuable, they present a risk in a way that the project cannot fully utilise their capacities or information or are subjected to the risk that they feel underappreciated and might leave. Those who are not deemed talented/valuable do not need extra attention and can stay in the network as peripheral figures. It has to be noted, though, that the peripheral figures with potential influence on the risk awareness are A27, A28 (omgevingsmanagers), A30 (BIM/Drafting/Modelling) and A32 (Geo-technical). These are essential players that have a good understanding of the potential risks in their field and are now only connected to the network through gatekeepers. Therefore, it would be advisable to involve them more in the network to enhance risk awareness.

Conclusion: node analysis

Based on the initial findings, the following gatekeepers and central figures have been established:

- **Gatekeepers:** Tender management assistant (A11) and Design manager (A12)
- **Central figures:** Tender manager (A1) and Design manager (A12)

The central figures have the largest influence on the network in terms of data control and dissemination. Moreover, we see that falling away of the tender manager and design manager results in a very sparse network, making the network prone to data loss and indicating potential data overload of the central players. The gatekeepers are established to be the tender manager and design manager. These are the players with access to critical outside data and knowledge relevant to the project. This indicates a vulnerability to the network as they can act as single points of failure, which can lead to data loss or extra time and resources spent on obtaining that data. This is detrimental as the tender phase is subjected to huge time pressures. The presence of the design manager as both a gatekeeper and a central figure make his position of very high importance in the network. In addition, the design manager is privileged to important design data that is only connected to the network through this player. In the case of risk awareness, attention needs to be given to the fact that the relay of data from these nodes only flows through A12 and can be subjected to subjective biases when the data is used in risk management.

Furthermore, if we look at the estimator network, we can see a silo effect between the same roles as this discipline is not fully connected to each other. This can limit efficiency and productivity as people in the same role are not (completely) aware of the involved data and risks. Moreover, to improve efficiency, it is advised to include the Drafting/Modelling/BIM group more in the network as this group has important information which can be beneficial to the network. Lastly, the planners might play a key role in the tenders, but comparison with other tenders still needs to occur to confirm or deny the assertion. The effect on risk awareness in the projects based on the SNA is mainly determined through the position of the nodes in the data sharing network. In the next section, other aspects retrieved from the survey related to risk awareness will be discussed.

4.1.4. Survey statistics

During the data collection, the survey was divided into three different parts: The first part relates to the risk awareness details, the second part relates to the social network analysis and is used to map the data sharing network, and the last part is used to retrieve some demographic details from the respondents. In this subsection, we will focus on statistics retrieved from the first part that relates to risk awareness. This part contained statements and questions related to the identified risk awareness factors from literature (see table 2.1), which allows for analysis of risk awareness factors in practice. Moreover, respondents were asked questions regarding the frequency of certain activities or training's or about their participation in activities or teams. The precise formulation of these questions and statements can be seen appendix D. Lastly, if the statistics have additional value in formulating recommendations or conclusions relevant for this report, they will be included in this subsection.

Statements related to identified risk awareness factors

In the survey, the first question posited 15 different statements related to the presence of the determined risk awareness factors in their project. The respondents had the opportunity to indicate if they agreed or disagreed with the statements given. The response can be seen in table D.2 and shows the specific division of the answers per statement. Moreover, in the last column, the mean value of the statements can be seen. With the score ranking being as follows: 1 for strongly disagree, 2 for disagree, 3 for neutral, 4 for agree and 5 for strongly agree. Here it can actually be seen that according to the respondents' opinion, most of the risk awareness factors are satisfied during the execution of the project. According to the respondents, the only statement that was not satisfied was the presence of an incentive system. Another statement that showed medium results was statement 6, the capturing and use of lessons learned. In addition, it has already been discussed in subsection section 4.1.2, but the establishment of lessons learned connections are very limited in the project network of project A. Lastly, all respondents were asked if they actively participated in risk management of which four respondents were neutral and nine agreed or strongly agreed. This fact is important for the next subsections.

Compatibility/accessibility of data and missing data

The first important observations retrieved from the survey are about the compatibility/ accessibility of data and missing data. The majority indicated that they did not suffer from missing data or compatibility/accessibility issues during the tendering, but when they did, it was mostly caused by the client who did not supply the

company with all the required data. Two other reasons when they did were the fragmentation of data across databases which made it hard to find data or the inexperience of employees with the use of project tools such as online collaboration platforms—both of which could be improved through training.

Trainings, activities and workshops

First respondents were asked questions regarding the frequency of their participation in certain workshops or training's, which can be seen in the second column of table 4.3. Furthermore, their response has been recorded and is also visible in table 4.3. The project had 13 respondents, and thus per row in both the upcoming tables, we have a total of 13 responses. In the table, we can see that actually only training 1 is executed to satisfaction. While for training 2, 3 and 4, 7 out of 13 respondents were trained less than once every two years. These are all aspects that if everyone is involved in risk management should be at least trained in and preferably more often than never or less than once every 2 years to be fully effective and up-to-date.

#	Training or Workshop	Semi-annually	Annually	Once every 2 years	Less than once every 2 years	Once during my BAM career	Never
1	During your BAM career how often have you been trained in your technical skills?	1	8	1	1	1	1
2	How often is there a workshop or training to educate staff about risk management practices, tools, processes, templates or risk awareness?	1	5	1	2	3	1
3	During your BAM career how often have you been trained in your communication skills, thus how you should communicate formally, informally, and verbally or written?	3	1	2	3	1	3
4	How often is there a workshop (or something similar) to educate staff on subjective biases when focusing on risks?	0	3	3	0	1	6

Table 4.3: Participation in trainings and workshops of respondents from project A.

Then the respondents of the survey were also asked how often they participated in the activities presented in the second column of table 4.4. Furthermore, in table 4.4 the response of the respondents has been recorded and can be seen. The first activity regarding risk-based dialogues seems to be complied with in a satisfactory manner. While on the other hand, activity 2 about the non-conformity seems to never be done by 9 out of 13 respondents. Moreover, 9/13 respondents participate in risk review meetings less than once every two years, and 8/13 participate less than once every two years in risk workshops. In a similar manner with the training's and workshops, these are all aspects that if the vast majority is involved in risk management should be at least participate in, and preferably more often than never or less than once every 2 to be fully effective and up-to-date.

#	Activity	Weekly	Monthly	Semi-annually	Annually	Less than once every 2 years	Once during my BAM career	Never
1	Conversation about risks (risk-based dialogues)	3	5	3	0	2	0	0
2	Deviation analysis regarding risk performance (NCR)	1	1	2	0	0	0	9
3	Risk review meetings	0	1	2	1	1	0	8
4	Risk workshops	0	0	3	2	3	0	5
5	Risk task-forces	0	0	0	0	0	0	13

Table 4.4: Response with regards to participation in teams or activities of project A.

Findings and quick wins

If we observe the survey results closely, there are some preliminary measures that could enhance the risk awareness of the team members. These are summarised below and can be seen as quick wins to enhance risk

awareness.

1. Put incentive system in place for good performance with respect to risks.
2. More training and workshops with respect to communication, subjective biases and risk management practices, tools, processes and templates.
3. Larger occurrence of activities such as risk review meetings, risk workshops, and non-conformity meetings.
4. Training in the use of digital systems at BAM at the commencement of work instead of initial trial and error.

Moreover, the statements of capturing lessons learned showed medium results, while the capturing and use of lessons learned is an important contributor to risk awareness. Especially the use of lessons learned connections is very limited in this project. Therefore, more attention needs to be given to this and what the reason for this is. In addition, further research needs to clarify more, but it seems that the risk management procedures are not consistent for smaller projects. With smaller projects is meant projects below a certain threshold in terms of budget and/or risk level. On this level, it seems risk management is more performed according to the interpretation and implementation of the tender manager.

4.2. Project B: Ombouw Emplacement, Den Haag Centraal

Project B is located in The Netherlands, with the main deliverable being a rail project. The works consisted out of the re-connection of a multitude of tracks, the complete construction and renovation of the railway yard over 900 meters, partial modifications to infrastructure at a Dutch railway station, modifications to tracks, replacement of tiles and retaining walls, including placing a catenary system, placement of multipurpose poles, lighting and various works to make the result TSI compliant. The tender was executed in 2020 and included a Build and Detailed Design/Engineering contract scope. Furthermore, the tender was performed in collaboration with a design and consultancy organisation and two additional external members that fulfilled specific roles and aided in the project. This means that the basic tender team consisted out of 33 team members, of which 19 people were under contract at BAM.

This research focuses on intra-organisational data sharing. Therefore, only the team members involved in BAM have been invited to participate in the survey with the exception of B4 who played an important role as tender manager in the collaborative company. However, it has to be noted that this was not communicated to the BAM team. Here it was still asked of the respondents to indicate whom they shared data with most during the tender. Surprisingly, a very small number indicated one or a maximum of two team members of the collaborative organisation as data sharing connections. This suggests that limited collaboration was present between the organisations, and this can be interesting to research further in inter-organisational oriented studies. Thus, the basic tender team that was asked to participate in the survey response consisted out of 20 employees, which makes it larger than the project team size of project A. Out of the 20 approached team members, 17 people filled out the survey. This resulted in a response rate of 85%, which, just like in project A is far above average for surveys (Baruch & Holtom, 2008). However, during the project, more than the initial 20 employees have worked on the tender. These employees have not been invited to participate in the survey due to their limited contribution or due to their placement at external organisations. Furthermore, the whole tender has been performed in The Netherlands. However, the involved team members worked mainly from home due to the COVID-19 pandemic. Therefore, just like in project A, it is very interesting to see the effect of that on the data sharing behaviour and network of the tender.

4.2.1. Results: Visualising the data sharing network

The data sharing network of project B can be seen in Figure 4.6 and shows a similar interconnected structure as the network graph of project A. At first glance, the network seems more crowded, which is also reflected in the general network information in table 4.5. In addition, the Force-Atlas layout has again been used, and as a consequence, the hub in the middle has been stretched out manually. This was done deliberately to enhance the readability of the data streams in the project network. The total number of nodes in the network is equal to 47, and they are connected by 97 edges resulting in an average degree of approximately 4.1 connections per node; this results in a graph density of 9%. The network shows a higher connectivity

between team members than in project A, which is also expressed in the clustering coefficient of 45.5% for the whole network. Furthermore, there are no isolated nodes detected in the network.

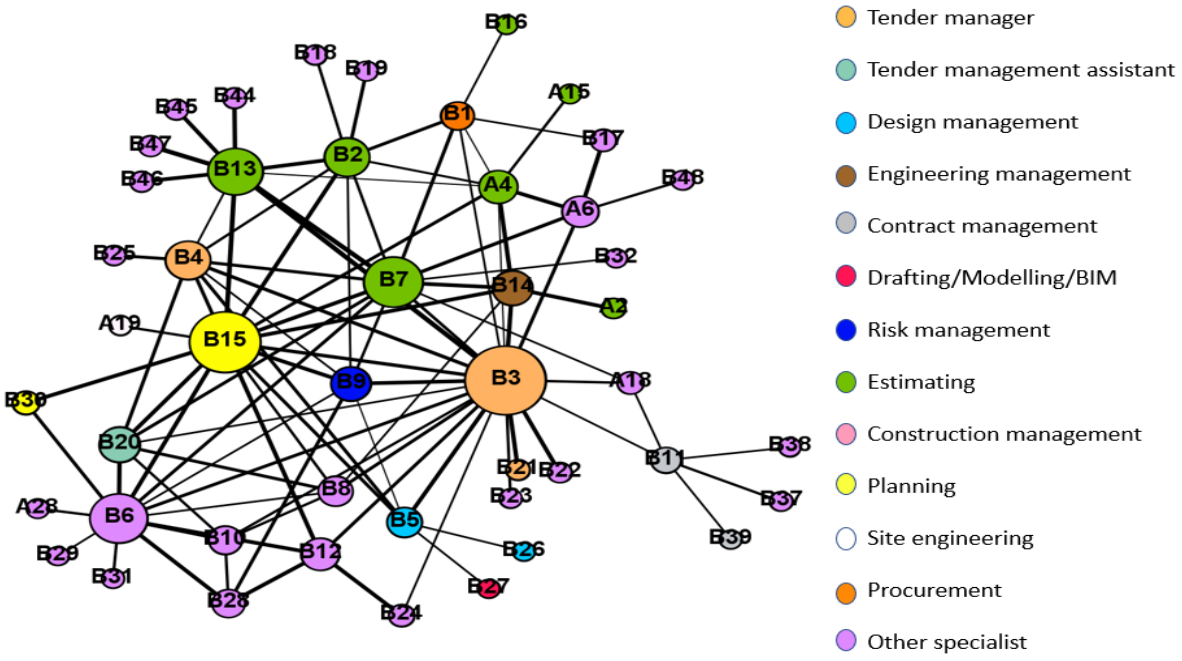


Figure 4.6: Data sharing network of project B.

The average frequency of data exchange for project B is 4.0, which indicates on average for each node data exchange with its connections on a monthly and weekly basis. Furthermore, the average perceived value of the data is 4.9, which indicates that the average perceived value of data is of high value. Moreover, from the 17 survey respondents, 9 of them indicated that data exchange is most preferably done through face-to-face contact. In Figure D.3 it can be seen what the actual use of tools was for the data exchange during the execution of the tender. Here it can be seen that although face-to-face contact is preferred, email is actually the most used tool with a distance after that the phone and after that video/virtual calls and only then face-to-face contact. Furthermore, the difference between preferred use and actual use could, of course, be a logical result of the pandemic and employees working from home.

Components	Statistic
Nodes	47
Edges	97
Graph density	0.09 (9%)
Average clustering coefficient	0.455 (45.5%)
Average degree	4.128
Average frequency of data exchange	4.0(/7.0)
Average indicated value of data	4.9(/7.0)
Most used tool in practice	E-mail
Most preferred tool	Face-to-Face

Table 4.5: General network information project B.

The division of the roles in project B can be seen in Figure D.4, here again, all nodes in the network have been represented and not only the respondents. Just like in project A for some of the identified actors, use was made of BAM's organogram to identify the work roles due to the wrong or deficient identification of the associated work roles by respondents. Consequently, this could have influenced the division of roles due to the highly specified work roles in the organogram resulting in a higher amount of other specialists in the role division. Nevertheless, when the role division is observed, we can see that all roles are present in the network, with the exception of the construction manager. When we look at project A, and the identification of construction managers as the least connected nodes and the limited value of their input at this stage, its missing presence in the data sharing network does not come as a surprise. Moreover, as stated in the scope, we focus on the tender phase in this research and projects in this stage require a lot of different data

for decision making, which can explain the wide variety of work roles. The most prominent group is by far the other specialist group, but because this group exists out of a wide variety that is often unrelated to one another, this will not be taken into account. Therefore, the estimators have the highest number of members within the data sharing network. Lastly, the group of estimators show a subtle form of team cohesion as they form a team with more edges within their own discipline than with any other roles, w.r.t. their total connections. The same applies to the left bottom part that mainly exists out of other specialists and, in this case, predominately omgevingsmanagers. Also, the design managers show a small sign of team cohesion, but this is mainly because the design manager in the basic tender team is the only one with connections to other people involved in the design process.

4.2.2. Analysis: Nodes, edges and metrics

In table 4.6 the centrality values of the best and worst scoring nodes involved in the data sharing network of project B are shown. In table D.4 an overview is given of all the nodes involved in this project, including their centrality metrics. From table 4.6 and the visualisation of the data sharing network in Figure 4.6 it can be deduced that B3, B15 and B7 are the most connected nodes in the network. This is because respectively, they have the highest degree centrality, closeness centrality, and eigenvector centrality. Node B3, the tender manager of the project, is the node that stands out most in terms of being the best connected node. His contribution to data sharing is the highest in comparison with other nodes. This is expressed, for example, in his eigenvector value. This value is equal to 1, which means that B3 is connected to all other highly connected nodes in the network. This is similar to the tender manager in project A. Moreover, his betweenness centrality is more than 2.5 times as high as B13 who has the second highest betweenness centrality in the network. This means that the network highly depends on B3 and that he can act as a bridge between nodes in the network and has more control over the flow of information. In addition, his clustering coefficient is one of the lowest in the network, which indicates that the nodes he is connected with rely on him more, indicating a strong local influence.

Furthermore, B15 holds the function of head planner and looks into the multidisciplinary execution methods. He is supported by external node B30 who has only two connections in the data sharing network. The work content of B15 is extensive and essential for the project as the planning has great consequences for the different disciplines and the timely delivery of the project. His responsibility in providing a successful project in practice and controlling the information flow within the network is thus high. This is also expressed in the eigenvector, closeness and betweenness centrality values of B15 as these lie closest to the tender manager's. B7 is the cost estimator and is the third best connected node in the network. The role of the cost estimator has a significant influence on the network and its structure. This is expressed in the high centrality values that lie very close to that of B15 the planner. These high centrality values, especially the high eigenvector values, illustrate that other nodes than the project manager can also act as essential points of contact for other actors in the network, which makes data sharing in the network less dependent on one person/function.

A large part of the identified actors in the network has a betweenness centrality of 0 (26 nodes), indicating little to no control over the flow of information in the network. In addition, 24 of these nodes have just a single edge connecting them to the data sharing network. All these nodes have an eccentricity of 4 or 5, which means that the network's diameter is equal to 5 data hops. The least connected nodes in this network are B37, a lawyer, B38, an insurance manager and B39, a contract manager. These nodes are all located on the network's periphery and score lowest on all centrality measures. The eigenvector centrality of these nodes is more than two times smaller in comparison with the weakest nodes in project A. However, the closeness centrality of these nodes are not necessarily low in comparison with the higher ranked nodes, implying a network with a low dispersion of actors.

Moreover, these nodes are all connected to the network through B11, the contract manager. The low centrality values are a result of being located on the periphery, and the only point of access to the network being B11. This is due to the fact that the only ties of B11 to the network are two weak ties, of which one at least is to an influential node (B3). This results instantly in the three weakest positioned nodes in the network. Therefore, it is worth taking a look at the worst scoring nodes after these actors as here the weakest identified nodes are clustered together with a single access point, neglecting other weak points in the network. Thus, if we look at the weakest nodes in the network after that, this results in B26, a design manager and B27, a BIM modeller. This is detrimental to the network as these nodes have important data with respect to the design

that can be beneficial to the network, but more attention will be given to this in the next subsection.

Label	Work role	Degree	Degree centrality	Eccentricity	Closeness centrality	Betweenness centrality	Eigenvector centrality	Clustering coefficient
B3	Tender manager	21	0,4255	3	0,6301	474,7971	1	0,190476
B15	Planning	15	0,2979	3	0,5542	153,6978	0,883957	0,342857
B7	Estimating	13	0,2553	3	0,5412	131,0881	0,782902	0,333333
...	...	...	...	...	...	...	...	...
B37	Other specialist (Lawyer)	1	0,0000	5	0,2949	0,0000	0,020629	0
B38	Other specialist (Insurance manager)	1	0,0000	5	0,2949	0,0000	0,020629	0
B39	Contract management	1	0,0000	5	0,2949	0,0000	0,020629	0

Table 4.6: Most and least influential nodes inside project B.

The mapping of the data sharing network of project B has provided additional insight into how data sharing is organised in the firm. Below, the general findings of the network are summarised and, when possible, supported with existing literature to provide additional explanation:

- **Network density**: The density of the network is only 9%, this is approximately the same percentage as for project A. Network B however, is larger than network A in terms of nodes, and literature does acknowledge the fact that it is harder to attain high-density rates in larger networks (Pryke, 2017), suggesting that network B is better connected than project A. To confirm, if we compare the average degree of the two projects, we can see that project B (4.128) has a higher average degree than project A (3.2). Furthermore, if we look at the low-density values in both project networks and the high amount of single connection nodes, and we base our findings solely on these two projects, we can conclude that a low-density value is a characteristic of project networks in the tender phase. This is due to the fact that tendering is one of the stages in a construction project that requires extensive data and document exchange (Laryea, 2011) to compose the tender bid, which also explains the high number of single connection nodes at the periphery in both project networks.

- **The clustering coefficient:** The clustering is equal to 0.455 (45.5%). The clustering coefficient is a bit higher than that of project A, and the structures are similar, with many single connection nodes on the periphery. However, the biggest difference is that project B contains more information hubs in the centre of the network. Due to the presence of 24 single connection nodes, it means that the basic tender team is actually very well connected. Role cohesion was already briefly discussed in the previous subsection, but slight role clustering can be seen in the other specialist (omgevingmanagers), estimators and design management groups. Nevertheless, data exchange between the different roles is high. This indicates conventional data sharing, which is also suggested by the tool use of the project participants. This can compromise the data integrity and increase the chance of errors and data loss (Alreshidi et al., 2018). Lastly, observing the graph, there is still some room left for potential data silos at various locations in the periphery of the network, but this will be discussed in more detail in the node type analysis.

- **High number of informational hubs:** There are multiple high connected nodes present in the network. B3, the tender manager, is the most connected node in the network, but it stands out that there are more informational hubs present. This is expressed in the high centrality values of the most connected nodes, which indicates a good number of information disseminators in the network. Moreover, it emphasises that other nodes than the tender manager can also act as critical points of contact for other actors in the network, which makes data sharing in the network less dependent on one person/function. This shows a high level of responsibility towards the tender or data sharing within the tender and is also demonstrated by the use of lessons learned by these high ranking nodes(See table D.3). Lastly, this is in accordance with findings of Hertogh and Westerveld (2010) who state that larger and more complex projects need more proficient team members to increase the chance of a successful project outcome.

- **Actual and preferred tool use:** The respondents indicated that the preferred way of sharing data is face-to-face contact. However, the results show that email was the most used tool by far, with face-to-face coming in fourth. The second and third most used tools were phone contact and virtual/visual

calls, these types of sharing limit data transparency and stimulate data loss. The fact that face-to-face is so low on the list can be a logical consequence of the fact that this project was executed during the COVID-19 pandemic and everyone had to work from home. Despite the differences in preferred tool use in projects A and B, the actual tool use is the same. This can indicate ineffective encouragement to use less conventional data sharing tools, or a reluctance of employees to change the current way of working, or that the endeavour of using 'new' technology might be too great (Barua et al., 2007). In addition, project B has shown little to no use of BIM as data sharing tool, that while the influence of BIM in this stage of the project life-cycle is great as it can reduce data loss, data search time and improve the accuracy of search results (Lee et al., 2016). Moreover, this project's high use of conventional tools can limit data accessibility and data transparency. This makes the project more susceptible to data loss and unavailability of data, as a result limiting risk awareness and the decision-making capabilities of employees.

- **Lessons learned:** In the appendix and more specifically table D.3 the lessons learned connections indicated by the respondents of project B are presented. Remarkable is that this project has shown to have made use of lessons learned connections quite a lot more than in comparison with project A, where only the design manager has indicated one lesson learned connection. Lessons learned have been identified in literature as a major factor contributing to risk awareness. In (in)formal interviews with involved people, more light on this should be shed to find out why this is the case. Moreover, the first connection between actors that span geographical boundaries is seen here. When firms are active in a multinational environment, research has shown that connections between people that cross physical boundaries can enhance opportunities to improve performance and improve entry to information (DeSanctis & Monge, 1999). However, a slight note needs to be placed here as this connection was made by a 'higher' ranking tender manager (B3), begging the question of whether the entry effort of making such a connection is as easy for lower ranking employees.

4.2.3. Node type analysis

In this subsection, a node type analysis is performed based on the associated work roles in the data sharing network of project B. A distinction will be made between gatekeepers, central figures, visible figures and peripheral figures. Moreover, special attention will be given to the risk manager's role in this project, as this function plays an essential part in the risk management process and the risk awareness of the project team. To repeat, for project B, the attributes of the nodes, including their centrality measures, can be found in table D.4.

Gatekeepers

In project B, it is a bit harder to determine who the gatekeepers are in the data sharing network. This is because of the high number of peripheral players and multiple nodes connecting these players to the network. Some of these nodes are the only access point to the network for these 'outside' actors. However, some of these outside connections, their roles, knowledge and data capacity are not deemed unique or beneficial enough to classify the bridge between them and the rest of the network as gatekeepers. B6, for example, has connections with three outside nodes; however, two out of the three nodes fulfil the same role as B6 and therefore do not bring critical or new information to the project. The same reasoning applies to B2, who has connections with people that have similar work packages. B11 has access to essential outside data, but this data is more relevant to his own position than that it is for the rest of the network. Therefore, the gatekeepers that are acknowledged in this project have access to unique and crucial knowledge and data. Moreover, they all have high betweenness centralities indicating that they act as bridges between nodes in the network and have more control over the flow of information. The gatekeepers identified are nodes B3, B5 and B13.

B3, the tender manager, is the only apparent connection to the client-side. Here crucial data and requirements from the client side are connected to the network through B3 providing essential data to the project that is needed to compose the tender and to take into account in the risk management process. It should be determined if other actors were present in the network with connections to the client-side as this would have consequences for the gatekeeper status of B3.

B5 is classified as a gatekeeper due to the same reasons as the design manager of project A. In this tender, especially node B5 is privileged to important design data that only flows through him. In the case of risk

awareness, attention needs to be given to the fact that the relay of data from these nodes only flows through B5 and can be subjected to subjective biases when the data is used in risk management.

B13 is harder to place, and this is due to the fact that he has contact with three actors that fulfil the role of manager operations rail and therefore do not bring unique data to the network in comparison with each other. However, they could have high-value input for the network in terms of risks during the execution of the works or about the works themselves, and that is why B13 is classified as a gatekeeper. Nevertheless, just like with B5, in the case of risk awareness, attention needs to be given to the fact that the relay of data from these nodes only flows through B13 and can be subjected to subjective biases when the data is used in risk management or input for planning.

Lastly, the vulnerability of a gatekeeper is that they can act as single points of failure. This is visualised in Figure 4.7 where you can see the network when the gatekeepers are removed from the network. Here one could also see the presence of potential data silos and that failure of these nodes to properly function will result in the loss of valuable data, which, of course, affects the risk awareness of the tender team. This also relates to the fact that when the gatekeepers do not adequately communicate all the data to the rest of the network.

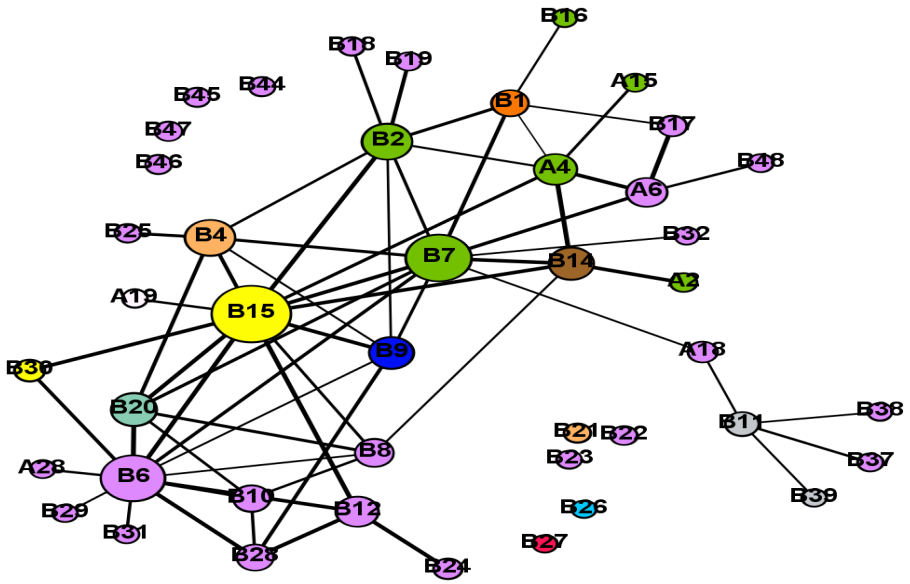


Figure 4.7: Data sharing network of project B when gatekeepers are removed from the network.

Central figures

When we look at the data sharing network of project B in Figure 4.6 we can see there are multiple high connected nodes present in the network. These nodes act as informational hubs and play a key role in controlling and disseminating information. Though not all the actors around which these hubs are formed are deemed central figures. For example, when we remove B7 from the network, we can see that a hub in the middle falls away (Figure 4.8). However, its connections are still all connected to the network when this node falls away. In addition, the function of B7 is an estimator of which we have multiple present in the network; that is why he is not classified as a central figure. Moreover, B13 is also not classified as a central figure, and this is due to the fact that his high centrality values are partially a result of its connections with four peripheral figures, while the rest of his connections to the network are limited.

The nodes deemed central figures are B3, the tender manager, and B15, the planner. We can see that if B3 and B15 are removed from the network (Figure 4.9), the network becomes a very sparse network with a high number of nodes and fewer data streams. If we combine that fact with the statistic that more traditional data

sharing tools are used according to Figure D.3. Then we can see that the network is more prone to information overload, data silos, loss of data and overview, and duplication (Alreshidi et al., 2018; Heras, 2019). Therefore, based on their high interconnectivity and centrality measures, careful attention needs to be given to ensure both nodes do not become bottlenecks or overloaded by the amount of data that flows through them. The loss or dysfunctioning of these two nodes would be very detrimental to the network.

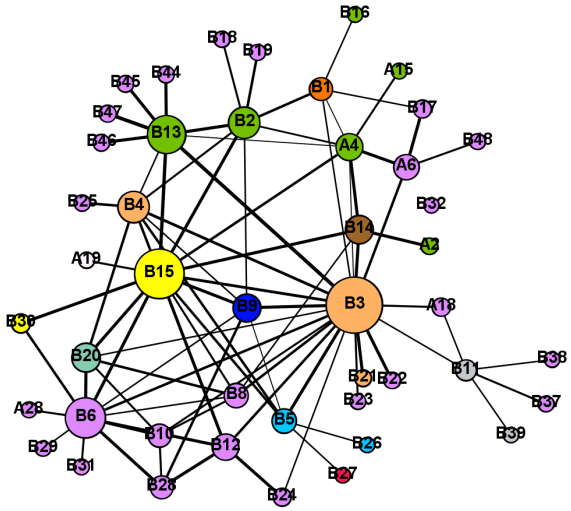


Figure 4.8: Project B network with node B7 removed.

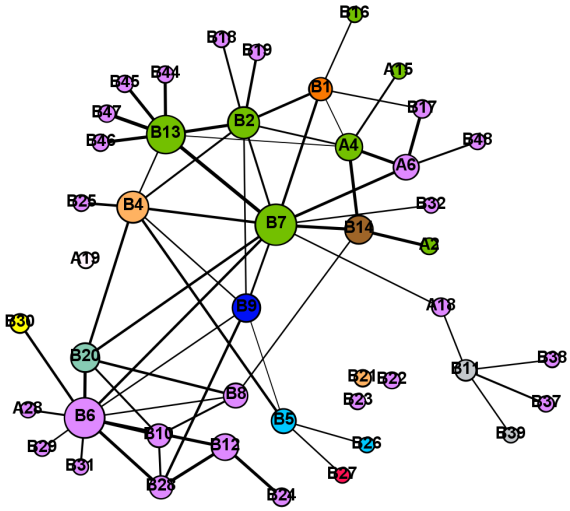


Figure 4.9: Project B network with central figures removed.

Visible figures

The visible figures in this network are the estimators, risk manager, B6 other specialist (omgevingsmanager), B4 tender manager and B20, the tender management assistant. The tender management assistant, B20, and the tender manager, B4, are externals and therefore will not be analysed further. Moreover, the risk manager will be discussed in more detail in its own paragraph.

The estimators (indicated in Figure 4.6 with the green colour) are with many and do not play a unique role in the project and are therefore easily replaceable. In comparison with the rest of the network, the estimators in the basic team actually have quite a high degree centrality and a medium betweenness centrality. However, due to the number of estimators present, it should not be too hard to replace them, and therefore they are classified as visible figures.

B6, the other specialist (omgevingsmanager) is very visible and plays a somewhat unique role. He is involved in lots of network activity and has high centrality metrics. Nevertheless, there are multiple of nodes with the same work package in the network, and therefore he is classified as a visible figure instead of a central figure.

Role of the risk manager

The risk manager is not a role in the project that is responsible for the spread of data. However, he is important in collecting data that is imperative to the risk management process. Therefore, focusing on the risk manager is mostly focusing on what crucial connections are missing with respect to risks or the risk management process.

In this era, it is hard to think of projects in which sustainability does not play a role. Therefore, it is remarkable to see no connection between the risk manager and the people involved in sustainability. Especially as one could expect agreements to be included in the contract regarding attaining certain sustainability goals and risks associated with particular works that complicate the process of attaining such goals, another important connection that is missing is the one with the contract manager, one should know the limitations of the contract and associated risks. As a contract may harbour many agreements and loopholes and, if they

are not met, will present the project with risks for which mitigation strategies should be developed. Lastly, with respect to the design, there is only a very weak tie between the risk manager and the design manager. Of which certainly no connections to the BIM modeller or other designers involved. Especially the input of a BIM modeller and issues with phasing can be beneficial to take into account during the risk management process.

The risk manager did, however, make use of lessons learned and approached project managers of similar projects to take into account their experiences with risks that occurred at their projects. In addition, there is a big difference in the use of lessons learned between the two projects. Therefore, it begs the question of whether the presence of a risk manager has consequences on the use of lessons learned by team members.

Peripheral figures

This network has many peripheral figures and actually 26 nodes that do not have more than a single connection. Not too much attention is given to the peripheral players if they are not deemed valuable or talented. The peripheral players that with potential influence on the risk awareness are the manager operations rail (B44, B45, B46) and B27 (BIM/Drafting/Modelling). These are essential players that have a good understanding of the potential risks in their field and are now only connected to the network through gatekeepers. Therefore, it would be advisable to involve them more in the network to enhance risk awareness.

Conclusion: node analysis

Based on the initial findings the following gatekeepers and central figures have been established:

- **Gatekeepers:** Estimator (B13) and design manager (B5).
- **Central figures:** Tender manager (B3) and Planner (B15).

The central figures have the largest influence on the network in terms of data control and dissemination. Moreover, we see that falling away of the tender manager and planner results in a much sparser network. If this is combined with the fact that this network mainly used conventional data sharing tools, it makes the network prone to data loss and data overload. The gatekeepers are established to be the estimator and design manager. These are the players with access to critical outside data and knowledge relevant to the project. This indicates a vulnerability to the network as they can act as single points of failure, which can lead to data loss or extra time and resources spent on obtaining that data. This is detrimental as the tender phase is subjected to huge time pressures. Again the design manager is privileged to important design data that is only connected to the network through this player. Making the role of the design manager a consistent gatekeeper across tenders and attention needs to be given to this. Therefore, to improve efficiency, it is advised to include the other design managers and the Drafting/Modelling/BIM group more in the network to prevent subjective biases and lack of decision-influencing data. Especially, the Drafting/Modelling/BIM group has additional relevant data which can be beneficial to the planning and risk management process.

Furthermore, when observing the risk manager, it can be noticed that there are no connecting data streams between some of the disciplines and the risk manager. This while every discipline could be expected to have its own characteristic risks. This can lead to insufficient identification and mapping of risks. The most surprising connections missing are those between the risk manager and the contract, Drafting/Modelling/BIM and procurement disciplines. However, the risk manager did show to have a positive effect on the risk management procedures in the project and the consistent use of lessons learned. Lastly, no clear silo effect in and between disciplines was found. The effect on risk awareness in the projects based on the SNA is mainly determined through the position of the nodes in the data sharing network. In the next section, other aspects retrieved from the survey related to risk awareness will be discussed.

4.2.4. Survey statistics

Just as for project A this subsection will dive deeper into the statistics retrieved from survey data that relate to risk awareness. The response for project B with regards to the statements that relate to the established risk awareness factors can be seen in table D.5. If the statistics have additional value in formulating recommendations or conclusions relevant for this report, they will be included in this subsection.

Statements related to identified risk awareness factors

In the survey, the first question posited 15 different statements related to the determined risk awareness factors in their project. The respondents had the opportunity to indicate if they agreed or disagreed with the statements given. The response can be seen in table D.5 and shows the specific division of the answers per statement. Moreover, in the last column, the mean value of the statements can be seen. With the score ranking being as follows: 1 for strongly disagree, 2 for disagree, 3 for neutral, 4 for agree and 5 for strongly agree. Here it can actually be seen that according to the respondents' opinion, most of the risk awareness factors are satisfied during the execution of the project. Similarly to project A, the only statement that showed to be not satisfied is the presence of an incentive system. Another statement that was rated neutral with a mean value of 3.13, thus more towards the agreeing side, was the presence of missing data. This will be discussed in more detail in the next sub-subsection. Lastly, when asked if the respondents were actively involved in risk management, 14 out of 17 respondents indicated to be actively involved, while two disagreed with the statement and one was neutral.

Compatibility/accessibility of data and missing data

With respect to the data retrieved, it was observed that the rated mean value of missing data was equal to 3.13, which overall means that the respondents indicated to have suffered from missing data. However, when we look closer at the responses when asked what the reason was for missing data according to themselves, the vast majority indicated, just like in project A, that at this point, the client did not supply the company with all the needed data. Again two other reasons when they did was employees being unfamiliar with the digital environment and not knowing where to find certain data—indicating the same reasons as project A for missing data. Regarding the compatibility and accessibility of data, the mean value was 2.44, indicating a disagreement of the population that they experienced problems with this that hindered them in doing their work. Reasons given when they were hindered were the lack of software to open certain files and data being in different documents and formats.

Trainings, activities and workshops

First respondents were asked questions regarding the frequency of their participation in certain workshops or training's, which can be seen in the second column of table 4.7. Furthermore, their response has been recorded and is also visible in table 4.7. The project had 17 respondents, and thus per row in both the upcoming tables, we have 17 responses. At the beginning of the project, 14 out of 17 respondents indicated to be actively involved in risk management; with that information in the back of our heads, we analyse table 4.7. Regarding training 1, we see that 10/17 of the respondents are trained in their technical skills less than once every two years and four employees never. Training with respect to risk management is done better, with just 6 out of 17 receiving training less than once every two years. This is a better representation than in project A, and with three people not involved in risk management, this is a smaller inconvenience. With respect to training 3, the numbers are very low, with 13/17 people being trained less than once every 2 years. Lastly, training 4 indicates a little bit less than half of the respondents to have been trained with respect to subjective biases. These are all aspects that if everyone is involved in risk management should be at least trained in and preferably more often than never or less than once every 2 years to be fully effective and up-to-date.

However, what is most remarkable about the findings is that the risk manager has indicated to have never received training on all the identified training's or workshops in the table. This comes as a shock, especially because he is the one responsible for risk management in the project. After following up with the risk manager, it was confirmed that this was also not offered to him. Therefore, this is definitely something that should be addressed within BAM. In addition, noteworthy was the fact that the risk manager indicated to totally disagree that risk management is supported by top management. Of course, this could be a case of role bias as he has a certain obligation towards risk and does not feel supported enough in the endeavour, or it could be a consequence of never being trained in anything related to risk awareness. Nevertheless, in this case, the benefit of the doubt will be given to the rest of the project team, who overall were neutral or agreed with

the statement. This does not take away the fact that progress can be made as a mean value of 3.42 does not indicate a strong belief in the support of top management towards risk management.

#	Training or Workshop	Semi-annually	Annually	Once every 2 years	Less than once every 2 years	Once during my BAM career	Never
1	During your BAM career how often have you been trained in your technical skills?	2	2	3	5	1	4
2	How often is there a workshop or training to educate staff about risk management practices, tools, processes, templates or risk awareness?	3	6	2	3	2	1
3	During your BAM career how often have you been trained in your communication skills, thus how you should communicate formally, informally, and verbally or written?	2	2	0	5	3	5
4	How often is there a workshop (or something similar) to educate staff on subjective biases when focusing on risks?	1	4	4	4	1	3

Table 4.7: Participation in trainings and workshops of respondents from project B.

Then the respondents of the survey were also asked how often they participated in the activities presented in the second column of table 4.8. Furthermore, in table 4.8 the response of the respondents has been recorded and can be seen. The first and second activity regarding risk-based dialogues and non-conformity meetings seems to be complied with satisfactorily. While on the other hand, activity 3 about risk review meetings can be performed better as 7 out of 17 members indicated never to have participated in this sort of activity. This also applies to activity 4, where 7 out of 13 respondents indicated to participate less than once every two years. Compared to project A, risk task-forces are done more, but this is an activity that might not be very beneficial to include people who do not have a risk-oriented job. All in all, these activities seem to be performed to a more satisfactory level than in project A although there is still some room for improvement.

#	Activity	Weekly	Monthly	Semi-annually	Annually	Less than once every 2 years	Once during my BAM career	Never
1	Conversation about risks (risk-based dialogues)	2	5	6	4	0	0	0
2	Deviation analysis regarding risk performance	1	2	8	3	1	0	2
3	Risk review meetings	0	1	5	3	1	0	7
4	Risk workshops	0	4	4	2	3	0	4
5	Risk task-forces	0	1	2	1	1	0	12

Table 4.8: Response with regards to participation in teams or activities of project B.

Findings and quick wins

When looking at the results of the survey statistics of project B, we see many similarities with project A. The problems in missing data are primarily caused by the client who does not provide the company with all the required data. Moreover, other reasons were employees being unfamiliar with the digital environment and not knowing where to find certain data. Potential disadvantages from this should be able to be mitigated through targeted training. Also, we can conclude that no incentive system is used among the tendering teams. A big difference, though, is the participation in activities between the two projects. Here it seems that the members of project B are participating more in this sort of activities than in project A. Tender teams are basically a reflection of the overall population inside the company that is concerned with tendering. Therefore it is remarkable to see irregularities in the participation rate of involved staff in the two projects. Most remarkably, though, is that the risk manager has not been trained in any of the training's and/or workshops specifically designed for risk management. In informal follow-up interviews, it has arisen that, indeed, BAM has no obligatory training with respect to this. However, the company states that they do offer these training's to involved

team members. Nevertheless, after following up with the risk manager, the risk manager stated that these sorts of training's were never offered to him. Showing that internal audit on participation and providing possibilities for training is lacking. This is something that should definitely be addressed within the company such that organisational members have the opportunity for organisational learning and can remain up-to-date.

4.3. Cross-case comparison

This chapter has analysed the connections between project participants in the form of data streams, including any project transcending connections. This gave insights into the structure and patterns of the data sharing network. In addition, data was collected and analysed that is specifically focused on addressing the identified risk awareness factors from literature. The aim was to find out what the structures and patterns of these data sharing networks were and locate the presence of data silos, while also determining the key roles in the network. Moreover, with the help of the survey, some statistics regarding the risk awareness factors in practice were obtained. In total, 30 project members from two different rail projects located in The Netherlands participated in the survey. Comparing the different projects based on the SNA proved to be more difficult due to the different project sizes and a lack of clarification of the participants on their data sharing behaviour. Nevertheless, literature provided additional understanding on comprehending the results and comparing findings.

4.3.1. General findings

It was found that email was the most used tool by far in both projects; this gives reasons for concern as emails are not the most efficient way of data sharing. In addition, when looking at the most used tools and preferred tools, it was evident that large parts of the project teams preferred more conventional data sharing tools and used these predominantly in practice. However, project A did use a more digital and central tool as the second most used tool through SharePoint (online collaboration platforms). The differences in tool use between the projects indicate that there is no clear direction on what tools to use and how to use them. If there is no direction in terms of what tools to use, old or new, team members often stick to the more easily accessible tools as this is less time consuming (Westin & Sein, 2014), or the endeavour of using the existing technology might be too great (Barua et al., 2007). This is because for members of an organisation, it takes time and effort to master new information technology systems that contribute to data sharing (Goodman & Darr, 1998). The use of conventional data sharing tools is detrimental for the availability and accessibility of data due to a multitude of reasons such as transparency limiting data trace-ability, the likelihood of double data circulating, loss of useful data, creation of data silos and team members not being aware of the latest files and updates, which all significantly hinder decision-making (Li & Lin, 2006). Therefore, a clear governance is preferred for employees with respect to what data sharing procedures and which tools to use preferably. When a clear governance that contains standardised procedures regarding data sharing and specified responsibilities for all the team roles towards data sharing is lacking, team members are inclined to depend on their managers instead of taking the initiative (Alreshidi et al., 2018). Thus as long as there is an absence of clear governance, the tender managers can be best utilised to implement the preferable solutions. Therefore, the tender managers have to be aware of the influence their data sharing methods have on the team members. In both tenders, it is very clear that a uniform digital approach is lacking, and as a result, data sharing in both projects is not performed in a similar manner. This is detrimental as Martınez-Rojas et al. (2016) state that data technology can become futile when not assisted by a standardised process. The advantages of integrating these technologies will then only remain locally, and interoperability will be hard to attain. Which makes the process of monitoring, managing and re-utilising data much more difficult to execute.

When looking at the identified structures and patterns of the data sharing networks in both projects, we have too little information to conclude which of the projects has the most effective data sharing structure. The density of the networks is approximately the same, and both networks are characterised by a high number of actors in their periphery with just a single data sharing connection. If we form a conclusion solely based on these two projects, we could state that due to the high data needs of the tender team and large amount of peripheral players, the low-density number of the data sharing network is a characteristic of the tender phase. However, a sample size of two projects is too small to make that conclusion, and further research is needed to substantiate the assumption. Moreover, we saw that in project B, the degree per node was higher than in A, but this begs the question of whether more data streams actually mean better data sharing. As already said in

the literature review, stronger relationships between actors can reduce the barriers to data sharing, but on the other hand, an increase in data streams can also increase the chance of information overload, redundancy and irregularity (Heras, 2019). Again emphasising the need to determine an efficient data sharing governance. Furthermore, the most prominent group present in both networks were the estimators. According to Drake et al. (2004) it is important to realise that each group can contain a sort of subculture. This means that these groups require different data and have different abilities and propensities to collect and acquire their own data. As a result, the attitude of, for example, the estimators towards data sharing can be different from that of other work roles. Therefore, the firm should be aware of the behaviour of the different majorities in the network and be able to anticipate on this.

Both networks showed a high clustering coefficient, meaning that overall the neighbours of each node had connections to other neighbours. It begs the question if this was a consequence of all employees working from home due to COVID-19 and if working on location would have an advantageous or disadvantageous effect on the clustering of the tender team. Moreover, in both networks, potential data silos were present. These were predominately located at the network's periphery and did not seem to be role-specific. However, this high amount of peripheral players does make the networks prone to multiple points of failure. As it is entirely possible that the identified gatekeepers do not actively transfer relevant data between actors in the periphery and the network and thus actually maintain those data silos. These gatekeepers obtain the most extensive insights and variety of data, which can enhance individual benefit but restricts group benefit. Therefore, the data needs of actors need to be clearly established, and a data sharing governance can help in getting the right data to the right person. Moreover, data silos can exist in project networks and between geographically scattered project networks. Overall, the different work roles have connected sub-networks, but most do not seem to establish connections with the same disciplines in geographically dispersed projects. This can also result in data silos and can bring about a lack of awareness, intra-organisational competition, diminished quality and reduced productivity (Wanberg et al., 2015). Overall, no discipline-specific data silos were found, except for one in project A, here a discipline-specific data silo was actually detected within the network of the estimators, as can be seen in Figure 4.2. Attention needs to be given to this, as data silos have the ability to introduce potential errors, limit efficiency, productivity and quality of projects (Wanberg et al., 2015) leading to loss of time and money (Dillon, 2015).

4.3.2. Role specifics

Observing the data sharing networks showed us different structures and patterns. Project A was characterised by two informational hubs, while project B showed us a number of informational hubs. The most influential nodes, thus the most connected, had a large responsibility towards the project as information users or had a large responsibility towards data sharing as information controllers. The information obtained from the two networks was too little to be able to distinguish the influential nodes between the two information types clearly. Nevertheless, the most influential nodes in both projects were clearly the tender managers. This was to be expected, but one could wonder if it is the best strategy to let the tender managers shoulder all the responsibility in data sharing. Involving the entire tender team in sharing data is of the essence to profit from the different disciplinary expertise and stimulate the dissemination of data. When roles are undefined towards data sharing, which seems to be the case for the tender managers, this decreases the data sharing quality (Alreshidi et al., 2018). Here other actors can also take on responsibilities when more familiarised with the data sharing environment (Alreshidi et al., 2018). Roles that could be of added value here are the senior planners. During the analysis, these nodes have shown to be part of the influential nodes in the network in terms of data control and dissemination and can therefore be utilised to aid in the endeavour and positively influence the project team in terms of data sharing.

Moreover, when observing the data sharing networks, it is obvious that the falling away of the tender managers in both projects results in a much sparser network. When we observe the fact that conventional data sharing tools were the way to go, then falling away of the tender manager would result in the loss of data, limit data trace-ability and transparency, and cause fragmentation of the network. Furthermore, no consistent data silos were detected in and among the two projects, although it needs to be stated that in both networks, especially the design manager was privy to specific design data that was only accessible to the network through him. Actually making the network susceptible to data silos in case of failure or information overload. In addition, if all design data is relayed through the design manager, it would make the data prone to subjective biases when taken into account in the risk management process. As in both projects, the de-

sign manager is the only one involved in the risk management process that has a design-focused role, but this needs to be confirmed in (in)formal interviews. Involving more disciplinary expertise in the process and defining the criteria together would increase the common understanding and application of relevant data. This enables a more transparent understanding of the problem and more rational choices (van der Meer, 2021). Due to this, discussions within tender teams are encouraged, and through these risk-based dialogues, underlying perceptions and reasoning based on their respective disciplinary expertise emerge such that risk awareness is enhanced (van der Meer, 2021). Therefore, involving team members more in the process, especially when roles are underrepresented, would reduce the detrimental effects on risk awareness. Other than these consistent data silo opportunities, there were a few project-specific potential data silos. However, these are, at this point, deemed unique and specific to the project themselves and not applicable uniformly through all projects. Therefore, these data silos and the associated gatekeepers are not taken into account further in the cross-case comparison and are researched in more detail in their respective subsections.

The visible nodes are involved in lots of network activity but do not play a unique role and should be easily replaceable. Therefore, the visible figures will not be discussed in further detail. Many nodes were identified when focusing on the peripheral players in the networks. If talented or valuable, they present a risk in a way that the project cannot fully utilise their capacities or information. The peripheral players looked at in more detail were specifically the nodes that were connected to the identified gatekeepers. However, similar to some of the gatekeepers in the previous paragraph, most of them are deemed unique and specific to the project themselves and not applicable uniformly through all projects. The only commonality between the projects in terms of peripheral players and not being fully utilised was the Drafting/ Modelling/ BIM group, of which in both projects, the specific node occupied the role of BIM modeller. Especially peripheral players such as the BIM modellers who can extensively see what the risks are in, for example, the phasing of the project, potential clashes in building methods and materials, and constructability conflicts should be able to provide the network with important data, also regarding the risks involved during construction. This means that both networks contained peripheral players that need to be involved much more in the network. A remarkable example was the non-existent connection between the planner and BIM modeller in both projects. Especially the planner should be able to profit from the input of the BIM modeller in terms of phasing, potential clashes and constructability. This is also the case in project B with the risk manager; here, the BIM modeller should also be able to identify and formulate specific risks associated with the clashing and constructability, which leads to the recommendation to include and utilise this group more consistently in the network.

4.3.3. Risk awareness factors

The presence of the risk awareness factors in practice have been analysed elaborately in their respective subsections already. Both projects showed many similarities in terms of the presence of these factors in practice, and most of the factors seemed to be satisfied according to the participants' responses. The first factor that both projects seemed to lack, and was identified as a contributor to risk awareness, was the presence of an incentive system. Furthermore, both projects indicated to have suffered from missing data that hindered them from making decisions involving risks. The vast majority indicated that this was due to the client not providing all the required data. Of which, a couple of participants indicated other reasons such as unfamiliarity/inexperience with the digital environment, fragmentation of data across databases, and not knowing where to find certain data.

When focusing on the occurrence of training's, activities and workshops, a difference was observed between the two projects. The participants in project B seemed to have higher participation rates in these sorts of activities than the members of project A. Where this irregularity stems from is to be determined and begs the question about the thoroughness of the company in training its staff and following up on it. Nevertheless, the overall participation rates in both projects leave room for improvement, especially when compared with the percentage of the people in both projects that state to be actively involved in the risk management process. Most remarkably, though, is that the risk manager has not been trained in any of the training's and/or workshops specifically designed for risk management. Again showing a lack of thoroughness in the company to train and get the staff up-to-date, and this can be particularly disadvantageous when it concerns the people who have to take the lead in the risk management process. Thus if we observe the survey results closely, there are some preliminary measures that could enhance the risk awareness of the team members. These are summarised below and can be seen as quick wins to enhance the risk awareness of members in the tender phase.

1. Put incentive system in place for good performance with respect to risks.
2. More and consistent training and workshops with respect to communication, subjective biases and risk management practices, tools, processes and templates.
3. Larger and more consistent occurrence of activities such as risk review meetings, risk workshops, and non-conformity meetings.
4. Training in the use of digital systems at BAM at the commencement of work instead of initial trial and error.
5. Formalisation of risk management procedures across all projects.

Moreover, the statements of capturing lessons learned showed medium results, that while the capturing and use of lessons learned is an important contributor to risk awareness. However, after capturing lessons learned, these still need to be utilised. This brings us to the most remarkable observation, which was the large difference between the established lessons learned connections in both projects. Project B showed a number of lessons learned connections (see table D.3), while project A indicated just one connection. One could wonder if this is an effect of the presence of a risk manager or due to other reasons such as a bigger budget. Nevertheless, this is in line with the earlier observation that it seems that the risk management procedures are not consistent across projects, especially the smaller ones. With smaller projects is meant projects below a certain threshold in terms of budget and/or risk level. On this level, it seems risk management is more performed according to the interpretation and implementation of the tender manager. The formalisation of standard procedures with respect to risk management among all projects would help attain a higher risk awareness. Nevertheless, the internal tendering procedures at this point do not seem to require lessons learned formally. This seems to be the case more often than not in the construction industry as Urquhart and Whyte (2018) have found that roughly 75% of contractors during tendering do not formally require lessons learned from previous tenders and/or projects to be used as input in following tender pursuits. This low use of lessons learned is in line with the findings from Shokri-Ghasabeh and Chileshe (2014), who states that although construction companies acknowledge the importance of lessons learned, only a third keeps hold of such information and utilises it when pursuing subsequent tenders. From a tendering efficiency standpoint, if construction companies do not evaluate if their actions result in the desired results, it will simply result in the expense of the tender team's time and money (Simu, 2017). Therefore, when the used information is insufficient, constant effort should be exerted into collecting meaningful data and accumulating experience within the organisation (Goto, 2004). As long as construction companies fail to use lessons learned in pursuing new tenders, they are fated to repeat errors and lessons learned will become lessons re-learned (Urquhart & Whyte, 2018).

Therefore, there is a need to utilise best practices and lessons learned from other projects as others most likely have been coping with similar problems and risks. Here the establishment of project transcending lessons learned connections is of the essence, even more so due to the multinational environment the firm is active in. As research has shown that connections between people that cross physical boundaries can enhance opportunities to improve performance and improve entry to information (DeSanctis & Monge, 1999). However, the effort of establishing such connections can be harder for some than for others. This can come due to multiple reasons, and one could be that some people do not have much experience collaborating outside their own project team, or the effort for people to establish these connections can be limited by the lack of intrinsic and extrinsic motivation to move out of their own silo's, or the type of medium utilised in the information exchange may also be a root of problems instead of the willingness of employees to share information. Therefore, ways should be sought after in which the effort for employees to move out their project silo's becomes little to none. That is why the company should try to design a system in which the effort of establishing lessons learned connections is very low, or design a system in which the data is readily accessible for all members within the organisation to use. Examples could be systems in which all the captured lessons learned are stored, including ownership making it possible to reach out and using queried search filters to search for the type of projects, activities and risks, which enables organisational members to take them into account in their own projects.

5

Expert panel

In this chapter, the validation of the research recommendations is performed with an expert panel's help. In section 5.1 an introduction is given of how the expert panel has been performed and what sort of experts were invited. After which in section 5.2 the research assumptions are presented on which the recommendations are based. Then, in section 5.3 the foundation of the recommendations are discussed. This entails a more elaborate explanation of why certain recommendations are made and which observations have led to this. To validate the aforementioned assumptions and recommendations, a data analysis is performed in section 5.4. Lastly, in section 5.5 a framework is created that takes into account the validated interventions and aims to increase the risk awareness of team members within the tender projects of the organisation.

5.1. Introduction

In this chapter, the expert panel is performed. The taken approach, including the slides of the expert session, is described in detail in appendix E. To summarise, first, the experts were sent the research assumptions, presented in the next section, to be validated before the commencement of the expert session. This was done to save time for the validation of the recommendations. After this, the expert session commenced, and with the use of a PowerPoint, an explanation was given of the research subject and objectives. Here also the observations from literature and the case study were presented, which have led to the given recommendations. After this, a discussion was stimulated between the experts to validate the various recommendations, which will be further elaborated upon in this chapter.

Furthermore, the expert panel consisted of four experts from the field. The first expert is the group head of the Uniform Project Approach department that aims to create group-wide standardisation of management processes such as the risk opportunity management and the associated creation of supporting IT systems. In addition, he has previous experience as manager tender desk and as a tender manager. The second expert is an IT business partner focused on digital transformation from an IT perspective within BAM and also has previous experience as a risk manager in tender projects. The third expert has 30 years of experience in the field of (rail)infrastructure and is currently an international tender manager in the (rail)infrastructure. The fourth expert is the head of the risk management department at BAM Infra NL, responsible for risk management and internal control.

5.2. Research assumptions

This research has performed a literature study and a case study. From the literature study, 18 factors were retrieved that were identified as factors that contribute to raising risk awareness. From those 18 factors, there were approximately 7 factors that could be related to the use of data and/or information systems involved when handling data. These factors led to the formulation of research assumptions on which the research and recommendations are based. The expert panel will also be used to validate these formulated assumptions. The research assumptions are stated below:

1. All kinds of data can be potentially important to risk management and risk awareness.

2. Establishment of data sharing and lessons learned connections leads to a higher variety of decision-influencing data and stimulates discussion between organisational members leading to an increased risk awareness.
3. Reducing the occurrence of missing data leads to a higher availability and variety of decision-influencing data, leading to an increased risk awareness. (includes preventing data silos)
4. Minimising compatibility/accessibility issues with data files and systems leads to a higher availability and variety of decision-influencing data, leading to an increased risk awareness.
5. Breaking down intra-organisational data sharing barriers leads to a higher availability and variety of decision-influencing data, leading to an increased risk awareness.
6. Using less conventional data tools leads to an increased availability of data which enhances data sharing and risk awareness.

5.3. Foundation of recommendations

Based on the literature review and the performed case study, a set of recommendations has been determined. This section will be used to present the observations of the literature review and case study that have led to the formulated recommendations and can be seen as the foundation. At the end of this chapter, the recommendations will be put together into a framework. This framework will consist out of a set of recommendations for interventions that enhance the data sharing behaviour of organisational members in project networks, which intend to lead to an increased risk awareness. First, in this section, the observations will be stated and elaborated upon, accompanied by the recommendations that followed from these observations. In addition, it will be indicated if these recommendations need to be performed on a project level or organisational level.

5.3.1. Data sharing recommendations

In this subsection, the recommendations are discussed that focus on the contribution of data sharing to risk awareness.

1. First, during the case study, it was observed that the tool use in both projects predominantly existed out of conventional data sharing tools. The use of conventional data sharing tools is detrimental for the availability and accessibility of data due to a multitude of reasons such as transparency limiting data trace-ability, the likelihood of double data circulating, loss of valuable data, creation of data silos and team members not being aware of the latest files and updates, which all significantly hinder decision-making (Li & Lin, 2006). Moreover, the combination of failure or falling away of influential players in the project networks with the use of conventional data sharing tools can lead to the potential creation of data silos and loss of data. From this, the following interventions are proposed that would lead to better availability, accessibility, control and overview of data on project level:

- Make clear agreements at tender kick-off how and when data should be shared and reused within the team and with whom to prevent redundancy, data silos and data loss. (project level)
- Use of less conventional data sharing tools to enhance the availability of data.

Moreover, in both tenders, it was clear that a uniform digital approach is lacking, and as a result, data sharing in both projects is not performed in a similar manner. This is detrimental as Martınez-Rojas et al. (2016) state that data technology can become futile when not assisted by a standardised process. The advantages of integrating these technologies will then only remain locally, and interoperability will be hard to attain, which makes the process of monitoring, managing and re-utilising data much more challenging to establish. Therefore, also taking the project level arguments into account, the following interventions are recommended on an organisational level:

- A clear data sharing governance that consists out of:
  - Creating a ready and standard to use data management plan that can be used uniformly throughout the company at tender kick-off.
  - Implement clear rules regarding data quality, databases, tools, security, responsibility, roles and procedures.
  - Internal audit that controls the actual implementation of governance in projects.

2. From literature, it was observed that lessons learned and data sharing connections and the associated risk-focused information-sharing are significant contributors to risk awareness. This research is based on the statement that the establishment of data sharing (and lessons learned) connections leads to a greater variety of decision-influencing data and stimulates discussion between organisational members leading to an increased risk awareness. This is illustrated by Casas-Arce et al. (2017) who state that adding decision facilitating data to employees dataset can positively influence employee behaviour in terms of decision-making, and by van der Meer (2021) who states that discussion between disciplines in tender teams leads to a higher risk awareness. Moreover, with respect to the use of lessons learned, there was a significant difference observed between projects A and B. While in project A, there was just one lesson learned connection, project B showed more than ten connections. On paper, the main differentiator between the two projects was the presence of a risk manager. One could wonder if this is an effect of the presence of a risk manager or due to other reasons such as a bigger budget. Nevertheless, this is in line with the earlier observation that it seems that the risk management procedures are not consistent across projects, especially the smaller ones. With smaller projects is meant projects below a certain threshold in terms of budget and/or risk level. On this level, it seems risk management is more performed according to the interpretation and implementation of the tender manager. This is also confirmed in informal interviews with members within the organisation. That is why formalisation of standard procedures with respect to risk management among all projects would help attain a higher risk awareness. In addition, when a risk manager is not present in the project, it means that the project has to deal with interdisciplinary roles due to other roles taking over the tasks of a risk manager. This leads to the following proposed interventions on project level:

- Implementation of a risk manager in all tenders regardless of size.
- Formalise risk management procedures across projects:
  - Consistent use of lessons learned.
  - Consistent procedures, templates and tools.
  - Internal audit to control implementation of procedures in projects and monitor correct execution of risk management procedures across projects.

The establishment of data sharing and lessons learned connections mainly relates to obtaining decision facilitating information which can lead up to an enhanced risk awareness of employees. This is illustrated by Casas-Arce et al. (2017) who state that adding decision facilitating data to employees datasets can positively influence employee behaviour in terms of decision-making. In addition, the multinational environment the firm is active in offers additional advantages, as research has shown that connections between people that cross physical boundaries can enhance opportunities to improve performance and improve entry to information (DeSanctis & Monge, 1999). However, the effort of establishing project transcending connections can be harder for some than for others. This can come due to multiple reasons, and one could be that some people do not have much experience with collaborating outside their own project team, or higher-ranking employees in the hierarchy are more comfortable approaching new people, or the effort for people to establish these connections can be limited by the lack of intrinsic and extrinsic motivation to move out of their own silos, or the type of medium utilised in the information exchange may also be a root of problems instead of the willingness of employees to share information. There are more reasons, but nonetheless, this all limits the use of relevant and applicable data. Therefore, ways should be sought after in which the effort for employees to move out their project silos becomes little to none. That is why the company should try to design a system in which the effort of establishing data sharing or lessons learned connections is very low, or design a system in which the data is readily accessible for all members within the organisation to use. This leads to the organisational demand to be able to mobilise data and make relevant data retrievable to organisational members. Mobilising data on an organisational level leads to recommendations with respect to systems that could facilitate the retrieval of such relevant data. This led to the following potential interventions on an organisational level:

- Actively mobilise relevant data which is accessible to all members within the organisation:
  - Systems in which the data is mobilised and accessible for all members within the organisation to retrieve, enabling employees to discover what has been done previously. Examples could be systems in which all the captured lessons learned, risks, risk reviews etc., are stored, including ownership making it possible to reach out, and using queried search filters to search for the type of projects, activities and risks.

  - Systems that enable employees to find specific experts within the whole company, nationally and internationally, by indicating and revealing their competencies and work.
  - Implement organisation-wide data managers that know the ins and outs of the information systems and where specific data is stored. Here organisational members have a point of contact in case of unknown data location or existence and can be directed to the correct databases and/or data.

3. In the survey response, it was indicated that both projects at times suffered from missing data that hindered them in decision making. However, when this happened, it was primarily due to the client not providing the company with all the data, which in the tender stage happens more often due to the high level of unknowns and uncertainty. When missing data was indicated to be a problem, it were reasons such as unfamiliarity/inexperience with the digital environment (e.g. SharePoint) and therefore not knowing where to find certain data. As a result, team members were unable to utilise or retrieve data fully. In addition to this, poor communication was also often referred to as a reason for missing or non-retrievable data. On an organisational level, this leads to the following recommendation:

- Provide routine and mandatory basic training in the use of digital systems and data sharing tools to all organisational members.

4. According to literature and the case study, another factor is related to the compatibility/accessibility of data. Survey respondents indicated to have suffered from this due to multiple causes. The main cause was that the data was often located in different databases, documents and formats. Another was the fragmentation of data across databases and team members not having access rights to these databases. Reasons given in the English branch were that colleagues were not using the Electronic Document Management System (EDMS) or presenting data in an unfamiliar or convoluted format. In addition, sometimes documents are referenced in tender files but were not accessible in the information portal. More reasons were the unavailability of software to open certain files. Taking these observations into account on a project level has led to the following interventions:

- Make clear agreements on formats, data types and databases used during the tender.
- Stick to limited amount of formats and use similar data types as much as possible.
- Consistency in use of databases and data formats.
- Discuss accessibility restrictions of databases early on and whom to contact in case of problems.

On an organisational level, this leads to the following recommendations:

- Implement more standard data formats and templates for tender projects and monitor consistent use.
- Only use data tools and information systems that allow for unhindered use of these templates and data formats.
- Try to limit the number of data sharing tools and databases throughout the company.

5. There is a wide variety of subgroups in each tender, and in both tenders, the estimators were the largest. According to Drake et al. (2004) it is important to realise that each group can contain a sort of subculture. This means that these groups require different data and have different abilities and propensities to collect and acquire their own data. As a result, the attitude of, for example, the estimators towards data sharing can be different from that of other work roles. Therefore, the firm should be aware of the behaviour of the different majorities in the network and be able to anticipate on this. In addition, to this when analysing the networks, next to potential data silos a role-specific data silo was found in the estimator network of project A. Attention needs to be given to this, as data silos have the ability to introduce potential errors, limit efficiency, productivity and quality of projects (Wanberg et al., 2015) leading to loss of time and money (Dillon, 2015). Therefore, the data needs of actors need to be clearly established, and data sharing governance can help in getting the right data to the right person. Moreover, when a clear governance that contains standardised procedures regarding data sharing and specified responsibilities for all the team roles towards data sharing is lacking, team members are inclined to depend on their managers instead of taking the initiative (Alreshidi et al., 2018). When roles are undefined towards data sharing, which seems to be the case, this decreases the data sharing quality (Alreshidi et al., 2018). Here other actors can also take on responsibilities when more familiarised with the data sharing environment (Alreshidi et al., 2018). Roles that could be of added value here are the roles that have been analysed to be key players in the tender networks. These roles are the tender

managers and senior planners. During the analysis, these nodes have shown to be part of the influential nodes in the network in terms of data control and dissemination and can therefore be utilised to aid in the endeavour and positively influence the project team in terms of data sharing. This leads to the following recommendations on project level:

- Make each sub-group (discipline) sit together at the beginning of the project and establish agreements on data needs and how to share data within the group to prevent role-specific data silos.
- Distribute responsibility by appointing more employees to take responsibility for parts of the data sharing strategy within the team or discipline (utilise most influential actors).
  - Implement a document controller, and in larger projects, this can be a job on its own.
  - Make clear agreements on further data sharing roles/responsibilities.
  - Utilise most influential actors in taking the lead.

6. When observing the data sharing networks of both projects, a high number of gatekeepers and peripheral players were determined. As a result, in both networks, many gatekeepers are present, which makes the network prone to multiple points of failure. As it is entirely possible that the identified gatekeepers do not actively transfer relevant data between actors in the periphery and the network and thus actually maintain those data silos. In addition, falling away of those gatekeepers would result in the loss of data, limit data trace-ability and transparency, and cause fragmentation of the network. Again emphasising the need for more centralised data sharing tools and databases as well as establishing data needs of actors. Luckily, no consistent data silos were detected in and among the two projects, although it needs to be stated that in both networks, especially the design manager was privy to specific design data that was only accessible to the network through him. Making the network susceptible to data silos in case of failure or information overload. In addition, if all design data is relayed through the design manager, it would make the data prone to subjective biases when taken into account in the risk management process. As in both projects, the design manager is the only one involved in the risk management process with a design-focused role.

Besides, involving more disciplinary expertise in the process and defining the criteria together would increase the common understanding and application of relevant data. This enables a more transparent understanding of the problem and more rational choices (van der Meer, 2021). Due to this, discussions within tender teams are encouraged, and through these risk-based dialogues, underlying perceptions and reasoning based on their respective disciplinary expertise emerge such that risk awareness is enhanced (van der Meer, 2021). Therefore, involving team members more in the process, especially when roles are underrepresented, would reduce the detrimental effects on risk awareness. This also applies on a discipline level. Stimulating discussion here regarding risks would involve more expertise in the risk management process and would further increase the common understanding and application of relevant data, after which it can be used in the risk management process. In addition, it would also allow the more quiet team members to speak up. Furthermore, the only commonality between the projects in terms of peripheral players and not being fully utilised was the Drafting/ Modelling/ BIM group, of which in both projects, the specific node occupied the role of BIM modeller. Especially peripheral players such as the BIM modellers who can extensively see what the risks are in, for example, the phasing of the project, potential clashes in building methods and materials, and constructability conflicts should be able to provide the network with essential data, also regarding the risks involved during construction.

On a project level, this leads to the following recommendations:

- Include and utilise roles more consistently in the data sharing network and risk management process that have important input and are now only connected through a gatekeeper (BIM/Modelling/Drafting group).
- Enhance risk awareness by stimulating risk discussion within the discipline.
  - Create discussion within disciplinary specific teams about potential risks, opportunities and mitigation and then relay back to risk manager and/or risk management process. Involving more disciplinary expertise in the risk management process and defining the criteria/risks together would increase the common understanding and application of relevant data. This also allows the more quiet members to speak up.

7. Improving the operational ease of use of information infrastructure is needed as literature emphasises the fact that: if there is no direction in terms of what tools to use, old or new, team members often stick to the more easily accessible tools as this is less time consuming (Westin & Sein, 2014), or the endeavour

of using the existing technology might be too great (Barua et al., 2007). This is because for members of an organisation, it takes time and effort to master new information technology systems that contribute to data sharing (Goodman & Darr, 1998). Therefore, in practice, more conventional data sharing tools are often used, which can be seen in the actual tool use of both tenders. The potentially detrimental effects of using such tools have already been discussed in detail in other points. Therefore, the argument is made to improve the operational ease of use of information infrastructure.

This leads to the following recommendations on the organisational level:

- Enhance the operational ease of use of information infrastructure.
  - Enhance the ease of use of information systems and tools through clear guidelines that enhance applicability across projects.
  - Make it clear whom to contact for support in case of occurring problems with data sharing tools and/or information systems.

5.3.2. Direct risk awareness recommendations

Here recommendations are discussed that have a direct influence on risk awareness. These recommendations also follow from the literature review and case study observations. Only here, the main difference is that these recommendations lead straight to an increased risk awareness instead of focusing on the contribution of data sharing to risk awareness. This means that these recommendations are not actually helpful in answering the main research question but can still scientifically contribute to risk awareness literature and definitely contribute practically to the company in increasing risk awareness. This is important because other factors contributing to risk awareness besides data sharing were researched to obtain a complete view of the research domain during the research. Nevertheless, these recommendations are discussed below:

8. During the research, the participation and occurrence of training's and activities involved with risk management processes, tools, templates and subjective biases were researched. As well as the occurrence of and participation in risk review meetings, risk workshops and deviation analysis regarding risks (non-conformity analysis). In both tender teams, the majority had indicated to be involved in risk management, while of that majority, a number indicated never to have received training in risk management processes, tools, templates and subjective biases. Moreover, it was also determined that there were big irregularities between the two different projects regarding participation in these training's and activities. Through these observations, we could determine that participation in these sorts of training's or workshops is not adequately monitored or obligatory. In addition, after informal interviews, it was confirmed that these sorts of training's in BAM are non-obligatory and on a voluntary basis. Nevertheless, the most remarkable finding was that the risk manager indicated also to have never participated in these sorts of training's or workshops and that these were also never offered to him. This is not desirable, especially when the people involved in the risk management process are not familiarised with the companies processes, templates and tools, even though they might have extensive knowledge of the subject.

This has led to the following recommendation on the organisation level:

- Provide routine and mandatory basic training and workshops to all tender team members regarding risk management procedures, templates, tools and subjective biases.
  - Mandatory for everyone involved in risk management.
  - Internal auditing to control occurrence and participation in these trainings, workshops and activities.

The following recommendations have all been retrieved from literature and have not been researched during the case studies. However, with the help of the expert panel, we can actually determine the usefulness and effectiveness of these recommendations. It could arise, for example, that the recommendations are already established in practice, and there is no need for them. On the other hand, it could be that the recommendations are not implemented, or literature is wrong according to experts in the field. Nevertheless, the recommendations can be validated and possibly used after the expert panel validation. These recommendations are shown below, including some extra information to elaborate on the reasoning behind the recommendations:

9. According to literature, pro-actively accepting responsibility for risks will increase the risk awareness of involved employees. Due to the fact that having a better comprehension of roles and accountability/responsibility in risk management will lead to increased risk identification, enhanced assumption of risk ownership and pro-active thinking of employees.

- Focus on risk ownership (responsibility/accountability).
  - Every risk has an owner and knows what his tasks are; risk owner continuously checks up on risk.
  - Leadership (tender manager or risk manager) continuously asks for risk status and is explicit about risk appetite on specific topics.

10. According to literature, introducing an incentive system in which employees are rewarded compensation for sound risk management will encourage personnel to be involved, which leads to a positive risk culture and people becoming more aware of the risks involved.
This has led to the following recommendation on the organisation level:

- Introduce incentive system with respect to risks.
  - Examples could be incentives for the tender team in case of proper identification and assessment of all risks that occur during the construction phase.

11. According to literature, a bottom-up perspective in which management is able to motivate communication and escalation of issues involving risks all the way from the lower levels to the upper ones is essential. By giving employees a voice in risk-related issues, upper management can take apart hierarchical barriers and support engagement of employees, which results in a higher motivation among firm employees to continuously contemplate about risk-related issues (Adler & Chen, 2011). Consequently, management fabricates a climate of trust and transparency and signals that it is approachable and focused on open communication and inspires and encourages openness to challenge.
This has led to the following recommendation on the organisation level:

- Bottom-up communication and escalation of risks awareness.

12. According to literature, to produce a satisfying level of risk awareness within the firm, upper management must dedicate its attention to issues involving risk, extensively support the risk management process, and transfer expectations regarding risk management behaviour, and encourage communication and escalation regarding issues involving risks to all levels (COSO, 2004; Lam, 2014). Doing this portrays that risk management matters because when upper management believes in risk awareness and dedicate their resources, effort, and time to issues involving risks, then others will follow, leading to a sound risk culture.
This has led to the following recommendation on the organisation level:

- Top-down encouragement with respect to the risk management process.

5.3.3. List of recommendations

The list below is created to summarise all recommendations to be used during the expert session and discussed in this section. Note here that the numbering is inconsistent with the numbering in the previous sections. This is due to the fact that points raised in the previous section at times have led to multiple recommendations. In addition, during the expert panel, we want to group recommendations that have the same focus, for example, people-oriented, process-oriented or technology-oriented. This is done so that the experts can focus and think more deeply about the recommendation instead of discussing an entirely different recommendation every time, which takes additional time to grasp how it fits into the research fully. As a result of the high time pressure on the expert session to discuss all recommendations, this is not desirable. Hence, the following list is created and will be used as input for the expert panel session and validation:

1. Meeting to prevent potential data loss, redundancy and data silos in project network and in discipline-specific networks.
   (a) Make clear agreements at tender kick-off how and when data should be shared and reused within the team and with whom to prevent redundancy, data silos and data loss. (project level)
   (b) Make each sub-group (discipline) sit together at the beginning of the project and establish consensus on data needs and how to share data within the specific discipline. (discipline level)

2. Tackle network consistent gatekeepers and data silos by including BIM/Modelling/Drafting group members in the data sharing network and risk management process. (project level)
3. Distribute responsibility by appointing dedicated team members to take responsibility for parts of the data sharing strategy within the team or discipline. (project level)
4. Create a clear data governance plan. (organisation level)
5. Implementation of a risk manager in all tenders. (project/organisation level)
6. Formalise risk management procedures across projects. (organisation level)
7. Create enhanced risk awareness by stimulating discipline discussion. (project level)
8. Provide routine and mandatory basic training in the use of digital systems and data sharing tools to all organisational members. (organisation level)
9. Improve the operational ease of use of information infrastructure. (organisation level)
10. Use less conventional data sharing tools to enhance the availability of data. (project level)
11. Enhance compatibility and accessibility of data and databases.
    (a) Project level.
    (b) Organisation level.
12. Actively mobilise relevant data which is accessible to all members within the organisation. (organisation level)
13. Provide routine and mandatory basic training and workshops to all tender team members regarding risk management procedures, templates, tools and subjective biases. (organisation level)
14. Focus on risk ownership (responsibility/accountability). (project level)
15. Introduce incentive system with respect to risks. (organisation level)
16. Bottom-up communication and escalation of risk problems. (organisation level)
17. Top-down encouragement with respect to risk management. (organisation level)

5.4. Data analysis

In appendix F an extensive data analysis of the assumptions and recommendations is performed. This includes an overview of the quotes and statements used by experts during the discussion to substantiate their opinion and choices during the expert panel. This section will be used to summarise the main findings and present the validation of the recommendations and assumptions.

5.4.1. Validation of assumptions

Before commencement of the expert panel, the experts were sent a word document that contained the research assumptions of this research, upon which the recommendations are based. This was done to save time during the expert panel since there were many recommendations to be validated. The experts were asked to give their opinions on the assumptions and indicate if they agreed or disagreed. In appendix F.1 some quotes and statements are included that substantiate the outcome of the validation of the first five assumptions. The validation has resulted in the following research assumptions:

1. All kinds of data can be potentially important to risk management and risk awareness.
2. Establishment of data sharing and lessons learned connections leads to a higher variety of decision-influencing data and stimulates discussion between organisational members leading to an increased risk awareness.
3. Reducing the occurrence of missing data leads to a higher availability and variety of decision-influencing data, leading to an increased risk awareness.
4. Minimising compatibility/accessibility issues with data files and systems leads to a higher availability and variety of decision-influencing data, leading to an increased risk awareness.
5. Breaking down intra-organisational data sharing barriers leads to a higher availability and variety of decision-influencing data, leading to an increased risk awareness.

The experts' response indicated that they agreed with all assumptions, except assumption 6. Hence, the outcome of the response resulted in the validation of assumptions 1 to 5. However, it has to be noted that although the experts agreed with the assumptions, they put the notion out there that too much data can also lead up to information overload, especially in the tender phase where the time pressure to process all the data is high. Therefore, in practice, attention needs to be given to this.

Assumption 6, at this point, was considered too vague and not clear enough regarding what was meant with conventional tools. During the expert panel session, additional time was allocated to dive deeper into

the concept of conventional tools and how they are used in the data sharing networks. In the end, assumption 6 showed to be not necessarily an assumption on which recommendations were based, but more a recommendation in its own right. This has been covered in point 10 of the recommendations and will be discussed in more detail in the next section.

5.4.2. Validation of recommendations

In this section, the recommendations are validated. To validate the recommendations, the experts were asked to give their opinion about the recommendation and discuss amongst themselves to reach a consensus. It is important to emphasise that the experts were asked to validate the recommendations with the end goal of raising risk awareness among the team members of the tender projects within the organisation. During the session, the researcher's place was more to moderate the discussion and give clarifications about the recommendations when needed. After discussing the recommendation, the experts were asked to rate the effectiveness of the recommendations on a scale of 1-5 with the following definition per score:

- 1 = Not effective
- 2 = Little effective
- 3 = Neutral
- 4 = Effective
- 5 = Very effective

This enables the research to also quantitatively substantiate the recommendations and rank them in terms of effectiveness instead of just qualitatively. In addition, this also reduces error when misinterpretation arises regarding the opinion of a specific expert. It has to be noted that during some of the recommendations, the discussion was very extensive and intensive and did not lead to consensus among the experts. In this case, the expert might have withheld his vote due to the blurriness of the discussion and inconclusive outcome. Nevertheless, if no consensus was reached, the experts were still asked to score the recommendation based on their own expertise. This resulted for some of the recommendations in three given scores instead of four, which was the case for recommendation 10, 12, 14 and 16. In Figure 5.1 the rated scores regarding the effectiveness of the recommendation towards risk awareness can be seen.

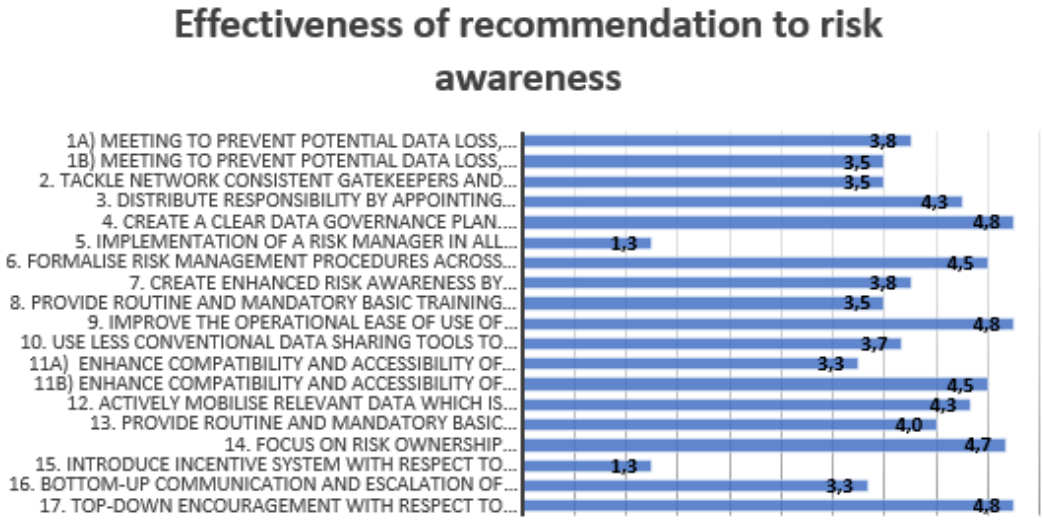


Figure 5.1: Score of the effectiveness per recommendation to risk awareness.

First of all, when looking at the rated scores, it can be determined that almost all recommendations were rated as effective considering the end goal of raising risk awareness among the project team members. Combining this with the substantiation of the experts in appendix F we can conclude that all recommendations are validated with the exception of recommendation 5, the implementation of a risk manager in all projects, and recommendation 15, the introduction of an incentive system with respect to risks. Moreover, we can see two recommendations that have a score of 3.3, which is just above neutral, namely recommendations 11 and 16. Recommendation 11, enhancing the compatibility and accessibility of data and databases, was stated by

the experts to be useful but that this can be best done on an organisational level as there is not much room for improvement during the tender. This is mainly due to the time pressure on the people during the tender and the fact that there is not enough time for the team members to take this adequately into account and also elaborately think about the compatibility and accessibility of data and systems. Moreover, the experts stated that this would not be necessary to implement on the project level if it is already done on an organisational level as then the team members can readily use the data, formats and databases. Therefore, recommendation 11 will be made on just an organisational level. Regarding recommendation 16, it was indicated that it was helpful to be able to escalate problems to the higher levels but that it is more important that leadership should be open to this instead of dismissing it. By being open to risk issues as leadership and showing role-model behaviour, you automatically allow for bottom-up escalation of risk issues. Therefore, recommendation 17 will change into 'Top-down encouragement and role-model behaviour', making recommendation 16 redundant.

Furthermore, very important to note is that the experts often, during the validation of the recommendations, indicated to distinguish between the bigger and smaller projects. They agreed that the recommendations are relevant and useful for all project sizes, but it can become difficult for smaller projects to implement. This is mainly due to the additional costs that accompany the implementation of the recommendations in the smaller projects and the necessity to keep the costs low at this stage. Nevertheless, this research will not make a distinction regarding the recommendations with respect to project size. It will be up to the company to decide if the tender costs will not increase too much or if they want to allocate additional funds for implementation. To summarise, based on the opinion of the experts, it can be determined that all recommendations, with the exception of 1 and 15, would support an increased risk awareness among project team members in the organisation. However, the biggest improvements in terms of risk awareness can be attained through organisational changes.

5.5. Risk awareness framework

In this section, the risk awareness framework will be presented. In essence, companies can use this framework as a guide to raise the risk awareness of tender team members within the organisation. When we observe the concept interrelatedness in section 1.3, it was determined that the factors contributing to risk awareness could be divided into three distinctive groups. Based on this, the risk awareness framework will be divided into two different parts: part A and B. In Figure 5.2 the concept interrelatedness, including the division of the risk awareness factors into the two different parts, is presented. Here, one can see that the risk awareness factors influenced by data sharing are allocated to part A and factors that contribute directly to risk awareness or indirectly through an improved risk culture are allocated to part B. Consequently, the framework is divided into a part A and B, in which part A encompasses recommendations that enhance risk awareness by improving data sharing, and part B encompasses recommendations that directly influence risk awareness or indirectly through an improved risk culture. As this research mainly focused on the relationship between data sharing and risk awareness and thus on factors belonging to part A, this part of the framework is logically more extensive.

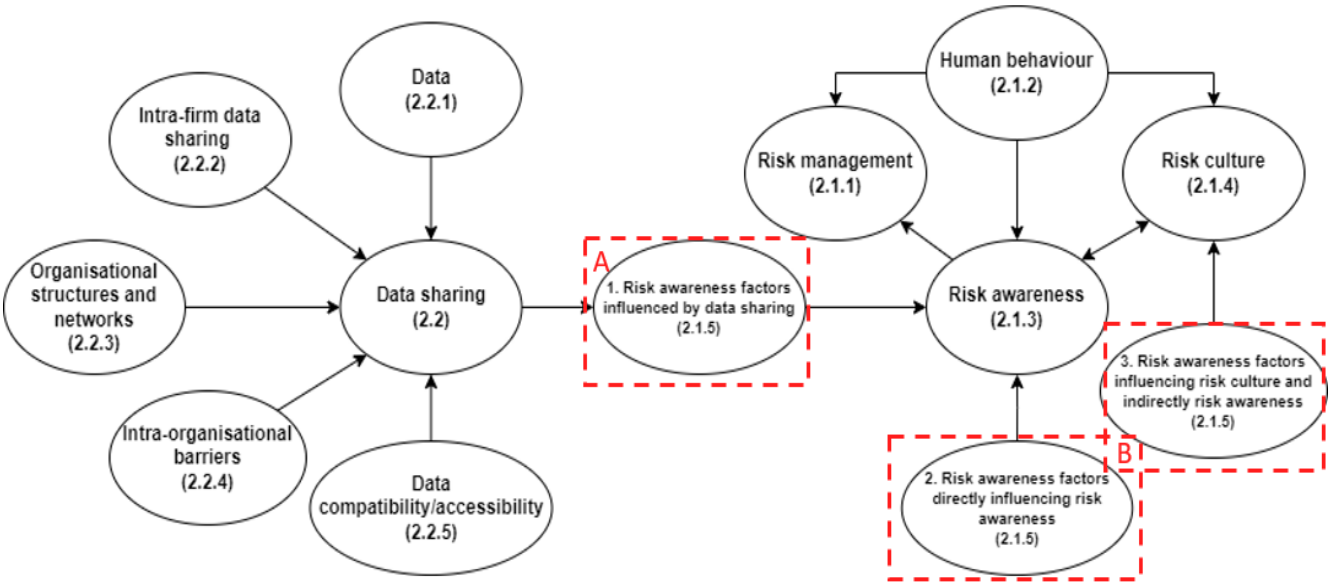


Figure 5.2: Concept interrelatedness including division of risk awareness factors.

Finally, it was also decided not to include recommendation 5, 'implementation of a risk manager in all tenders', recommendation 15, 'introduce an incentive system with respect to risks' and recommendation 16, 'Bottom-up communication and escalation of risk problems'. Moreover, recommendation 11, 'Enhance compatibility and accessibility of data and databases', will only be given on an organisational level. Precise explanations as to why these recommendations are altered or not included can be found in the previous subsection. All other recommendations have been validated and, as a result, will be incorporated into the risk awareness framework.

The final framework is presented in Figure 5.3. The framework's goal is to raise risk awareness of project team members within the organisation during the tender phase. The risk awareness framework is intended to be used as a guide by construction and engineering companies to improve the risk awareness of team members in the tender projects regardless of their complexity. This framework shows that enhancing risk awareness can be done in two ways: (i) By stimulating risk awareness on a project level and (ii) by stimulating risk awareness on an organisational level. Furthermore, the recommended interventions are presented based on their effectiveness from high to low in terms of raising risk awareness. The rated scores of the recommendations can be found in Figure 5.1. When possible, it is advised to prioritise the implementations of the recommendations in accordance with their effectiveness. The validation and scored ratings of the recommendations in the previous section have shown that the organisational interventions are expected to attain a higher effectiveness in increasing the risk awareness of tender team members than interventions on a project level. While on the other hand, the project level recommendations can be seen as quick wins as these can be implemented at the start of the tender without too much effort. Lastly, the numbers in the framework correspond to the numbers of the given recommendations for intervention in section 5.3.3.

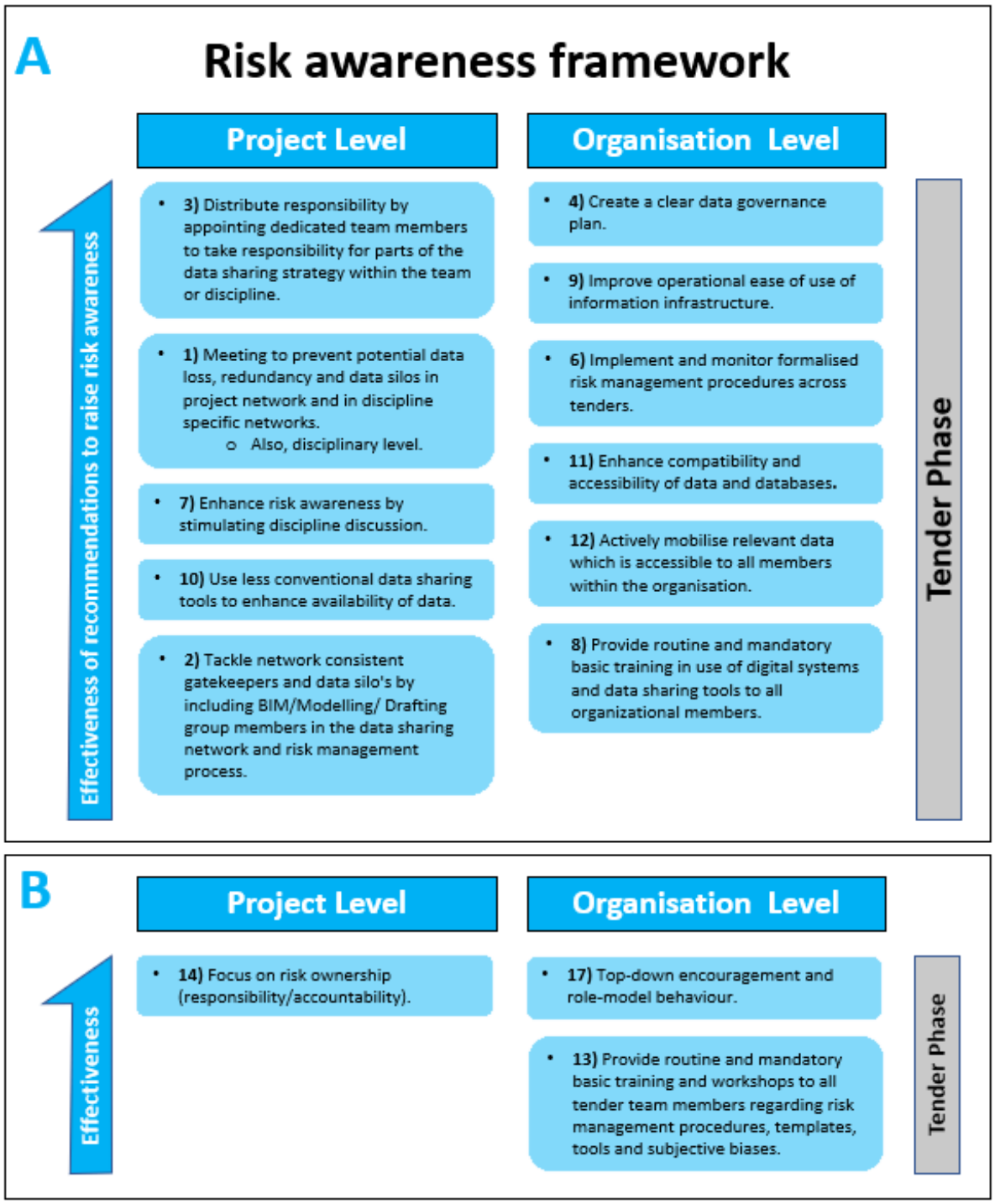


Figure 5.3: Risk awareness framework.

6

Discussion

In this chapter, the research results will be discussed. At first, the research results will be interpreted and explained in section 6.1. Then, in section 6.2 the added value of this research to science and practice will be elaborated upon. Lastly, in section 6.3 the research limitations are discussed.

6.1. Interpretation of research results

This thesis aimed to determine if data sharing could contribute to risk awareness of project team members in the tender phase. At a first glance, it seems that the research results are in accordance with the initial expectation that data sharing contributes to risk awareness in the tender phase. However, it is important to note that the connection between the two concepts at the beginning of the research was based on assumptions. These assumptions have been validated with the use of an expert panel and therefore are presumed to be valid. As a result, based on the case study and literature review, a set of recommendations was given, which companies can use to raise the risk awareness of project team members through enhancing data sharing. These recommendations can be split into two main categories: project level and organisation level. The project level recommendations can be seen as quick wins as these do not take much effort to implement. Additionally, the costs of incorporating these recommendations are considered little to none.

Overall, if we look at the recommendations, they are almost all in essence related to facilitating the data sharing process and thus enabling the team members to share, retrieve, search and find data more easily. This prevents organisations from wasting large amounts of money, time and resources in pursuit of data or by making decisions based on incomplete data. The project level recommendations mainly contribute to the control and overview of data on a project level. Having control and overview of data can offer companies many advantages in terms of preventing data loss, redundancy and data silos, as often emphasised in this research. Employees spend much time eliciting requests for data or satisfying requests for data, while these often may not consist of the correct information (Yang & Maxwell, 2011). This extra work interferes with an employee's work time and resources which takes up unnecessary time and effort, especially in the tender phase where the time pressure is high. Having control and overview, therefore, provides great benefit to companies. Here using more centralised networks and tools is believed to also add benefit. It was often observed that conventional tools were used, combining that with the network structures, the projects were prone to redundancy, loss of data and overview, and outdated data. By systematically using more centralised ways of working, data is more easily accessible, retrievable, and updated, increasing data availability.

The organisation level recommendations are more focused on providing training's and enhancing the ability to use and obtain data throughout the company. Moreover, on an organisational level, the recommendation for a clear data sharing governance was given. This entails creating a data management plan that can be used uniformly throughout the projects and implementing rules regarding data quality, databases, tools, procedures, security and roles. This comes with its practical implications as implementing a data governance involves many different elements and a wide variety of rules and guidelines, which is prone to error due to its extensive nature. Striving for a data governance can therefore be complicated. However, considerable advantages in productivity can be achieved when this is done continuously (Matthews et al., 2018). This continuous

process is of the essence since the accompanied technology often already gets outdated within a few months after it is launched (Rastogi & Trivedi, 2016), and to remain efficient and competitive, companies need to adapt and embrace future advancements.

Another organisational recommendation was related to the formalisation of risk management procedures as this would increase the availability and completeness of data (Teller, 2013), leading to an increased risk awareness. Surprisingly, it was observed that procedures are often done differently throughout the projects, especially in tenders with a smaller risk level and budget. After follow-up research, it was evident that risk management procedures are formalised but not officially implemented and monitored. Therefore, it is important for companies to realise that not only formalising procedures is needed but also really implementing and monitoring this to reap the benefits. In relation to this on a practical level, it would be good to see differences with respect to the complexity of the projects. As very complex projects logically should be subjected to more procedures, rules and regulations than smaller projects. This can be the main driver as to why this difference in procedures was observed in the first place. In addition, the ease of use of information systems has also been determined as a positive contributor to data sharing. This is primarily due to the fact that team members often stick to the more easily accessible tools as this is less time consuming (Westin & Sein, 2014). This is because, for members of an organisation, it takes time and effort to master new information technology systems that contribute to data sharing (Goodman & Darr, 1998). Through enabling organisational members to use the preferred tools, efficiency can be increased and data sharing enhanced.

The most remarkable observations were made with respect to the occurrence of training and activities related to risk management. It was observed that the majority of both tender teams indicated to be actively involved in risk management, while of that majority, many indicated to have not received training or very little in a long time span. Most remarkably, though, is that the risk manager has not been trained in any of the training's and/or workshops specifically designed for risk management. This can be particularly disadvantageous when it concerns the people who have to lead the risk management process. After follow-up research, it was determined that these sorts of trainings and activities are non-obligatory and are only offered. In addition, it was also determined that there is no internal audit on who has or has not received training. It is very much believed that when a company does not consistently provide trainings and activities and checks up on this, it will be less competitive in the long run. In addition, organisational members must be able to grow and go along with potential advancements and remain up-to-date. If companies do not do this and are afraid of making activities or trainings partially obligatory, the company can standstill in its progress. This results in less equipped employees, which can have a disadvantageous effect on the tenders.

Next to confirming the added benefit of factors retrieved from literature, also contradictions have arisen. Literature (Posch, 2020; Zainudin et al., 2019) has often emphasized the use of an incentive system to raise risk awareness. However, during validation, experts from the industry firmly disagreed with the idea of such a system and were quick to reject the idea. The experts stated that "this sort of behaviour belongs to the standard work of employees" and that "rewarding behaviour that actually belongs to the basic competencies of project members is highly unwanted and not desirable". Therefore, although such systems work good in theory and do well in literature, this research rejects the applicability of such systems in practice.

Moreover, a factor that was determined through the research that was not established beforehand was role-model behaviour. The research found out that role-model behaviour is important in stimulating and motivating employees to perform the job properly. This is indirectly supported, as literature states that team members are inclined to depend on their managers instead of taking the initiative (Alreshidi et al., 2018). In addition, it also concluded that proper role-model behaviour discards the factor of being able to escalate problems to higher management. This is due to the fact that although it is helpful to be able to escalate problems to the higher levels, it is more important that leadership should be open to this instead of dismissing it. By being open to risk issues as leadership and showing role-model behaviour, you automatically allow for bottom-up escalation of risk issues. This, in combination with top-down encouragement in which leadership dedicates its attention to issues involving risk, extensively supports the risk management process and transfers expectations regarding risk management behaviour. It portrays that risk management matters, enhancing the risk culture and subsequently risk awareness.

All in all, the recommendations mostly facilitate the availability and variety of decision-influencing data to increase the risk awareness of project team members. This is done by making modifications to the technologies, procedures and processes organisational members can use and follow. However, still, an essential

factor to take into account is the human factor. Although we can make the process of sharing, retrieving, searching and finding data for organisational members better and easier, we still depend on the people to do it correctly. Therefore, companies should never forget that these things should be implemented from a human viewpoint and with an eye on how humans perceive its usability. Nevertheless, this research argues that by breaking down intra-organisational barriers and positively influencing project team members' data sharing behaviour, the ability of project team members to obtain decision-influencing data can be improved. As a result, the perspective of the decision-makers can be broadened regarding risks, attaining a higher risk awareness.

6.2. Added value of research

For a master thesis to be complete, there needs to be added value to existing literature or the addition of new knowledge to literature. This section will dive deeper into the added value of this research in terms of science and practice.

6.2.1. Contribution to science

This research has shown added benefits in multiple ways with respect to risk awareness literature. To start off, existing literature that focuses on risk awareness was found to be very limited during the literature review. A translation had to be made from other sectors such as accounting and insurance to the construction industry on many occasions. In addition, information was often obtained regarding risk awareness within literature that elaborates on the use of Enterprise Risk Management (ERM), which is a one size fits all approach for all sectors that want to integrate risk management into their practice. Therefore, it can be deduced that the concept of risk awareness is not new but rather underexposed in the construction industry science. This thesis research shows added benefit by focusing and applying the concept of risk awareness solely to the benefit of the construction industry. Here, this research has created an extensive oversight of which factors can contribute to risk awareness in the sector. This includes discarding the factor of an incentive system as a contributor to risk awareness in practice and the addition of role-model behaviour as a contributing factor. In addition, a social network analysis has not been applied before to research the raising of risk awareness, and as a consequence, will also expose new knowledge to the scientific field. Nevertheless, the main focus and addition of this research is investigating specifically how data sharing in intra-organisational project networks contributes to risk awareness in the tender phase. During the exploratory literature research, no article has been found with the main focus on the relation between these two concepts, which again allows for new insights into the matter. Lastly, this research created a framework that the construction industry can use to raise risk awareness of project team members during the tender phase in their company.

Therefore, when it comes to the scientific value of the research, it is believed that this research has allowed for new insights into the matter of risk awareness in the construction industry. More specifically, exposing and emphasising the link between how companies use the power of data to increase the risk awareness of organisational members in the tender phase.

6.2.2. Contribution to practice

On a practical level, the findings of this research will contribute to the data sharing practices and risk awareness within multinational construction companies. The construction sector can use the information obtained throughout this research and the created risk awareness framework as a strategy to raise risk awareness of project team members in the tender phase. This particularly applies to BAM as the research has been conducted at the company and is based on real-life cases within the company. By increasing risk awareness in the company, the effectiveness of risk management can be enhanced (Braumann, 2018). As risk management directly affects the project success, the chance of project exceedances gets smaller, and as a consequence, the chance of project success should be enlarged. Lastly, this research focused on the tender phase, but it is believed that many of the recommendations will positively affect the other project life-cycles as well.

On a more specific level for companies, it is advised to pay more attention to the details and the technology and processes involved and consider the complexity of projects. Of course, the recommendations and conclusions drawn in this research are more generalised with the viewpoint of contributing to science. However, companies should dive a bit deeper into the conclusions and look at how this fits explicitly into their business. An example is the formalisation of risk management procedures and the internal audit to control

implementation and execution. This is a recommendation for the entire industry, but on a more detailed level at BAM, we can, for example, distinguish between the risk level of tenders. The larger and riskier tenders are preferred to have a higher level of detail, using more extensive procedures, utilising lessons learned more, stimulating organisational learning. While the smaller projects should be subject to clear procedures as well, the level of detail, however, is less wanted and needed. This can come due to many things such as costs or just that the necessity to go through a multitude of procedures can simply hinder the progress at smaller projects.

6.3. Research limitations

This thesis research was subjected to certain limitations and setbacks. These are elaborated upon below and need to be taken into account when interpreting the results and conclusions of this research.

- **Contract scope:** The researched case studies were all subjected to the same contract scope, namely the design and build scope. This limits the usefulness of the results when used in projects that handle a different contract scope, for example, DB(F)MO, build only, alliance contracts, etcetera. As it can be expected that every contract scope requires a different team composition and with it different data requirements and expected ways of working.
- **Project type:** This limitation is similar to the previous argument but then relates to the specific type of project. The tender projects researched in the case study were all focused explicitly on rail infrastructure tenders. This may limit the usability of the results when taking them into account for other types of projects in the built environment.
- **Generalisability:** As stated in the beginning of the research the plan was to perform three case studies during this research. Unfortunately, this has resulted in just two case studies due to the limited time of the master thesis and the ineligibility and unresponsiveness of various projects. This, of course, affects the reliability of the results as a sample size of two projects is a bit small to generalise the findings across all projects in the company. Therefore, a larger sample size is preferred to obtain a more substantiated conclusion.
- **Intra-organisational data sharing:** This research focused particularly on the intra-organisational data sharing behaviour and its effect on risk awareness. However, risk awareness in practice is also dependent on inter-organisational data sharing. One could think of essential data held by external companies that are needed in the tender phase or compatibility issues between inter-organisational databases and information systems. These are all data sharing problems that affect the risk awareness and availability of data. In addition, external companies can also exert their influence on the dynamics of the data sharing network. These are all aspects that can have an effect on the observed outcomes that are not taken into account in the current research.
- **Survey respondents:** The social network analysis was performed with the help of a survey, and the most important contributors have been selected to participate in the survey in consultation with the tender manager. However, not all the determined team members were able to participate in the survey. Some of the team members worked for collaborative companies, and due to the intra-organisational scope of this research, they have not been invited to participate. Other team members simply never replied to the survey, and others were not able to be contacted due to the fact that they left the company or were on leave. The inability to incorporate these people in the social network analysis has an effect on the results. Moreover, all survey respondents were asked to fill in the survey from memory. Observing that some of the projects were finished more than a year ago, this can also have an effect on the outcome. Therefore, the findings do not always provide a complete perspective on the dynamics of the data sharing network but still reveal valuable insights.
- **Survey language:** The initial plan was to send out a survey in the English language to both the Dutch and English tender projects. However, the survey has been sent out in Dutch and English due to an insufficient control of the English language by some of the participants. Therefore, some interpretation issues can arise due to the fact that respondents can interpret the questions in a different manner.
- **Network influence:** The survey has asked the participants to provide at least five and at most ten data sharing connections. The connectivity, and thus the centrality measures used in the analysis, are actually influenced by the amount of data sharing connections each actor has in the network. This means

that the effort put in by the survey participants to fill in data sharing connections can determine their connectivity in the network. This can be seen as biased because a participant can have a high number of data sharing connections if the respondent actually takes more effort to fill in names compared to other respondents.

- **Edge weight:** A limitation of the used social network analysis tool, Gephi, is related to the weighted edges of the data sharing network. The edge weight in this research is determined by the frequency and perceived value of the data by participants. In the visualisation of the different data sharing networks, this weight has been taken into account in the size of the nodes and edges, which only enabled the researcher to visually analyse the network based on the weight of the edges. Thus, unfortunately, Gephi could not take the weights of the edges into account when calculating the centrality measures of the weighted network. As a result, the networks are only analysed qualitatively and not quantitatively on the frequency and perceived value of the data streams.

- **Data types:** This research has mainly focused on risk awareness and how data sharing contributes to that. The primary assumption was that all data that is being shared could be relevant for the risk management process in terms of identifying, assessing and mitigating risks. However, not much attention has been given during this research to the types of data that is being shared in and between project networks. Thus, little information was retrieved about what sort of data is communicated between project members, what types of data are useful, which data types are used and potentially preferred, and similar aspects related to data types. By not taking this into account we neglected aspects that can positively contribute to the outcome of the research.

- **COVID-19:** All selected cases were executed during the COVID-19 pandemic. Consequently, it was harder to determine the effect of geographical location on data sharing within project networks and thus ultimately on risk awareness. This is because due to the pandemic, everyone was forced to work at home and online. This should logically result in different tool use and data sharing behaviour of organisational members when compared with non-pandemic situations.

7

Conclusion

In this chapter, a final conclusion is formulated based on the research findings. In section 7.1 the research sub-questions will be answered. Followed by the answer to the main research question in section 7.2. Finally, the chapter will be concluded with recommendations for further research in section 7.3.

7.1. Research sub-questions

In this section, the research sub-questions will be answered before moving on to the main research question:

1. What does risk awareness in the construction industry entail based on literature and what are factors that contribute to this?

In this research, literature was consulted to determine what risk awareness entails, including factors contributing to this. Firstly, this has resulted in risk awareness being defined in this research as "the raising of understanding within the population of what risks exist, their potential impacts, and how they are managed". Literature argues that risk awareness has a positive effect on the effectiveness of risk management, and some scholars have even found evidence for this (Braumann, 2018). This is due to the fact that a risk-aware employee pro-actively identifies risks for their firm and thinks deeply about the impact and response of the identified risks. Therefore, risk awareness can be seen as the outcome of all employees sharing and reflecting on how their behaviour and activity are related to results and causes of possible risks to the firm. When risk awareness is high within the firm, decision-makers in the company can use the understanding of risks to be more reactive to changes in the environment. As a result, risk awareness is an essential cultural component of proper risk management. By having this, all employees within the firm accept individual responsibility for risk management and motivate others to engage in this risk-aware approach. In practice, it is shown that, to a large degree, organisational members often tend to depend on their implicit knowledge and experience when interpreting risk-related information. This shows that individuals can act without being aware of potential risks and, consequently, can make the wrong decisions with respect to risk-related events. By raising the risk awareness of the organisational members, one broadens the view of people making the decisions regarding risk-related problems. As a result, risk awareness has the ability to influence decision outcomes as it enables the examination of disappointing and significant results in the decision-making process.

Lastly, after an extensive literature review, 18 factors were retrieved that contribute to risk awareness. These can be divided into three different factor focused groups:

1. Factors that contribute to risk awareness by enhancing data sharing within the company.
2. Factors that contribute indirectly to risk awareness by stimulating a risk culture in the company.
3. Factors that contribute to risk awareness by directly improving risk awareness.

All the 18 factors are presented in table 2.1.

2. What does data sharing in the construction industry entail based on literature?

In this research, data sharing is defined as the operation of sending and/or receiving data from one person to another. In the current construction industry, activities are often data-driven, and literature emphasises the

fact that great benefits can be obtained for firms that effectively utilise data sharing. This is due to the fact that data sharing is crucial to the competitiveness of the organisation, and a lack of it across the firm has the potential to cost time and resources spent on replicating the same mistakes. Although it needs to be noted that utilising data sharing is easier said than done. Especially the construction industry, renowned for its fragmentation and project-based and temporary teams, faces additional obstacles to sharing data. In every organisation, there are barriers opposing effective data sharing, and businesses can benefit tremendously from removing these barriers. Most of the identified barriers are related to the use of organisational systems, the attitude of the organisation towards data sharing, relationships between members within an organisation and how data is treated as an asset.

Furthermore, the autonomous nature of construction projects can lead to project teams becoming siloed, making organisational data sharing across projects challenging, which is even further emphasised for global firms that have to deal with the additional obstacle of geographical distribution. Consequently, multinational firms spend many resources creating data sharing networks that can connect employees aligned in interest or tasks across geographical boundaries. Such connections can enable new chances for data sharing by having entry to a larger variety of task-related information, which can lead to an increased performance. Lastly, when essential data is shared, this often happens within the social network of organisational members. This fact substantiates the choice of using a social network analysis in this research to examine data sharing behaviour.

3. How does a data sharing network of a construction project look like in practice?

With the help of the social network application, Gephi, this research was able to visualise the data sharing network of the two researched case studies. The data sharing networks of projects A and B can be seen in Figure 7.1 and Figure 7.2, respectively. With the help of both maps, it can be determined who is sharing data with whom and awareness of the data flow routes can be obtained such that opportunities in the network can be identified and acted upon. Both networks show a similar structure with a high clustering of the basic tender team and a high amount of one-connection nodes in the network's periphery. Such a structure allows for a high number of gatekeepers which can lead to the creation of data silos in the network. A consistent gatekeeper was found in the role of design manager in the project, which led to the recommendation to include other design managers and the Drafting/Modelling/BIM group more predominantly in the network. Furthermore, within the discipline specific network of the estimators in project A, a data silo was found. This needs to be addressed in the project and discipline teams to prevent this from occurring in the future.

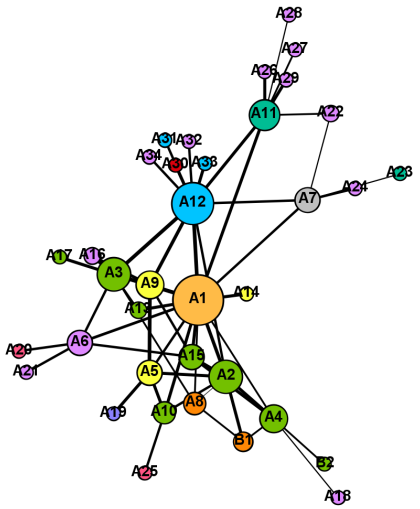


Figure 7.1: Data sharing network project A.

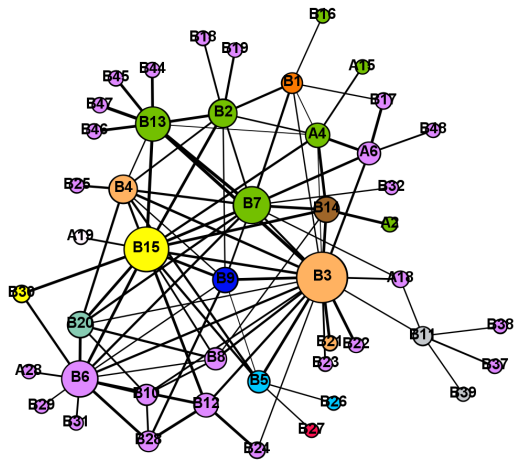


Figure 7.2: Data sharing network project B.

Both networks showed to have a similar (low) density of around 9%. This low density can be seen as a characteristic of the tender phase and is caused by the high demand for different input data at this stage. Moreover, based on the data sharing network and tool use in the projects, we can determine that a uniform approach with respect to data sharing is lacking. In addition, both projects mainly used conventional data sharing tools which led to more decentralised networks, which in turn limits the availability of data. This

can be improved by embracing a more centralised approach to the network and tool use. Lastly, no country transcending data sharing connections were determined. Only in project B, one lessons learned connection had been found that transcends country borders. This shows that the firm does not fully use its multinational potential in utilising company-wide data and organisational learning. While at the same time, there is a need to utilise best practices and lessons learned from other projects, as others most likely have been coping with similar problems and risks.

4. What are the key roles in a project network of data sharing?
This research has used a social network analysis to map the data sharing networks. By mapping the data sharing network, one can reveal who controls, facilitates, or inhibits the data flow and which actors have comparable information needs or uses. It was evident that in both projects, the most influential nodes were the tender manager. In both projects, this role was the most connected node and scored highest on the centrality measures. This was to be expected, but another role that showed to exert a strong influence on the network was the role of the senior planner. During the analysis, these nodes have shown to be part of the influential nodes in the network in terms of data control and dissemination. In both projects, it was clear that a uniform approach to data sharing was lacking in the form of a clear data sharing governance. Literature stresses the fact that when a clear governance that contains standardised procedures regarding data sharing and specified responsibilities for all the team roles towards data sharing is lacking, team members are inclined to depend on their managers instead of taking the initiative. Therefore, the roles of the tender manager and senior planner are key to aid in the endeavour of data sharing and positively influence the project team in terms of data sharing.

Moreover, in both networks, we can see that removing the tender manager and senior planner from the network results in a very sparse network with a high number of nodes and fewer data streams. Combining this with the fact that conventional data sharing tools are used, we can conclude that the network is more prone to information overload and loss of data and overview. Furthermore, in the networks, consistent gatekeepers were found in the role of the design manager. Actually making the network susceptible to data silos in case of failure or information overload of the design manager. In addition, if all design data is relayed through the design manager, it would make the data prone to subjective biases when taken into account in the risk management process. Therefore, it is also key to address the role this actor plays in the network and include its connections more systematically in the network to reduce the chance of data silos and loss of essential data, among other things.

7.2. Main research question

By taking into account the answers to the research sub-questions, an answer to the main research question will be given. The main research question is formulated as follows:

How does data sharing in intra-organisational project networks contribute to risk awareness in the tender phase?

To start with, this research states that the risk awareness of project team members in the tender phase can be improved when organisations utilise data sharing to obtain a higher availability and variety of decision-influencing data. This has been determined by reviewing literature and by analysing the data sharing networks of two different case studies and ultimately validating the findings using an expert panel. After extensively analysing the data sharing networks and data sharing behaviour of the project team members, it is concluded that the network structure and how team members share data with one another, together with the associated information systems, influence the level of risk awareness of the project team members.

First of all, it is essential to underline that this report made use of assumptions (see section 1.3) on which this research is built. These assumptions have been validated with the help of an expert panel and resulted in basically three fundamental findings this research uses to link data sharing and risk awareness together. The findings are as follows: 1) All data is potentially important to the risk management process and risk awareness, 2) The establishment of data sharing and lessons learned connections leads to a wider variety of decision-influencing data and stimulates discussion between organisational members leading to an increased risk awareness, and 3) obtaining a higher availability and variety of decision-influencing data broadens the perspective of project team members and leads to an increased risk awareness. In summary, obtaining a higher

availability and variety of decision-influencing data leads to an increased risk awareness.

To achieve this, companies must change the way they approach data sharing in their projects and throughout the company. Here it is essential that all project team members are handed the tools and ability to retrieve the relevant data and effectively share this. Aspects opposing effective data sharing, and therefore obstructing the availability of relevant data for organisational members to use, are defined as intra-organisational barriers in this research. These intra-organisational barriers have a limiting effect on data sharing, and by breaking down those barriers, that effect will be reduced or eliminated. This research has determined intra-organisational barriers and, based on this, has made recommendations to reduce the effect of such barriers. As a result, companies can determine which recommendations apply to them and apply the necessary recommendations for intervention. This enables the company to enhance data sharing and, ultimately, risk awareness by implementing appropriate interventions. The recommendations for interventions with the most significant impact on risk awareness through enhancing data sharing are:

- Creating a clear data governance plan.
- Improving operational ease of information infrastructure.
- Implementing and monitoring formalised risk management procedures across tenders.
- Enhancing compatibility and accessibility of data and databases.
- Actively mobilising relevant data which is accessible to members within the organisation.

During the research, it was evident that a uniform digital approach was lacking in both project networks, and as a result, data sharing in both projects is not performed in a similar manner. This leads to inconsistent data sharing and inconsistent use of databases and information systems, which can lead to a lack of coordination and the loss of data and overview. By applying and maintaining a clear data governance, this can be counteracted. This requires setting rules and guidelines with respect to data and its management.

Furthermore, risk management procedures initially seemed to be formalised within the company. However, after analysis, it was discovered that although rules and guidelines were present, they were not adequately followed, especially in tenders with a smaller risk level and budget. That while formalisation of procedures leads to an increased risk awareness and elicits a thought process on what lies ahead. If processes are formalised, it will increase the availability and completeness of data and processes, leading to transparency and clarity for the employee as to what to expect, where to retrieve data, and how to act in case of risk-related issues. Therefore, processes do not only need to be formalised but also implemented and monitored.

Moreover, the accessibility and compatibility of data and information systems have shown to be a recurring problem across the project networks. The main cause was that the data was often located in different databases, documents and formats. Another was the fragmentation of data across databases and team members not having access rights to these databases, also obtaining data in an unfamiliar or convoluted format showed to be a problem. This is detrimental as literature emphasises that data technology can become futile when not assisted by standardised processes. The advantages of using data technologies and integrating these in the work process will then be hard to attain, making the company and project-wide use of data harder.

Accessibility has also to do with the ease of use of information systems. Literature has often emphasised that the ease of use of systems can be a large limiter on the use of new or other (better) information systems. If there is no direction in terms of what tools to use, old or new, team members often stick to the more easily accessible tools as this is less time consuming, or the endeavour of using the existing technology might be too great. Therefore, to fully utilise the potential of data sharing, companies should enhance the ease of use of the most preferred and/or optimal information systems. This will positively affect data sharing in and between project networks.

The establishment of data sharing and lessons learned connections mainly relates to obtaining decision facilitating data which can lead to an enhanced risk awareness of employees. When teams are able to effectively share data and communicate lessons learned with their colleagues within and between project teams, this will enhance efficiency and provide opportunities for organisational learning, enriching the understanding of involved individuals. However, establishing data sharing connections or lessons learned connections can be challenging due to the presence of intra-organisational barriers. The cause of this can have many reasons, including having a small network, the effort of establishing connections is too great, or not knowing whom to contact. By actively anticipating this, organisations can reduce the adverse effects of not establishing the proper connections by creating clear points of contact and actively mobilising data to retrieve for

organisational members.

Furthermore, it can be concluded that the interventions regarding data sharing on an organisational level contribute more to risk awareness than interventions on a project level. If we look at the interventions that are scored highest, they are all in essence related to facilitating the data sharing process and thus enabling the team members to share, retrieve, search and find data more easily. This is especially important in the tender phase as this is a phase that is often characterised by an enormous time pressure. In such a manner, a lack of data sharing across the firm has the potential to prevent time and resources spent on finding and retrieving relevant data or basing decisions on incomplete data leading to potential errors.

Nevertheless, a pivotal barrier that has been identified in achieving successful data sharing and obtaining desired outcomes appears to be of human nature. This is because organisations are dependent on the human factor as their success factor. As in the end, it are the people who decide how to retrieve and share data, and it are the people who decide what data is relevant. Therefore, it is not about obtaining particular data, as there is no winning formula as to what data is needed to be effective or risk-aware, especially since people have different opinions about which data is relevant. It is more about establishing the right connections and having the possibility of obtaining the data you need. By breaking down intra-organisational barriers and positively influencing the data sharing behaviour of project team members, we can improve the ability of project team members to obtain the right and relevant data. As a result, the perspective of the decision-makers can be broadened, attaining a higher risk awareness. This results in a higher effectiveness of risk management, and ultimately better risk management leads to a higher chance of delivering a successful project.

Thus to conclude, by leveraging data sharing and enabling organisational members to obtain and use decision-influencing data more easily, the risk awareness of the project team members in the tender phase can be improved.

7.3. Recommendations for further research

Given the time and resources of the master thesis, this research aimed to address the scope established in the introduction. This scope has set boundaries on the research, and as a result, there are potential elements undiscussed that can provide additional insights into the matter. Therefore, suggestions are made for future research based on the existing research. In addition, the limitations of the research addressed in section 6.3 are utilised in helping determine potential future research possibilities. The recommendations are elaborated upon below and can be used by researchers active in a similar domain or students pursuing a similar master thesis.

- **Contract scope and project type:** As said in the research limitations, this research has only focused on design and build contracts. Therefore, it would be interesting to see if the conclusions and recommendations obtained in this research are also applicable to other contract scopes or that the data sharing networks and, therefore, their effect on risk awareness is fundamentally different. The same reasoning applies to the different project types.
- **Correlation analysis:** This research has qualitatively established a relationship between data sharing and risk awareness with the help of a social network analysis and an expert panel. However, future researchers could also try to establish a quantitative relationship between the two concepts through a correlation analysis. This could, for example, be done by statistically linking data sharing and risk awareness factors in the project networks. In such a way, a quantitative relationship between the concepts of data sharing and risk awareness can be established instead of solely a qualitative substantiation.
- **Project life-cycle:** This research focused on the tender phase. It would be very interesting to analyse the data sharing behaviour of employees in other phases of the project life-cycle as well and determine its effect on risk awareness. As one could expect the dynamics of the data sharing network to be different for each project life-cycle as the needs of team members would be different as well as the composition. In addition, other life-cycles are subject to different boundary conditions in terms of aspects like time pressure, uncertainty, dependencies, etcetera.

- **Data types:** This research has mainly focused on risk awareness and how data sharing contributes to that. The primary assumption was that all data that is being shared could be relevant for the risk management process in terms of identifying, assessing and mitigating risks. However, not much attention has been given during this research to the types of data that is being shared in and between project networks. Therefore, studies that focus and take into account the data types more extensively would be interesting to see. Thus, determining what sort of data is communicated between project members, what types of data are useful, which data types are preferred, and similar aspects related to data types.

- **Multinational environment:** This research's initial objective was to analyse the data sharing behaviour and put it into a multinational context. However, unfortunately, due to various reasons, this research was only able to analyse tender cases in The Netherlands. Therefore, it would be very interesting to see what the effects of data sharing are on risk awareness in a multinational context. As DeSanctis and Monge (1999) states that connections between people that cross physical boundaries can enhance opportunities to improve performance and improve entry to information. In addition, related to the multinational environment, it would also be interesting to explore the influence of different cultural backgrounds on data sharing within project networks.

- **Inter-organisational data sharing:** As already said in the research limitations inter-organisational data sharing has not been taken into account and this can have a large influence on the risk awareness of employees. The survey and (in)formal interviews with organisational members showed that the role of the client and other collaborative companies are important in establishing proper data sharing within the company. Therefore, next to construction and engineering companies, there are numerous other organisations with different specialisations present and additional research is required to fully grasp the data sharing dynamics between the company and subcontractors/suppliers/client/etcera. This can reveal differences in data sharing behaviour and aid in comprehending potential collaboration problems, and further research should try to include the inter-organisational aspects.

- **Network details:** In the social network analysis, choices were made to include or exclude particular graph elements, network attributes and metrics. As a result of the limited time in which the master thesis had to be performed, not all details that could have been included are incorporated. Consequently, this can give a slightly less accurate representation of the real-world data sharing dynamics. As an example, future researchers could look into the effects of using directed edges instead of undirected edges, or give more attention to the frequency of data exchange and the associated perceptive value of that data, or look more into the exact tool use of respondents, or look more into the different layout possibilities of the data sharing network, or look more into the background and experience of actors. The possibilities are not just limited to these options but show that there is room for a higher level of detail in analysing project networks. In addition, it should be noted that a larger sample size should be used than in this research to verify the findings due to the higher level of precision. However, this also relates to the fact that a sample size of just two projects like in this research is too small to be able to substantiate the findings fully and in any case, a larger sample size is preferred.

- **Data quality:** This research has been mainly focused on risk awareness and how data sharing contributes to that. The primary assumption was that all data that is being shared could be relevant for the risk management process in terms of identifying, assessing and mitigating risks. However, not much attention has been given to the quality of the data that is being used in the data sharing network. Therefore, interesting to see would be studies that focus more on the data requirements as to what the standards are that the data should adhere to or in what formats the data should be presented. Basically, studies that focus on the quality of data that is put into the system.

- **Data mobilisation :** As stated in the previous recommendation, this research has specifically looked at the contribution of data sharing to risk awareness. One of the suggestions were systems in which data is properly mobilised for organisational members such that they can retrieve data relevant for their projects in terms of risks, leading to an increased risk awareness. Therefore, future studies could look into how such systems should function, how they should be implemented, what is actually organisationally required for creating such systems and ultimately make a roadmap for companies in terms of mobilising data.

Bibliography

Ackoff, R. L. (1989). From data to wisdom. *Journal of applied systems analysis*, *16*(1), 3–9.

Adler, P. S., & Chen, C. X. (2011). Combining creativity and control: Understanding individual motivation in large-scale collaborative creativity. *Accounting, organizations and society*, *36*(2), 63–85.

Ahiaga-Dagbui, D. D., & Smith, S. D. (2014). Dealing with construction cost overruns using data mining. *Construction management and economics*, *32*(7-8), 682–694.

Akinci, B. (2015). Situational awareness in construction and facility management. *Frontiers of Engineering Management*, *1*(3), 283–289.

Akintoye, A. S., & MacLeod, M. J. (1997). Risk analysis and management in construction. *International journal of project management*, *15*(1), 31–38.

Almeida, P., Song, J., & Grant, R. M. (2002). Are firms superior to alliances and markets? an empirical test of cross-border knowledge building. *Organization science*, *13*(2), 147–161.

Alreshidi, E., Mourshed, M., & Rezgui, Y. (2018). Requirements for cloud-based bim governance solutions to facilitate team collaboration in construction projects. *Requirements engineering*, *23*(1), 1–31.

Ayodele, T., & Kajimo-Shakantu, K. (2021). The fourth industrial revolution (4thir) and the construction industry-the role of data sharing and assemblage. *IOP Conference Series: Earth and Environmental Science*, *654*(1), 012013.

Baiden, B. K., & Price, A. D. (2011). The effect of integration on project delivery team effectiveness. *International Journal of Project Management*, *29*(2), 129–136.

Barua, A., Ravindran, S., & Whinston, A. B. (2007). Enabling information sharing within organizations. *Information Technology and Management*, *8*(1), 31–45.

Baruch, Y., & Holtom, B. C. (2008). Survey response rate levels and trends in organizational research. *Human relations*, *61*(8), 1139–1160.

Bastian, M., Heymann, S., & Jacomy, M. (2009). Gephi: An open source software for exploring and manipulating networks. http://www.aaai.org/ocs/index.php/ICWSM/09/paper/view/154

Baxter, P., & Jack, S. (2008). Qualitative case study methodology: Study design and implementation for novice researchers. *The Qualitative Report*, *13*(4), 544–556.

Beasley, M. S., Clune, R., & Hermanson, D. R. (2005). Enterprise risk management: An empirical analysis of factors associated with the extent of implementation. *Journal of accounting and public policy*, *24*(6), 521–531.

Berck, D. (2020). *Breaking through data silos in multinational engineering companies* (Master's thesis). The Netherlands, TU Delft.

Bilal, M., Oyedele, L. O., Kusimo, H. O., Owolabi, H. A., Akanbi, L. A., Ajayi, A. O., Akinade, O. O., & Delgado, J. M. D. (2019). Investigating profitability performance of construction projects using big data: A project analytics approach. *Journal of Building Engineering*, *26*, 100850.

Bilal, M., Oyedele, L. O., Qadir, J., Munir, K., Ajayi, S. O., Akinade, O. O., Owolabi, H. A., Alaka, H. A., & Pasha, M. (2016). Big data in the construction industry: A review of present status, opportunities, and future trends. *Advanced engineering informatics*, *30*(3), 500–521.

Blumberg, R., & Atre, S. (2003). The problem with unstructured data. *Dm Review*, *13*(42-49), 62.

Bock, G.-W., Zmud, R. W., Kim, Y.-G., & Lee, J.-N. (2005). Behavioral intention formation in knowledge sharing: Examining the roles of extrinsic motivators, social-psychological forces, and organizational climate. *MIS quarterly*, 87–111.

Boddy, D., Boonstra, A., & Kennedy, G. (2005). *Managing information systems: An organisational perspective*. Pearson Education.

Boisot, M., & Canals, A. (2004). Data, information and knowledge: Have we got it right? *Journal of evolutionary economics*, *14*(1), 43–67.

Bragança, L., Vieira, S. M., & Andrade, J. B. (2014). Early stage design decisions: The way to achieve sustainable buildings at lower costs. *The scientific world journal*, *2014*.

Braumann, E. C. (2018). Analyzing the role of risk awareness in enterprise risk management. *Journal of Management Accounting Research*, *30*(2), 241–268.

Braumann, E. C., Grabner, I., & Posch, A. (2020). Tone from the top in risk management: A complementarity perspective on how control systems influence risk awareness. *Accounting, organizations and society*, *84*, 101128.

Buvik, M. P., & Rolfsen, M. (2015). Prior ties and trust development in project teams–a case study from the construction industry. *International journal of project management*, *33*(7), 1484–1494.

Casas-Arce, P., Martınez-Jerez, F. A., & Narayanan, V. (2017). The impact of forward-looking metrics on employee decision-making: The case of customer lifetime value. *The Accounting Review*, *92*(3), 31–56.

Chen, M., Ebert, D., Hagen, H., Laramee, R. S., Van Liere, R., Ma, K.-L., Ribarsky, W., Scheuermann, G., & Silver, D. (2008). Data, information, and knowledge in visualization. *IEEE computer graphics and applications*, *29*(1), 12–19.

Cheng, E. W., Li, H., Love, P. E., & Irani, Z. (2001). Network communication in the construction industry. *Corporate Communications: An International Journal*.

Chinowsky, P. S., Diekmann, J., & O'Brien, J. (2010). Project organizations as social networks. *Journal of construction engineering and management*, *136*(4), 452–458.

Chmutina, K., Rose, J., Shrestha, S. D., & Bhatta, D. (2018). Pathways to raising disaster risk reduction awareness among the informal construction stakeholders: A case of nepal. *Procedia engineering*, *212*, 784–791.

Coleman, J. S. (1988). Free riders and zealots: The role of social networks. *Sociological Theory*, *6*(1), 52–57.

Collier, P. M., Berry, A. J., & Burke, G. T. (2006). *Risk and management accounting: Best practice guidelines for enterprise-wide internal control procedures* (Vol. 2). Elsevier.

Constant, D., Kiesler, S., & Sproull, L. (1994). What's mine is ours, or is it? a study of attitudes about information sharing. *Information systems research*, *5*(4), 400–421.

COSO, I. (2004). Enterprise risk management-integrated framework. *Committee of Sponsoring Organizations of the Treadway Commission*, *2*.

Cress, U., Kimmerle, J., & Hesse, F. W. (2006). Information exchange with shared databases as a social dilemma: The effect of metaknowledge, bonus systems, and costs. *Communication Research*, *33*(5), 370–390.

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS quarterly*, 319–340.

De Bakker, K., Boonstra, A., & Wortmann, H. (2011). Risk management affecting is/it project success through communicative action. *Project management journal*, *42*(3), 75–90.

Demirkesen, S., & Ozorhon, B. (2017). Impact of integration management on construction project management performance. *International Journal of Project Management*, *35*(8), 1639–1654.

DeSanctis, G., & Monge, P. (1999). Introduction to the special issue: Communication processes for virtual organizations. *Organization science*, *10*(6), 693–703.

Dey, P. K., Kinch, J., & Ogunlana, S. O. (2007). Managing risk in software development projects: A case study. *Industrial Management & Data Systems*.

Dillon, B. (2015). Knocking down data silos with bim. *International Railway Journal*, *55*(5).

Drake, D. B., Steckler, N. A., & Koch, M. J. (2004). Information sharing in and across government agencies: The role and influence of scientist, politician, and bureaucrat subcultures. *Social Science Computer Review*, *22*(1), 67–84.

Du, D. (2020). Social network analysis: Lecture 3-network [powerpoint presentation] [Retrieved from: http://www2.unb.ca/~ddu/6634/Lecture_notes/Lec3_network_statistics_handout.pdf].

Dudovskiy, J. (n.d.). Research approach [Retrieved from:https://research-methodology.net/research-methodology/research-approach/#_ftn2].

Farshchi, M. A., & Brown, M. (2011). Social networks and knowledge creation in the built environment: A case study. *Structural Survey*.

Fiegenbaum, A., & Thomas, H. (1988). Attitudes toward risk and the risk–return paradox: Prospect theory explanations. *Academy of Management journal*, *31*(1), 85–106.

Fisher, C., Laurıa, E., & Chengalur-Smith, S. (2012). *Introduction to information quality*. AuthorHouse.

Franz, B., Leicht, R., Molenaar, K., & Messner, J. (2017). Impact of team integration and group cohesion on project delivery performance. *Journal of construction engineering and management*, *143*(1), 04016088.

Frické, M. (2018). Data-information-knowledge-wisdom (dikw) pyramid, framework, continuum. *Encyclopedia of Big Data, LA Schintler and CL McNeely, Eds. Cham: Springer International Publishing*, 1–4.

Goodman, P. S., & Darr, E. D. (1998). Computer-aided systems and communities: Mechanisms for organizational learning in distributed environments. *MIS quarterly*, 417–440.

Gorzeń-Mitka, I. (2011). Risk-aware culture in enterprise risk management. *Theory of Management, 4*, 222–225.

Goto, S. (2004). A behavioral risk management system.

Goto, S. (2007). The bounds of classical risk management and the importance of a behavioral approach. *Risk Management and Insurance Review, 10*(2), 267–282.

Grabner, I., & Moers, F. (2013). Management control as a system or a package? conceptual and empirical issues. *Accounting, Organizations and Society, 38*(6-7), 407–419.

Gustafsson, J. (2017). Single case studies vs. multiple case studies: A comparative study. academy of business. *Engineering and Science, Halmstad University, Halmstad, Sweden*, *12*(1).

Hansen, M. T., Mors, M. L., & Løvås, B. (2005). Knowledge sharing in organizations: Multiple networks, multiple phases. *Academy of Management journal*, *48*(5), 776–793.

Hatala, J.-P. (2006). Social network analysis in human resource development: A new methodology. *Human Resource Development Review*, *5*(1), 45–71.

Hatala, J.-P., & Lutta, J. G. (2009). Managing information sharing within an organizational setting: A social network perspective. *Performance Improvement Quarterly, 21*(4), 5–33.

Haythornthwaite, C. (1996). Social network analysis: An approach and technique for the study of information exchange. *Library & information science research*, *18*(4), 323–342.

Henri, J.-F. (2006). Management control systems and strategy: A resource-based perspective. *Accounting, organizations and society*, *31*(6), 529–558.

Heras, A. D. (2019). Introduction to management information systems (mis): A survival guide [Retrieved from: https://courses.edx.org/courses/course-v1:UC3Mx+IM.1x+3T2019/course/].

Hertogh, M., & Westerveld, E. (2010). Playing with complexity. management and organisation of large infrastructure projects.

Hillson, D., & Murray-Webster, R. (2004). Understanding and managing risk attitude. *Proceedings of 7th Annual Risk Conference, held in London, UK, 26*.

Hoezen, M., Reymen, I., & Dewulf, G. (2006). The problem of communication in construction. *CIB W96 Adaptable Conference, University of Twente)*.

Huang, J. C., Newell, S., Galliers, R. D., & Pan, S.-L. (2003). Dangerous liaisons? component-based development and organizational subcultures. *IEEE Transactions on Engineering Management*, *50*(1), 89–99.

Ibrahim, C. K. I. C., Sabri, N. A. M., Belayutham, S., & Mahamadu, A. (2019). Exploring behavioural factors for information sharing in bim projects in the malaysian construction industry. *Built Environment Project and Asset Management*.

Ivčević, A., Bertoldo, R., Mazurek, H., Siame, L., Guignard, S., Moussa, A. B., & Bellier, O. (2020). Local risk awareness and precautionary behaviour in a multi-hazard region of north morocco. *International Journal of Disaster Risk Reduction*, *50*, 101724.

Javernick-Will, A. (2011). Knowledge-sharing connections across geographical boundaries in global intra-firm networks. *Engineering Project Organization Journal*, *1*(4), 239–253.

Jen, R. (2012). How to increase risk awareness. *Paper presented at PMI® Global Congress 2012—North America, Vancouver, British Columbia, Canada. Newtown Square, PA: Project Management Institute*.

Jiao, Y., Wang, Y., Zhang, S., Li, Y., Yang, B., & Yuan, L. (2013). A cloud approach to unified lifecycle data management in architecture, engineering, construction and facilities management: Integrating bims and sns. *Advanced Engineering Informatics*, *27*(2), 173–188.

Johanson, J.-E. (2000). Formal structure and intra-organisational networks. an analysis in a combined social and health organisation in finland. *Scandinavian Journal of Management, 16*(3), 249–267.

Kaplan, R., & Mikes, A. (2012). Managing risks: A new framework. *Harvard business review*.

Kaplan, R. S., & Mikes, A. (2016). Risk management—the revealing hand. *Journal of Applied Corporate Finance*, *28*(1), 8–18.

Kogut, B. (1989). Research notes and communications a note on global strategies. *Strategic Management Journal*, *10*(4), 383–389.

Krnc, M., Sereni, J.-S., Skrekovski, R., & Yilma, Z. (2018). Eccentricity of networks with structural constraints.

Kumar, S. (2003). Managing a procurement and the associated risks. *Paper presented at PMI® Global Congress 2003—EMEA, The Hague, South Holland, The Netherlands. Newtown Square, PA: Project Management Institute*.

Kutsch, E., & Hall, M. (2005). Intervening conditions on the management of project risk: Dealing with uncertainty in information technology projects. *International Journal of Project Management*, *23*(8), 591–599.

Lam, J. (2014). *Enterprise risk management: From incentives to controls*. John Wiley & Sons.

Laryea, S. (2011). Quality of tender documents: Case studies from the uk. *Construction Management and Economics*, *29*(3), 275–286.

Laudon, K. C. et al. (2007). *Management information systems: Managing the digital firm*. Pearson Education India.

Lee, C.-Y., Chong, H.-Y., Liao, P.-C., & Wang, X. (2018). Critical review of social network analysis applications in complex project management. *Journal of Management in Engineering*, *34*(2), 04017061.

Lee, D.-Y., Chi, H.-l., Wang, J., Wang, X., & Park, C.-S. (2016). A linked data system framework for sharing construction defect information using ontologies and bim environments. *Automation in Construction*, *68*, 102–113.

Li, S., & Lin, B. (2006). Accessing information sharing and information quality in supply chain management. *Decision support systems*, *42*(3), 1641–1656.

Martınez-Rojas, M., Marın, N., & Miranda, M. A. V. (2016). An intelligent system for the acquisition and management of information from bill of quantities in building projects. *Expert Systems with Applications*, *63*, 284–294.

Matthews, J., Love, P. E., Mewburn, J., Stobaus, C., & Ramanayaka, C. (2018). Building information modelling in construction: Insights from collaboration and change management perspectives. *Production planning & control*, *29*(3), 202–216.

Mckinsey&Company. (n.d.). Reinventing construction [https://www.mckinsey.com/~/media/McKinsey/Business%20Functions/Operations/Our%20Insights/Reinventing%20construction%20through%20a%20productivity%20revolution/MGI-Reinventing-Construction-In-Brief.pdf].

Mikes, A. (2009). Risk management and calculative cultures. *Management Accounting Research*, *20*(1), 18–40.

Moberg, C. R., Cutler, B. D., Gross, A., & Speh, T. W. (2002). Identifying antecedents of information exchange within supply chains. *International Journal of Physical Distribution & Logistics Management*.

Nikou, T., & Klotz, L. (2014). Application of multi-attribute utility theory for sustainable energy decisions in commercial buildings: A case study. *Smart and Sustainable Built Environment*.

Ogbonna, E., & Harris, L. C. (2002). Organizational culture: A ten year, two-phase study of change in the uk food retailing sector. *Journal of Management studies*, *39*(5), 673–706.

Posch, A. (2020). Integrating risk into control system design: The complementarity between risk-focused results controls and risk-focused information sharing. *Accounting, organizations and society*, *86*, 101126.

Pryke, S. (2017). *Managing networks in project-based organisations*. John Wiley & Sons.

Rastogi, N., & Trivedi, M. (2016). Pestle technique–a tool to identify external risks in construction projects. *International Research Journal of Engineering and Technology (IRJET)*, *3*(1), 384–388.

Rittenberg, D. L., & Martens, F. (2012). Understanding and communicating risk appetite', the committee of sponsoring organizations of the treadway commission. *Martens.–2012. URL: https://www.coso.org/Documents/ERM-Understanding-and-Communicating-Risk-Appetite.pdf*.

Robertson, I. (2020). Covid-19 data sharing platform [image front page] [https://www.innovatorsmag.com/covid-19-data-sharing-platform/].

Roeschmann, A. Z. (2014). Risk culture: What it is and how it affects an insurer's risk management. *Risk Management and Insurance Review*, *17*(2), 277–296.

Ropponen, J., & Lyytinen, K. (2000). Components of software development risk: How to address them? a project manager survey. *IEEE transactions on software engineering*, *26*(2), 98–112.

Rosenkopf, L., Metiu, A., & George, V. P. (2001). From the bottom up? technical committee activity and alliance formation. *Administrative Science Quarterly*, *46*(4), 748–772.

Rowley, J. (2007). The wisdom hierarchy: Representations of the dikw hierarchy. *Journal of information science*, *33*(2), 163–180.

Ruddock, L. (2002). Measuring the global construction industry: Improving the quality of data. *Construction Management & Economics*, *20*(7), 553–556.

Sarkar, D., & Thakkar, P. (2018). Integrated bim-cloud model for enhancing coordination and communication in real estate projects in india. *International journal of construction project management*, *10*(1), 55–68.

Shokri-Ghasabeh, M., & Chileshe, N. (2014). Knowledge management: Barriers to capturing lessons learned from australian construction contractors perspective. *Construction Innovation*.

Simu, K. (2017). How do project based organisations develop, implement and follow up on strategies and objectives? *THIRTY-THIRD ANNUAL CONFERENCE*, 562.

Sinkula, J. M. (1994). Market information processing and organizational learning. *Journal of marketing*, *58*(1), 35–45.

Sitkin, S. B., & Pablo, A. L. (1992). Reconceptualizing the determinants of risk behavior. *Academy of management review*, *17*(1), 9–38.

Soibelman, L., Wu, J., Caldas, C., Brilakis, I., & Lin, K.-Y. (2008). Management and analysis of unstructured construction data types. *Advanced Engineering Informatics*, *22*(1), 15–27.

Stenmark, D. (2002). Information vs. knowledge: The role of intranets in knowledge management. *Proceedings of the 35th Annual Hawaii International Conference on System Sciences*, 928–937.

Teller, J. (2013). Portfolio risk management and its contribution to project portfolio success: An investigation of organization, process, and culture. *Project Management Journal*, *44*(2), 36–51.

Urquhart, S., & Whyte, A. (2018). Impact of contractor internal tendering procedure governance on tender win-rates: How procedures can be improved. *Proceedings of the 34th Annual ARCOM Conference*, 786–795.

van der Meer, J. (2021). *Raising risk awareness in infrastructure tenders* (Doctoral dissertation). University of Twente. Netherlands, University of Twente. https://doi.org/10.3990/1.9789036551694

Verschuren, P., Doorewaard, H., & Mellion, M. (2010). *Designing a research project* (Vol. 2). Eleven International Publishing The Hague.

Vo-Tran, H., & Kanjanabootra, S. (2013). Information sharing problems among stakeholders in the construction industry at the inspection stage: A case study. *Clients and Users in Construction*, 50.

Wanberg, J., Javernick-Will, A., Taylor, J. E., & Chinowsky, P. (2015). The effects of organizational divisions on knowledge-sharing networks in multi-lateral communities of practice. *Engineering project organization journal*, *5*(2-3), 118–132.

Wasserman, S., Faust, K. et al. (1994). Social network analysis: Methods and applications.

Westin, S. (2014). Managing data and information quality in construction engineering: A system design approach.

Westin, S., & Sein, M. K. (2014). Improving data quality in construction engineering projects: An action design research approach. *Journal of Management in Engineering*, *30*(3), 05014003.

Wheatley, M. (2011). *Leadership and the new science: Discovering order in a chaotic world*. ReadHowYouWant.com.

Whitley, R. (2006). Project-based firms: New organizational form or variations on a theme? *Industrial and corporate change*, *15*(1), 77–99.

Willem, A., & Buelens, M. (2007). Knowledge sharing in public sector organizations: The effect of organizational characteristics on interdepartmental knowledge sharing. *Journal of public administration research and theory*, *17*(4), 581–606.

Xu, Y., Lewis, M., Sycara, K., & Scerri, P. (2004). Information sharing in large scale teams.

Yang, T.-M., & Maxwell, T. A. (2011). Information-sharing in public organizations: A literature review of interpersonal, intra-organizational and inter-organizational success factors. *Government information quarterly*, *28*(2), 164–175.

Yin, R. K. (1981). The case study as a serious research strategy. *Knowledge*, *3*(1), 97–114.

Yin, R. K. (2009a). *Case study research: Design and methods* (Vol. 5). sage.

Yin, R. K. (2009b). How to do better case studies. *The SAGE handbook of applied social research methods*, *2*(254-282).

Zainudin, Z., Samad, S. A., Altounjy, R., et al. (2019). The determinants factors of an effective risk-aware culture of firms in implementing and maintaining risk management program. *International Journal of Financial Research*, *11*(5), 459–465.

Zhang, J., Dawes, S. S., & Sarkis, J. (2005). Exploring stakeholders' expectations of the benefits and barriers of e-government knowledge sharing. *Journal of Enterprise Information Management*.

Zhang, P., & Ng, F. F. (2012). Attitude toward knowledge sharing in construction teams. *Industrial Management & Data Systems*.

Zhu, T., Wang, B., Wu, B., & Zhu, C. (2014). Maximizing the spread of influence ranking in social networks. *Information Sciences*, *278*, 535–544.

Zins, C. (2007). Conceptual approaches for defining data, information, and knowledge. *Journal of the American sociarticle ety for information science and technology*, *58*(4), 479–493.

A

Literature review steps

In search for relevant articles and papers with respect to the researched phenomena, a step-wise search framework has been developed. Such a framework is helpful in ensuring the quality, completeness and relevance of articles and papers used in this research. The process of searching for relevant and useful resources contains many iterations and different search queries. In addition, there are search queries and keywords that have been used in retrieving relevant information that are omitted from this report due to the reason that search queries sometimes come to mind spontaneously and therefore are not written down. This illustrates that the process is not perfect, and sometimes a bit of luck is needed to find the proper articles. In the end, the desired outcome is to retrieve a set of research articles and papers that aid in exploring the phenomena and answering the research questions.

A.1. Step 1: Defining the research

For this research, the following main research question and associated sub-questions are formulated:

How does data sharing in intra-organisational project networks contribute to risk awareness in the tender phase?

1. What does risk awareness in the construction industry entail based on literature and what are factors that contribute to this?
2. What does data sharing in the construction industry entail based on literature?
3. How does a data sharing network of a construction project look like in practice?
4. What are the key roles in a project network of data sharing?

A.2. Step 2: Defining the phenomena and concepts

The research questions in the previous section are based upon certain phenomena and concepts that need to be explored. In this step, the main research and sub-questions will be dissected, and the relevant concepts will be listed together with alternative terms and concepts which the researcher can use to achieve the same goal. The deduced terms and concepts will, later on, be used in the formulation of different search queries. By applying this method, the researcher prevents the loss of relevant articles that aid in answering the research questions as much as possible. Below, the two main phenomena, risk awareness and data sharing, are elaborated upon, and the deduced search terms are summarised in their respective sections.

It has to be noted as well that this was the first draft of concepts that contributed to answering the research question. Often during the search for and reading of articles, you find other words that might bring you closer to the most relevant articles instead of your initial determined search queries. These concepts and queries are included as much as possible in these lists as well. However, the list is not complete as sometimes the search queries were lost due to the sudden nature in which terms sometimes come to mind. Nevertheless, the vast majority is included and can be seen below.

Risk awareness

The following keywords were used in the literature search to explore the phenomena of risk awareness: risk awareness, awareness construction industry, construction project risk assessment, risk management early phase, risk management tender phase, tender phase, risk(-aware culture), risk culture, enterprise risk management, project teams, situational awareness, awareness hazards and mitigation measures, project-related risk awareness, risk appetite, project risk maturity (models), behavioural risk, risk assessment (models), risk information, risk maturity, risk attitude, risk awareness factors, knightanian risk, risk perception.

Data sharing

The following keywords were used in the literature search to explore the phenomena of data sharing: Data management, information management, data quality, intranet, construction tender, open communication, information sharing, data sharing, knowledge sharing, data sharing networks, information sharing networks, project networks, types of data sharing, project network types, data compatibility, information sharing advantages, organisational structures, (social) network typologies, network structure, data sharing barriers, information sharing barriers, information exchange, data exchange, organisational social structure, social network analysis, organisational members, knowledge management, organisational networks , knowledge sharing, information exchange, barriers to information/data sharing, intra-organisational data/information sharing, inter-firm data/information sharing.

These are a vast amount of terms used in the search for literature. It is important to emphasise that these were the main concepts and terms explored but that often a combination of the terms was used in search of relevant literature.

A.3. Step 3: Relevant scientific engines and journals

There are many different scientific research engines that contain a wide variety of scientific journals and articles. This research has mainly used google scholar and ResearchGate as search engines for retrieving literature. When the search engines did not suffice, scientific publisher websites were used, such as Elsevier and PMI. An oversight is given below; it has to be noted that mainly the engines were used as they retrieved a wide variety of journals and articles. The use of Elsevier and the project management institute were only occurring when the researcher felt that the search engines were exhausted and did not properly supply the researcher with relevant articles. Here PMI was mainly used to retrieve extra articles with respect to risk awareness and Elsevier with respect to data sharing.

- Search engines:
  - Google scholar
  - ResearchGate
- Scientific publishers:
  - Elsevier
  - Project Management Institute

B

Risk awareness factors explanation

From the literature review, 18 factors that contribute to risk awareness were retrieved and summarised below. Here the risk awareness factors are elaborated upon in more detail, with in some cases specific ways to improve the utilisation of the factors such that risk awareness can be improved.

1. **Formalisation of risk management procedures:** The formalisation of risk management procedures leads to an increased awareness among employees and elicits a thought process on what lies ahead (Kumar, 2003). Furthermore, if processes are formalised, it will increase the availability and completeness of information and processes, leading to transparency and clarity for the employee as to what to expect, where to retrieve information, and how to act in case of risk-related issues. In addition, it ensures clear commitment, reliability, and responsibilities and facilitates resource prioritisation and allocation (Teller, 2013). Ultimately, this embeds risk awareness in the population and leads to a sound risk culture.

2. **Role clarity:** This partially relates to the formalisation of risk management procedures. Due to an increased risk awareness, involved members are able to adjust their expectations and behaviour properly. From this angle, clarity of roles can positively contribute to risk awareness as clear definitions of responsibilities are established, and employees are more aware of who is responsible for risk-related issues, whom to contact, and where to retrieve information, which positively affects risk management.

3. **Accountability (responsibility):** Pro-actively accepting responsibility for risks (management) will increase the risk awareness of involved employees. Due to the fact that having a better comprehension of roles and accountability/responsibility in risk management will lead to increased risk identification, enhanced assumption of risk ownership and pro-active thinking of employees.

4. **Reward/incentive system:** By providing a reward/incentive system in which employees are rewarded a compensation for good risk management will encourage personnel to be involved, which leads to a positive risk culture and people becoming more aware of risks involved.

5. **Lessons learned:** Lessons learned can be seen as sharing insights, information and knowledge with employees within the firm. As by applying lessons learned management, valuable information regarding risks is collected from projects and key elements are learned by participants and taken into account in future projects, raising the overall awareness of employees regarding risks.

6. **Raise level of experience:** Jen (2012) states that the simplest way of raising experience is staffing the project with the most experienced resources. However, when this is not possible, experience can be enhanced by simulations, case studies, mentorship, examples and lessons learned.

7. **Increasing technical skills:** This one is straightforward as by increasing the technical skills of an employee you enhance the skill set and the knowledge that goes with it. As a result, the employee would be able to identify additional risks, raising employees' risk awareness. This can be done by technical training, mentorship, supervision, and feedback.

8. **Raising knowledge of risk management:** By raising the knowledge on risk management practices within the firm, employees become more aware of risks. As knowing how the risk management tools, processes and templates in the firm work will help the employee in identifying, estimating and responding to risks. This can be done through training, risk planning involvement, status meetings and risk identifications meetings.

9. **Normalising risk tolerances:** Everyone has different perceptions of risks based on their experience and knowledge. Therefore, it is assumed that employees are willing to take on varying amounts of risks and thus have varied risk tolerances. However, to gain a better and more consistent approach and consensus on risks, it should be attempted to achieve a tighter range of risk tolerances. This can be done by, for example, using probability-impact matrices, checklists/questionnaires, simulations, dictionaries, risk level definitions and examples.

10. **Enhancing communication:** If an employee can't or does not communicate risks suitably, it is almost the same as not managing these risks. Communication can be performed formally and informally and in verbal or written formats. When risks are badly communicated or not to the right person, this can basically lead to bad risk management as employees misunderstand risks or are not aware of certain risks. Therefore, it is needed to open up the lines of communication when blocked and enhance employees' communication skills. Methods to train this could be simulations, training, coaching and status meetings.

11. **Risk-focused information sharing:** By using risk-focused information sharing firms can bypass the shortcomings of conventional risk management procedures as risk-focused information sharing supports the creation of a risk culture that embeds risk awareness in organisations (Kaplan & Mikes, 2016). Firms have multiple options to engage in risk-focused information sharing stated in the article of Collier et al. (2006). Next to firm guidelines about the character of risk and its interaction with performance, firms can encourage conversations about risks, involving employees in deviation analysis regarding performance, organising risk review meetings, risk workshops, and creating risk task-forces. Tools like these assist companies in sharing risk-related information from a top-down approach, which provides a decision facilitating motive, and bottom-up through the access of local information of workers (Posch, 2020).

12. **Educating staff on subjective biases:** As explained in section 2.1.2 when humans make decisions, it needs to be taken into account that this can involve subjective biases in the decision-making process. As subjective biases hinder the willingness and/or ability of individuals in the decision making process to evaluate even objective probabilities. On an individual level, biases can be diminished by educating staff on how to recognise and make up for them. On an organisational level, risk evaluation models can help to make the reasoning of employees more explicit. Moreover, providing a choice architecture can help decision-makers to enhance their own awareness with respect to their own cognitive bias that can lead to irrational choices. When employees are more aware of their subjective biases, they will be better able to identify, assess and respond to risks and thus have an increased risk awareness.

13. **Missing data:** A limiter that has been identified in terms of risk awareness is the presence of missing data. When information bottlenecks are present, employees their awareness will be challenged due to a lack of data and not having the correct information at the right time. Therefore, more effort should be made to facilitate the exchange of data, information and knowledge such that risk awareness can be increased. Here firms should also look at possible advancements in information and communication technologies that can help alleviate information bottlenecks.

14. **Data compatibility and accessibility:** A limiter that has been identified in terms of risk awareness was the presence of data in a format that is not easily accessible and actionable. Therefore, firms should look for ways to get data in the right format and to get it easily accessible for employees. When this is achieved, employees have more information to base their decisions on and will be more aware of involved risks. Also, firms should look at possible advancements in information and communication technologies that can help alleviate data incompatibility and accessibility.

15. **Top down management support:** To produce a satisfying level of risk awareness within the firm, upper management must dedicate its attention to issues involving risk, extensively support the risk management process, and transfer expectations regarding risk management behaviour, and encourage communication and escalation regarding issues involving risks to all levels (COSO, 2004; Lam, 2014). Doing

this portrays that risk management matters because when upper management believes in risk awareness and dedicate their resources, effort, and time to issues involving risks, then others will follow, leading to a proper risk culture.

16. **Bottom-up communication and escalation of risk issues:** A bottom up perspective in which management is able to motivate communication and escalation of issues involving risks all the way from the lower levels to the upper ones. By giving employees a voice in risk-related issues, upper management can take apart hierarchical barriers and support engagement of employees, which results in a higher motivation among firm employees to continuously contemplate about risk-related issues (Adler & Chen, 2011). Consequently, management fabricates a climate of trust and transparency, and signals that it is approachable and focused on open communication, and also inspires and encourages openness to challenge.

17. **Employee involvement:** A requirement of a risk culture is that all employees are actively involved in risk management or are taking into account risks in their daily practices. This leads to a positive risk culture and embeds risk awareness among employees.

18. **Common risk language:** Each person is unique and has its own interpretation and definition of items, which can be risks, estimates or changes. A common risk language enables everyone within a firm to understand each other, and misunderstandings can be mitigated. Here a company could use dictionaries, definitions specific to projects, glossaries. This helps in developing a positive risk culture and embedding risk awareness in the population.

C

Social Network Survey

The survey sent out to the respondents starts on the next page. The survey was created with the use of Qualtrics through a paid licence of the TU Delft. The survey shown below also includes the back-end survey logic used during the execution of the data collection. Lastly, below the survey's goal, aim, and deadline are presented.

- Goal: Gathering data about the data networks in the different case projects and retrieving data about the application of risk awareness factors in practice.
- Aim: The aim of the data collection is to retrieve information about the data users, data generators and data routes such that the data sharing network can be mapped. In addition, gaining elaborate information about the risk awareness factors, used tools, frequency, value and network preferences.
- Deadline: First week of October.

Social Network Analysis

Start of Block: Introduction

Introduction
Thank you for taking the time to participate in this survey, which will take around 15 minutes of your time.

The aim of this survey is to measure the data sharing behaviour within BAM. This will contribute to my thesis topic: How does data sharing within the company contribute to risk awareness during the tender phase.

Your participation is of great value and will contribute to a strong data set that enables analyses in data use and behaviour within BAM. After completion of this research it is possible for all participants to receive individual feedback about their position in the data sharing network.

Survey goals
My research applies the Social Network Analysis which enables the mapping of the data network in your organisation and allows for both quantitative and qualitative analyses on human connections. The main goal of this survey is to identify who is sharing data with whom and to determine how this relates to risk awareness of employees within the firm. Some participants might later be asked to take part in an interview that focusses on conducting the qualitative analysis of this research.

Your Consent
When participating in this survey you will be asked to provide information about colleagues you regularly share data with such as names and other background information. Once data is collected, all names will be replaced with anonymous codes.

At the bottom of this page you can confirm that you have read and understand the purpose of this survey. You understand that your name will be replaced with an anonymous code and that you can send me an email if you have any questions.

Kind regards,
Skip de Metz

Delft University of Technology
MSc Construction Management and Engineering
skip.de.metz@bam.com or skip_demetz@hotmail.com

Please select your answer

- ○ I choose to participate and give permission to the researcher to analyse my answers
- ○ I choose to **NOT** participate in this research

Page Break

Q1 Please indicate on which of the following BAM tenders you have spent the most time and therefore will fill out this survey for.

- ○ Spoorverdubbeling (SVHL), Heerlen-Landgraaf
- ○ Ombouw Emplacement Den Haag CS
- ○ Curzon Street Station for HS2

End of Block: Introduction

Start of Block: Risk awareness details

Part 1 - Risk awareness details (Q2 - Q10)
Welcome to the first part of the survey. In this section I will ask some questions related to risk awareness which later on in the research can be used to help identify factors that contribute to risk awareness among employees within the firm.

In some of the questions the terms data and information are used. In this research data and information are defined as "*numbers, facts, statistics and documents in information flows that can be interpreted and used for examination or decision-making*".

Q2 In this question a number of statements is given with the response ranging from strongly disagree to strongly agree. Please indicate if you agree or disagree with the statements.

	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree	Not applicable
I am aware and up-to-date about BAM's guidelines and procedures regarding risk management.	○	○	○	○	○	○
During the execution of the project the steps to properly perform procedures with respect to risks were clear to me. (Think about clarity for the employee as in what to expect, where to retrieve information and how to act in case of risk-related issues).	○	○	○	○	○	○
During the project everyone's role and work responsibilities in the team were clear and known to me.	○	○	○	○	○	○
During the project I pro-actively accepted responsibility for risks (management).	○	○	○	○	○	○
During my project there was an incentive system for project members in case of excellent performance or successful completion of the project.	○	○	○	○	○	○
Lessons learned are always used and captured in the projects.	○	○	○	○	○	○
During the project I made use of lessons learned.	○	○	○	○	○	○
During the project I approached members of similar projects to learn from their experiences and try and take them into account in the current project.	○	○	○	○	○	○
During the project I experienced missing data that I needed to make decisions involving risks.	○	○	○	○	○	○
During the project I experienced problems with the	○	○	○	○	○	○

compatibility/formatting of data that hindered me in making decisions involving risks.						
During the project I experienced problems with the accessibility of data that hindered me in making decisions involving risks.	○	○	○	○	○	○
I feel that within BAM, top management dedicates its attention to issues involving risks, extensively supports the risk management process, and transfers expectations regarding risk management behaviour to employees.	○	○	○	○	○	○
In case of issues involving risks it is possible for me to communicate my issues directly to upper management, therefore bypassing my direct manager.	○	○	○	○	○	○
During the project I was actively involved in risk management.	○	○	○	○	○	○
During the project a common risk language was used.	○	○	○	○	○	○

Q3 If you ever experienced missing data that you need, what was the cause of the problem according to yourself?

_____

Q4 If you ever experienced problems with the compatibility/accessibility of information that hindered you in making decisions. What was the cause of the problem according to yourself?

_____

Q5 If you received an incentive or additional reward during the project, please indicate why you have received this.

_____

Q6 If you made use of lessons learned, please indicate how you made use of this.

_____

Page Break

Q7 Here a number of questions with regards to the frequency in which they occur are presented, please indicate which frequency applies to you.

	Semi-annually	Annually	Once every 2 years	Less than once every 2 years	Once during my BAM career	Never
During your BAM career how often have you been trained in your technical skills?	○	○	○	○	○	○
How often is there a workshop or training to educate staff about risk management practices, tools, processes, templates or risk awareness?	○	○	○	○	○	○
During your BAM career how often have you been trained in your communication skills, thus how you should communicate formally, informally, and verbally or written?	○	○	○	○	○	○
How often is there a workshop (or something similar) to educate staff on subjective biases when focusing on risks?	○	○	○	○	○	○

Q8 During risk management which of the following tools have you used? (multiple answers possible)

- [ ] Probability-impact matrices
- [ ] Checklists/questionnaires
- [ ] Simulations
- [ ] Risk language dictionary
- [ ] Risk level definitions
- [ ] Risk examples
- [ ] Brainstorming
- [ ] Lessons learned register
- [ ] None of the mentioned options

Q9 How often do you participate in one of the following activities or teams?

	Weekly	Monthly	Semi-annually	Annually	Less than once every 2 years	Once during my BAM career	Never
Conversation about risks (risk-based dialogues)	○	○	○	○	○	○	○
Deviation analysis regarding risk performance	○	○	○	○	○	○	○
Risk review meetings	○	○	○	○	○	○	○
Risk workshops	○	○	○	○	○	○	○
Risk task-forces	○	○	○	○	○	○	○

Q10 To ensure understanding among employees regarding risks, a common risk language is preferred. Within BAM is there use made of any of the following? (Multiple answers possible)

- ☐ Risk language dictionary
- ☐ Project specific definitions
- ☐ Glossary: an alphabetical list of words relating to a specific subject, text, or dialect, with explanations
- ☐ None of the mentioned options

End of Block: Risk awareness details

Start of Block: Social Network Analysis

Part 2 - Social Network Analysis (Q11 - Q20)
Next up you will be asked to identify people you share project or company related data with within BAM. In this research data is defined as *"numbers, facts, statistics and documents in information flows that can be interpreted and used for examination or decision-making"*. Therefore you can think of any sort of data when filling in this survey. Data can be shared verbally and non-verbally.

Nevertheless, to provide you with some examples the following categories can be considered but are definitely not limited to: time data, cost data, risk data, design data, resource data, quality data, quantity data. However, in any case do **NOT** take into account personal experiences. Therefore, things related to someone's personal life that have no effect on or are related to the project or company should **NOT** be taken into account.

Page Break

Q11 Identify people you connected with **MOST** with within BAM when it comes to sharing data relevant for the ${Q1/ChoiceGroup/SelectedChoices} tender, these can be people within and outside your tender team. Please share at least **FIVE** people but preferably as many as possible up to **TEN**.

	Full Name	Role	Located in	Which project
Person 1*				
Person 2*				
Person 3*				
Person 4*				
Person 5*				
Person 6				
Person 7				
Person 8				
Person 9				
Person 10				

Page Break

If you filled in less than 10 people in the previous question there will be rows present without a name in the upcoming questions, you can ignore these rows and leave them blank.

Q12 Please indicate for each person you identified how **frequently** you shared data with that person, with you as the data **RECEIVER** from the identified person.

	Occasionally	Every Month	Every Week	Every Day
${Q11/ChoiceTextEntryValue/1/1}	○	○	○	○
${Q11/ChoiceTextEntryValue/2/1}	○	○	○	○
${Q11/ChoiceTextEntryValue/3/1}	○	○	○	○
${Q11/ChoiceTextEntryValue/4/1}	○	○	○	○
${Q11/ChoiceTextEntryValue/5/1}	○	○	○	○
${Q11/ChoiceTextEntryValue/6/1}	○	○	○	○
${Q11/ChoiceTextEntryValue/7/1}	○	○	○	○
${Q11/ChoiceTextEntryValue/8/1}	○	○	○	○
${Q11/ChoiceTextEntryValue/9/1}	○	○	○	○
${Q11/ChoiceTextEntryValue/10/1}	○	○	○	○

Page Break

Q13 Please indicate for each person you identified how **frequently** you shared data with that person with you as the data **SENDER** to the identified person.

	Occasionally	Every Month	Every Week	Every Day
${Q11/ChoiceTextEntryValue/1/1}	○	○	○	○
${Q11/ChoiceTextEntryValue/2/1}	○	○	○	○
${Q11/ChoiceTextEntryValue/3/1}	○	○	○	○
${Q11/ChoiceTextEntryValue/4/1}	○	○	○	○
${Q11/ChoiceTextEntryValue/5/1}	○	○	○	○
${Q11/ChoiceTextEntryValue/6/1}	○	○	○	○
${Q11/ChoiceTextEntryValue/7/1}	○	○	○	○
${Q11/ChoiceTextEntryValue/8/1}	○	○	○	○
${Q11/ChoiceTextEntryValue/9/1}	○	○	○	○
${Q11/ChoiceTextEntryValue/10/1}	○	○	○	○

Q14 Who did you most often rely on when needing data **fast**?

_____

Page Break

Q15 Please indicate for each person you identified the value of the data that you **RECEIVED** from them in helping to do your work (so you as data **RECEIVER**).

	Low	Moderate	High	Very High
${Q11/ChoiceTextEntryValue/1/1}	○	○	○	○
${Q11/ChoiceTextEntryValue/2/1}	○	○	○	○
${Q11/ChoiceTextEntryValue/3/1}	○	○	○	○
${Q11/ChoiceTextEntryValue/4/1}	○	○	○	○
${Q11/ChoiceTextEntryValue/5/1}	○	○	○	○
${Q11/ChoiceTextEntryValue/6/1}	○	○	○	○
${Q11/ChoiceTextEntryValue/7/1}	○	○	○	○
${Q11/ChoiceTextEntryValue/8/1}	○	○	○	○
${Q11/ChoiceTextEntryValue/9/1}	○	○	○	○
${Q11/ChoiceTextEntryValue/10/1}	○	○	○	○

Q16 Who did you most often turn to before making an important decision for your work?

_____

Page Break

Q17 Please indicate for each person you identified what tool you used in sharing data with you as the **RECEIVER** from the identified person (you can select more options).

	Chat Applications (MS teams, etc.)	Email	BIM 360 / Revit	Online collaboration platforms (e.g. sharepoint)	Phone (text messages included)	Face-to-Face	Video/virtual calls
${Q11/ChoiceTextEntryValue/1/1}	☐	☐	☐	☐	☐	☐	☐
${Q11/ChoiceTextEntryValue/2/1}	☐	☐	☐	☐	☐	☐	☐
${Q11/ChoiceTextEntryValue/3/1}	☐	☐	☐	☐	☐	☐	☐
${Q11/ChoiceTextEntryValue/4/1}	☐	☐	☐	☐	☐	☐	☐
${Q11/ChoiceTextEntryValue/5/1}	☐	☐	☐	☐	☐	☐	☐
${Q11/ChoiceTextEntryValue/6/1}	☐	☐	☐	☐	☐	☐	☐
${Q11/ChoiceTextEntryValue/7/1}	☐	☐	☐	☐	☐	☐	☐
${Q11/ChoiceTextEntryValue/8/1}	☐	☐	☐	☐	☐	☐	☐
${Q11/ChoiceTextEntryValue/9/1}	☐	☐	☐	☐	☐	☐	☐
${Q11/ChoiceTextEntryValue/10/1}	☐	☐	☐	☐	☐	☐	☐

Q18 Please indicate for each person you identified what tool you used in sharing data with you as the **SENDER** to the identified person (you can select more options).

	Chat applications (MS Teams, etc.)	Email	BIM 360 / Revit	Online collaboration platforms (e.g. SharePoint)	Phone (text messages included)	Face-to-Face	Video/virtual calls
${Q11/ChoiceTextEntryValue/1/1}	☐	☐	☐	☐	☐	☐	☐
${Q11/ChoiceTextEntryValue/2/1}	☐	☐	☐	☐	☐	☐	☐
${Q11/ChoiceTextEntryValue/3/1}	☐	☐	☐	☐	☐	☐	☐
${Q11/ChoiceTextEntryValue/4/1}	☐	☐	☐	☐	☐	☐	☐
${Q11/ChoiceTextEntryValue/5/1}	☐	☐	☐	☐	☐	☐	☐
${Q11/ChoiceTextEntryValue/6/1}	☐	☐	☐	☐	☐	☐	☐
${Q11/ChoiceTextEntryValue/7/1}	☐	☐	☐	☐	☐	☐	☐
${Q11/ChoiceTextEntryValue/8/1}	☐	☐	☐	☐	☐	☐	☐
${Q11/ChoiceTextEntryValue/9/1}	☐	☐	☐	☐	☐	☐	☐
${Q11/ChoiceTextEntryValue/10/1}	☐	☐	☐	☐	☐	☐	☐

Q19 Which tool do you prefer most when sharing data with others?

- ○ Chat applications (MS teams, etc.)
- ○ Email
- ○ BIM 360 / Revit
- ○ Online collaboration platforms (e.g. sharepoint)
- ○ Phone (text messages included)
- ○ Face-to-Face
- ○ Video/Virtual calls

Q20
During the ${Q1/ChoiceGroup/SelectedChoices} tender have you approached members of similar projects to learn from their experiences and try and take them into account in the current tender. If yes, please fill in their data.

	Full name	This person's role	Work location of this person	Which project was this person active in?
Person 1				
Person 2				
Person 3				

End of Block: Social Network Analysis

Start of Block: Work Details

Part 3 - Work details (Q21 -Q31)
This is the last part of the survey, you are almost finished!

Q21 What is your full name?

_____

Q22 What is your operating company?

- ○ BAM Infra NL
- ○ BAM Construct
- ○ BAM Nuttall
- ○ Wayss & Freytag
- ○ Other: _____

Skip To: Q24 If What is your operating company? = Other:

Display This Question:
If What is your operating company? = BAM Infra NL

Q23 What is your business unit inside BAM Infra NL?

- BAM Infra Projecten
- BAM Infra Rail
- BAM Infra Regionaal
- BAM Infra Regionaal Verkeerstechniek
- BAM Infraconsult BV
- BAM Telecom
- Other: _____

Display This Question:

If What is your operating company? = BAM Construct

Q23 What is your business unit inside BAM Construct?

- BAM FM (Construct)
- BAM Construction
- Other: _____

Display This Question:

If What is your operating company? = BAM Nuttall

Q23 What is your business unit inside BAM Nuttall?

- ○ Highways
- ○ Major Projects (Nuttall)
- ○ Rail
- ○ Other: _____

Display This Question:

If What is your operating company? = Wayss & Freytag

Q23 What is your business unit inside Wayss & Freytag?

- ○ Environmental Engineering
- ○ Major Projects (Wayss & Freytag)
- ○ Central
- ○ North
- ○ South
- ○ Special foundations
- ○ Tunneling
- ○ Other: _____

Q24 On how many similar tenders have you worked for at BAM?

- None
- 1 project
- 2-3 projects
- 4-5 projects
- 6-7 projects
- 8-10 projects
- Over 10 projects

Q25 Who was your direct line manager?

_____

Page Break

Q26 What city and country were you located when working on the ${Q1/ChoiceGroup/SelectedChoices} tender?

_____

Q27 What was your role when working on the ${Q1/ChoiceGroup/SelectedChoices} tender?

_____

Q28 How many years of experience do you have in your current role at BAM?

- ○ <1 year
- ○ 1-4 years
- ○ 5-9 years
- ○ 10-19 years
- ○ 20-29 years
- ○ 30-40 years
- ○ >40 years

Q29 How many years have you worked for BAM?

- ○ <1 year
- ○ 1-4 years
- ○ 5-9 years
- ○ 10-19 years
- ○ 20-29 years
- ○ 30-40 years
- ○ >40 years

Q30 Under what category do you place your role when working on the ${Q1/ChoiceGroup/SelectedChoices} tender?

- ○ Tender manager
- ○ Tender management assistant
- ○ Design Management
- ○ Engineering management
- ○ Contract Management
- ○ Drafting / Modelling / BIM
- ○ Risk management
- ○ Estimating
- ○ Construction Management
- ○ Planning
- ○ Site engineering
- ○ Procurement
- ○ Other specialist (HSE/Sustainability/Geotechnical/etc.)

End of Block: Work Details

We thank you for your time spent taking this survey.

Your response has been recorded.

D

Social network results

The following network analysis has been performed in the Gephi environment, providing more insights into the structure, metrics and roles of the network:

- **Degree** - The number of connections of each node.
- **Degree centrality** - Degree centrality is the most simple form of centrality and simply measures the number of direct connections a node has to other nodes. Generally, nodes with a high degree are the local connectors.
- **Closeness centrality** - Closeness centrality measures the average distance of a specific node to all the other nodes in the network. Generally, nodes with a high closeness can more easily spread information to the rest of the network and often have a good oversight of what is happening.
- **Betweenness centrality** - The betweenness centrality measures the number of times a node is present on the shortest path between two other nodes. Therefore, it identifies all the shortest paths in the network and counts how many times the node is present on these paths. Nodes with a high betweenness act as bridges between nodes in a network and have more control over the flow of information. However, they can also be potential single points of failure.
- **Eigenvector centrality** - Similarly to the degree centrality, the eigenvector centrality measures the influence of a node based on the number of connections it has to other nodes in the network. However, the eigenvector centrality goes beyond this by also considering how well connected a node is, and how many links the connected nodes have to other nodes, and so on. Generally, eigenvector centrality can identify nodes that have a strong influence on the whole network, but they may not have the strongest local influence.
- **Clustering coefficient (Network clustering)** - The clustering coefficient can be seen as a form of centrality, although one that takes on small values for powerful individuals and is a measure of the degree to which nodes in a graph cluster together (Du, 2020). A node's clustering coefficient is calculated by dividing the number of closed triplets in the node's neighbourhood over the total number of triplets in the neighbourhood. It is also known as transitivity. Evidence indicates that in most real-life networks, the nodes have the tendency to create tightly knit groups that are characterised by a relatively high density of ties (Du, 2020).
- **Eccentricity** - The eccentricity of a node in a network is the maximum distance from that node to any other node in the network. Thus it is the distance from the starting node to the farthest node from it in the network. Thus a higher eccentricity number indicates that the furthest away node in the network is a long way away. This says something about the connectivity of a node in the network. It shows how 'quickly' a node can transfer information to the furthest away node and says something about the node proximity of that particular node with respect to other nodes in the network.

The findings for both projects with respect to the network analysis are summarised in the next two subsections. For both projects, the actual tool use of the respondents and the role division of the identified actors are presented. In addition, the nodes, including their centrality measures, are presented. Here, it should be noted that the tables are ranked from top to bottom on the eigenvector centrality. Furthermore, for project B also the lessons learned connections are included; for project A, these are missing due to the presence of just

a single connection in the whole network. Lastly, the respondent response towards the statements related to the risk awareness factors in their project are included as well.

D.1. Project A

Tool use in project A

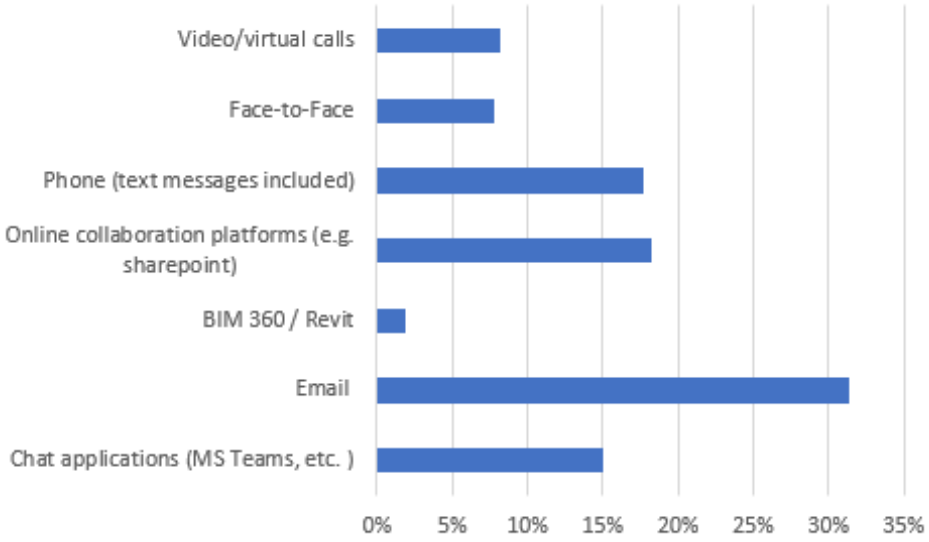


Figure D.1: Tool use in project A.

Role division of respondents project A

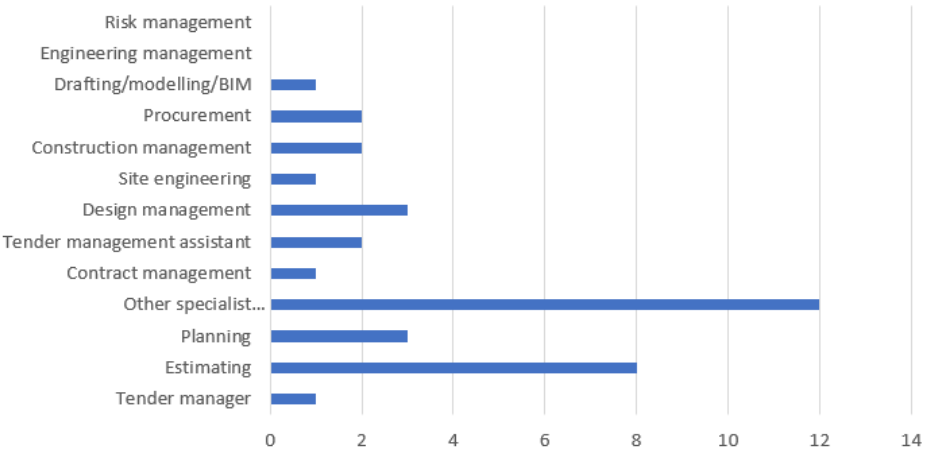


Figure D.2: Role division of actors involved in the network of project A.

Node analysis

Label	Work role	Degree	Degree centrality	Eccentricity	Closeness centrality	Betweenness centrality	Eigenvector centrality	Clustering coefficient
A1	Tender manager	14	0,4000	2	0,6250	286,24	1,0000	0,2088
A12	Design management	11	0,3143	3	0,5385	191,08	0,6751	0,1091
A2	Estimating	8	0,2286	3	0,4795	51,58	0,6626	0,3571
A3	Estimating	8	0,2286	3	0,4795	70,97	0,5858	0,2500
A9	Planning	6	0,1714	3	0,4545	24,74	0,5555	0,4000
A15	Estimating	5	0,1429	3	0,4375	11,14	0,4924	0,5000
A5	Planning	5	0,1429	3	0,4268	36,18	0,4335	0,4000
A4	Estimating	6	0,1714	3	0,4268	71,92	0,4185	0,2667
A8	Procurement	4	0,1143	3	0,4167	8,48	0,4089	0,5000
A6	Other specialist (Sustainability)	5	0,1429	3	0,4268	67,67	0,3636	0,2000
A10	Estimating	4	0,1143	3	0,4167	34	0,3538	0,5000
A11	Tender management assistant	7	0,2000	3	0,4730	143,5	0,3481	0,0476
A7	Contract management	5	0,1429	3	0,4487	80,5	0,3210	0,1000
A13	Estimating	2	0,0571	3	0,4023	0	0,2604	1,0000
B1	Procurement	3	0,0857	4	0,3500	1	0,2440	0,6667
A16	Other specialist (Projectleider)	2	0,0571	4	0,3398	0	0,1869	1,0000
A14	Planning	1	0,0286	3	0,3889	0	0,1639	0,0000
A22	Other specialist (Sales coach)	2	0,0571	4	0,3431	5	0,1164	0,0000
A30	Drafting/Modelling/BIM	1	0,0286	4	0,3535	0	0,1131	0,0000
A31	Design Management	1	0,0286	4	0,3535	0	0,1131	0,0000
A32	Other specialist (Geotechnical)	1	0,0286	4	0,3535	0	0,1131	0,0000
A33	Design management	1	0,0286	4	0,3535	0	0,1131	0,0000
A34	Other specialist (Afdelingshoofd Rail)	1	0,0286	4	0,3535	0	0,1131	0,0000
A17	Estimating	1	0,0286	4	0,3271	0	0,0964	0,0000
A19	Site engineering	1	0,0286	4	0,3017	0	0,0708	0,0000
A18	Other specialist (Commercial manager)	1	0,0286	4	0,3017	0	0,0695	0,0000
B2	Estimating	1	0,0286	4	0,3017	0	0,0695	0,0000
A26	Other specialist (Project manager)	1	0,0286	4	0,3241	0	0,0613	0,0000
A27	Other specialist (Omgevings management)	1	0,0286	4	0,3241	0	0,0613	0,0000
A28	Other specialist (Omgevings management)	1	0,0286	4	0,3241	0	0,0613	0,0000
A29	Other specialist (Tender strategist)	1	0,0286	4	0,3241	0	0,0613	0,0000
A20	Construction management	1	0,0286	4	0,3017	0	0,0606	0,0000
A21	Other specialist (sustainability)	1	0,0286	4	0,3017	0	0,0606	0,0000
A25	Construction management	1	0,0286	4	0,2966	0	0,0582	0,0000
A23	Tender management assistant	1	0,0286	4	0,3125	0	0,0552	0,0000
A24	Other specialist (Lawyer)	1	0,0286	4	0,3125	0	0,0552	0,0000

Table D.1: Nodes including their centrality measures for project A.

Respondent response towards the presence of risk awareness factors in practice

#	Question	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree	Total	Mean
1	I am aware and up-to-date about BAM's guidelines and procedures regarding risk management.	0	0	3	7	3	13	4.00
2	During the execution of the project the steps to properly perform procedures with respect to risks were clear to me. (Think about clarity for the employee as in what to expect, where to retrieve information and how to act in case of risk-related issues).	0	1	2	7	3	13	3.92
3	During the project everyone's role and work responsibilities in the team were clear and known to me.	0	1	0	10	2	13	4.00
4	During the project I pro-actively accepted responsiblity for risks (management).	0	0	2	10	1	13	3.92
5	During my project there was an incentive system for project members in case of excellent performance or succesful completion of the project.	3	2	3	1	0	9	2.22
6	Lessons learned are always used and captured in the projects.	0	4	4	2	3	13	3.31
7	During the project I made use of lessons learned.	0	2	3	5	3	13	3.69
8	During the project I approached members of similar projects to learn from their experiences and try and take them into account in the current project.	0	2	3	5	3	13	3.69
9	During the project I experienced missing data that I needed to make decisions involving risks.	0	4	5	2	1	12	3.00
10	During the project I experienced problems with the compatability/formatting of data that hindered me in making decisions involving risks.	0	8	3	1	0	12	2.42
11	During the project I experienced problems with the accessibility of data that hindered me in making decisions involving risks.	1	9	2	0	0	12	2.08
12	I feel that within BAM, top management dedicates its attention to issues involving risks, extensively supports the risk management process, and transfers expectations regarding risk management behaviour to employees.	0	1	5	5	2	13	3.62
13	In case of issues involving risks it is possible for me to communicate my issues directly to upper management, therefore bypassing my direct manager.	0	1	2	5	3	11	3.91
14	During the project I was actively involved in risk management.	0	0	4	6	2	12	3.83
15	During the project a common risk language was used.	0	1	4	7	0	12	3.50

Table D.2: Respondent response towards the presence of risk awareness factors in project A.

D.2. Project B

Tool use

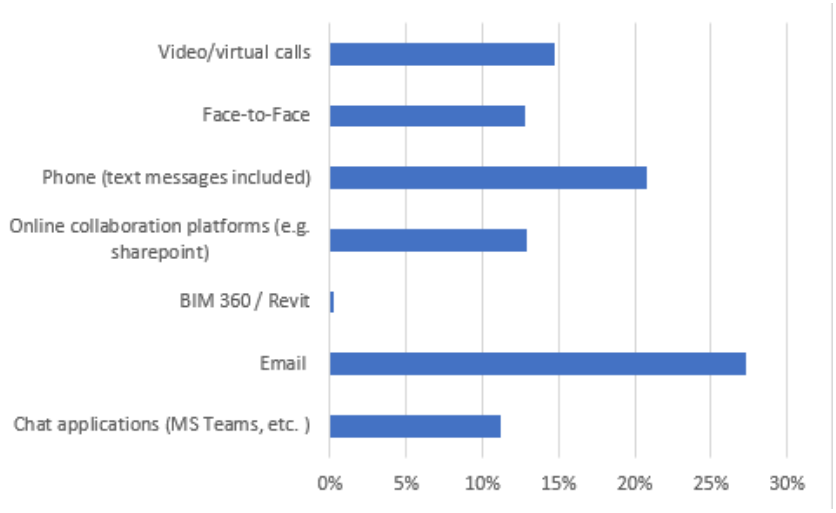


Figure D.3: Tool use in project B.

Role division of respondents

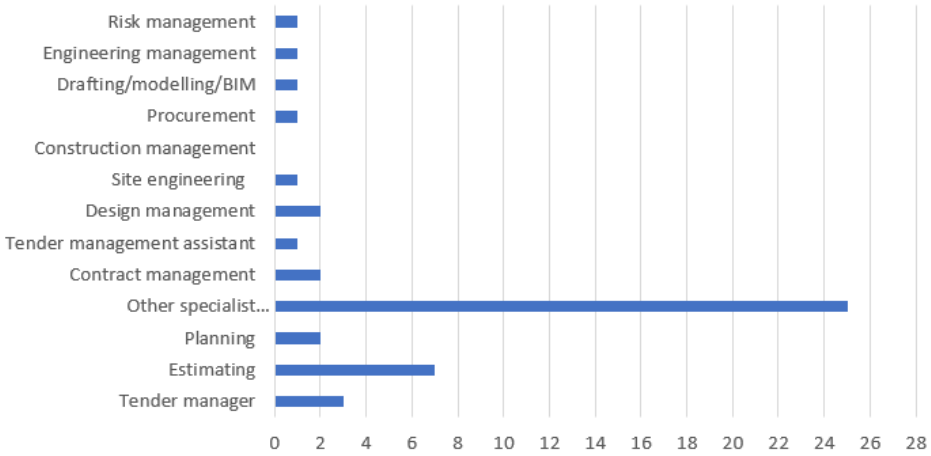


Figure D.4: Role division of actors involved in the network of project B.

Lessons learned connections

Actor (Function)	Lessons learned connections (Function)
B2 (Estimating)	B40 (Construction management)
B3 (Tender manager)	B5 (Design manager), B36 (Managing director - Transport sector, BAM Nuttall)
B6 (Omgevings manager)	A28, A29 (omgevings managers) both also taken into account in regular data sharing network and B35 (omgevings manager)
B7 (Cost estimator)	B5 (Design management) also taken into account in regular data sharing network, B33(project manager - similar project), B34 (Site engineer)
B9 (Risk manager)	B32, B33 (All project managers of similar projects)
B12 (Traffic management)	B41, B42, B43 (All traffic management specialists)
B15 (Planning)	B32 (Project manager - similar project) also taken into account in regular data sharing network

Table D.3: Lessons learned connections of project B.

Node analysis

Label	Work role	Degree	Degree centrality	Eccentricity	Closeness centrality	Betweenness centrality	Eigenvector centrality	Clustering coefficient
B3	Tender manager	21	0,4255	3	0,6301	474,7971	1	0,190476
B15	Planning	15	0,2979	3	0,5542	153,6978	0,883957	0,342857
B7	Estimating	13	0,2553	3	0,5412	131,0881	0,782902	0,333333
B6	Other specialist (Omgevings management)	13	0,2553	3	0,4792	157,9170	0,651233	0,269231
B4	Tender manager (Arcadis)	9	0,1702	3	0,4894	63,3938	0,616402	0,527778
B9	Risk management	8	0,1489	3	0,4792	35,7659	0,587971	0,571429
B20	Tender management assistant (External)	7	0,1277	3	0,4554	5,4333	0,549382	0,714286
B13	Estimating	10	0,1915	3	0,4842	179,3607	0,530483	0,266667
B2	Estimating	9	0,1702	4	0,4510	100,8295	0,507254	0,361111
A4	Estimating	8	0,1489	3	0,4842	71,7044	0,472999	0,357143
B8	Other specialist (QHSE advisor)	6	0,1064	3	0,4466	4,5636	0,448127	0,733333
B14	Engineering management	6	0,1064	3	0,4381	46,6381	0,424957	0,466667
B5	Design management	6	0,1064	3	0,4423	89,0000	0,371276	0,4
B12	Other specialist (Traffic management)	5	0,0851	3	0,4381	10,2540	0,342026	0,5
B1	Procurement	6	0,1064	3	0,4423	72,7446	0,33947	0,266667
B10	Other specialist (Omgevings management)	5	0,0851	4	0,4220	5,0077	0,335682	0,7
A6	Other specialist (Sustainability)	5	0,0851	3	0,4299	64,1875	0,279311	0,2
A18	Other specialist (Commercial manager)	3	0,0426	3	0,4220	5,5000	0,228764	0,666667
B28	Other specialist (Traffic management)	4	0,0638	4	0,3566	1,1167	0,224146	0,5
B30	Planning (External)	2	0,0213	4	0,3770	0,0000	0,178668	1
B24	Other specialist (Ecologist)	2	0,0213	4	0,3966	0,0000	0,157647	1
B11	Contract management	5	0,0851	4	0,4144	132,0000	0,156862	0,1
B21	Tender manager (Client)	1	0,0000	4	0,3898	0,0000	0,117287	0
B22	Other specialist (Project manager - Client)	1	0,0000	4	0,3898	0,0000	0,117287	0
B23	Other specialist (Secretariat department)	1	0,0000	4	0,3898	0,0000	0,117287	0

Label	Work role	Degree	Degree centrality	Eccentricity	Closeness centrality	Betweenness centrality	Eigenvector centrality	Clustering coefficient
A19	Site engineering	1	0,0000	4	0,3594	0,0000	0,102287	0
B32	Other specialist (Project manager - similar project)	1	0,0000	4	0,3538	0,0000	0,090848	0
A28	Other specialist (Omgevings management)	1	0,0000	4	0,3262	0,0000	0,076381	0
B29	Other specialist (Omgevings management)	1	0,0000	4	0,3262	0,0000	0,076381	0
B31	Other specialist (External Stationmanager NS)	1	0,0000	4	0,3262	0,0000	0,076381	0
B17	Other specialist (Sustainability)	2	0,0213	4	0,3172	1,0000	0,074263	0
B25	Other specialist (System engineer)	1	0,0000	4	0,3309	0,0000	0,071203	0
B44	Other specialist (manager operations rail)	1	0,0000	4	0,3286	0,0000	0,062615	0
B45	Other specialist (manager operations rail)	1	0,0000	4	0,3286	0,0000	0,062615	0
B46	Other specialist (manager operations rail)	1	0,0000	4	0,3286	0,0000	0,062615	0
B47	Other specialist (Teamleider rail)	1	0,0000	4	0,3286	0,0000	0,062615	0
B18	Other specialist (Projectmanager - Arcadis)	1	0,0000	5	0,3129	0,0000	0,059421	0
B19	Other specialist (Advisor tracksystems - Arcadis)	1	0,0000	5	0,3129	0,0000	0,059421	0
A15	Estimating	1	0,0000	4	0,3286	0,0000	0,055775	0
A2	Estimating	1	0,0000	4	0,3067	0,0000	0,049503	0
B26	Design management	1	0,0000	4	0,3087	0,0000	0,043654	0
B27	Drafting/Modelling/BIM	1	0,0000	4	0,3087	0,0000	0,043654	0
B16	Estimating	1	0,0000	4	0,3087	0,0000	0,04058	0
B48	Other specialist (Maintenance engineer)	1	0,0000	4	0,3026	0,0000	0,033682	0
B37	Other specialist (Lawyer)	1	0,0000	5	0,2949	0,0000	0,020629	0
B38	Other specialist (Insurance manager)	1	0,0000	5	0,2949	0,0000	0,020629	0
B39	Contract management	1	0,0000	5	0,2949	0,0000	0,020629	0

Table D.4: Nodes including their centrality measures for project B.

Respondent response towards the presence of risk awareness factors in practice

#	Question	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree	Total	Mean
1	I am aware and up-to-date about BAM's guidelines and procedures regarding risk management.	0	1	2	11	3	17	3.94
2	During the execution of the project the steps to properly perform procedures with respect to risks were clear to me. (Think about clarity for the employee as in what to expect, where to retrieve information and how to act in case of risk-related issues).	0	0	3	9	5	17	4.12
3	During the project everyone's role and work responsibilities in the team were clear and known to me.	0	3	1	7	6	17	3.94
4	During the project I pro-actively accepted responsiblity for risks (management).	0	0	4	9	4	17	4.00
5	During my project there was an incentive system for project members in case of excellent performance or succesful completion of the project.	3	6	3	0	0	12	2.00
6	Lessons learned are always used and captured in the projects.	0	2	3	9	2	16	3.69
7	During the project I made use of lessons learned.	0	0	4	7	5	16	4.06
8	During the project I approached members of similar projects to learn from their experiences and try and take them into account in the current project.	0	3	2	7	5	17	3.82
9	During the project I experienced missing data that I needed to make decisions involving risks.	0	3	7	5	0	15	3.13
10	During the project I experienced problems with the compatability/formatting of data that hindered me in making decisions involving risks.	3	7	3	2	1	16	2.44
11	During the project I experienced problems with the accessibility of data that hindered me in making decisions involving risks.	4	8	2	2	0	16	2.13
12	I feel that within BAM, top management dedicates its attention to issues involving risks, extensively supports the risk management process, and transfers expectations regarding risk management behaviour to employees.	1	1	7	6	2	17	3.41
13	In case of issues involving risks it is possible for me to communicate my issues directly to upper management, therefore bypassing my direct manager.	1	2	3	8	1	15	3.40
14	During the project I was actively involved in risk management.	0	2	1	11	2	16	3.81
15	During the project a common risk language was used.	0	0	4	12	1	17	3.82

Table D.5: Respondent response towards the presence of risk awareness factors in project B.

E

Expert panel guide

This appendix covers the approach taken for the expert panel. Basically, the expert panel session was divided into three main components: introduction, main research results and validation of the recommendations. To present all the main components and validate the recommendations, a PowerPoint was used, which is added to the report on the next page.

First, during the introduction, an explanation was given of the research subject and objectives. After that, the main results of literature and the case studies were presented and elaborated upon. Due to the time restraints of the session, it was not possible to discuss all observations and based on that fact, only a selection of the observations were presented. Nevertheless, during the validation of the recommendations, there was ample opportunity to request extra information about the recommendations and ask for additional clarification when something was unclear.

After the presentation of the main findings, the validation of the recommendations could commence. Here an open dialogue was held between the researcher and members of the expert panel to discuss the added benefit of the recommendations and come to a consensus. The recommendations themselves and how the validation was performed are described in more detail in appendix F. In addition, the recommendations can be seen in the PowerPoint slides on the next page and in the main body in chapter 5. However, important to note is that before the commencement of the expert panel, a word document was sent to the participants of the expert panel that contained the research assumptions on which the recommendations are based. This was done to save time during the expert panel since there were a high number of recommendations to be validated. This is also discussed in more detail in appendix F.

Lastly, also important to note is that the expert session has been performed in Dutch due to the experts being Dutch natives and not being accustomed to speaking English on a day-to-day basis. By carrying out the expert panel in Dutch, it was expected that discussion amongst the experts would be stimulated, and possible misunderstandings that would follow from using the English language prevented. As a result, the PowerPoint slides added to this report, and presented on the next page, are in the Dutch language. In addition to this, the quotes and statements used for substantiation of the recommendations in appendix F are also presented in the Dutch language.

26-11-2021

MSc Thesis
Expert session

Faculty of Civil Engineering and Geosciences
Track: Construction Management and Engineering
Skip de Metz

1

1

Expert sessie agenda

- Onderzoeksonderwerp
- Onderzoek aannames
- Observaties van literatuur en casussen
- Aanbevelingen (maximaal 4 minuten per aanbeveling)

2

2

Onderzoeksonderwerp

3

3

Onderwerp

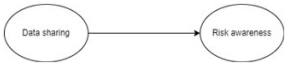
- Het hoofddoel van het onderzoek is om te onderzoeken:

Wat het effect is van data sharing binnen project netwerken op het risicobewustzijn van medewerkers in de organisatie

4

4

The twee hoofdconcepten



5

5

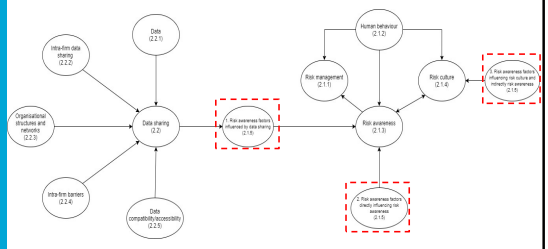
Literatuur onderzoek

- Het concept van data sharing binnen het bedrijf onderzocht.
- 18 factoren verzameld uit de literatuur die bijdragen aan het risicobewustzijn.
- Deze factoren kunnen onderverdeeld worden in drie verschillende bouwstenen.

6

6

Relatie tussen de concepten



TUDelft

7

7

Onderzoek aannames

TUDelft

8

8

Onderzoek aannames

1. All kinds of data can be potentially important to risk management and risk awareness.
2. Establishment of data sharing (and lessons learned) connections leads to a higher variety of decision-influencing data and stimulates discussion between organisational members leading to an increased risk awareness.
3. Reducing occurrence of missing data leads to a higher availability and variety of decision-influencing data, leading to an increased risk awareness. (includes preventing data silo's)
4. Minimising compatibility/accessibility issues with data files and systems leads to a higher availability and variety of decision-influencing data, leading to an increased risk awareness.
5. Breaking down intra-firm data sharing barriers leads to a higher availability and variety of decision-influencing, data leading to an increased risk awareness.
6. Using less conventional data tools leads to an increased availability of data which enhances data sharing and risk awareness.

TUDelft

9

9

Observaties Casussen

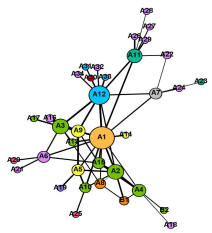
TUDelft

10

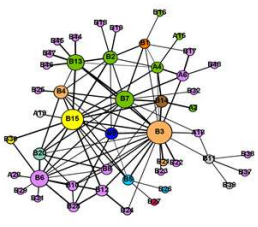
10

Data sharing networks

Project A



Project B

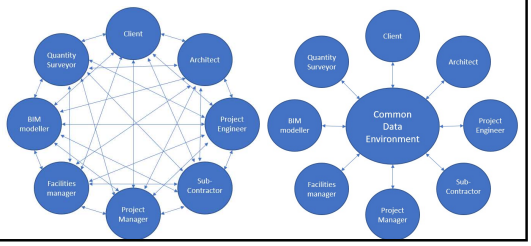


TUDelft

11

11

Two types of data sharing



TUDelft

12

12

Onderscheid

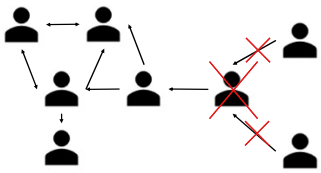
- Conventionele data sharing tools:
  - E-mail
  - Face-to-face gesprekken
  - Telefoon
  - MS teams en soortgelijke tools
- Non-conventionele data sharing tools:
  - BIM
  - SharePoint
  - Dropbox en soortgelijke tools

TUDelft 13

13

Conventionele valkuilen

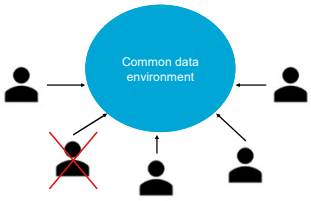
Wie heeft welke data??



TUDelft 14

14

Conventionele valkuilen



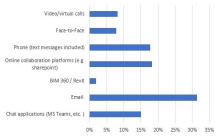
TUDelft 15

15

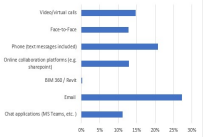
Tool gebruik

- Tool gebruik in beide projecten bestaat voornamelijk uit conventionele data sharing tools

Project A



Project B



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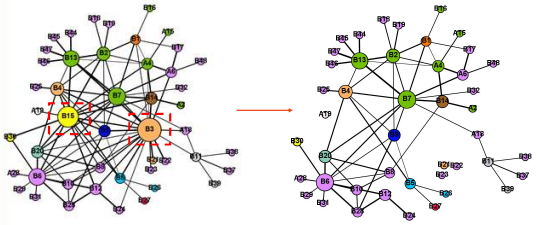
Networks without most influential players



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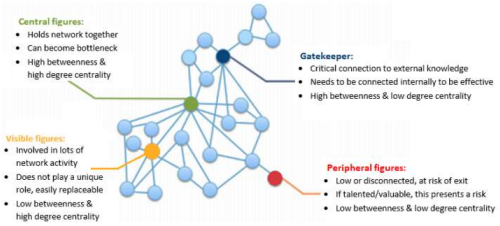
Node analysis



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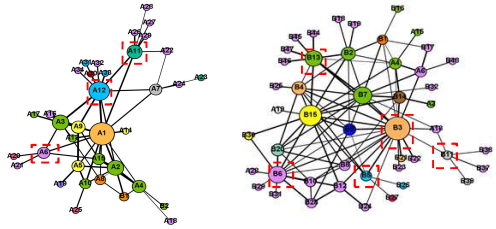
Gatekeepers

Project A

Project B



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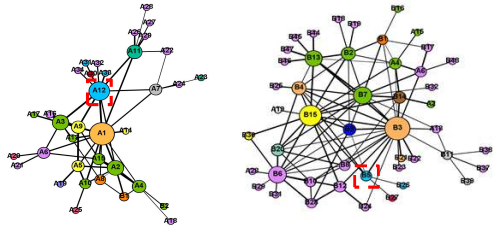
Gatekeepers

Project A

Project B



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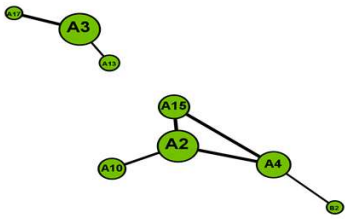
Calculators netwerk project A



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Comptabiliteit problemen van data en databases

- Veel respondenten aangegeven dat:
  - Data in te veel verschillende en/of ingewikkelde formats word aangeleverd door mensen in de organisatie wat leidt tot onbruikbare data.
  - Data niet te vinden is door bijvoorbeeld spreiding over te veel verschillende databases en plekken.
  - Respondenten aangeven te onervaren zijn of niet goed genoeg met de bestaande systemen overweg kunnen met als gevolg het niet kunnen gebruiken van data.
  - Het gebruik van informatie systemen en tools teveel moeite kan kosten ten opzichte van de conventionele systemen

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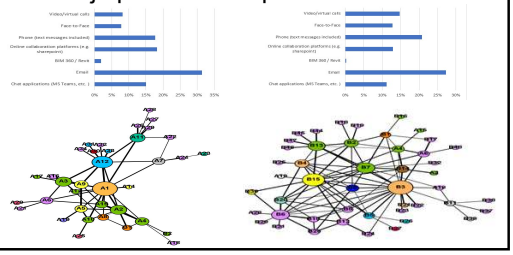
Data governance

- Duidelijk plan van aanpak mist



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Mobiliseren van data

- Lessons learned en data sharing connecties: Intra-organisatorische barrières voorkomen het tot stand brengen van deze connecties
- Actief mobiliseren van data kan hier een oplossing voor zijn.
  - Systemen waarin alle vastgelegde lessen, risico's, risicobeoordelingen enz. worden opgeslagen, inclusief document eigenaar waardoor het mogelijk is om contact op te nemen met deze mensen.
  - Systemen waarmee medewerkers specifieke experts kunnen vinden binnen het hele bedrijf, nationaal en internationaal, door hun competenties en werk aan te geven en erop te kunnen zoeken.
  - Implementeren van organisatie brede datamanagers die de ins en outs van de informatiesystemen kennen en waar specifieke data is opgeslagen.

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Risico manager

- Lessons learned: Groot verschil tussen projecten

Lessons learned project A	Lessons learned project B
1	15

- Formalisatie van risico management procedures niet consistent in kleinere projecten:
  - UPA RSK01_risk and opportunity management
  - Onder bepaald budget of risico niveau blijkt dat het proces en implementatie ervan meer naar interpretatie van de tender manager is.
  - Geen controle op uitvoering

TUDelft

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Risico management trainingen en workshops

- Meerderheid binnen projecten heeft aangegeven betrokken te zijn bij het risico management.
  - Terwijl van deze meerderheid een (groot) deel heeft aangegeven nooit een training ontvangen te hebben gehad m.b.t. risicobeheerpraktijken, process, tools, templates en subjective biases.
- Groot verschil in deelname aan trainingen en workshops tussen de twee projecten
- Opmerkelijkst risico manager aangegeven nooit getraind te zijn in risk management tools, processen en templates.

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Data sharing aanbevelingen

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Aanbevelingen

Alle aanbevelingen hebben als einddoel het verbeteren van het risicobewustzijn van de tender teamleden binnen de organisatie.

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Score

- Alle aanbevelingen krijgen een score van 1-5 betreffende de verwachte effectiviteit van de aanbevelingen
- 1 = Niet effectief
- 2 = Weinig effectief
- 3 = Neutraal
- 4 = Effectief
- 5 = Heel effectief

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Aanbevelingen

- Aanbevelingen worden onderverdeeld in drie verschillende categorieën:

- Als je het eens bent met de aanbeveling in het algemeen maar niet met de bulletpoints geef dit dan aan in de discussie.

TUDelft

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People

Aanbevelingen

- 1. Meeting om potentieel data verlies, redundantie en datasilo's in project netwerken en discipline specifieke netwerken te voorkomen.
  - A) Maak bij de tender kick-off afspraken over hoe, wanneer en met wie data gedeeld/hergebruikt wordt om redundantie, datasilo's en dataverlies te voorkomen. (Project niveau)
  - B) Zorg ervoor dat elke discipline aan het begin van het project bij elkaar zit en overeenstemming bereikt wordt over hoe er nog specifieker data gedeeld zou moeten worden binnen de discipline en wat de databehoeften van de verschillende mensen in de discipline zijn om data silo's binnen de subgroep te voorkomen. (Discipline niveau)

TUDelft

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People

Aanbevelingen

- 2. Pak netwerk consistente gatekeepers en data silo's aan door de BIM/Modelleur/Ontwerp mensen te betrekken in het data sharing netwerk en het risico management proces.

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People

Aanbevelingen

- 3. Verdeel de verantwoordelijkheid in het team door toegewijde teamleden aan te stellen om verantwoordelijkheid te nemen voor delen van de data sharing strategie binnen het team of de discipline
  - Implementeer een documentcontroller en bij grotere projecten kan dit een op zichzelf staande klus zijn.
  - Maak duidelijke afspraken over data sharing verantwoordelijkheden voor rollen.
  - Benut de meest invloedrijke spelers in het team om het voortouw te nemen in de strategie en dit uit te dragen naar team leden (tender manager en senior planner).

TUDelft

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Process

Aanbevelingen

- 4. Maak een duidelijk data governance plan.
  - Creëer een standaard en gebruiksklaar data management plan dat gebruikt kan worden bij de tender kick-off en eventueel uniform door het hele bedrijf.
  - Implementeer duidelijke regels met betrekking tot de data kwaliteit, databases, tools, toegankelijkheid, verantwoordelijkheden en procedures.
  - Interne audit die de daadwerkelijke implementatie en gebruik van dit plan binnen tenders controleert.

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Process

Aanbevelingen

- 5. Implementeer een risico manager in elke tender.

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Process

Aanbevelingen

- 6. Formaliseer risico management procedures voor alle projecten.
  - Consistent gebruik van lessons learned
  - Consistente risicio procedures, templates en tools.
  - Interne audit om implementatie en juiste executie en gebruik van procedures, templates en tools te controleren.

TUDelft

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Aanbevelingen

Process

- 7. Creëer bottom-up risk awareness door discussie binnen de discipline te stimuleren
  - Creëer een discussie binnen de disciplinaire teams over potentiële risico's, kansen en mitigatie en geef dit vervolgens door aan de risicomanager en/of het risicobeheerproces. Het betrekken van meer disciplinaire expertise bij het risicobeheerproces en het samen definiëren van de criteria/risico's zou het gemeenschappelijk begrip en de toepassing van relevante data moeten vergroten.
    - Hierdoor kunnen ook de stillere teamleden hun stem laten horen.

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Aanbevelingen

Process

- 8. Zorg voor routinematige en verplichte basistraining in het gebruik van digitale systemen en data sharing tools aan alle leden van de organisatie.

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Aanbevelingen

Process

- 9. Verbeter het operationele gebruiksgemak van informatie infrastructuur
  - Verbeter het gebruiksgemak van informatiesystemen en tools door middel van duidelijke richtlijnen en handleidingen die de toepasbaarheid in projecten vergroten.
  - Maak duidelijk met wie in het bedrijf contact op te nemen voor ondersteuning bij problemen met data sharing tools en/of informatiesystemen.

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Aanbevelingen

Technology

- 10. Gebruik minder conventionele data sharing tools om de beschikbaarheid van data te verbeteren.

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Aanbevelingen

Technology

- 11a. Verbeter de compatibiliteit van data en databases.
  - Project level:
    - Maak duidelijke afspraken over welke formats, datatypes en databases te gebruiken tijdens de tender.
    - Houdt het bij een beperkt aantal formats en gebruik zoveel mogelijk vergelijkbare data types.
    - Consistentie in gebruik van databases.

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Aanbevelingen

Technology

- 11b. Verbeter de compatibiliteit van data en databases.
  - Organisatie level:
    - Implementeer meer standaard data formats en templates in het bedrijf.
    - Gebruik ook alleen datatools en informatiesystemen die ook het gebruik van deze formats en templates ongehinderd mogelijk maken.
    - Probeer het aantal tools en databases voor het delen van data in het bedrijf te beperken.

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Aanbevelingen

Technology

- 12. Mobiliseer actief relevante data die toegankelijk is voor leden van de organisatie.

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Aanbevelingen die direct effect op het risicobewustzijn hebben

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Aanbevelingen

- 13. Verstrek routinematige en verplichte training en workshops aan alle leden van het tenderteam met betrekking tot risico management procedures, templates, tools en subjectieve biases.
  - Verplicht voor iedereen die betrokken is bij risico management
  - Interne audit om te controleren op plaatsvinden van deze trainingen, workshops en activiteiten en deelname eraan.

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Aanbevelingen

- 14. Focus op risico-eigenaarschap (verantwoordelijkheid/aansprakelijkheid)
  - Ieder risico heeft een eigenaar en weet wat zijn taken zijn; risico-eigenaar controleert continu risicostatus
  - Leiderschap (tendermanager of risicomanager) vraagt continu naar de risicostatus en is expliciet over risicobereidheid (risk appetite) op specifieke onderwerpen

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Aanbevelingen

- 15. Introduceer incentive(beloning) systeem met betrekking tot risico's.
  - Voorbeelden kunnen zijn beloningen voor goede identificatie en beoordeling van alle risico's die zich later in de bouwfase voordoen

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Aanbevelingen

- 16. Bottom-up communicatie en escalatie van risicoproblemen.
  - Een bottom-up perspectief waarin het management in staat is om communicatie en escalatie van onderwerpen met risico's te motiveren van de lagere niveaus tot aan de hogere. Dus door werknemers een stem te geven in risico gerelateerde kwesties, kan het hogere management hiërarchische barrières uit de weg ruimen en de betrokkenheid van werknemers ondersteunen, wat resulteert in een hogere motivatie onder medewerkers om continu na te denken over risico gerelateerde kwesties.

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Aanbevelingen

- 17. Top-down aanmoediging met betrekking tot het risico management proces.
  - Om binnen het bedrijf een bevredigend niveau van risicobewustzijn te het management moet zijn aandacht besteden aan risicokwesties, het risicobeheerproces uitgebreid ondersteunen en verwachtingen met betrekking tot risicobeheergedrag overdragen, en communicatie en escalatie met betrekking tot kwesties met risico's naar alle niveaus aanmoedigen

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Done!

TUDelft

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F

Expert panel data analysis

This appendix contains the data analysis of the performed expert panel, including an overview of quotes and statements used by experts in the discussion during the expert panel. These quotes and statements are used to substantiate the recommendations presented to the experts.

F.1. Validation of the research assumptions

Before the commencement of the expert panel, the experts were sent a word document that contained the research assumptions. This was done to save time during the expert panel since there were a high number of recommendations to be validated. The experts were asked to give their opinion on the assumptions and indicate if they agreed or disagreed with the assumptions. The research assumptions can be seen below:

1. All kinds of data can be potentially important to risk management and risk awareness.
2. Establishment of data sharing and lessons learned connections leads to a higher variety of decision-influencing data and stimulates discussion between organisational members leading to an increased risk awareness.
3. Reducing occurrence of missing data leads to a higher availability and variety of decision-influencing data, leading to an increased risk awareness.
4. Minimising compatibility/accessibility issues with data files and systems leads to a higher availability and variety of decision-influencing data, leading to an increased risk awareness.
5. Breaking down intra-organisational data sharing barriers leads to a higher availability and variety of decision-influencing data, leading to an increased risk awareness.
6. Using less conventional data tools leads to an increased availability of data which enhances data sharing and risk awareness.

The response of the experts indicated that they agreed with all assumptions, except assumption 6. Hence, the outcome of the response resulted in the validation of assumptions 1 to 5. However, it has to be noted that although the experts agreed with the assumptions, they put the notion out there that too much data can also lead up to information overload, especially in the tender phase where the time pressure to process all the data is high. Therefore, in practice, attention needs to be given to this.

Assumption 6, at this point, was considered too vague and not clear enough regarding what was meant with conventional tools. During the expert panel session, additional time was allocated to dive deeper into the concept of conventional tools and how they are used in the data sharing networks. In the end, assumption 6 showed to be not necessarily an assumption on which recommendations were based, but more a recommendation in its own right. This has been covered in point 10 of the recommendations and will be discussed in more detail in the next section. Lastly, below are some quotes from the experts that substantiate the outcome of the validation of the first five assumptions. The number behind the quote indicates towards which assumption the statement is directed.

"Eens. Hoe diverser de input, hoe beter de conclusie. Maar valkuil: overload aan data, waardoor je door de bomen het bos niet meer ziet" (1)

"Eens. Delen van data helpt ons te leren van fouten uit het verleden. Maar ook hier de valkuil dat je op een gegeven moment vastloopt in het de hoeveelheid data" (2)
"Fully agree, we work too much on a project-by-project basis and exchange of knowledge to the full extent of our group is insufficiently utilised. Knowledge exchange occurs accidentally more then in an organised matter" (2)
"Agree. Hier is het wel zoeken naar een goede balans om de tenderinspanning beheersbaar en beperkt te houden (ivm kosten) en toch voldoende kennis en expertise aan boord te trekken om de projectrisico's voldoende in beeld te krijgen." (3)
"Fully agree, but please be aware that I think we do not explicitly know that we are "missing data", missing sounds a bit "aware", while in reality we are underestimating the amount of experience we as a group have on specific topics. " (3)
"Yes, "waarheid als een koe", but very complex in reality. The language and way of working in the different countries is very various. 1:1 translation of UK and NL on Civiel/Construction language is very ineffective. " (4)
"Eens. data moet zo goed mogelijk beschikbaar zijn. " (4)
"Of course, but it depends on the feasibility of breaking down these barriers. The cost of that has to be in balance with the benefit. In construction the devil is often in the details. On one side we don't want to focus on differences too much, on the other side, if we don't we are not comparing apples with apples and have the risk of making the wrong decisions. " (5)
"Yes, I believe in it very much. Less discussion of outcomes" (5)

F.2. Validation of the recommendations

In this section, the recommendations are validated. To validate the recommendations, the experts were asked to give their opinion about the recommendation and discuss amongst themselves to reach a consensus. It is important to emphasise that the experts were asked to validate the recommendations with the end goal of raising risk awareness among the team members of the tender projects within the organisation. The researcher's place was more to moderate the discussion and give clarifications about the recommendations when needed. After discussing the recommendation, the experts were asked to rate the effectiveness of the recommendations on a scale of 1-5 with the following definition per score:

- 1 = Not effective
- 2 = Little effective
- 3 = Neutral
- 4 = Effective
- 5 = Very effective

This enables the researcher to also quantitatively substantiate the recommendations and rank them in terms of effectiveness instead of just qualitatively. In addition, this also reduces error when misinterpretation arises regarding the opinion of a specific expert. It has to be noted that during some of the recommendations, the discussion was very extensive and intensive, which did not lead to consensus among the experts. In this case, it was possible that the expert withheld his vote due to the blurriness of the discussion and inconclusive outcome. Nevertheless, if no consensus was reached, the experts were still asked to score the recommendation based on their own experience. This resulted for some of the recommendations in three given scores instead of four, which was the case for recommendations 10, 12, 14 and 16. In Figure F.1 the rated scores regarding the effectiveness of the recommendation towards risk awareness can be seen.

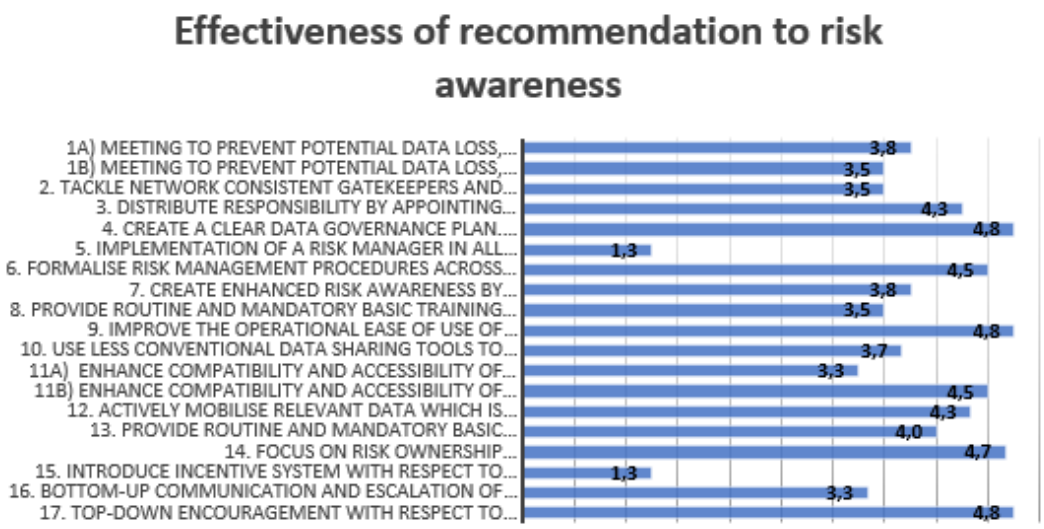

Figure F.1: Score of the effectiveness per recommendation to risk awareness.

First of all, when looking at the rated scores, it can be determined that almost all recommendations were rated as effective considering the end goal of raising risk awareness among the project team members. Combining this with the substantiation of the experts, we can conclude that all recommendations are validated with the exception of recommendation 5, the implementation of a risk manager in all projects, and recommendation 15, the introduction of an incentive system with respect to risks. Moreover, we can see two recommendations that have a score of 3.3, which is just above neutral, namely recommendations 11 and 16. Recommendation 11, enhancing the compatibility and accessibility of data and databases, was stated by the experts to be useful but that this can be best done on an organisational level as, during the tender, there is not a lot of room for improvement. This is mainly due to the time pressure on the people during the tender and the fact that there is not enough time to take this properly into account. Moreover, the experts stated that this would not be necessary to implement on the project level if it is already done on an organisational level as then the team members can readily use the data, formats and databases. Therefore, recommendation 11 will be made on just an organisational level. Regarding recommendation 16, it was indicated that it was helpful to be able to escalate problems to the higher levels but that it is more important that leadership should be open to this instead of shutting it down.

Furthermore, very important to note is that the experts often would like to make a distinction between the bigger and smaller projects. They agree that the recommendations are relevant and useful for all project sizes, but it can become difficult for smaller projects to implement. This is mainly due to the additional costs that accompany the implementation in the smaller projects and the necessity to keep the costs low. Nevertheless, these recommendations will remain and shall not make a distinction between project sizes. It will be up to the company to decide if the tender costs will not increase too much or if they want to allocate funds for this. Lastly, the statements and quotes hereafter show various substantiations of the experts about their opinion and choices during the expert session. Based on the opinion of the experts, it can be determined that all recommendations, with the exception of 1 and 15, would support an increased risk awareness among project team members in the organisation, but the biggest improvements can be attained through organisational changes.

"Ik ben het met de stelling eens alleen ik denk wel dat we enig onderscheid moeten maken in complexiteit en afhankelijk van die onderstal werk daadwerkelijk iets toe gaat voegen. Voor kleinere projecten denk ik dat dit ook onnodig de tenderkosten kan opstoken om alle mensen te betrekken. Maar zeker denk ik dat hiermee winst te behalen valt. " (1)

"Nou, ik denk dat wij nu nog niet heel bewust bij een kick-off van een tender of bij kick-off van een project, het maakt eigenlijk niet uit welk. We zijn gewoon niet gewend om heel bewust na te denken: welke informatie slaan we nou wel en welke informatie slaan we nou niet op en wie is waar daarvoor

verantwoordelijk. Dus terug naar de vraag: Ik ben het ermee eens dat dit moet gebeuren, maar het moet heel bewust gebeuren met wat vinden wij nu belangrijk dat we vastleggen en waar willen we dan ook met die informatie wat op de korte en lange termijn doen" (1)

"Kijk eigenlijk wat Bas net zei, beetje afhankelijk van de formaat van de project. Als je bijvoorbeeld een enorm groot project hebt ja dan doe dit en betrek er iedereen maar bij die een kleine bijdrage heeft. Het is wel effectief maar voor kleinere projecten veel moeilijker ivm kosten om zulke kleine sessies bij elkaar te krijgen. Vaak zijn rollen verdeeld over dezelfde mensen, vaak is iemand de BIM modelleur en misschien ook wel een stukje risk manager bij wijze van spreken. Maar in de basis is dit precies wat je wil, het liefst zou je dit overal hebben. " (2)

"Ik ga volledig met je mee Niels. Sterker nog als ik kijk naar de C en D tenders daar zul je zelden een bim modelleur zien. Maar ik zal hem breder trekken als ik discussies heb met bijvoorbeeld de contractmanager wil ik ook dat dit allemaal consistent is met bijvoorbeeld de ROMR en dan heb ik daar discussies over en zal dit zelden klakkeloos overnemen. En dit geldt ook voor een BIM modelleur op het moment dat die clash detecties gedaan heeft dan zou ik dit graag terug willen zien in de ROMR als project specifieke risico's. En dan ook weer zo een open deur je kan het hier niet mee oneens zijn maar ik zet hier ook wel weer een opmerking bij maak wel onderscheid tussen de onderstroom projecten en de grote projecten. Want aan de andere kant heb je ook weer het zwaard van damokles, houd je tender kosten lean en dan moet je dus ook keuzes maken van dit wel dat niet he. Dus zeker eens, maar wel handig om onderscheid te maken tussen de grote en de kleine tenders" (2)

"Ja, dit is wel, ja, voor mijn vakgebied zou dit het heel erg werken." (4)

"Ja , dit is natuurlijk ook wat we in gang proberen te zetten met UPA (Uniform project Approach)" (4)

"Dit is tender desk, dit is UPA, dit is wat we willen. " (4)

"Nou ik ben niet helemaal voor maar vind wel dat je iemand moet aanwijzen die daar mee bezig is. Dus als functie zeg ik een 1 maar als rol een 5. Op de kleinere projecten kan dit prima een tender manager oid zijn. " (5)

"Ja, wat mij betreft zou hier een aanbeveling bij kunnen komen en volgensmij hebben we dat wel redelijk ingericht. Maar dat een risk manager een review rol op zich zou kunnen nemen voor de kleinere projecten en dan hoef je dit niet eens op alle projecten te doen maar dan krijg je wel een goed beeld van wat er speelt. Dus eens op de kleinere projecten kan dit prima bij de tender manager of calculator liggen " (5)

"Ja op alle projecten risk based approach heb je gelijk. Dus alle grote projecten zou ik er aandacht voor hebben. Kleinere projecten moet je het wat meer scatteren. " (6)

"In principe hebben we dit toch gewoon een gestandaardiseerd risicomanagement project alleen we doen het niet. Dus eigenlijk vooral deze aanbeveling veranderen naar implementeren en monitoren" (6)

"Je zou het inderdaad moeten hebben maar wel voor die kleinere projecten moet je gewoon telemetrische solutions hebben per type project en beter monitoren. Hier zou in process ook weer onderscheid gemaakt kunnen worden tussen kleine en grote projecten betreffende de uitwerking. Dus je zou een generiek systeem kunnen maken en voor kleinere projecten dingen kunnen laten wegvallen." (6)

"Helemaal waar, maar ik heb wel moeite met bottom-up. Dat is precies wat er slecht is aan risicomanagement binnen deze organisaties moet topdown ook eens een keer echt geduwd worden." (7)

"Specifieke brainstormsessies dragen absoluut bij aan risk awareness en creëren ook een soort vliegwiel effect bij het benoemen en uitwerken van de risico's. Op kleine niet complexe projecten kan dit ook als onderdeel van een tenderoverleg praktisch worden ingevuld." (7)

"Ik ben het hiermee oneens als de mensen training moeten hebben in die systemen, dan zijn systemen

gewoon niet goed. Dan moeten de systemen gewoon gebruiksvriendelijker." (8)

"Ik zie wel bij een aantal mensen zo gauw de tool te ingewikkeld wordt en er word iets meer als excel of word document dan wordt het gewoon genegeerd. Dus ik denk absoluut dat training een toegevoegde waarde heeft voor het process. " (8)

"In principe gebruiken we de minder conventionele tools. Maar als de vraag is gebruiken we deze goed dan is het antwoord nee. Het probleem is meer dat deze systemen niet goed geïntegreerd zijn waardoor ze niet informatie kunnen uitwisselen. Maar in principe werken wij met redelijk onconventionele tools. Allen als jij in een fantastische onconventionele data tool allemaal data propt dan maja ze gaan het niet zoeken. Je gaat niet als je op een understaffed tender zit waar je met 10 man op zou moeten zitten, maar uiteindelijk met 6 man zit gaat iemand niet op zn gemakje gras duinen en door allemaal data ploeteren. " (10)

"Nee, hier kan je niet op tegen zijn. Maar het is wel heel moeilijk. Ik denk dat je dit meer op organisatie niveau moet doen want binnen een tender kan je niet heel veel verbeteren omdat je in een hele korte tijd met heel weinig mensen allemaal dingen moet doen. Dus mijn beeld is dat dit echt op organisatie niveau moet gebeuren en dan kunnen de projecten zich daaraan conformeren " (11)

"Ja, je ziet het bijvoorbeeld in tenderdesk he dat heeft een CRM systeem ingericht en daar worden allerlei informatie, en formats voorgeschreven en dat moet je dan gaan gebruiken. Maar als je naar CRM specifiek kijkt als systeem dan is het een prima bundeling om informatie te verzamelen. Maar eigenlijk data technisch kan je er helemaal niks mee want er worden allemaal pdf formats ingelezen, daar kan ik vervolgens niks mee dus ook aan de platform kant moet je goed kijken welke informatie wil ik kwantitatief en kwalitatief hebben. En dat word echt niet gedaan op een tender, die zegt gewoon oh dit moet je hebben neem het. Dus vooral op organisatieniveau nodig. " (11)

"Ik denk dat je hier één van de grootste ontwikkel punten hebt vanuit vanuit jouw studie, zeg, maar ik denk dat we hier nog het meest kunnen groeien. De grotere tenders die sturen daar wel al wat meer actief op, dus met peer reviews en rapportages over lessons learned eh. Maar voor de C en D tenders vooral hebben we hier nog wel echt huiswerk te doen. " (12)

"Eigenlijk zou je kunnen zeggen de aanbeveling is een behoefte, namelijk makkelijker snel relevante informatie terug kunnen halen. Is die behoefte er? Die is er. Bestaat dit systeem al? nee die bestaat niet." (12)

"Nou ik, ik ben eigenlijk geneigd om hier bijvoorbeeld een vier aan te geven. Ik denk dat een bepaalde basis gewoon ook absoluut nodig is en daar hangt natuurlijk veel meer aan vast. Maar bepaalde basis trainingen vind ik helemaal niks mis mee hoor, want ik zie dat alles in projecten eigenlijk draait om risico's. (13)

"Een training binnen BAM is super vrijblijvend daar hoort gewoon een stop of go eigenlijk bij. Dus we willen ook wel even meten of je achterovergehangen hebt en gedacht hebt nou ik zit mn tijd wel ff uit. De basis moet dan wel gemeten kunnen worden om het maar even zo te kunnen zeggen. Ik zeg dit vooral door de statement internal audit om te checken of dit heeft plaatsgevonden. Maar als organisatie wil je ook weten heeft diegene een aanwezigheidsverplichting heeft of heeft ie daadwerkelijk iets opgestoken. Dat wil ik dan ook kunnen meten. (13)

"Wie is er niet van nadrukkelijk alloceren in het team! Maar het projectresultaat blijft wel een gezamenlijke verantwoordelijkheid. Dus medewerkers mogen zich niet verschuilen achter een demarcatie of wijsgedrag vertonen. " (14)

"Nee Nee Nee gaan we niet doen zulke prikkels dat is gewoon werk van mensen dat ze moeten doen en dat gaat niet werken." (15)

"Wel voorbeeldleiderschap borgen! Maar belonen van gedrag wat tot de basiscompetenties van tender- en projectmedewerkers behoort is niet wenselijk. Dit is geborgd in de jaarlijkse beoordelingsgesprekken." (15)

"Wat we wel nodig hebben is voorbeeld leiderschap en bijvoorbeeld leiderschap op het gebied van risico's

heeft er onder andere te maken met jezelf kwetsbaar opstellen. En aangeven hoe jij in het verleden succesvol bent geweest door nou ja dingen open te delen en dat soort dingen en dat ontbreekt wel echt in dit bedrijf. Dit zit wel een beetje in jouw 17 he topdown aanmoediging met betrekking tot risicomanagement proces, maar dat heeft dus te maken met voorbeeld gedrag. Dus als jij zegt van kom naar me toe met je problemen en rapporteer transparant en de eerste en tweede keer dat een tender manager dat doet dan wordt ie op zn hoofd geslagen dan, ja dan doet ie het de derde keer niet. Dus dit heeft ook weer te maken met 16 aangezien je moet open blijven van onder naar boven en dan voorbeeld gedrag door het niet neer te slaan." (16 + 17)