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Understanding inter-organizational information sharing

A case study in the context of Risk and Opportunity Based Asset Management of Critical Infrastructures (ROBAMCI)

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A case-study in the context of Risk and Opportunity Based Asset Management for Critical Infrastructures (ROBAMCI)

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by

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Preface

This report is the outcome of a research conducted in the context of the course SPM5910, SEPAM Master's Thesis Project. It is the first deliverable for fulfilling the master Systems Engineering, Policy Analysis and Management (SEPAM) of the faculty Technology Policy and Management of the Delft University of Technology. The second deliverable, a scientific paper, is attached separately. The research project is conducted at Deltares, an independent institute for applied research in the field of water and subsurface. This was done within a time period of 6 months (February – August 2017).

The subject of this thesis is inter-organizational information sharing. The objective is to understand on an analytical level how exchange of knowledge and information is influenced in decision making processes where multiple organizations are involved. To study this in a practical environment, a case-study methodology was used. The context of this case-study is the adoption of risk and opportunity based asset management strategies to manage and maintain critical infrastructures in the ground, road and water sector in a systematic way: a project that is initiated by Deltares and is being conducted on a national level.

Last months have been experienced as very instructive, both on an academic and personal level. I hope that the content of this report is also experienced as informative by the reader.

Nishchal Sardjoe

Rotterdam, July 31, 2017

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Abstract

On a daily basis we (in) directly make use of functions of various infrastructures: we drive on roads and bridges or we live without worries behind the safety of a dike. Only when there are cracks in the dike or a particular bridge is not accessible due to for example a broken pillar, we realize how critical these infrastructures are for our society and economy. These infrastructures are not build to last forever and they are susceptible to breakdowns, especially as some are reaching the end of their technical lifespan. Building new infrastructures is simply not an option, as this is often financially and logistically not feasible. Getting as much as possible out of the remaining technical lifespan of such critical infrastructures is then down to employing innovative maintenance strategies, such as risk and opportunity based asset management, as is being done in the ROBAMCI project, initiated by Deltares.

Management and maintenance of infrastructures already takes place in a multi-actor environment. Adding systematic approaches on top of this multi-actor environment requires maintenance managers to further integrate their decision making processes. However, analysis have shown that there is a clear lack of this integrated decision making. Literature has further shown that this could be as a result of a lack of information sharing between organizations. Improving inter-organizational information sharing, however first requires further understandings. This research project is done with the goal to achieve that understanding.

A case-study in the context of ROBAMCI was used to study this concpt in a practical environment. The asset in this case was a sea-lock complex located in Delfzijl, which not only performs functions for shipping, but also has various other direct and indirect functions, influencing for example local nature, economy and regional water management. Theoretical knowledge, gained from literature studies, was then used to interpret the data from in-depth interviews with employees of identified organizations.

The empirical findings, interpreted through various sources of literature showed that there is a wide array of factors influencing inter-organizational information sharing in the case-study. Among the most mentioned and expected were trust, competing interests/self-interests and legislations & policies. Organizations also add value to the importance of personal physical interactions and even though the information sharing takes place between actors of one national government, concern for information misuse is also seen as a potential barrier for information sharing. The data has also led to the formation of some factor-relations, we see e.g. that trust forms a positive causal relation with not only information sharing itself, but also has a negative causal relation with concerns of the quality of the information. Data also makes it clear that there is an interrelation between the 3 levels of information sharing. These findings, backed by theory have led to the identification of 2 general fundamentals that can be taken into account when trying to further understand information sharing. The first one focuses on trust and legislations, whereas the second one addresses on the embeddedness of the information sharing levels.

Conclusively it can be said that inter-organizational information sharing helps to make more efficient and effective decisions for the management and maintenance of assets. There are many factors that can either positively or negatively influence information sharing. It is recommended that through further studying factor relations their importance can be determined. This can also help to reduce the high number of factors and frameworks. For ROBAMCI it is recommended to use the results of this research as input for a maturity analysis focusing on the inter-organizational information management of organizations in the sector.

Samenvatting

We zijn dagelijks afhankelijk van de functies van verschillende infrastructuren, voor zowel woon, werk en plezier activiteiten. We rijden en lopen op verschillende wegen en bruggen, en leven ongestoord achter dijken. Soms zien wij echter pas bij negatieve gebeurtenissen de belangrijkheid van deze infrastructuren in: de brug is niet toegankelijk, omdat er zich een aanvaring heeft voorgedaan, of er is door experts een scheur in de dijk ontdekt. We moeten ons realiseren dat de infrastructuren niet blijvend zijn: hoe ouder ze worden, hoe meer kwalen verschillende componenten kunnen gaan vertonen. Bouwen van nieuwe wegen of nieuwe bruggen is simpelweg te duur. Het is daarom van groot belang om zoveel als mogelijk rendement te halen uit de resterende output van deze infrastructuren. Mede daarom onderzoekt Deltares, i.s.m. andere partijen binnen het ROBAMCI project hoe publieke actoren deze efficiëntie slag kunnen realiseren. Dit kan bv. door het toepassen van systematisch risico gestuurd beheer & onderhoud.

De aanwezigheid van een multi-actor systeem in het beheer en onderhoud van infrastructuren, gecombineerd met dit onderhoudsconcept eist verbeterde integratie van beslisprocessen. Analyses hebben echter uitgewezen dat dit vaak in gebreke is. Literatuur laat zien dat dit kan komen door gebrek aan informatie deling tussen organisaties. Maar voordat dit überhaupt verbeterd kan worden, zijn er meer inzichten nodig in hoe en op welke manier inter-organisatorische informatie deling beïnvloedt wordt.

Naast wetenschappelijke literatuur is hiervoor ook gebruik gemaakt van een casus binnen ROBAMCI, waarin een zeesluis in Delfzijl de centrale asset is. Dit object is niet alleen belangrijk voor de doorvoer van schepen, maar speelt ook een rol in de lokale natuur, de regionale economie en verschillende waterbeheer functies. Verschillende actoren zij dus hierbij betrokken en informatiedeling tussen deze actoren is gewenst. Met vertegenwoordigers van sommige van deze organisaties zijn er diepte-interviews gehouden om inter-organisatorische informatie deling verder te begrijpen. Een analytisch kader en wetenschappelijke literatuur zijn gebruikt om deze resultaten te interpreteren.

Resultaten hebben uitgewezen dat, uit een groot aantal factoren die inter-organisatorische informatie deling beïnvloeden, vertrouwen, concurrerende/eigen belangen en wetgeving & beleid sommige van de belangrijkste zijn. Daarnaast hechtten respondenten, ondanks dat informatiedeling grotendeels plaatvind via steeds innovatievere media, ook veel waarde aan persoonlijke ontmoetingen. Bezorgdheid dat informatie misbruikt kan worden kwam ook frequent naar voren. Nog interessanter waren de verschillende relaties tussen de factoren: vertrouwen bijvoorbeeld vormt een positieve causale relatie met informatiedeling, maar vormt ook een negatieve causale relatie met bezorgheden gerelateerd aan de kwaliteit van informatie. De interrelatie van verschillende niveaus van informatie deling kwam sterk naar voren binnen de casus. De resultaten hebben tot slot geleid tot het voorstellen van 2 fundamentele eigenschappen van inter-organisatorische informatiedeling: de ene focust zich op de rol van vertrouwen en wetgeving & beleid, terwijl de andere zich focust op de interrelatie van informatie deling niveaus.

Concluderend kan gezegd geworden dat informatie deling tussen organisaties zowel negatief/positief beïnvloed wordt door een groot aantal factoren. Het is echter belangrijk voor het verhogen van de efficiëntie van beslis processen. Relaties tussen factoren kunnen helpen om een de belangrijke factoren te identificeren. Sommige relaties zijn besproken in dit onderzoek, echter zijn er veel meer factoren: verder onderzoek is dus hierin gewenst. Voor ROBAMCI kunnen de resultaten van deze studie dienen als input in een studie waarin per organisatie de huidige staat van de factoren onderzocht worden, bijvoorbeeld d.m.v. een maturiteitsmodel.

Acknowledgements

Conducting this research and writing this report has not been possible without the support and guidance of others. In this section I would like to briefly express my thanks to these individuals for their contributions and cooperation.

First of all I would like to thank all the members of my graduation committee for always being open and providing me with the necessary feedback during our many meetings. The feedback from Prof. Dr. Bartel van De Walle, Dr. Ir. John Baggen and Ir. Mark de Bel has always been appreciated. I especially want to thank my first supervisor, Dr. Ir. Leon Hermans: from the very first meeting he has guided me both content wise and process wise. The knowledge gained from our frequent get-togethers have most certainly contributed to this research report. Apart from this, Dr. Ir. L.M Hermans has shown me how to correctly structure and deal with such a project and its complexities. This has also positively affected other areas of my personal and academic life, so for all that: thank you Dr. Ir. Leon Hermans.

I have spent most of the last months at Deltares, who provided me with the opportunity and support to do this research. As an international student this practical experience in the Netherlands has been integral. Thanks especially go out to Mark de Bel and Sien Kok for sharing their extensive knowledge with me, their guidance and their feedback on various versions of this report. Thanks also go out to Gerald Jan Ellen, who provided me with the opportunity to participate in some other projects within Deltares. I am also grateful for the support of all my colleagues and fellow interns at Deltares.

The results from this research would have not been possible without the important content provided by the interviewees. I therefore thank all these organizations and their representatives for taking the time and effort to talk and interact with me.

I would also like to pay attention to the people in my private life. Thank you to my loving parents, Hendrekpersad Sardjoe and Andjanie Sardjoe-Durga for providing me with the opportunity to study abroad and for your believe in me. Thank you to my partner in this life, Marina Bersaoui, for your emotional guidance, your love and support. Thank you Tanisha Sardjoe, my sister, for always having my back. Thank you to my aunt, Sherita Thakoerdat-Sardjoe, for providing me with a home and a family like environment. Special thanks go out to my grandmother, Bidiadharie Bharos-Durga for her inspiration and continuous support. Last, but not least, thanks to all my friends, especially Ravish Mehairjan for not only his professional contributions, but also for being there for me when I needed that.

Tables and Figures

Tables

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1 Introduction

This chapter starts by first introducing the socio-technical role of infrastructures in our society (paragraph 1.1). Gathering maximum effectiveness and efficiency out of these infrastructures asks for systematic maintenance and management strategies such as risk based asset management (RBAM) (paragraph 1.2). Introducing and successfully adopting such a strategy in an organization, let alone a complete sector is not without its issues. One of these issues, information sharing is introduced in paragraph 1.3. In paragraph 1.4 the technical elements of the research (research scope, main and sub questions, research methods and deliverables), together with a reading guide and an overview of the thesis are presented.

1.1 Aging (Critical) Infrastructures

Society's dependence on Infrastructures

Access to electricity, clean drinking water, public transport, wastewater systems, communications and nowadays even the internet are considered to be some of society's basic needs. These needs are being delivered and distributed to us by means of various critical infrastructures. Some of these are privately owned, but the vast majority, e.g. roads, bridges, the regional electricity distribution grid, dikes, etc. are still publically owned, managed and maintained by various governmental institutions. These infrastructures not only perform technical functions, they also have a strong socio-technical-economic dimension: they are one of the foundations on which societies all over the world are functioning (Verlaan & Schoenmaker, 2013). Negative effects resulting from failures in functioning of these infrastructures can therefore cause both economic and social losses (De Bruijne & van Eeten, 2007). Loss of functions and interruptions can be caused by multiple incidents, ranging from technical failures to natural elements such as storms and floods to acts of terrorism. See for example a recent storm that hit the Netherlands on 23 February 2017, leading to disruptions in different modalities of public transport, chaotic situations on the roads and impassable dikes and bridges (Luchtenberg, 2017; NOS, 2017), or the multiple acts of terrorism in which critical transport infrastructures were specifically targeted

Text Box 1 What are critical infrastructures?

What are critical infrastructures?

The term critical infrastructure requires some elaboration. An infrastructure is critical as defined by the Dutch government "*when it includes products, services and underlying processes, which, if they fail would and can potentially cause social disruption"* (NCTV, 2015). This definition can be supplemented by adding some aspects of the definition used by the government of the United States of America: "*the social disruption can include debilitating impacts on security, national economic security, public health and/or safety or any combination of those matters"* (Moteff, Parfomak, & Ave, 2004). De Bruijne and Van Eeten have further described some of the characteristics of these critical infrastructures: they are technically tightly coupled consisting of complex organizational and management activities, they provide non-substitutable services to the public from networks that often operate in a monopoly market, and the public is keenly afraid when and if these infrastructures lose certain functions or if their service is interrupted (De Bruijne & van Eeten, 2007).

(train bombings Madrid, 2004) or used as weapons (World Trade Center attacks, 2001) (Dunn, 2007).

Still, sometimes these infrastructures are taken for granted by society. Their importance is sometimes only made visible when they fail e.g. when rail infrastructure is not accessible to trains and other rail vehicles as a result of icy conditions. This often leads to the Dutch Railways (Nederlandse Spoorwegen) altering their timetables and schedules on advice of ProRail, the Dutch government agency responsible for the maintenance activities of the national railway network infrastructure. Another well-known example in the Dutch culture is the flood event that occurred in 1953, killing 1836 people in the Netherlands (Slager, 2013). Multiple flood defense systems such as dikes broke, roads were not accessible and communications were down. This event triggered the development of a stable and improved network of flood defense systems in the Netherlands. This corresponds with the findings of De Bruijne and Van Eeten, who state that the consequences of operating failures to users and outsiders can be very alarming and fatal to these groups (De Bruijne & van Eeten, 2007).

Efficient and effective maintenance

In current times, where our society is gradually feeling the effects of phenomena like climate change, urbanization, migration, cybercrime, terrorism, the refugee-crisis and population growth it is even more important to keep our infrastructures running and maintained, as a greater number of people means a higher demand of basic needs, and thus a higher occupancy rate of our infrastructures (Black and Veatch Holding Company, n.d.). Many countries are dealing with the issue of outdated infrastructures and could benefit from using effective and efficient maintenance practices to prolong the life of their infrastructures and to save finances (Mugira, 2011). Furthermore, infrastructures have become increasingly complex due to their high number of interdependencies and internationalization (Verlaan & Schoenmaker, 2013). Water basins for example cover geographic areas that overlap national territories, such as the Rhine river which covers 6 countries (Auger, Bouma, & Künneke, 2009). Furthermore, many critical infrastructures depend on another critical infrastructure to function adequately, for example the traffic management system on highways and the air traffic control system at airports, both of which can only function if there is information communication, i.e. internet & electricity and/or power. It was already shown previous sections that deliberate acts and breakdowns can cause loss of functions. These breakdowns can occur naturally or could be a result of a lack of maintenance.

1.2 Risk and Opportunity Based Asset Management as a maintenance strategy

It is therefore important that the competent authorities and organizations keep these infrastructures running adequately, by employing effective and efficient maintenance and management activities such as asset management or extensions of this form of management, in this case risk and opportunity based asset management. This is however getting more and more challenging as many of our existing infrastructures such as roads, electricity grids and the

sewerage system were designed some decennia ago, which means that some of them are reaching the end of their technical lifespan, which is typically between 50-70 years (Techwriter, 2014). Instead of designing and building new infrastructures, which are usually associated with high costs, the government then has, in collaboration with other actors, a strong incentive to gather as much of an efficiency rate out of the current components of the different assets. (Deltares, 2016). This, coupled with the interdependencies, high replacement costs and the aging of these public infrastructures is a complex socio-technical task that requires a multi-disciplinary approach. Employing and adopting the risk and opportunity based management approach can lead to significant gains in the infrastructure's technical lifespan.

Multi-actor operating environment

Most infrastructures consist of many assets which are designed, managed and maintained by various actors. Governments, public institutions and private organizations (or combinations of these: public-private partnerships) work together to design, finance, build, operate and maintain our infrastructures. As most of the critical infrastructures have public functions, the role and responsibilities of governmental institutions are considerably higher. This is however changing, as recently the governance of many of these infrastructures has been institutionally restructured, affecting the way their reliability and service is ensured. Privatization, liberalization and deregulation have thus changed and complicated the dimensions in our public infrastructures (De Bruijne & van Eeten, 2007). This complexity can include the increase of actors and technologies as a result of for example outsourcing of activities (Coutard, 1999).

This multi-actor setting is almost always present in the maintenance activities of public infrastructures. Governmental and knowledge institutes, contractors and other actors are collaborating and doing research to increase and optimize efficiency and thus prolong the lifespan of the infrastructures. Over the years this has resulted in innovative maintenance and management concepts and plans for different levels of different organizations. By employing these best practice methods, such as systematic risk and opportunity based asset management the proposed efficiency can be reached. In this method a predetermined risk allows the management to allocate finances to the maintenance of specific assets (Heinz, 2003).

Text Box 2 Maintaining the Maeslandkering

Maintaining the Maeslandkering

The Maeslandkering is a storm surge barrier, located at Hoek van Holland (figure 1). It protects the citizens of the province of South Holland from potential floods resulting from high sea levels.

Figure 1 Maeslandkering Hoek van Holland

Its operation and maintenance is in hands of Rijkswaterstaat, who, together with other organizations already applies probabilistic asset management strategies to conduct integral and multi-disciplinary maintenance activities. Not only are contractors involved, but also other organizations, for example the Port of Rotterdam (Rijkswaterstaat, n.d.-a; Techconsult, n.d.).

Various parameters such as the level of the sea and wind force are measured in real time, and if necessary, shared with the decision makers, who, when certain conditions are met, give the go-ahead to close/open the barrier.

The role of information and information sharing in maintenance

However, there are a number of barriers to successfully implement these systematic variations of maintenance management. Finances, technical knowledge and lack of information are just some of these barriers. As is sketched by the text above, the situation is highly multi-actor oriented and multi-dimensional. Working together to maintain these infrastructures usually requires active sharing of information as a basis for sound decision making on strategic, tactical and operational level. This information can for example be historic and current data of certain parameters, policies, rules, etc. This sharing of information is however precisely where the bottleneck can occur. The lack of information and its asymmetry can also occur between organizations themselves, potentially also leading to higher costs and unnecessary investments. Sharing information between the relevant organizations and institutions has been identified as being crucial to increase efficiency in many sectors (Byrne & Heavey, 2006; S. Dawes, 1996; Yang & Maxwell, 2011).

1.3 Information sharing as a bottleneck

Information asymmetry resulting from diversified objectives within organizations employing asset management practices has been identified in the current literature as an issue (Breeveld, Hermans, & Veenstra, 2013). These authors have shown the existence of information asymmetry between different departments in an organization employing asset management practices, resulting in higher costs as a result of diversified objectives for this organization (Breeveld et al., 2013). A second issue that organizations adopting asset management practices are facing in current times is the quality of their data (Lin, Gao, Koronios, & Chanana, 2007). Data in itself is however not meaningful. Data is a building block that is processed and turned into information, ultimately becoming useful to decision-makers. Thirdly, Halfawy mentions the lack of sharing of this information as one of the challenges in the maintenance of assets of public municipal infrastructures (Halfawy, 2008). This is concerning, as information, together with management and engineering is defined as one of the three pillars of competency of a robust asset management structure (Brown & Humphrey, 2005). Sharing information with each other and overarching organizations can also result in certain uncertainties regarding the content or context of the information, which could be related to the fact that sometimes information is interpreted differently by actors with different backgrounds and professions (Hansen & Järvelin, 2005). Finally, data and process fragmentation in current

Text Box 3 Looking further then information sharing

Looking further then information sharing

Even though the improvement of information sharing is a crucial factor, it is wise to mention that it is definitely not the only factor. The effective adoption of new practices and tools in such a high multi-actor and multi-disciplinary environment can generally be a difficult part in the project cycle, as there are a number of administrative, technical and judicial (and more) challenges to overcome.

Phi et al. for example mention that the successful implementation of plans and/or policies is heavily dependent on the actors that are involved (Phi, Hermans, Douven, Van Halsema, & Khan, 2015). Top management support, the nature of technical tasks at hand and financial capabilities are also factors that play a role when new practices and tools have to be adopted sector wise (Slevin & Pinto, 1987).

processes regarding the maintenance of assets of municipal infrastructures can lead to low efficiency rates.

There is an increasing need to adopt multi-disciplinary approaches, as systems become more interdependent and complex. Efficient coordination and information, maximizing data re-use and information sharing**,** technology transfer, data integration and enhancement of current available tools are identified by multiple authors as the main requirements of public infrastructure management environments (Halfawy, 2008; Vanier, 2001). Coordination and data integration have been identified as some of the challenges. Research has also shown that there are few tools in the area of strategic asset management to assist managers of municipal infrastructures to improve their decision making (Halfawy, 2008). Overcoming the information asymmetry has been identified as a crucial activity by Breeveld et al. in order to not only improve this decision making in the asset department, but also to increase transparency of this process (Breeveld et al., 2013).

The above text makes it obvious that there is a lack of information sharing between and within responsible organizations involved in the maintenance of critical public infrastructures. It is also shown that improving on this information sharing leads to efficient operations and transparent decision making processes. The following problem statement is therefore introduced:

"In the field of maintenance practices of critical public infrastructures there is a lack of information sharing between organizations, leading to information asymmetry and inefficient decision making processes"

Even though this sounds simple, it is (as shown) sometimes still not that straight forward. Why and how this sometimes happens, requires a better and deeper understanding.

1.4 Research Design

The boundaries within which this research takes place are sketched in subparagraph 1.4.1, the research scope. This then introduces the possibility to critically formulate a research question. Breaking this main research question down in small pieces ensures that the question can ultimately be answered in a methodological way. These first and second order research questions are found in subparagraph 1.4.2, followed by the research methods to be used in subparagraph 1.4.3. Subparagraph 1.4.4 elaborates on what the deliverables and the goals of this research are, after which finally in subparagraph 1.4.5 a reading guide and an overview of this report is shown.

1.4.1 Research Scope

ROBAMCI project

Figure 2 Different Infrastructures of the ROBAMCI project (Deltares, 2016)

In trying to increase the efficiency rates of current assets in the critical infrastructures, as well as tackling the lack of integration in the governance and organization between the different actors responsible for maintenance activities of these infrastructures, Deltares has, in collaboration with a number of other stakeholders (companies, governmental institutions and other knowledge institutes) initiated the ROBAMCI project, which stands for Risk and Opportunity Based Asset Management of Critical Infrastructures. There are unused chances that can lead to higher efficiency rates in the ground, road and water sector (Dutch: grond-, weg- en waterbouw sector), because there is a lack of integrated management regarding the assets of infrastructures to maintain their public functions (Deltares, 2016). In this project infrastructures from this sector from the are subjected to studies (see figure 2 for some of the studied infrastructures). Some of these, studied in cases within ROBAMCI are shown in appendix 1.

This publically funded project has the following objectives:

- Researching the possible application of risk and opportunity based asset management practices in the public sector by developing best practices, knowledge methods and tools to maintain assets of different infrastructures
- Encouraging the adoption of above mentioned practices and tools in different levels of the organizations (strategic, tactical and operational) that are responsible for maintenance activities

Literature has identified the existence of an information asymmetry between departments of an organization that employs asset management strategies, (Breeveld et al., 2013). This partly corresponds with research findings of Deltares, specifically focusing on the ground, road and water sector. These findings show that there is a lack of integrated management that can be attributed to a number of factors, of which inadequate information and knowledge is one of. Other factors are a lack of transparency and poor decision making on different levels, both in and between organizations *(Deltares, 2016).*

1.4.2 Research questions

The formulation of the problem statement as well as having the scope in place lead to the main research question, which is further decomposed into to several sub-questions, each leading to separate deliverables to ultimately provide an answer to the main research question:

"How is information sharing between actors involved in risk and opportunity based asset management decision making being influenced?

The following sub questions are proposed in order to methodologically answer above main research question

Sub-question 1 Risk and Opportunity Based Asset Management

What is the role of information sharing in risk and opportunity based asset management?

a. What is risk and opportunity based asset management?
b. What are the practical experiences of risk and opportunity based asset management?
c. What are potential benefits and possible barriers of this variant of asset management?

Sub-Question 2 Information sharing

What theoretical information sharing framework can be used as an analytical lens for this research project?

a. What is information sharing?
b. In which ways is information sharing classifiable?
c. What are potential benefits of information sharing between actors?
d. What are the factors that influence information sharing between organizations in the public sector?
e. Which factors are important to be considered in the context of this study?

Sub-Question 3 Information sharing in a multi-actor environment (case-study)

How is information sharing being influenced between actors involved in the risk and opportunity based asset management of critical infrastructures?

a. What functions does the asset perform in the socio-technical environment?
b. What are the roles and responsibilities of actors related to the asset?
c. What information needs to be shared with whom and why?
d. What are the most important factors that affect inter-organizational information sharing in practice? (based on analytical framework)
e. Are there possible relations between these factors and how are these

Sub-Question 4 Fundamental principles to understand inter-organizational information sharing

What are some fundamental principles to analytically understand inter-organizational information sharing?

a. How can these fundaments be used to improve the understanding of information sharing in general?
b. Is it possible to generalize these inter-organizational information sharing principles to the ground, road and water sector and/or even beyond this sector?

1.4.3 Research Methods

As can be seen a case-study is used in this research. This allows the research to both have an empirical basis as well as a practical one (Creswell, 2003) . In table 1 an overview is given about which research method for the 4 sub-questions is used.

This study takes a descriptive approach where mainly qualitative data is gathered and analyzed. Sub-questions 1 and 2 respectively deal with the risk and opportunity based asset management and information sharing literature, therefore desk research and literature reviews are done to provide answers for the questions in these sections. Sub-question 3 deals with the case- study exploration, its analysis and interpretation. A case-study, developed in the context of the ROBAMCI project is used to investigate and study information-sharing on inter-organizational level. By using a case-study an understanding can be created of this complex issue within a real-life context. Furthermore a case-study is suitable to study complex social phenomena where the extent of control over behavioral events is limited (Yin, 2013). In-depth interviews with actors involved in this case-study as well as with experts from Deltares is the data gathering method, supplemented by direct observations and documents (Yin, 2013). Through sub-question 4 some general insights for inter-organizational information sharing are extracted from the case-study and the literature, resulting in some important fundamental principles for inter-

organizational information sharing. To do this more specific ,literature related to these principle insights is used.

Table 1 Research Methods

Research Question	Research Method
1	Desk research Asset management literature
2	Desk Research Information sharing literature
3	Case-study with In-Depth Interviews
4	Information sharing literature

1.4.4 Research Goals and Deliverables

The goal of this research project is to gather an understanding of how inter-organizational information sharing is influenced and what this means for decision making. The ROBAMCI case is then used to provide a context in which to understand information sharing from a practical point of view, of course based on theoretical frameworks and relevant literature.

Providing some scientific knowledge as to what influences inter-organizational information sharing in this context as well as focusing on some important fundamental principles are the deliverables of this research project. The insights result from analyzing the findings of one case-study through theoretical frameworks from the literature. Based on the findings from the analysis of the data gathered through the in-depth interviews a number of conclusive remarks of how inter-organizational information sharing between actors is being influenced are given, both from an organizational point of view as a scientific point of view. Furthermore, effort is made to come up with some scientific and organizational recommendations. The findings of this study could possibly be beneficial for other authorities in other sectors in the Netherlands or other countries.

1.4.5 Thesis Overview

Reading Guide

This chapter (1) has provided an introduction into the topic of this research as well as the technical elements of the study. Chapter 2 gives insight in the conceptual and technical aspects of risk and opportunity based asset management, as well as its use for critical infrastructures. In chapter 3, an extensive literature review is done regarding information-sharing, looking at its different levels as well as the factors influencing information sharing, followed by a brief chapter in which a case-study methodology is designed (chapter 4). The case-study is introduced and analyzed according to this methodology in chapter 5. This chapter also showcases the research results, interpreted through the studied theory. This allows for a discussion of the results. In chapter 6, fundamental principles that are seen as some of the building blocks to understand inter-organizational information sharing are presented. Chapter 7 provides some conclusions, recommendations and a reflection. There are a number of appendixes attached to this report, providing in-depth information. Where this is the case, the relevant appendix is mentioned in the text. Furthermore, throughout this report there are numbered text boxes, which sometimes provide interesting examples or some additional information.

Thesis Outline

Figure 3 on the next page gives a structured overview of this report, based on above reading guide.

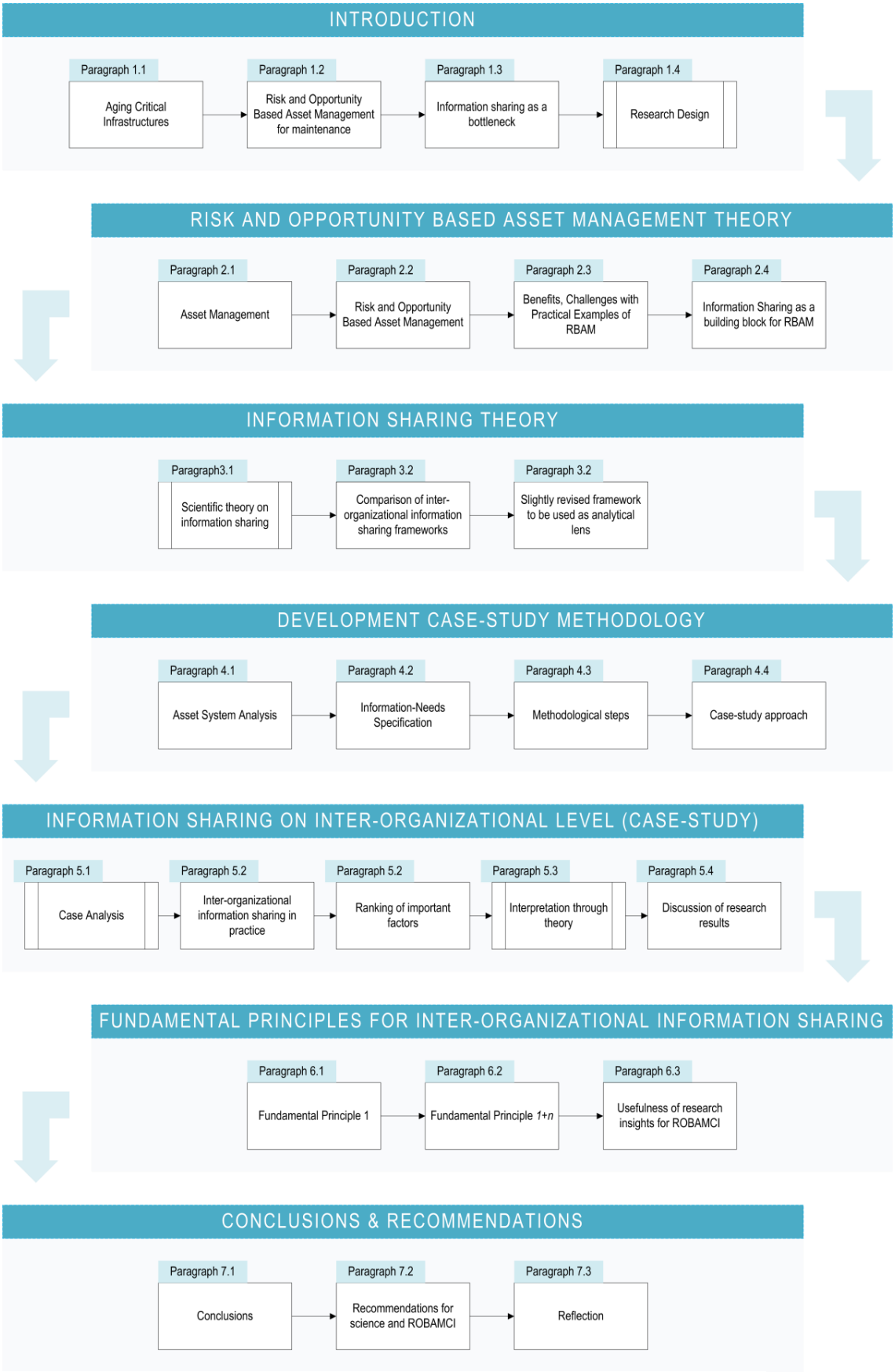


Figure 3 Thesis Outline

2 Risk and Opportunity Based Asset Management for Critical Infrastructures

In this chapter the theoretical foundations of the ISO 55000 standardized concept of asset management are introduced (paragraph 2.1), followed by discussing its extension with risks and opportunities in paragraph 2.2. Both these paragraphs provide the necessary knowledge to understand the basics of asset management for this research. This knowledge is important, because it can assist in pinpointing potential information that is subjected to sharing, becoming an essential research need for this project. This form of maintenance can result in some useful benefits, but is it not without challenges and barriers. These are shown, together with some practical examples in paragraph 2.3 In paragraph 2.4 the barriers are scoped down: the importance of correct and up to date information as a building block of adopting and applying risk based maintenance methods is assessed. In paragraph 2.5, some conclusive remarks of this chapter and an introduction to the next chapter are presented.

2.1 Asset Management (ISO 55000:2014)

The need for standardization

Achieving strategic objectives by the organization and meeting the needs of the client are only possible if the assets of that specific organization can perform their intended functions. Managing and maintaining these assets is therefore a key aspect in organizations. Nowadays, asset management has internationally been accepted as a standard for such practices.

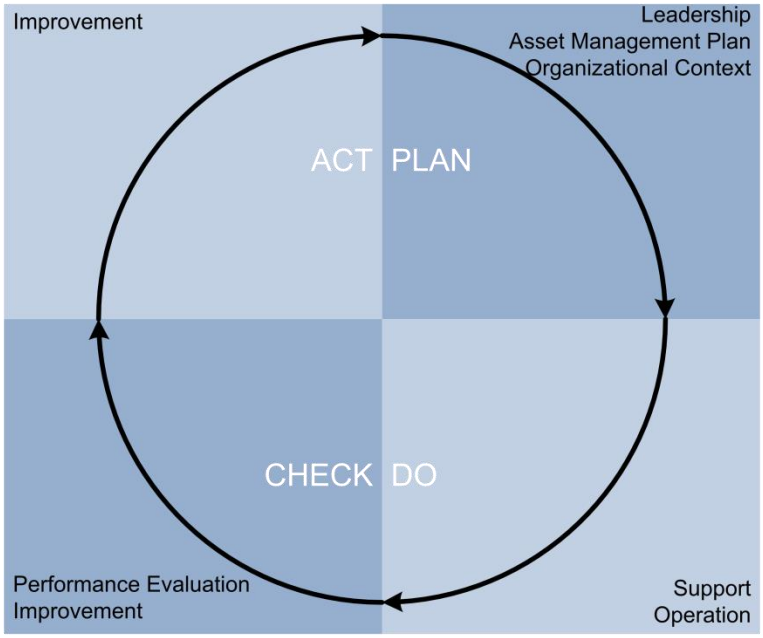
ISO 55000:2014 defines asset management as the *"coordinated activity of an organization to realize value from its assets"* (International Organization for Standardization (ISO), 2014). This coordinated activity can include the approach, selection, inspection, planning, implementation and renewal of physical assets and/or their corresponding plans. However, other important aspects such as information, finances, competence that are related to asset management decisions are also part of the scope of ISO 55000:2014. Balancing costs, risks, opportunities and performance benefits is a key activity of the management layer of the organization to realize values from asset management plans.

Plan-Do-Check-Act Cycle

ISO 55001:2014, the main standard is implicitly based on the Plan-Do-Check-Act (PDCA) cycle by William Edwards Deming (Van den Honert, Schoeman, & Vlok, 2013). Figure 4 shows some of the activities in the different parts of the cycle defined by the ISO 55001:2014 standard, supplemented with some further explanations.

To act on the results of the performance evaluation the organization must identify in its asset management plans how to deal with consequences from the potential failures of assets and the asset management system. Furthermore opportunities to improve on potential failures should be identified, assessed and implemented, as well as taking preventive and predictive actions to promote continual improvement.

Asset management planning discusses the strategy and objectives on strategic, tactical or operational level across the asset life cycle. These measurable objectives have been previously identified in the asset management strategies coming from the organizational objectives, taking into account the internal and external risks and expectations related to asset management from different stakeholders. These stakeholders make up the context of the organization, as they sometimes have different objectives and expectations. The planning is initiated by top management in the definition of certain goals and allocation of resources to encourage asset management activities.



To continuously demonstrate the conformance of the asset management operations with the standard the organization must correctly do performance and condition monitoring of the assets, as well as handling, investigation and evaluating possible asset-related failures and incidents in compliance with applicable legal requirements. Reviews by top management to assess the implementation of the plans should be done regularly.

Support and operations refers to the multiple arrangements and support systems such as appropriate training, awareness and competence of employees as well as legal documentation, communication and information support systems. All these aid decision making processes and are needed to implement the asset management plans in their operations. In the operation of the asset management activities the organization must also identify the risks that can potentially control the implementation of the processes.

Figure 4 PDCA Cycle for ISO 55001:2014 (Van den Honert et al., 2013)

Benefits of asset management

Equipment maintenance must be given considerable attention in an organization's strategic planning, as it helps the organization to positively influence factors such as price, technology, quality, reliability and information management (Madu, 2000) . Furthermore, the adoption of asset management strategies in operational procedures of organizations can ultimately yield in benefits that are more than only financially related. Better decision making as a result of more information, higher customer satisfaction, improved reputation, improved transparency leading to traceability of decisions and improved knowledge management are some of the added benefits (AssetPouwer, n.d.; Schneider et al., 2006). This was for example illustrated by a case-study developed for irrigation and drainage infrastructure for the La Khe Irrigation System in Vietnam (Malano, Chien, & Turral, 1999). After applying asset planning, operation and maintenance, accounting, performance monitoring and multiple other dimensions of a asset management program, the study identified the investment requirements for the next 40 years, as well a current shortfall in revenues. These results would help to increase the quality of decision making in the future. Another practical example where asset management not only benefitted the organizations financial investments strategies, is the case of ProRail. As a result of incorporating objectives, costs and risks in their maintenance activities, it helped the company to achieve a punctuality of 95% regarding the delay of trains in 2014 (RPS, 2015). This was the second highest figure in Europe that year.

As the above examples illustrate, asset management can generally be implemented in multiple sectors. In the context of critical infrastructures asset management is primarily used to strategically time maintenance investments to extend the asset's life cycle (Cagle, 2003). This in turn helps to increase the infrastructure's technical lifespan. As was identified in chapter 1, under normal circumstances most of the existing infrastructures have limited technical life spans of close to 50-70 years (extreme situations such as acts of terrorism or strong earthquakes can for example instantly and permanently damage a road or a bridge). Of course the technical lifespan is not only determined by the technical condition of certain assets, but it is dependent on many factors, such as the infrastructure type and weather.

The assets of most infrastructures, however mostly wear out gradually in time, degrading the overall performance of the system on one hand and simultaneously increasing the operating costs. This is seen in the deterioration curves (figure 5 and figure 6), illustrations of the general degradation in condition and performance of respectively the structural deck of a bridge in Virginia and a sewerage system in Indianapolis.

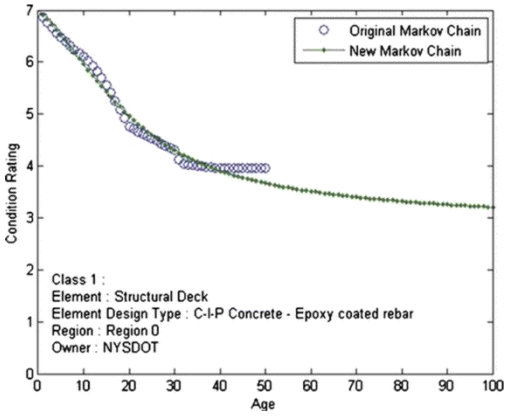


Figure 5 Deterioration curve of a structural deck of a bridge, (Agrawal, Kawaguchi, & Chen, 2010)

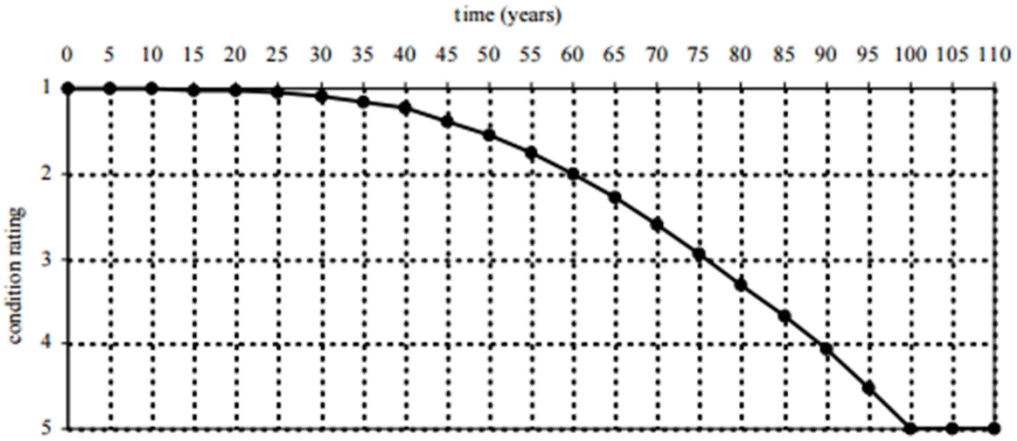


Figure 6 Deterioration curve of a sewerage system, (Lacasse, Vanier, Abraham, & Wirahadikusumah, n.d.)

In recent years there has been a high level of progress in the development of maintenance strategies. Different forms of maintenance management techniques such as condition based monitoring, reliability-centered maintenance and expert systems have been either modified or improved (Khan & Haddara, 2003). Risk based maintenance management, proposed by Chen and Toyoda is one of these variants that give another dimension to the management and maintenance of assets (Chen & Toyoda, 1990).

2.2 Risk and Opportunity Based Asset Management (ROBAM)

Risks

In the ISO 55000:2014 standard, risk management is considered to be an indispensable aspect of asset management (Deloitte Enterprise Risk Service, 2015). In risk based asset management practices the reliability and economic importance of assets is analyzed, together with the long term monetary risks (Heinz, 2003). The key term that sets this form of the concept apart from the basic asset management is risk. Risk is identified as a product of probability of failure and consequence of that failure. Stated more specifically it has to do with the probability failure of an asset and the consequence of the degree of damage that occurs when this asset fails. Minimizing potential hazards to humans and the environment as a result of the failure of the asset , coupled with the cost-effectiveness of the maintenance strategy are key aspects of managing assets based on risks (Khan & Haddara, 2003). Prioritization is coordinated together with the targeted dimensions. Assets in cost relevant areas are assessed on multiple parameters such as their condition, importance and future behavior using methods such as risk analysis. Risk analyses identifies, characterizes, quantifies and evaluates the potential effects and losses from failure events. The more the organization and the operators understand about the demand, the condition, the remaining operational life, their risks and the consequences of failure of the assets, the higher the confidence in the functioning of the assets are as well as investments in for example replacements for these assets. As with asset management, risk

based asset management can be used in a variety of sectors e.g. risk based approaches have been used to maintain assets in the petroleum industry as well as assets in the medical sector (Capuano & Koritko, 1996; Nessim & Stephens, 1995).

Different actors

For infrastructures this can be a complex task, as there is a diversification of assets. These different assets can have different probabilities of failures, complicating the coordination of a systematic coordination plan. The existence of a multi-actor environment also contributes to an increase in complexity. Diverging requirements and objectives of these actors can lead to different decision making on different levels (strategic, tactic and operational) as well as different planning horizons (short, medium and long term) (Nordgård, 2007).

Asset management in itself is already taking a multi-disciplinary approach, but adding risks to the equation, especially in a situation where many actors are working together such as infrastructures, correctly and efficiently organizing plus managing the practice can become even more difficult.

Methodology

The basic methodology of risk based maintenance is shown in figure 7 (Khan & Haddara, 2003). This methodology finds its basis in ISO:31000, Risk Management. After identifying the different assets of the system, each unit's effect on the system is considered separately. Estimating the risks starts by describing a series of events that can lead to a system failure or failures, based on operational characteristics of the system, physical operational conditions, safety arrangements etc. After this scenario

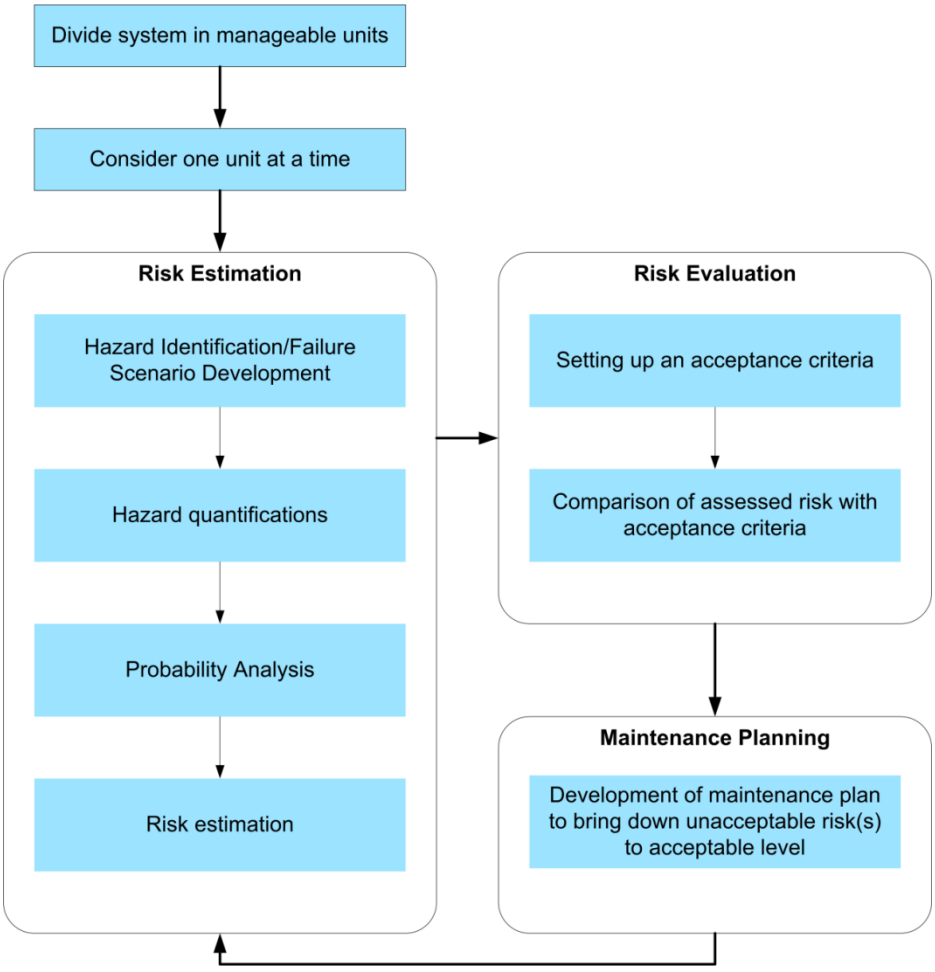


Figure 7 Risk Based Maintenance Methodology (Khan & Haddara, 2003)

development the quantification of the hazards takes place. Equipment is prioritized as a result of their contribution to the system failure(s). System performance loss, financial loss, human health loss and environmental and/or ecological losses are qualitatively and quantitatively considered. This leads to a probability analysis in which by means of various techniques such as a Fault Tree Analysis and failure and human reliability data the frequency of system failure(s) is (are) assessed. The consequences and probabilities are then used to calculate the risk(s) resulting from (a) system failure(s). Risk evaluation consists of setting up an acceptable level of risk depending on the systems nature and type. Different acceptance criteria can be used such as ALARP (As Low As Reasonably Possible) or MEM (Minimum Endogenous Mortality, which is based on the fact that there are various age-dependent death rates in society, with each death rate partially caused by technological systems (Nordland, 2001)). A comparison resulting in the estimated risk of a specific unit being higher than the acceptable risk leads to an improved maintenance plan for that specific unit. This in order to reduce the level of risk. After identifying and implementing the maintenance plan the cycle is repeated after a specific time-period.

Opportunities

The word opportunity refers to a positive risk. Apart from identifying threats from failures it is also critical to identify opportunities emerging from within and beyond the organization (Bekefi, Epstein, & Yuthas, 2008). This can lead to for example process improvements and collaborative efforts with other stakeholders (Deltares, 2016). Opportunities can also lead to emerging technologies and scientific developments, which in turn can then lead to for example sharing of information and availability of data: this was the case during the introduction of electronic in-house medical records in the healthcare industry (Bekefi et al., 2008). Furthermore, also including opportunities broadens the perspective to not only the organization and its assets, but also to the technical and social system in which it operates (Sieswerda, 2010).

2.3 Benefits and Challenges of Risk and Opportunity Based Asset Management

Added Benefits of RBAM

Adopting and correctly employing risk and opportunity based asset management practices in the organizations operations and strategies obviously has its benefits. These benefits are to a great extent similar to the benefits of basic asset management strategies (paragraph 2.1 of this chapter). The identification of critical assets where inspections can provide benefits to reduce overall risks is an area in which risk based maintenance excels (Khan, Haddara, & Khalifa, 2012). Added benefits are the existence of a specific methodology, its ability to quantify results and the definition of opportunities for incremental improvement by eliminating low value tasks (Asset-Insights, n.d.).

Critical infrastructures in the ground, road and water sector can be vulnerable to extreme events, leading to loss in functions. Incorporating risk based asset management in the maintenance and planning can thus help to determine priority and urgency level of each asset in

the infrastructure (Dicdican, Haimes, & Lambert, 2004). A framework developed to apply risk based asset management for highway infrastructures in the United States, based on the general principles of the concept, for example lists various sources of risks to that particular system, ranging from political considerations to oil spills (U.S. Department of Transportation, 2015) . The benefits for the different levels of organizations that deal with road maintenance were the comprehensive information, the ability for managers to support their decisions on quantitative analysis based on engineering evidence and the availability of a full set of maintenance options coupled with quantified consequences and strategies for decision-makers. This illustrates that the application of risk-based asset management not only affects operational activities, but also tactical and strategic one's.

Challenges

The added benefits as a result of the incorporation of risk-analysis in the asset management strategies can however also be the most significant challenge. To make the proper decisions regarding maintenance activities, the risk analysis study must be of high quality (Arunraj & Maiti, 2007). Multiple techniques to conduct risk-analysis exist, ranging from qualitative to semi-quantitative nature, having either deterministic or probabilistic approaches. A cause-and-effect analysis by Backlund and Hannu revealed that factors such as the goals of the organization, experiences, the method being used, team work and data & information all affect the quality of a risk analysis (Backlund & Hannu, 2002). These factors are mostly related to the technical specifications of risk analysis.

However, individual biases and cultural norms also affect a risk analysis, as shown by Harner (Harner, 2010), commonly referred to as "risk appetite". Decisions are ultimately being taken by individuals, whose confirmation and/or overconfidence bias may play a role. The culture of the organization can also be a barrier affecting the risk-analysis. A risk-aggressive

Text Box 4 Practical Examples of RBAM

Practical examples of RBAM

Risk based inspection methods were introduced in the early 90's. A risk based inspection and maintenance strategy was used as a basis for inspections in the process industry by the American Petroleum Institute (API) (Khan & Haddara, 2003). Below are three short practical examples of industries that make use of risk and opportunity based practices to manage their assets. Variants of risk based maintenance such as Reliability-Centred Maintenance (RcM) are sometimes also being used by organizations.

Water sector

The water sector consists of thousands of assets. Pumps, sewerage pumping stations, treatment plants, pipes and dikes are all critical assets that ensure that cities have drinking water and the multiple other functions of water at their disposal. In the Netherlands there are a number of organizations that are either implementing or looking to implement risk based asset management strategies. One of them being Brabant Water, an organization that yearly extracts, purifies and distributes around 180 million m^3 water to households and industries in North-Brabant. The organization had to plan their maintenance activities while cutting costs. This lead to the search of new maintenance strategies. Instead of having maintenance activities based on knowledge and experience of people, the attention shifted to a system-oriented strategy. With the implementation of risk based maintenance for their assets the organization was able to achieve costs savings of 10% (CMS Asset management, 2010). Positive results were also achieved by Delfuent Services BV, a private organization responsible for water purifying installations in the Hague region (CMS Asset Mangement, 2012) . Rijkswaterstaat, the Dutch agency responsible for the public works and water management, is encouraging the use of risk based maintenance strategies for assets in the ground, road and water sector by the development of a guidance principle for the sector (Van den Bogaard & Van Akkeren, 2011).

Railway sector

Railway managers are also under the increasing pressure to minimize costs as well as

organization is assessing its risk in an entirely different way compared to an organization that is more risk averse (Harner, 2010). This organizational culture is transferred through the organization by motivation and leadership (Kriege & Vlok, 2015). For the ROBAMCI project these findings mean that successful adoption of risk based asset management in the ground, road and water sector is not only dependent on the methods and tools, but also on the culture of the organizations in this specific sector.

Apart from the barriers elaborated on above, a number of other challenges are mentioned:

- The availability of a highly specialized team and their competence to quantify specific risks (Nordgård et al., 2007)
- Data and software integration to integrate and manage infrastructure lifecycle data (Halfawy, 2008; Vanier, 2001)
- The absence of an enhancement and standardization of the currently available tools
- Resistance to change, as in most cases the benefits of asset management strategies are not directly visible (Stillman, 2015)
- Cooperating and sharing with other public infrastructure services (Nordgård et al., 2007)

The availability of shared experiences and best practices of other organizations as well as an improved communication and collaboration between organizations in the sector and research institutes can help to address some of above challenges (Vanier, 2001). Training risk assessment personnel and outside assessment can possibly limit individual biases.

Reaping the rewards of asset management thus requires not only engineering skills, but also economic and social skills. This corresponds to the multi-disciplinary approach of asset management and its essential foundations that enable sound maintenance management plans (process management, quality management, knowledge management and ICT management) (Mehairjan, 2016). Without the proper

simultaneously maintaining reliability of the functions (Bharadwaj, Silberschmidt, & Wintle, 2014). Increasing environmental and safety regulations do not make this easier. Research has shown that a risk based approach in the context of railroads will be highly effective in railroad safety optimization (Sakai, 2010) . The East Japan Railway Company (JR East) has been successfully implementing risk based asset management practices in their operations to reduce their expenses. In the Netherlands, ProRail is also implementing risk based asset management to manage the many different assets on the rails. The company is continuously improving the price and performance ratio by means of risk based asset management. Not only is ProRail in this way identifying the negative risks, they are also looking for explicit opportunities to collaborate with other stakeholders, in this case the service providers such as the Dutch Railways (NS) (Swier, 2015).

Electricity sector

Increasing customer demands, aging assets and constrained finances are also trends that are presently evolving in the electricity sector. Network operators and organizations in this sector are also looking to implement more effective and efficient maintenance approaches in their operations. Risk management as part of their asset management practices are therefore seen as ways to ensure sustainable investments (Mehairjan, 2016). In Norway for example, electricity distribution companies are seeking to develop holistic maintenance strategies balancing cost effectiveness with risk dimensions, but to do this successfully, challenges such as changes in mentality, support tools and methods and input data have to be overcome first (Nordgård, Istad, & Sand, 2008). Stedin, a Dutch power distribution company makes use of the ISO 55000:2014 and NTA 8120 (asset management focus on quality, safety and capacity management) norms to structure their risk based asset management approach. Risks are evaluated on aspects such as safety, quality of delivering the utility, financial performance, laws, regulations and the company's image (Stedin, 2016) . Risk based asset management is also part of the maintenance activities of Liander, another Dutch utility company distributing electricity and gas (Liander, 2015).

foundations in place for a basic asset management system, it is impossible for an organization to add the dimension of risk to its strategic maintenance planning (Poland, 2011) .

2.4 Information as a building block for Risk and Opportunity Based Asset Management

Up to date data and information, key aspects of knowledge management, provide the foundation for operational, tactical and strategic decision making, leading to plans, opportunities and improvements (Levitin & Redman, 1998). Research has shown that not the technical aspects of risk based asset management are considered as the greatest challenges (Amadi-Echendu et al., 2010). It is often the data collection, data entry, data sharing and its analysis into usable information that limit the success of asset management in general (Arunraj & Maiti, 2007; Stillman, 2015; U.S. Department of Transportation, 2015).

It is obvious that the data and information is asset-specific and therefore different in sectors and organizations. Assets within the ground, road and water sector's infrastructures are for example dikes, bridges, waterways, roads and other civil works. All these assets have specific parameters that need to be monitored. Information as part of knowledge management has been identified to have a significant influence on asset management systems (Kriege & Vlok, 2015). But as a result of poor implementation of a proper knowledge management system, ambiguous information, complicated protocols and personnel's unwillingness to share information, this process and its application is usually poor. This takes away the possibility of having the right information available at the right place and time for management, leading to decision-making without a basis (Kriege & Vlok, 2015).

Risk estimation and risk evaluation (figure 7 in chapter 2.2) can only be done if the data is available. This data needs to be analyzed and translated into information to be of use for managers to develop maintenance plans. Without this data and information a risk based asset management strategy cannot be successful. Asset specific failure data, in-service data, reliability data, performance data, condition data, valuation data, when recorded, can then be translated into statistical distributions of failure (Lin et al., 2007). These data-sets in turn provide information on failure rates, probability of failures and other parameters (Mehairjan, 2016).

It is with this data and information driven approach and the new insights from this data that strategic asset management planning can be enhanced as well as linking these plans to tactical and operational procedures. However, dependencies on information held by other organizations increase the complexity. Actors responsible for managing and maintaining assets of critical infrastructures need this diversified data if they want to adopt a system oriented view to schedule maintenance activities based on risks. In this case, apart from the earlier identified foundations of asset management (chapter 2.3), it could be argued that another pillar can be added: the sharing of information between organizations (in the case of assets in critical infrastructures).

2.5 Conclusion & Outlook

This chapter has addressed the theoretical foundations of asset management and its extension with risks. Asset management, internationally standardized in ISO:55000:2014 not only takes note of the technical state of a specific asset, but also takes into consideration many other dimensions.

Employing it successfully in an organization can help the organization to streamline its operations, but this is not without it challenges. Appropriate channels and resources should be in place to collect and analyse data. Moreover, it is essential, especially when managing and maintaining assets of nation-wide infrastructures, that information is shared within and with organizations. This makes information sharing one of the building blocks of asset management in this context.

In the next chapter the theory behind information sharing is presented.

3 Information Sharing

Chapter 3, as the previous one, continues with providing theoretical insights, this time for the concept of information sharing. Doing this methodologically first requires defining information and then information sharing (paragraph 3.1). This paragraph, 3.1 consists of 5 subparagraphs: these eventually lead to the focus of this research being on information sharing between actors (inter-organizational). Existing analytical frameworks to study this level of information sharing are compared, this in order to come up with a scientific basis for this research (paragraph 3.2). Finally, paragraph 3.3 addresses the key points that were discussed in this chapter, as well as providing the bridge for the next chapter.

3.1 Theoretical foundations

Information is a word that is being used in different contexts and fields. To have a clear understanding of what information means for this particular study, various definitions are presented in paragraph 3.1.1. The same is done for the concept of information sharing (paragraph 3.1.2). Studying information sharing shows that there is a distinction of different levels, therefore in paragraph 3.1.3, these levels (inter-personal, intra-organizational and inter-organizational) are reviewed. Literature however also shows, that even though this distinction is necessary for defining a scope, the different levels are also related (see paragraph 3.1.4). In the final sub paragraph (3.1.5), the choice for focusing on information sharing on the level of intra-organizational is elaborated on.

3.1.1 Information

The word information, studied as part of information science and with its Latin roots, is subjected to many definitions in the literature. At first sight information is something that flows between a sender and a receiver (Capurro & Birger, 2003). Oxford English Dictionary defines information as "*facts provided or learned about something or someone"* ("Information," 2016). Other definitions include:

- *A quantitative measure of communicative exchanges* (Shannon, 1948). Shannon's model consists of a source, an encoder, a message, a channel, a decoder and a receiver. However, a critique on this theory is the fact that it is not concerned with the communication of a meaningful message, therefore it does not matter what is being communicated (Capurro & Birger, 2003; Sveiby, 1994).
- *"Information is what is capable of yielding knowledge, and since knowledge requires truth, information requires it also"* (Dretske, 1981). However, this author states that there is an obvious link between information and the receivers background knowledge, but this particular point is not included in his proposed definition. This can be an issue, depending on the situation in which the receiver operates (Barwise & Perry, 1981).

For this research, information as defined by the Oxford English Dictionary is deemed sufficient. It is however important to know that even within scientific literature, there is no general consensus about what how information is actually defined.

3.1.2 Information sharing

Information sharing can be classified through different parameters: type of information shared, goal of information shared and level of sharing (Talja, 2002). This research focuses on the latter. In table 2 a number of scientific definitions of the term information sharing on different levels are presented. As the definition of information in the previous subchapter, the table below shows that authors attach different meanings to information sharing, depending on the context they are doing research in. Effort was made to find literature in which these levels were explicitly studied, such that a definition in that particular context could be presented.

Table 2 Scientific Definitions of Information Sharing

Year	Author	Level	Information Sharing defined as
2006	(Johnson et al., 2006)	Within teams	*"the degree to which team members share information with each other"*
1987	(Stasser & Titus, 1987)	Within groups	*"the way the information is distributed among group members before discussion"*
2002	(Calantone, Cavusgil, & Zhao, 2002)	Within an organization	*"collective beliefs or behavioral routines related to the spread of learning among different units within an organization"*
2008	(Wu, 2008)	Between organizations	*"the mutual sharing of business and market information between exchange partners"*
1996	(S. Dawes, 1996)	Between organizations	*"exchanging information between and across government agencies or otherwise giving them access to information"*

As can be seen in above table, there are different levels of information sharing. The main classification in levels are inter-personal, intra-organizational and inter-organizational. These levels are elaborated on in the next paragraph.

3.1.3 Different levels of information sharing

As was shown in the previous sub-paragraph, there is a classification in levels of information-sharing. These are inter-personal, intra-organizational and inter-organizational information sharing. The following sections pay attention to these levels. Literature is gathered by studying the sources cited in Yang and Maxwell's literature review (Yang & Maxwell, 2011).

Inter-personal IS

Interpersonal relationships can lead to a flow of information between individuals. These relationships occur in many different contexts: between friends, neighbors or classmates. Socialization is both a critical influential factor and process to facilitate the sharing of both explicit and tacit knowledge on the level of interpersonal information sharing (Yang & Maxwell, 2011). However, research has shown that as a result of a lack of shared information between individuals within groups, decisions are often sub-optimal (Stasser & Titus, 1987).

To understand information sharing in groups, the motivation sharing framework (figure 8) was developed by Stasser and Titus in 1985 (Stasser, 1992) and revised by Wittenbaum et al. (Wittenbaum, Hollingshead, & Botero, 2004). This framework shows that the sharing of information within groups that are expected to make decisions is a deliberate process that could be facilitated by members' goal(s) attainment: group members to share information with are intentionally selected as well as the decisions of what information to share and how to do this. This corresponds with the work of Rioux, who assumes that as a result of the cognitive state of an individual, information is only shared if that individual is willing to (Rioux, 2005).

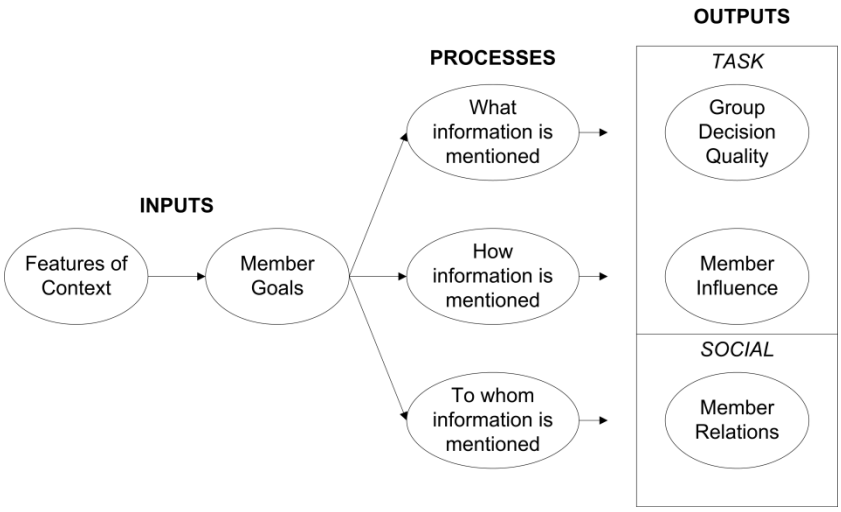


Figure 8 Motivation Sharing Framework (Stasser & Titus, 1987)

This selection is further dependent on the goals and the context. Logically, these information-sharing strategies by group members then influence the task outcomes such as group decision quality and member influence. Regarding the context a distinction can be based on the influences of a particular individual. This leads to a difference in the quantity and quality of information that is being shared when individuals are acting alone, or if these individuals are influenced by their social and organizational environment (Constant, Kiesler, & Sproull, 1994).

Also in organizations, complex decision-making tasks are being performed by groups of people, rather than individuals. This in order to make adequate use of pooled information, possibly leading to higher quality decisions (Mesmer-Magnus & DeChurch, 2009) (see for more benefits of information sharing appendix 2). However, this leads to more complications. Information can become a strategic and powerful asset to protect an individual's place and status within an organization. This can, in both collaborative and competitive settings, limit the sharing of information between individuals in an organizational context.

Intra-Organizational IS

The internal sharing of information is a phenomenon that is essential in the functioning of an organization. Units or departments within organizations must be able to reuse knowledge and information from each other to increase efficiency of the organization, but at the same time these departments are sometimes competing with each other for resources. Information is shared on the basis of formal hierarchical structures and informal lateral relations. However, research has shown that as a result of these hierarchical structures, the level of information sharing is being impacted in a negative way (Tsai, 2002). The same can be said for increasing horizontal structures, such as departmentalization.

The advances in information technologies are increasing the possibilities for organizations to facilitate information sharing between their departments. Networks and applications focusing on groupware are increasingly being used by organizations to improve information exchange. However, as Barua et al. argue, it is not only technology that enables and/or disables the information sharing within organizations. The organizations culture, appropriate rewards systems and IT capabilities are all aspects that can help to achieve inter-organizational information sharing (Barua, Ravindran, & Whinston, 1997). In figure 9 the influential factors for this level which are mentioned in the literature are grouped in layers, based on a literature study by Yang and Maxwell (Yang & Maxwell, 2011).

Figure 9 Intra-Organizational Information Sharing Framework (Yang & Maxwell, 2011)

Inter-Organizational IS

Inter-organizational information sharing that occurs across two or more independent organization's boundaries has been identified by research as being one of the important aspects that can lead to an increased efficiency and interoperability within governmental organizations (Pardo, Cresswell, Dawes, & Burke, 2004). This inter-organizational information sharing thus takes place in networks. The role of information in networks is crucial, as De Bruijn and Ten Heuvelhof argue. Correct and timely information is the main element leading to proper decision making. To deal with the issue of different objectives from different actors in such a network like environment, these authors recommend that actors have to establish the right information in interaction with each other. This is called negotiated knowledge (De Bruijn & Ten Heuvelhof, 2008). This firstly requires that organizations share the right information with each other. Due to this multi-actor environment, the factors that influence inter-organizational information sharing are believed to be not only more, but can also be of a higher complex nature than in intra-organizational information sharing (Gil-Garcia, Schneider, Pardo, & Cresswell, 2005).

There are multiple complex interactions between these organizations in the context of information sharing, as the literature review by Yang and Maxwell identified (Contents, 2014; Gil-Garcia, Chun, & Janssen, 2009; Gil-Garcia, Pardo, & Burke, 2007; Klischewski & Scholl, 2008; Luna-Reyes, Andersen, Richardson, Pardo, & Cresswell, 2007; Pardo & Tayi, 2007; Ramon Gil-Garcia, Chengalur-Smith, & Duchessi, 2007; Zhang & Dawes, 2006). Furthermore, the degree of information shared (no information sharing, partial information sharing and full information sharing), scope of information shared (transactional, operational, strategic, strategic and competitive) and the level of intensity of the relationship between actors (cooperation to full collaboration) are also distinctions that different researchers have made in the context of inter-organizational information sharing (Gavirneni, Kapuscinski, & Tayur, 1999; Seidmann & Sundararajan, 1998; Spekman, Jr, & Myhr, 1998).

Based on different literature studies, Yang and Maxwell have developed an inter-organizational information sharing framework, as seen in figure 10. As these authors state, "*this framework can be a comprehensive analytical tool to perceive the multi-faceted influential factors that can play a role, both in the private and public sector"* (Yang & Maxwell, 2011). The figure lists a total of 25 factors, categorized in the three primary themes that could potentially influence inter-organizational information sharing in the public sector (organizational and managerial, technological, political and policy). However, the authors also state that it is still not clear what factors are for example more important or less important. Through studying relations between factors this research gap can be addressed.

Increasing technological solutions with regards to information and communication technologies have made it more feasible for organizations to share information. The disability of organizations to not generate all of the required information internally makes inter-organizational information sharing an important aspect, as well as the high level of skills and knowledge of organizations that are nowadays required from these actors to perform their tasks. Sharing information can

have multiple benefits for these organizations (see appendix 2), however, facilitating this process can be a difficult and complex task (Yang & Maxwell, 2011).

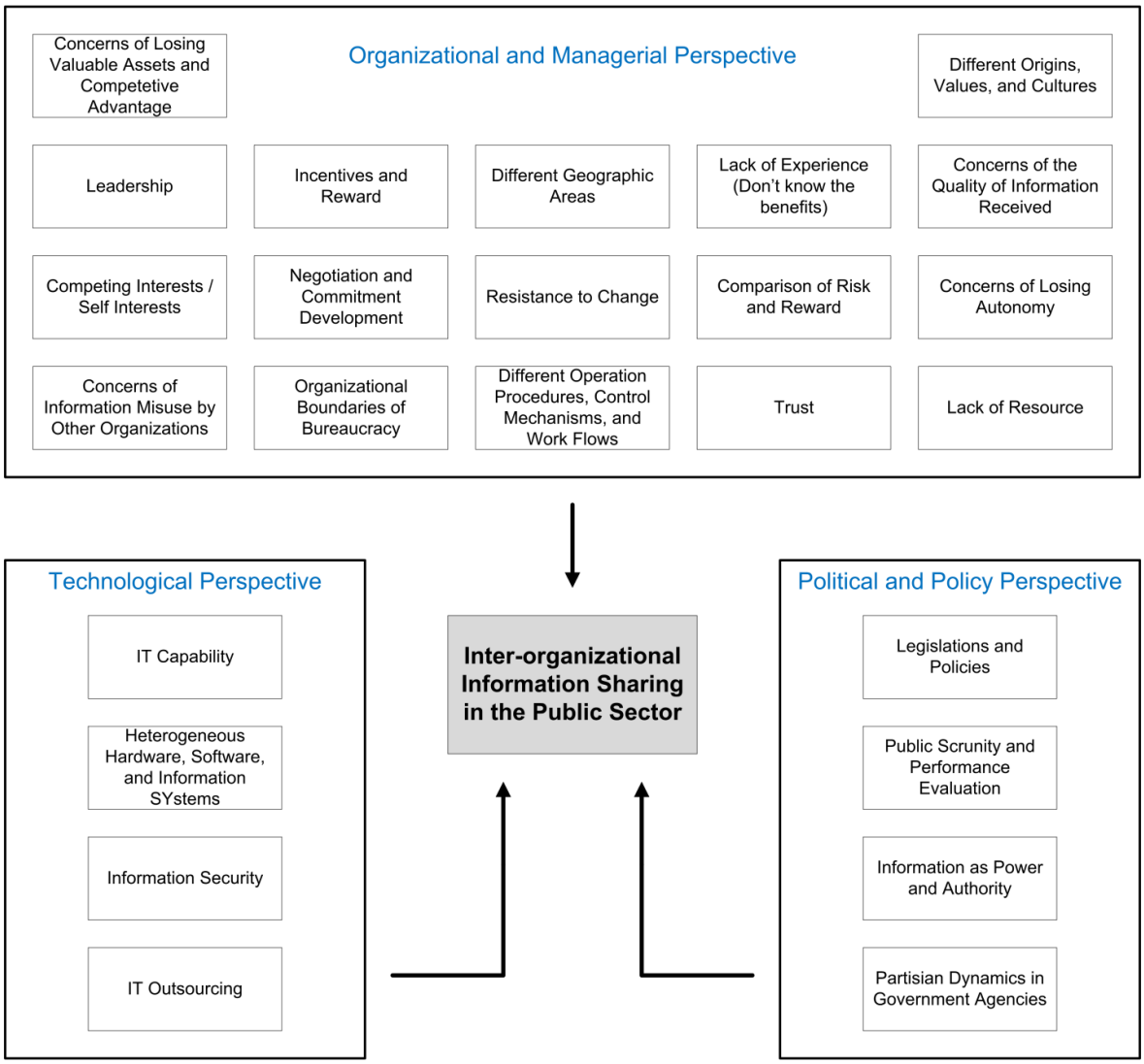


Figure 10 Inter-Organizational Information Sharing Framework (Yang & Maxwell, 2011)

3.1.4 The interrelation

Even though a distinction is made in the literature between different levels of information sharing (interpersonal, intra-organizational and inter-organizational), it is made explicitly clear that the different forms of information sharing levels are interrelated (Yang & Maxwell, 2011). Multiple researchers have further shown that capabilities to share data, information and knowledge must not only be improved across departmental barriers, but also across organizational geographic and institutional ones (Schooley & Horan, 2007). Both interpersonal and intra-organizational

information sharing are respectively embedded in intra-organizational and inter-organizational information sharing. This is made clear when information shared between organizations has to reach different departments and/or individuals within those departments. Yang and Maxwell argue that in an ideal situation, the three levels of information sharing should be connected with each other to form an information-sharing environment as shown in figure 11. It seems logical that there is an interrelation; however, the literature does not sufficiently address these interrelation interfaces.

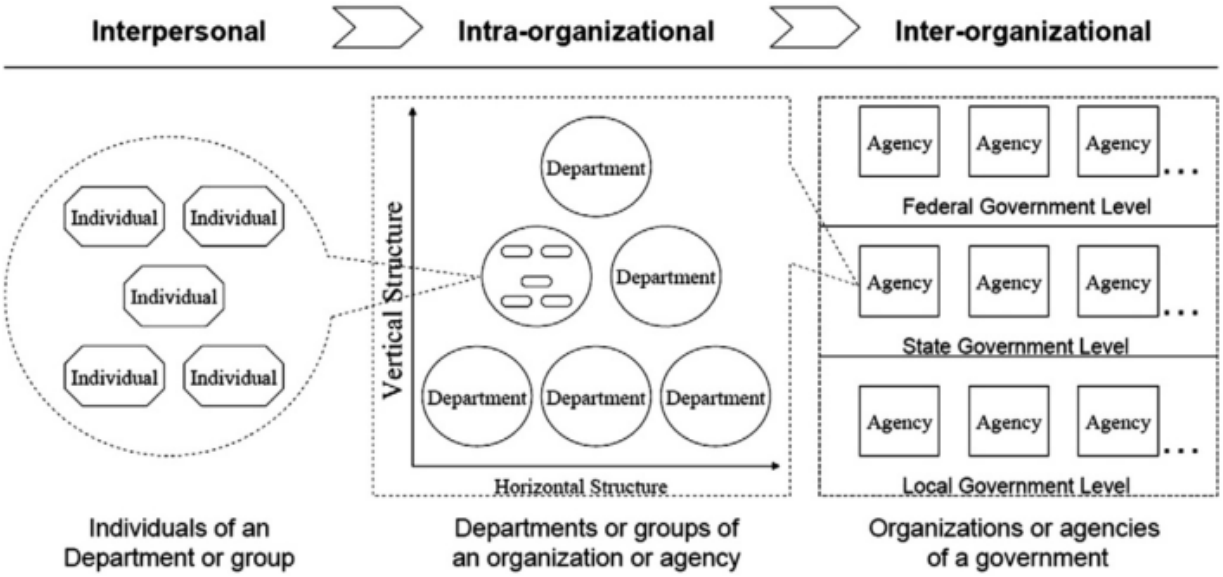


Figure 11 Interrelation between different levels of Information Sharing (Yang & Maxwell, 2011)

3.1.5 Inter-Organizational Information Sharing for ROBAMCI

As was shown in paragraph 2.2, there is a strong multi-actor dimension when planning and conducting maintenance practices of assets in critical infrastructures. Not only are there many organizations involved on one side, downtime of assets as a result of maintenance can have devastating consequences for the public and the economy, depending on the various functions the asset performs. The essence of the ROBAMCI project is to analyze and plan maintenance activities based on a system wide perspective, therefore an inclusion of objectives, plans, policies and other type of interfaces from different organizations should be taken into account by the asset owner/manager. The dependency of the asset owner/manager on information, the actual sharing of this information by other organizations and the fact that research has shown that the availability of data and information as key aspects for adequate risk and opportunity based asset management have led to the focus of this research being on the level of inter-organizational information sharing.

Expected Benefits of inter-organizational information sharing for Risk Based Asset Management

Cost savings, improvements related to decision making and an increase in transparency have been explicitly defined as to be potential benefits if this risk and opportunity based asset management strategy can be successfully adopted by organizations in the sector (Deltares, 2016). These benefits, as shown in appendix 2 and the existence of a multi-actor environment, are all related to inter-organizational information sharing. Thus, having this sharing of information between organizations, where needed, act as a cornerstone for risk and opportunity based asset management in this sector is critical to reaching the objectives of the ROBAMCI project.

Apart from the expected benefits of information sharing between organizations as mentioned above, all three categories of factors identified by Yang and Maxwell's framework are expected to play a role in understanding how information sharing on this level influences the decision making process.

Technology factors in Risk and Opportunity Based Asset Management

Technology plays a considerable role in risk and opportunity based asset management practices, especially if information is being shared by organizations. Calculating risks requires the availability of not only experts, but also the right computational power, hardware and software, thus adequate IT Capability. Furthermore, when dealing with information about assets of critical infrastructures, a high level of security is expected to be required, to prevent certain data and/or information reaching the wrong organizations or people.

Political and Policy factors in Risk and Opportunity Based Asset Management

When studying inter-organizational information sharing for risk and opportunity based asset management, it is important to consider the political and policy environment. Legislations and policies, or even politics can prevent the sharing of certain information of a particular asset. Organizations can even keep certain information related to risks of asset failures to themselves in order to not pay fines related to reaching certain key performance indicators.

Organizational and Managerial factors in Risk and Opportunity Based Asset Management

Strategic and tactical asset management requires the knowledge and support of managers in organizations. Asset management plans, as well as the encouragement to use these should be initiated by management (leadership), as was shown in chapter 2. These asset management plans include multiple assets, thus information from different departments or different organizations is required. Trust, competing interests/self-interests and the availability of resources are thus important to consider when studying inter-organizational information sharing in the context of risk and opportunity based asset management.

3.2 Inter-organizational information-sharing frameworks

After the different levels of information sharing have been studied and the arguments for focusing on the level of inter-organizational have been provided, the literature review continues with the next step in which this level of information sharing is focused on. Different frameworks are compared in paragraph 3.2.1 to ensure that a choice for an analytical framework is taken methodologically. This framework is then slightly adapted to the situation and context at hand in paragraph 3.2.2.

3.2.1 Comparing inter-organizational information sharing frameworks

Apart from Yang and Maxwell, other authors have also studied inter-organizational information sharing, all in different contexts. Different frameworks or models have been used to identify benefits, barriers and factors that could be of influence. The table below (3) shows for four studies how the authors have categorized the factors that can potentially influence inter-organizational information sharing. An important criteria for choosing these four studies is their focus on the public sector, as this corresponds with the focus of ROBAMCI. In appendix 3 an overview is provided of the factors that have been listed in each category of every framework from the studies below.

Table 3 Inter-Organizational Information Sharing Frameworks Overview

	Frameworks			
(Author, Year)	**(Gil-Garcia et al., 2005)**	**(Cresswell, Dawes, Burke, & Pardo, 2004)**	(Akbulut, 2003)	**(Yang & Maxwell, 2011)**
Context of study	An examination of factors influencing successful selected criminal justice integration initiatives.	A study to address and improve the understanding of information system development and inter-organizational collaboration. This is done by modelling the social and technical processes that are required when information is	Investigation of factors that are of influence when local governments are participating in information sharing processes with state agencies.	A literature-review of existing insights in information sharing research. In this review three levels of information sharing (inter-personal, inter-organizational and inter-organizational) are assessed.

		shared between agencies.		
Categories	Turf and Resistance to Change	Social Processes	Characteristics of Electronic Information Sharing	Organizational and Managerial Perspective
	IT and Data Incompatibility	Resources	Agency Characteristics	Technological Perspective
	Organizational Diversity and Multiple Goals	Organizational Artefacts	Environmental Characteristics	Political and Policy Perspective
	Environmental and Institutional Complexity	Technology Artefacts		

As can be seen, studies have categorized potential influencing factors differently. Yang and Maxwell's inter-organizational framework, as shown in figure 10 in subparagraph 3.1.3, not only lists almost all of these factors (table 8 in appendix 3), it also adds other factors that are currently getting more important, one of them being information security. Furthermore, this framework has been internationally published in the Government Information Quarterly Journal and has been used by other authors to examine information sharing in different contexts (supply chain management (Rashed, Azeem, & Halim, 2013), incident management (Allen, Karanasios, & Norman, 2014), software development (Ghobadi, 2015) and e-Governments (Aman, Al-Shbail, & Mohammed, 2013)). This contributes to the choice for using Yang and Maxwell's framework as the analytical lens of this research.

3.2.2 Revised framework for ROBAM

It is expected that not every factor listed in the developed framework by Yang and Maxwell is relevant for the case to be studied in the next chapters. Based on conversations with project members, practical examples where risk and opportunity based asset management practices are being used as maintenance strategies and the literature, a slightly revised framework was developed (figure 12).

Added factors

Yang and Maxwell do not mention the importance of collaboration, compared to the other authors. The size of the organization, as well as the costs of potential changes are also not mentioned. Sharing information is dependent on different social and technological factors, as well as strategic behaviour of organizations (De Bruijn & Ten Heuvelhof, 2008; Yang & Maxwell, 2011). One of them being the size of the network. "Weak" ties between members in such a network are usually enough to share explicit information, however, sharing tacit knowledge requires the presence of "thick" ties with other network members. This illustrates that a small network can potentially have a higher level of information sharing. Other aspects that are of

influence are the ability to assimilate the information and the appropriate processes to share the information (Dyer & Nobeoka, 2000).

Removed factors

Decisions mostly take place on the strategic and tactical level, often excluding operational information. The factor “different operation procedures, control mechanisms and work flows” is more targeted on operational asset management. This factor has therefore been removed from the framework.

Furthermore the factors from the organizational and managerial perspective have been further classified into factors influencing management, the organization and uncertainties for the organization and its environment. The choice to replace “top management” with “management” is made as management employees do not necessarily have to be part of top organization executives. Other small changes include the removing of a direction of factors: “lack of resources” has been restructured in “resources”. An extensive explanation of every factor mentioned in the above framework can be found in appendix 4.

The above changes have led to the revised framework shown in figure 12.

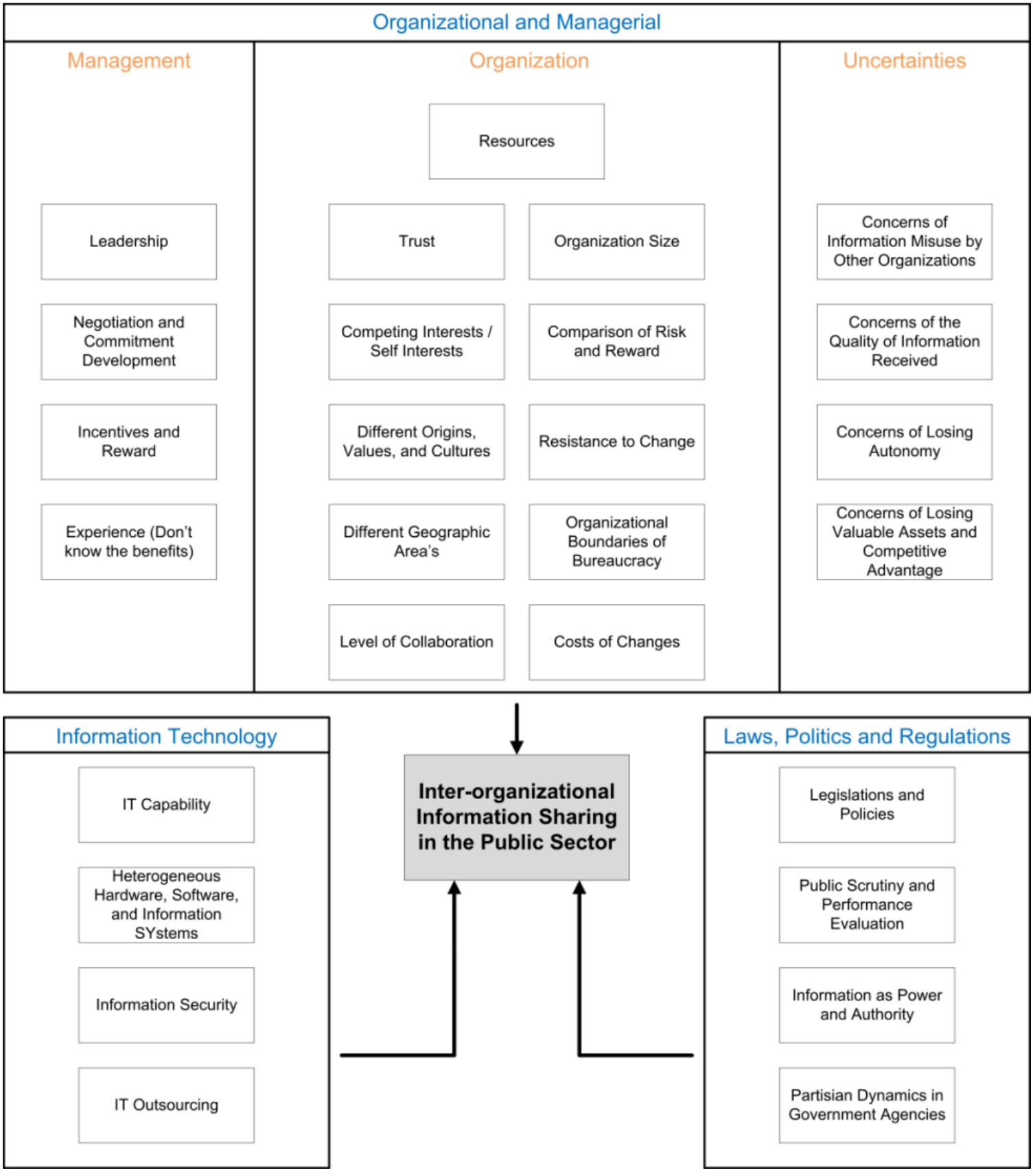


Figure 12 Revised Inter-Organizational Information-Sharing Framework

3.3 Conclusion & Outlook

This chapter elaborated on the theory behind information and information sharing. Doing this has led to critical insights in how information sharing is categorized and how this is being influenced. The categorization in different levels and the context of this research have led to setting the scope of this study on inter-organizational information sharing. Inter-organizational information sharing has many benefits, and a lack of information sharing can sometimes lead to devastating consequences. These benefits and consequences are not limited to one specific sector.

Comparisons of literature focusing on inter-organizational information sharing have led to a slightly revised framework (based on Yang and Maxwell's inter-organizational information sharing framework) to be used as the analytical lens of this research

With chapter 3 as the final piece of the essential theory the bridge can be made to using a case to study the role of information sharing between actors in a practical environment. This will be, as said, done in the context of the ROBAMCI project.

However, before the case-study is introduced, a methodology to extract the necessary information out of the case must be developed. This is done in the next chapter.

4 Case-study Methodology

Within the cases of ROBAMCI, inter-organizational information sharing takes place in relation to a specific asset. The technical elements of the asset, its role in the system and its role for the local, regional, national or even international environment is important to study in order to extract which information is or should be subjected to sharing. In order to have this view, a case methodology is developed. A criteria for this methodology is that it should have a general character, making it applicable for other cases and assets.

The unit of analysis in this research is an organization (Sedgwick, 2013; Yin, 2013). The phenomenon information then travels between these organizations. The methodology should therefore also pay specific attention to organizations (actors) and information.

In chapter 4.1 a system perspective is taken for the asset. Different factors and functions in relation to the asset are then identified. This system analysis also results in the identification of involved actors. Through further analysis of these actors in relation to the asset (their objectives and their core values), potential information that is subjected to sharing can be identified (information needs, paragraph 4.2). The steps in this methodology are summarized in paragraph 4.3.

The necessary knowledge gained from chapter 2 and 3 (asset management and information sharing theory respectively) as well the case-analysis paves the way to tackle the case in practice. How this is done is shown in paragraph 4.4. In the last paragraph, 4.5 the conclusions from this chapter, as well as next steps are presented.

4.1 The Asset System Analysis

It order to determine what information is needed from whom in what setting it is first important to have an overview of the technical and social system a particular asset operates in. Within these systems a distinction could be made between the inputs and the outputs of the asset. As identified earlier, maintenance is one of the key activities that guarantee that the asset delivers its outputs. In this system analysis factors that influence the maintenance works and functions that are influenced by the maintenance works are identified. This can be done through assessing the technical dimension of the asset. The actors involved in these factors and functions are also listed. See figure 13 for this general illustration.

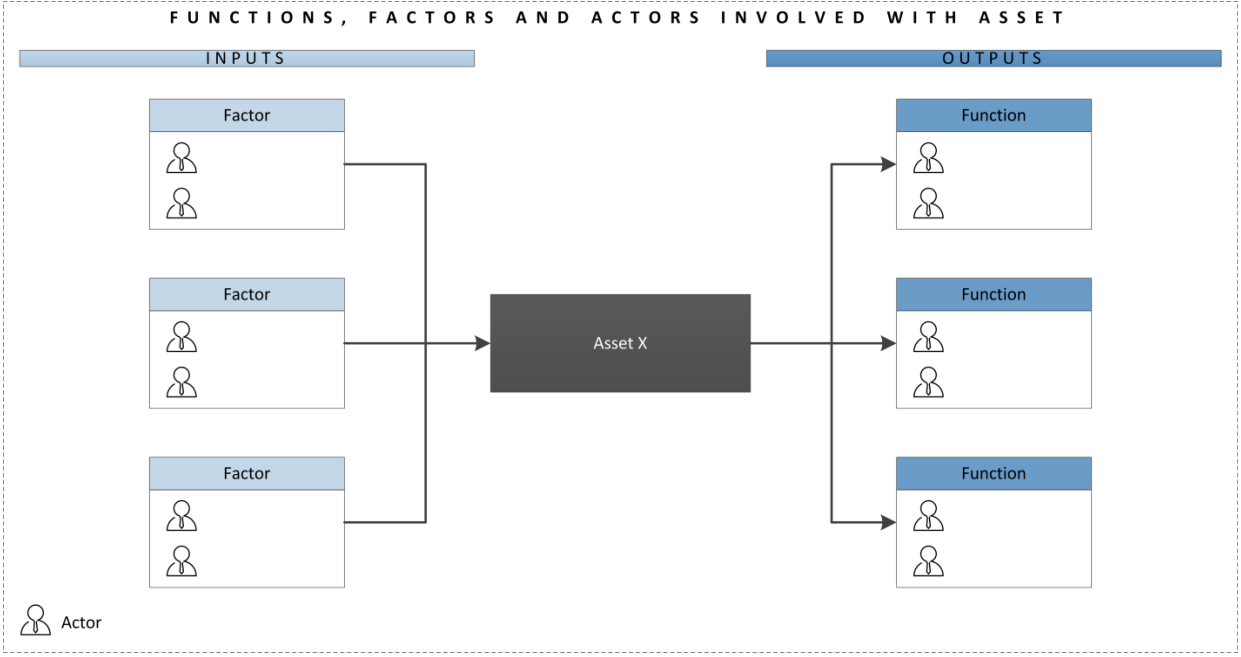


Figure 13 Functions, factors and actors involved in the asset (template)

The actors involved with these factors or functions can e.g. propose or set certain constraints or conditions for the asset owner/asset manager. For both sides of the spectrum information needs to be shared with the asset owner/asset operator with the other actors.

This system analysis should therefore include the following sub-analyses:

- An analysis into the different functions the asset or artefact performs, as well as the factors that influence maintenance activities of the asset, taking into account different social, environmental and technical aspects.
- An actor analysis that can help to identify the actors involved in these functions and with the factors, as well as their objectives, interests and their possible attitude towards potential maintenance works. These maintenance works are identified through a brief technical systems overview.

Together, the results of these sub-analyses will serve as input for determining what type of information is specifically needed to efficiently maintain and manage the asset.

4.2 Specifying information needs

After the 2 sub-analysis have been conducted, the next step is to identify which type of data or information is needed by the asset owner/ asset manager (or other actors) from the other organizations to plan/perform maintenance activities. To identify the type, relevancy, timespan, etc. of the data/information case specific literature can be studied, possibly supplemented with interviews with actors involved in the case. The way this will be illustrated is seen in figure 14.

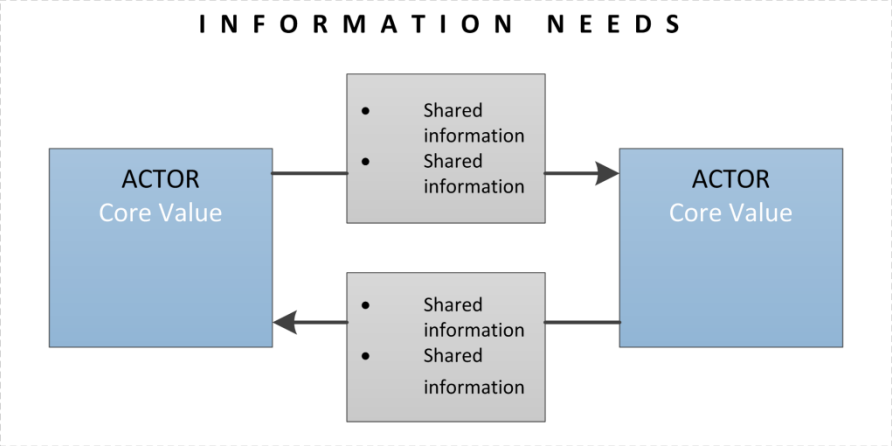


Figure 14 Information needs between actors (template)

The more actors are involved, the more complex the information needs can get. The type of data/information is heavily dependent on the type of asset, as in, the factors that influence the asset and the functions that are being influenced by the asset. Through interaction between these organizations, agreements (e.g. contracts) should be made regarding the form of the datasets or information that will be shared, the potential costs of sharing, and the potential confidentiality issues. It should also be determined by the actors via what medium the information will be shared and in what form. Another critical aspect is the relevancy of information. In a network setting it is effective to have *nice-to-know* information, opposed to *need-to-know* information in a strict project management setting (De Bruijn & Ten Heuvelhof, 2008). However, this is dependent on the functions and the context of the asset in question. Therefore, to prevent information overload and as there are both process and project management elements in this case-study, a combination of *nice-to-know* and the *need-to-know* principle should be used to determine what information is relevant to share. The insights gained through the analysis of the case are then used to identify where extra insights are needed, paving the way for the data-collection phase.

4.3 Methodological steps

In the flowchart (figure 15), as well as in table 4 the steps related to the system analysis (4.1) and the information specification (4.2) in the context of maintenance and management are summarized.

Table 4 Explanation of steps to take

Step	Description
1	The asset(s) in question is (are) identified. A technical analysis assists in determining maintenance activities of the asset.
2	Identification of factors that influence maintenance activities of the asset.
3	On the other hand, functions that the asset performs are also influenced by maintenance activities. These are also as specific as possible listed
4	Correctly identifying the organizations involved in the previous 2 steps is the basis for determining where information is/should be/needs to be shared. By means of a formal chart, their formal relationships are also shown.
5	In this step the information that flows between the previous identified organizations is specified, enabling a sharper identification of actors to gain insights from. The information needs are partly identified through the risk based methodology.

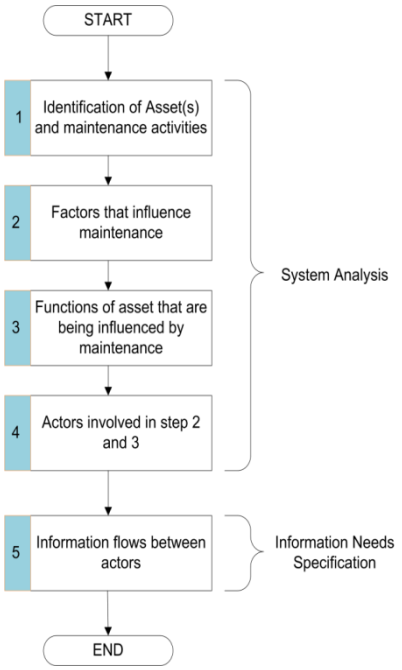


Figure 15 Case-study methodology

4.4 Case-study approach

The case-study methodology provides insights in the information sharing needs of the actors involved. However, it can also provide the potential research gaps. These are the aspects that still need more understanding. To research these gaps in the case in-depth interviews are held with organizations that have been identified as a result of the analysis. The following sections mention the important parts of the practical research.

Case Analysis

An analysis of the particular case is done based on the steps presented in figure 15. This ultimately provides

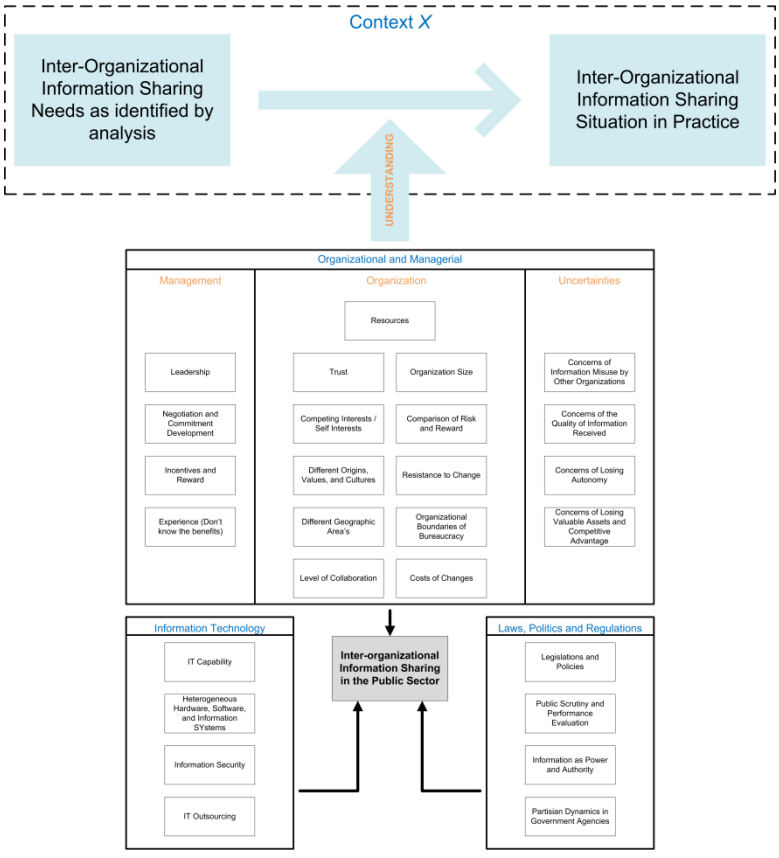


Figure 16 Use of framework to study practice

an overview which corresponds to the systematic overview that is presented in paragraphs 4.1 and 4.2. The analysis provides insights, as well as gaps. As can be seen in figure 16, the analytical framework (subchapter 3.1.5) then helps to bridge these identified gaps between the information-sharing needs of actors and inter-organizational information sharing in the practice, given a certain context (in this case ROBAMCI).

Data gathering and data sources for analysis of case-study

Mapping the existing situation i.e. determining the system in which the asset operates, identification of the actors and their information-needs will mostly be done by means of desk research, complemented by additional talks with 3 case-experts from Deltares. In the particular case used in this research, insights were also gathered through attending a multi-stakeholder dialogue session. In this session representatives of various organizations involved in the case-study were present.

Data gathering and interview respondents

To bridge the gap between the information sharing needs of the actors in the case and the actual information sharing in the case in-depth interviews are used. The organizations that are interviewed were determined through the case-analysis in the paragraph 5.1. Seven organizations were interviewed: Rijkswaterstaat, Water Authority Hunze en Aa's, HKBS, Province of Groningen, De Laar, Groningen Seaports and Stedin. After identifying the employees of the actors to be interviewed an administrative interview protocol is set up (appendix 6).

In Depth interviews

The in-depth interviews start by presenting a number of statements, followed by questions related to the views of the actors regarding these statements.

Through statement 1 the aim is to gather insights from the interviewees regarding the system analysis: which actors or type of information is not present? What needs to be added or improved? Can the system analysis be verified?

Statements 2-6 cover the blocks (organizational, managerial, uncertainties, laws and policies and information technology) of the slightly revised framework by Yang and Maxwell (see subchapter 3.1.5). Depending on the answers or views of the interviewee regarding these statements, more in-depth questions can be asked.

Effort was made to standardize the content of the interviews as much as possible to benefit the coding process. Table 5 shows the statements presented to the interviewees. A complete script, with questions related to the asset that is to be studied in the next chapter is shown in appendix 6.

Table 5 Statements presented to Interviewees

Number	Category	Statement
1	Awareness and dependency	The organization actively shares information with other actors related to maintenance strategies of asset in question
2	Uncertainties	Sharing information can possibly weaken our strategic position due to misuse
3	Management	Sharing information with other agencies is encouraged by our organization
4	Organization	Inter-organizational information sharing overall improves efficiency and effectiveness of decision making
5	Laws, Politics and Regulation	Legislative and regulative procedures influence inter-organizational information sharing
6	Information Technology	Different IT related factors influence our ability to share information

Data Analysis and Findings

Data gathered from these in-depth interviews are expected to be mainly of a qualitative nature. In this case it is wise to simultaneously collect and analyse the transcripts of the interviews, in order to efficiently manage time and resources. Summaries of these interviews are sent back to the interviewee for verification.

The data is coded through 2 rounds:

1. The first round of coding concerns factors that explicitly match the factors from the used analytical framework (slightly revised version of Yang and Maxwell's inter-organizational information sharing framework), as well as factors that are obvious synonyms.
2. In the second round factors that are mentioned under totally different names are as much as possible interpreted through first the analytical lens of Yang and Maxwell. If that is not possible, interpretation takes place through the other studied inter-organizational frameworks, shown in chapter 3 and appendix 3 (Akbulut, 2003; Cresswell et al., 2004; Gil-Garcia et al., 2005). If that is still not possible, the factors are categorized as "other". This does however not mean that they do not appear in literature, just not in the studied literature for this research project.

After the data set has been coded, some quantitative analysis can be conducted. A simple way to identify which factors are more important than others, is to rank them according to how many respondents have named them during their respective interview. Out of the most mentioned factors, three are selected for further elaboration. The choice for these three is based on the depicted importance of them during the interviews. This does however not mean that the other factors are not important: for logistical reasons it is simply not possible to extensively elaborate on all factors.

4.4 Conclusion & Outlook

In this chapter a short but necessary intermediate step is discussed in order to gain necessary insights out of a case-study. The developed methodology in this step gives insights in the asset and its surrounding system: factors that can influence maintenance activities, functions that are influenced by maintenance activities, actors involved with these factors and functions, and their respective information needs. The methodology has a general character and can be used in other contexts.

The analysis also helps to identify where research gaps are and what aspects need more understanding. In-depth interviews with actors that can provide these additional insights are used as the research method, and the slightly revised framework by Yang and Maxwell will be used to link practical results with theoretical insights,

The developed methodology is put in use in the next chapter, in which a specific ROBAMCI case is used to understand what factors influence inter-organizational information sharing.

5 Inter-organizational information sharing: a case-study

In this chapter a ROBAMCI case-study is researched to study information sharing between organizations. Conform the developed methodology in the previous chapter, the system and information surrounding the asset is analysed (paragraph 5.1). Employees from organizations are contacted and those that have responded positively have been interviewed. The results first show a ranking of factors (paragraph 5.2). More interestingly however, some inductive relations between these factors are interpreted through the studied literature (paragraph 5.3). This paragraph also shows some other case insights, apart from only the ranking of factors. In paragraph 5.4 a discussion of the results is provided. Paragraph 5.5 draws the conclusions of this chapter, as well as providing an outlook to chapter 6.

5.1 Case Analysis

This case-study is chosen out of the other case-studies done in the ROBAMCI project (see appendix 1 for a brief overview of other cases), because in contrary to the other cases, the multi-actor perspective appears strongly. This corresponds with the multi-actor environment of maintaining critical infrastructures (shown in chapter 1) and system approach of risk based asset management (shown in chapter 2), making it an interesting case to study inter-organizational information sharing (shown in chapter 3).

In this case the asset is owned, managed and maintained by Rijkswaterstaat. This means that only this organization can give orders to perform maintenance and/or management activities. However, this does not mean that Rijkswaterstaat should not take into account other aspects, functions and factors related to the asset when either planning or performing their maintenance and management activities, because as will be seen in this chapter, the asset in question has technical, social, nature-related and economic relevance for not only local and regional societies, but for international ones.

In subparagraph 5.1.1 some background information is given about this case and the asset in question. Subparagraphs 5.1.2 and 5.1.3 showcase the results of the case-study analysis, conform the developed methodology of chapter 4. As was said earlier, the following insights are gained through talks with case experts at Deltares, supplemented with information obtained from a workshop where many of the actors involved in this case-study were present.

5.1.1 Case Background

Anticipating economic growth

The waterway Lemmer-Delfzijl (figure 17), is currently being updated to accommodate Va class ships (L=110m, B= 11,4, D=3.5). The load capacity of these ships is close to 3000 tons. Accommodating the type of ships requires an expansion of the waterway. This particular stretch of water is one of the most important national waterways for commercial shipping. It connects the north of Germany and the Ports of Rotterdam and Amsterdam. The shipment of goods is expected to increase over the next years, so enabling bigger ships to travel this route is a key activity to anticipate on this growth. This is being done by widening and deepening of the waterway, as well as replacing bridges (Provincie Fryslan, Rijkswaterstaat, & Provincie Groningen, n.d.). The asset in question, sea locks in the municipality of Delfzijl and the town of Farmsum, are the last hurdle in this expansion. They thus perform not only a critical role for shipping and economy regionally, but also internationally.

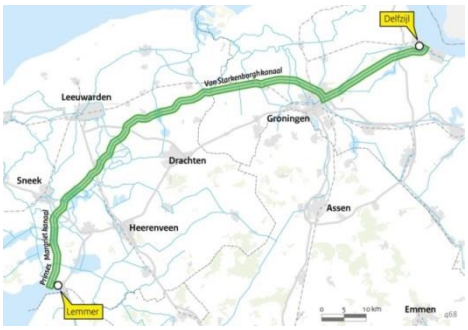


Figure 17 Waterway Lemmer-Delfzijl (Ministerie van Infrastructuur en Milieu, 2016)

Delfzijl's water related infrastructures

In the municipality of Delfzijl there are a number of hydraulic civil structures relevant for the water system. These structures perform different functions in different domains: accommodation of maritime traffic, maintaining specific water levels as well as availability and drainage of freshwater, water quality, water safety, nature, recreation and various living and working functionalities (De Bel, 2016). Figure 18 gives an overview of the civil waterworks in the region. Not all of these assets perform all of the previously mentioned functions. In table 6 an overview is given of the **main** functions of these assets, as well as their current technical state (Kok, Wessels, De Bel, Van Meerveld, & Van der Wiel, 2017). As can be seen from this table, the sea lock complex of Farmsum plays a role in most of the functions within the system.

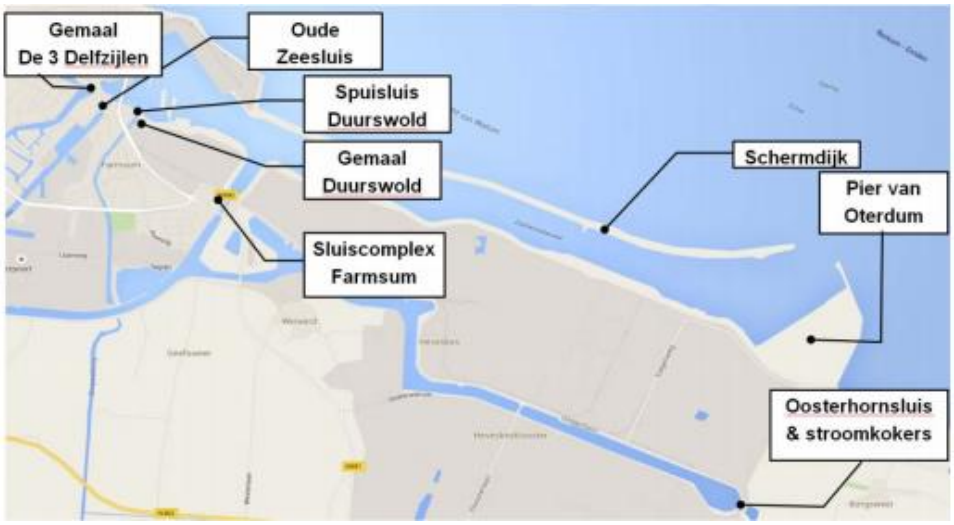


Figure 18 Overview of hydraulic assets in the region

Table 6 Assets in the region and their functions

		Functions						
Asset	**Technical State**	**Commercial Shipping**	**Recreational Shipping**	**Water Safety**	**Water Drainage**	**Water Quality**	**Fresh and Saltwater Nature**	**Living and Working**
Big Sealock Farmsum	Good	x				x	x	Indirectly influenced by entire system
Small Sealock Farmsum	Good	x	x		x	x	x	
Old Sealock Delfzijl	Good				x	x		
Screen dike	Good			x				
Pumpingstation 3 Delfzijlen	Good							
Pumpingstation Duurswold	Good							
Oosterhoorn sealock	Good						x	
Pumpingstation Rozema	Good							

What is the problem with this asset?

The sea-locks located in the town of Farmsum in Delfzijl are the last physical structure that ships have to pass in this waterway. The issue in this case-study is the expansion/replacement of the sea locks. A previous study trying to justify this investment led to the decision that replacing this sea lock would not be economically feasible (Bückmann, Witmond, & Roozenbeek, 2007). However, this study lacked a system's perspective, as only the assets shipping accommodation function was taken into account. This lack of a systems perspective could have influenced the decision, therefore, to make a more efficient and well-grounded decision, where many other factors and functions are taken into consideration, the ROBAMCI approach was applied to perform a new and improved study (Kok et al., 2017).

5.1.2 Sea Locks System Analysis

Conform the developed methodology (chapter 4), the case is analyzed in this and the following subchapters.

Step 1: Identification of the asset and maintenance activities

The asset in question is as stated before the sea-lock complex located in the town of Farmsum in the municipality of Delfzijl. The complex was constructed in the 1970's and is owned and maintained by Rijkswaterstaat. It consists of two sea locks with the following dimensions (table 7) (Rijkswaterstaat, 2016). Estimations have shown that the sea locks still have an estimated technical lifespan of 33 years, till 2050.

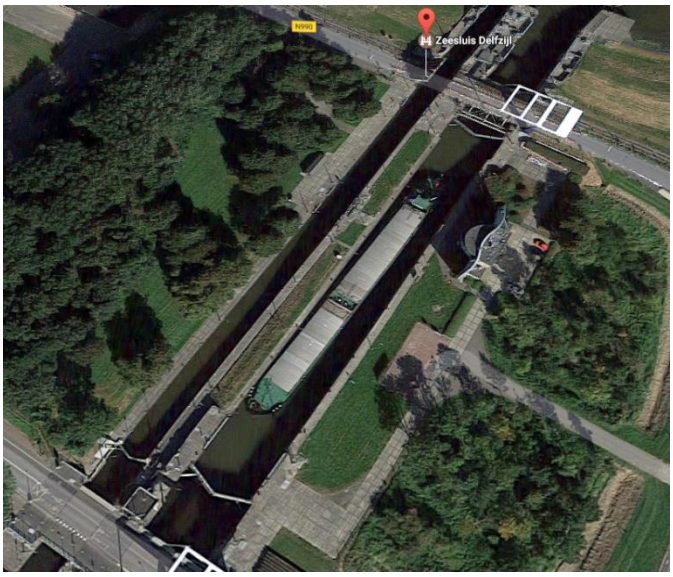


Figure 19 Sea-Lock Complex Farmsum

Technical System Overview

In figure 20, the main components of the sea locks are shown. The sea lock complex consists, as previously stated of 2 locks, one for commercial and one for recreational shipping. Each of these sea locks have 4 massive doors to open/close, in order to let water flow in/out and let vessels navigate through the chamber (8 doors in total for both locks). The watertight chamber consists of 2 walls (4 in total for both locks). Everything must be controlled via an operational facility, which has communication equipment and other technical systems to control the opening,

Text Box 5 Sea Locks Farmsum

Sea-locks Farmsum

Table 7 Dimensions Sea Locks

	Sea Lock 1 (m)	Sea Lock 2 (m)
Length	123	119
Width	7	16
Depth	2,40	5,45

Sea lock 1, the smaller one in the left of figure 19, is mainly used for recreational shipping, where-as the bigger lock is used for commercial shipping. Because these locks are placed next to each other, there are increased risks of collisions between recreational and commercial vessels. The sea locks connect the Zeehaven channel with the Eems channel by raising and lowering vessels between these 2 different levels of water systems.

The locks each consist of three subsystems: a watertight chamber which connects the 2 water systems by varying the water level, 2 sets of doors at each end of the water chamber and a lock gear to empty/fill the water chamber in order to lower/raise the water level. Each of these systems consist of many different components that could be subject to wear and tear of the environment, especially as most of the components are often submerged in the water. A thorough technical analysis would be needed to specifically identify every component and its maintenance strategies, this is however not within the scope of this study.

closing, filling and emptying of the asset, as well as systems to monitor and measure various other parameters to ensure safety and functionality.

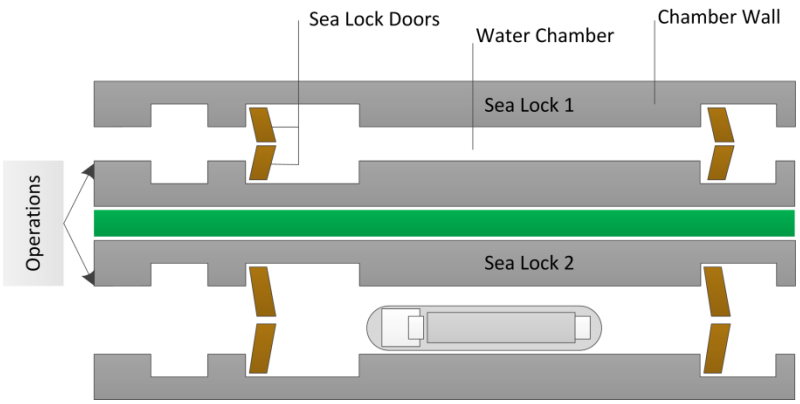


Figure 20 Main components of the sea lock complex

When readings of one or combinations of parameters show that there is a loss of functionality or the safety is compromised, procedures could indicate that various maintenance activities should take place. This could mean temporary closing of the locks. The (partial) loss of functionality or safety can be as a result of uncontrollable events such as storms or other weather related situations, or incidents such as vessel collisions with the sea-lock doors or walls. Maintenance activities can then for example be:

- Replacing, reinforcing or repainting the sea lock doors
- Replacing or maintaining the hydraulic system to open/close the doors
- Painting, replacing or reinforcing the walls
- Fixing, replacing or reinforcing cables, updating software systems or other communications systems

Functional systems-overview of the sea locks

The main function of the sea-locks is the facilitation of a safe transit for both commercial and recreational maritime vessels. However, as figure 21 shows, there are some other indirect functions in other disciplines that the sea lock has.

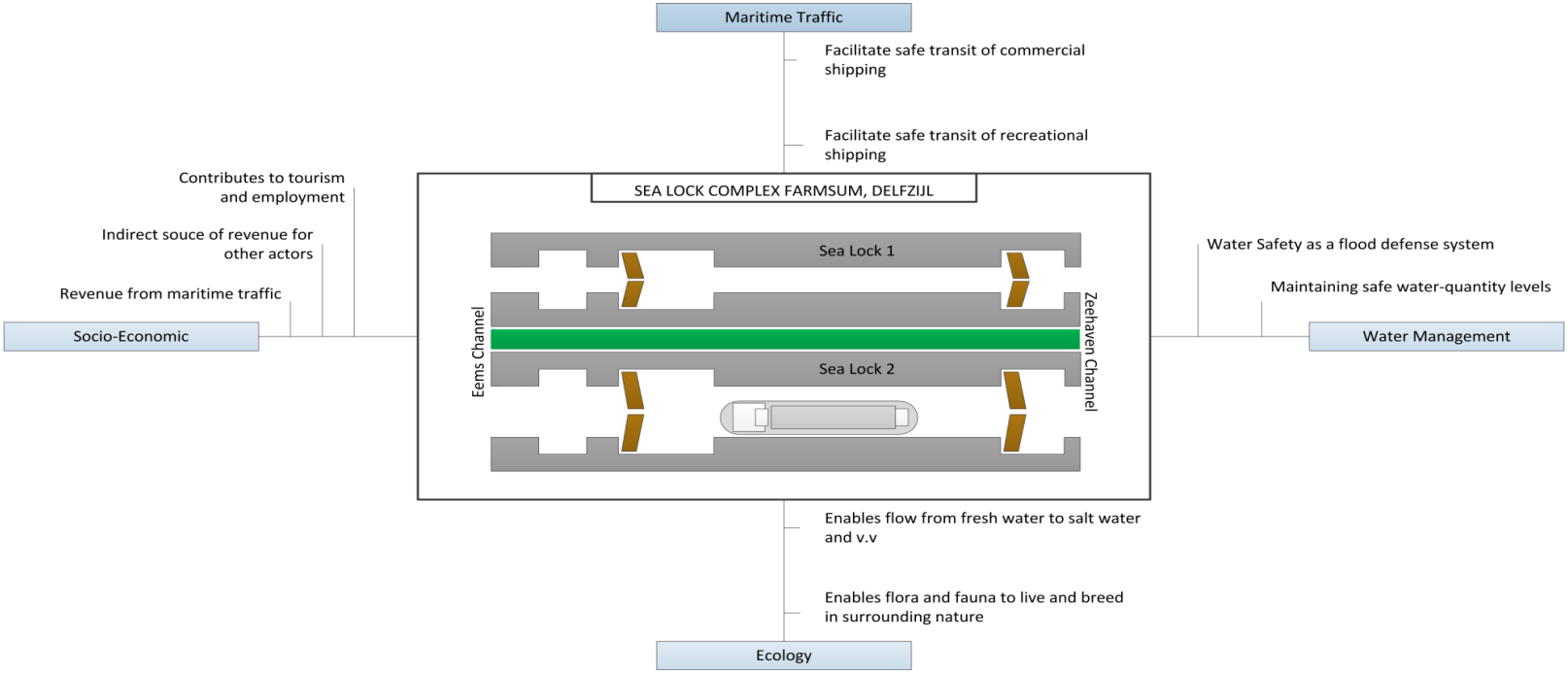


Figure 21 Functional system overview

- Its direct function, is, as was said the facilitation of a safe transit for both commercial and recreational vessels. To perform this function, technical components of the asset have to be in safe operational condition: sea lock doors have to be able to open and close mechanically. Signals to open and close are given through ICT systems, thus these also have to be operational.
- The sea lock has an indirect function for the economy of not only the municipality, but also the region and even for other countries, in particular Germany. Through the operation of its direct function, vessels are able to load and offload goods at the different docks located in the region. Passing through the locks also requires shippers to pay fees, generating additional

revenue, both for recreational as well as commercial ships. Furthermore, the asset, again through its main function enables the companies in the region to increase their economic activity in turn increasing employment opportunities. This creation of jobs also helps to prevent the demographic shrink that is currently occurring in the municipality of Delfzijl.

- The surrounding nature is also being influenced indirectly by the sea locks direct function. The continuous opening and closing of the doors enables fresh water to flow out to sea and salt water into the channel. This can enable specific type of flora and fauna to live and breed in these type of waters, as well as migrate from one water system to the other.
- When water levels are high in the inland, the sea lock is being used as an additional system to sluice this surplus water back to sea. The asset is also a secondary water defence system. High water from sea can for example be prevented to enter the inland by closing the outer sea lock doors.

Step 2: Factors that influence maintenance activities of the asset

There are a number of factors related to the above shown functions of the sea locks that can potentially have an influence on the planning of the maintenance activities. Some of these can be:

- Water levels of both the Eems channel and the Zeehaven channel. Planning maintenance in times of high water levels could for example be risky and thus certain water management aspects should be taken into account.
- Maritime traffic numbers: considerable high numbers of maritime traffic or recreational traffic in specific periods (e.g. summer) are for example not ideal to plan maintenance activities, as they can limit the main functionality of the sea lock
- Maritime traffic safety: planning or performing activities while the safety of vessels transiting is compromised is not acceptable. Sound trade-offs need to be made for relatively simple maintenance activities such as software updates
- Breeding periods of animals or other nature. Just as shipping, certain periods (e.g. migration of fish species) should be taken into account when plans are made

Step 3: Functions of the asset that are being influenced by maintenance

On the other hand, there are functions that can be influenced by maintenance activities. These are mostly related to the above factors.

- Safe commercial and recreational shipping transit accommodation: without the asset, vessels would not be able to travel from the inland to sea and vice versa. Downtime of the asset, as a result of maintenance, can thus have a high influence on maritime traffic and indirectly on the economy (goods that are being shipped). Maritime traffic can also queue up when the sea lock is not operational, increasing the chance of vessel collisions

- Water Management (water level, water quantity and water safety). This water management related aspect (under the responsibilities of other actors) is influenced by potential downtime as a result of maintenance. Excess water could for example not be sluiced back into sea. Downtime can also deter the function of the asset in case of high sea level: it can for example not be closed to serve its indirect function of water safety
- Ecology. Opening and closing the sea locks result in the inflow and outflow of different type of water (from sea to inland and vice versa). Also for this factor, downtime as a result of maintenance can have an influence on the flora and fauna, especially if this downtime is lengthy, affecting total populations of flora and fauna.

Step 4: Actors involved in step 2 and step 3

Step 4 dictates that the actors involved in the previous 2 steps should be identified. These are shown, with the respective functions and factors they are involved with in figure 22. Putting these actors in relations with each other, if applicable is done through a formal chart, which is seen in figure 23.

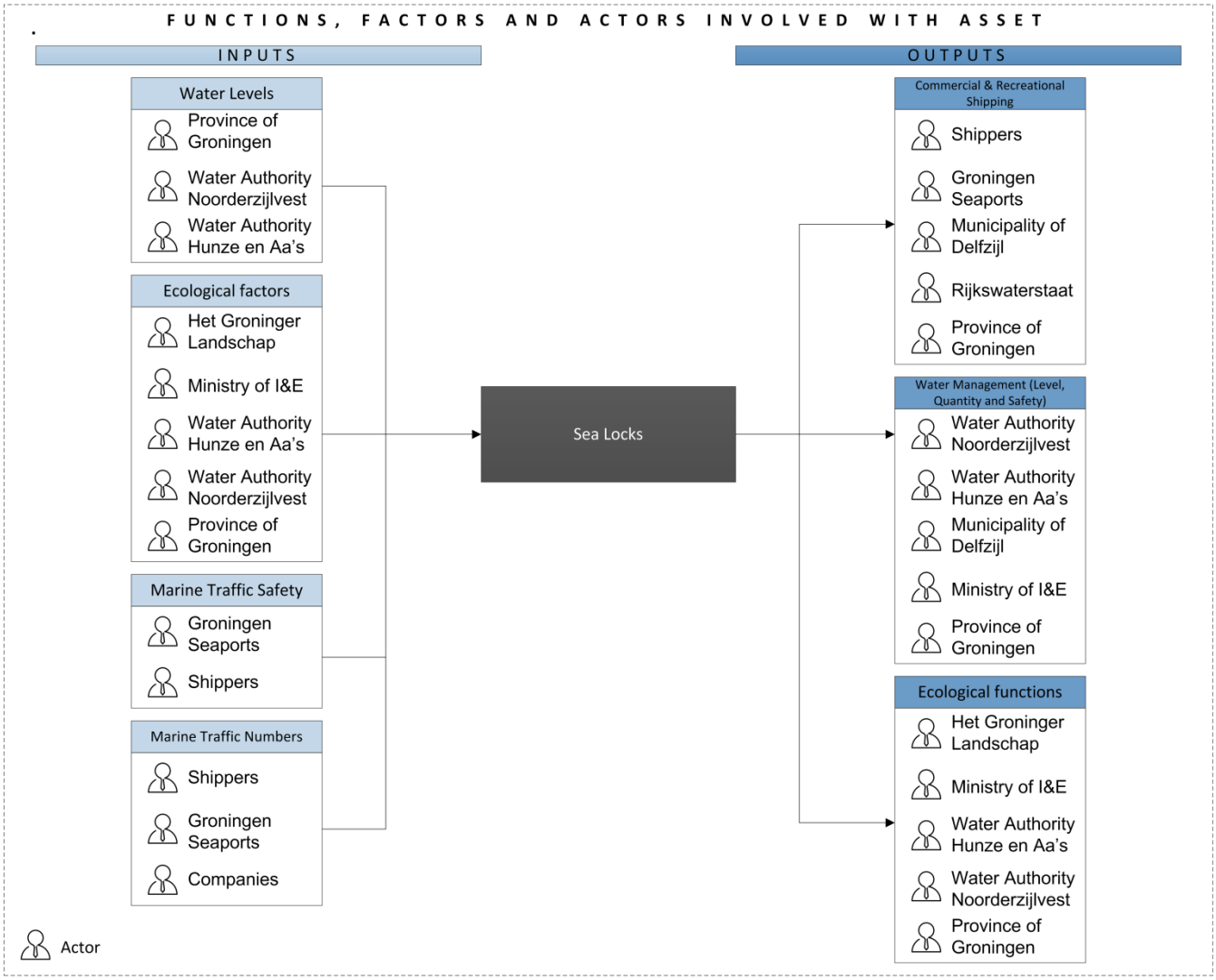


Figure 22 Actors involved with the various factors and functions

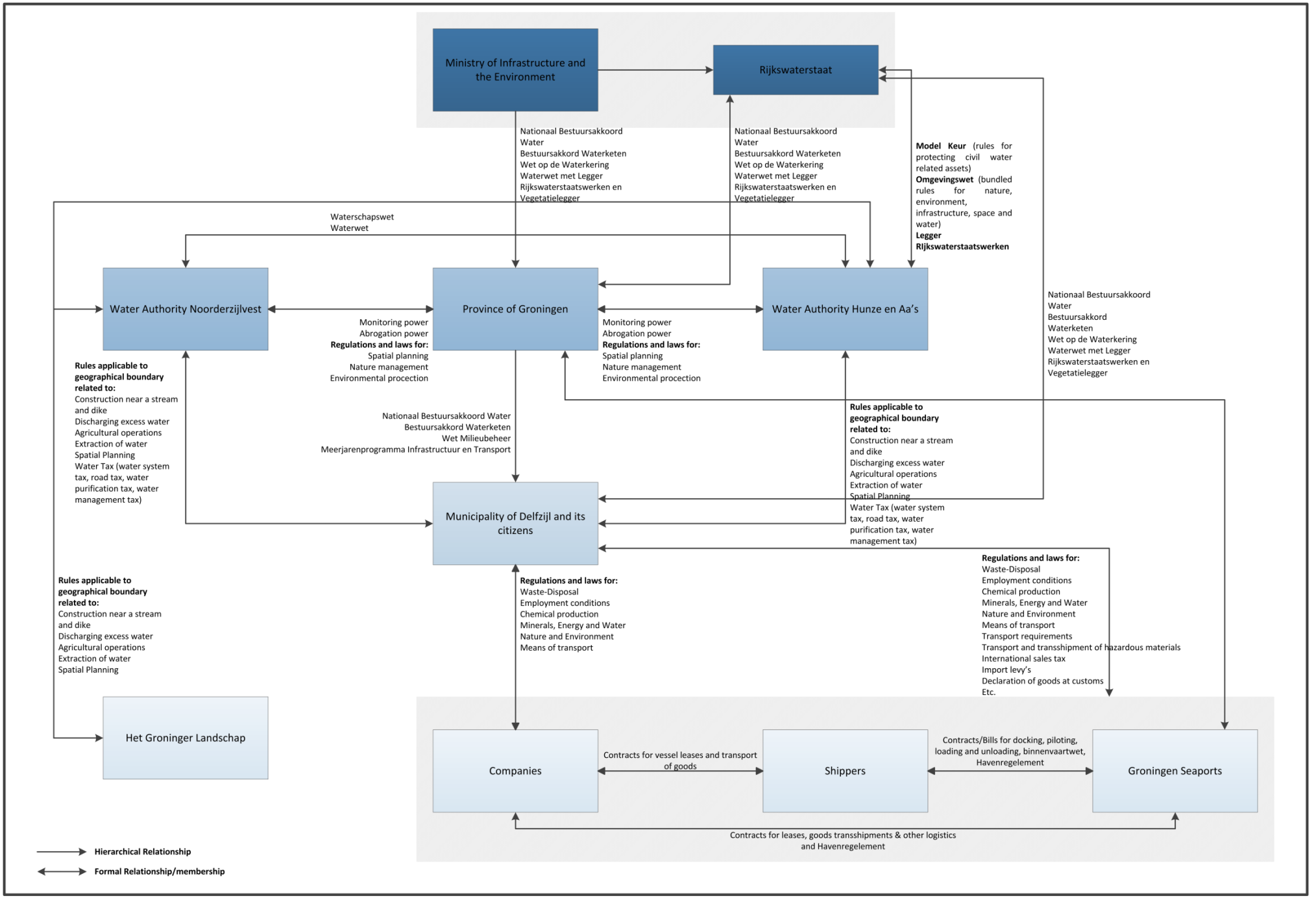


Figure 23 Formal Chart of actors

This chart shows what type of laws, legislations or policies actors are dealing with in their interaction with each other. These are not only shown in the context of the maintenance of the sea locks, but a wider system view is taken, because it could well be possible that this can lead to information required by some of these actors. For example: in their relationship with the municipality and the citizens the water authorities have also strict regulations regarding the discharge of excess water by citizens or companies. This in turn can have an effect on the water quantity and water level in the municipality, requiring the water authority to request for additional sluicing capacity to get rid of the excess water. This capacity can then be provided by the sea locks. For more in-depth information, see appendix 5.

5.1.3 Sea Locks information needs

Step 5: Information flows between actors

Based on the formal relations of the actors and their influence in the factors and functions the type of information (on a global level) that flows between these actors can be determined.

The information needs analysis is not only a result of (in)formal talks with experts, literature study and desk research. Additional information gained through the interviews have for example also contributed in the insights that were necessary to draw the information needs overview (figure 24). Both the flow and type of information between actors is provided, as well as their core values.

The figure is constructed with the goal to specifically identify who needs what type of information in order to pinpoint which actor(s) information is needed to manage and maintain the asset. This general overview also aims to show key aspects that require further understanding. Apart from information subjected to sharing, the in-house information of the asset-owner and manager (Rijkswaterstaat) is also shown. Actors are the same as identified in the previous step, except that the 2 water authorities as well as the shippers and companies have been combined, as these groups mainly have the same interests (extensive elaboration on actors interests and objectives is provided in appendix 5).

INFORMATION-NEEDS BETWEEN ORGANIZATIONS

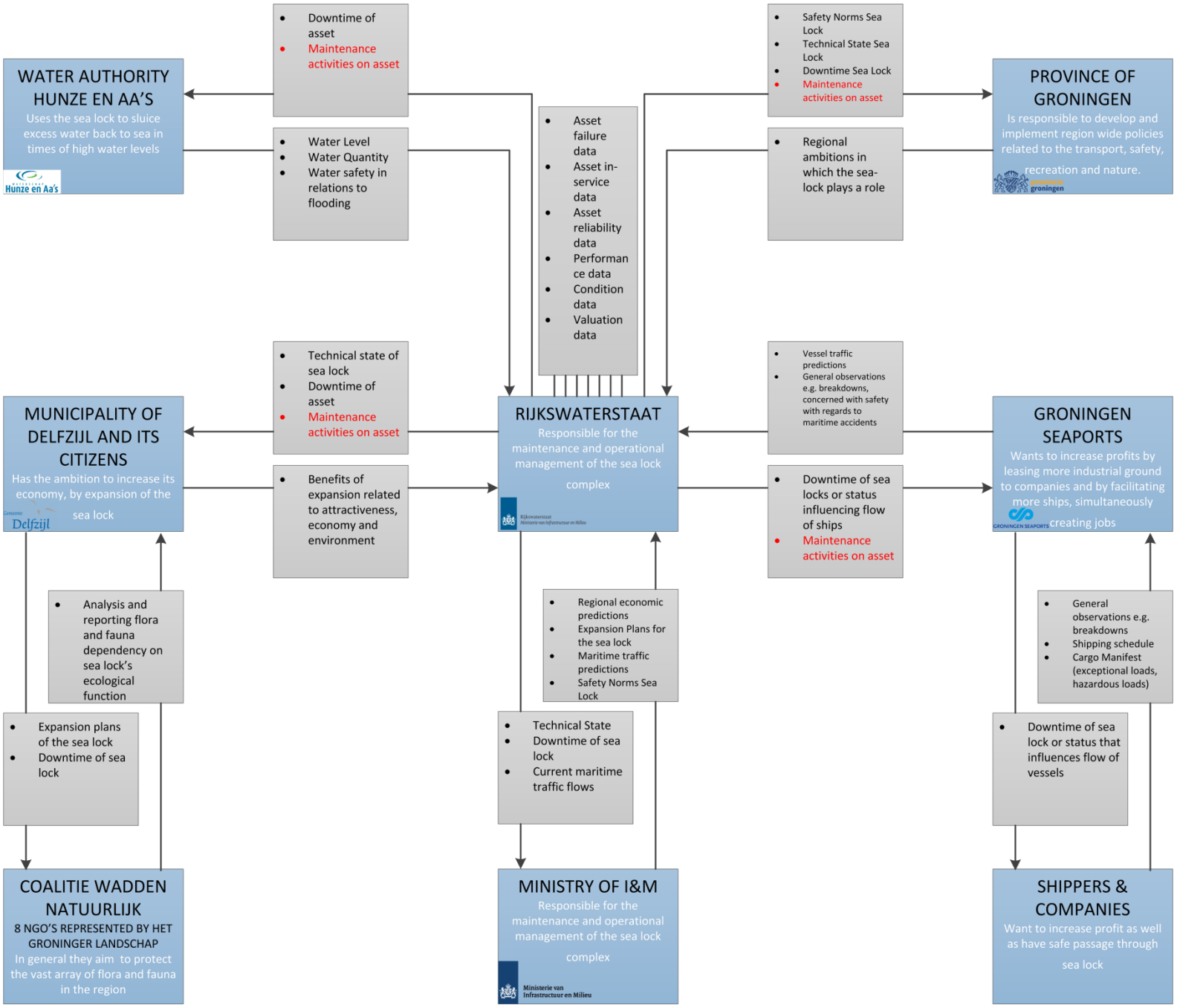


Figure 24 Information needs

Focus of the case-study research

The analysis shows the following: there is indeed sharing of information required between a number of organizations that could be influential to manage and maintain the sea lock. As was said earlier, the management and maintenance is done by Rijkswaterstaat, so in an ideal situation they would not have to check or interact with other organizations, but in the systems perspective of ROBAMCI, they must take into account other functions and factors of the asset. They have to provide information to other actors regarding for example downtime of the asset as a result of operational failure, but other actors must also provide Rijkswaterstaat with information, such as Groningen Seaports whom supplies the actual and updated traffic predictions, such that Rijkswaterstaat can plan its operational activities.

The analysis however, does not give insights in the following aspects, and thus these require further research and understanding:

- If this information is actually being shared, and if not, why?
- If the actors are aware that they need information of other organizations
- What the added benefits can be for the system, if the information exchange takes place
- What internal and external factors potentially influence this inter-organizational information sharing.

Even though there is other exchange of information between some of these actors, this does not directly influences Rijkswaterstaat's asset management plans for the sea locks. For this case-study it is therefore sufficient to interview employees of the following actors:

- Rijkswaterstaat, which is the direct representative of the Min istry of Infrastructure and the Environment
- Groningen Seaports
- Municipality of Delfzijl
- Province of Groningen
- Water Authority Hunze en Aa's

In-Depth Interviews

In-depth interviews are conducted with employees of the identified organizations (see appendix 6 for details of interviewees), to try and address the points that this analysis did not provide. The questions and statements shown in the case-study methodology (chapter 4) are used for guidance.

Text Box 6 Interview Respondents

Interview respondents

Apart from the organizations and their respective employees that have been identified as a result of the case-analysis (see the list on the left), opportunity was also provided to conduct an interview with an organization not involved in this case-study: Stedin, a regional distribution network operator of gas and electricity in the Netherlands. A representative of the organization De Laar, who was intermediating the project on behalf of the municipality of Delfzijl was also interviewed.

Stedin is also a maintenance manager of another critical infrastructure, even though this is not in the ground, road and water sector. However, it is obvious that without the electricity grid and gas infrastructure, societies would not be able to function. Furthermore, Stedin also increasingly applies risk based asset management strategies to manage and maintain their infrastructures (Mehairjan, Zhuang, Djairam, & Smit, 2015).

Gathering top-down insights from the "intermediary" can also result in significant results for this research. It is expected that this person is actively involved in either facilitating or encouraging information sharing in the process.

5.2 System insights and ranking of factors

This paragraph showcases the results of the interviews conducted with employees of organizations that were identified in the previous paragraph. The interview scripts are attached separately to this report in a confidential appendix (7). In the first subparagraph some additional insights gained from respondents related to the system and information needs analysis are presented (5.2.1). Subparagraph 5.2.2 quantitatively ranks the factors mentioned during the interviews.

5.2.1 Inter-organizational information sharing situation in practice

Conform the case-study approach in paragraph 4.4, the inter-organizational information sharing situation in practice is first determined, after which possible differences and complications will be interpreted through the analytical lens, Yang and Maxwell's revised framework. The 1st question of the interviews focused on the situation in practice. For the most parts, the analysis had correctly portrayed the situation in practice. Some additional insights and recommendations were given by some respondents. These included the following, and have already been included in figure 24.

- Stakeholder Het Groninger Landschap is not only representing itself, but also 7 other environmental organizations. They are grouped under the name Coalitie Wadden Natuurlijk. One interviewee stated: *"Het Groninger Landschap, being the representative of 7 other organizations as well its self, now has other interests to serve, this changes the information that they share with other actors. They now also have a stronger basis with the Nature Environment law".* Gil-Garcia showed that the institutional setting in which an actor operators can for example also strengthen their legal position (Gil-Garcia et al., 2005).
- Water safety can be interpreted in two ways: water authority Hunze en Aa's is more concerned with water safety from the perspective of floods, while Groningen Seaports is more concerned with safety for the various maritime activities.
- Some other small insights:
    - Water Authority Noorderzijlvest could be disregarded, as their influence as a result of geographical operational boundaries is limited.
    - The analysis in first instance also included citizen groups, however in practice these were not represented adequately. One interviewee stated "*that this is a valuable insight, and in the future this group should be included in the process"*
    - Possibly including some sort of time dimension in the analysis, because as will be shown in the upcoming chapters, timing of information sharing is a frequent appearing factor.

Figure 24 had also shown where potential problems lied, see the red coloured text in the figure and an example in box 7. These insights, together with knowledge gained from literature and the analytical lens provide a stepping stone to more thoroughly understand the factors that influence information sharing in practice.

5.2.2 Ranking of factors influencing inter-organizational information sharing

Most of the mentioned factors were, after coding, interpretable through one of the many factors identified by Yang and Maxwell. Akbulut's, as well as Gil-Garcia et al.'s frameworks were used to interpret 2 factors ("backing of management" , "top management support" and "external influences respectively). Furthermore, there were 5 factors not appearing in the studied literature. 3 of these factors were however fitting to be part of existing categories: role of organization and physical interactions (category organization) and concerns of not being acknowledged (category uncertainties). Timing of sharing information was also mentioned, this can be adhered to inter-organizational information sharing in Yang and Maxwell's information sharing framework. The coding process (further details in appendix 8) has thus added a total of 6 factors on top of the 27 factors already identified in the slightly revised framework of Yang and Maxwell. In figure 25 it can be seen how the mentioned factors are ranked.

Text Box 7 Replacement of the sea lock doors

Replacement of the Sea Lock Doors

An interesting topic that many interviewees found to be a perfect example of where sharing of information was needed, but did not happen or did not happen on time was the replacement of the sea lock doors. This corresponds to the system analysis, which showed that this is a possible maintenance activity. These maintenance works were however not communicated on time and via proper channels, leaving many actors perplex and having to deal rapidly with this new information.

This however has consequences regarding the system wide analysis that is central in the ROBAMCI context, especially because with the replacement of sea lock doors, the technical life-span of the asset increased by a significant 20 years. This extension of an assets technical lifespan, is as already shown one of the primary uses of asset management in the management and maintenance of critical infrastructures (Cagle, 2003).

A definitive reason why this information was not shared, or shared late could not be provided by the organization responsible for the maintenance activities. The comment was that *"this asset being a physical object, thus it can be seen that these maintenance works taken place".*

However, as was shown by both the literature review as well as the interviews, geographical distance is sometimes also a factor influencing the information sharing processes: Delfzijl, the municipality in which the asset is located, is considerably further away than for example the offices where the decisions take place, therefore it is not as easy "to see maintenance works taking place", and the information should have been communicated on time through proper channels.

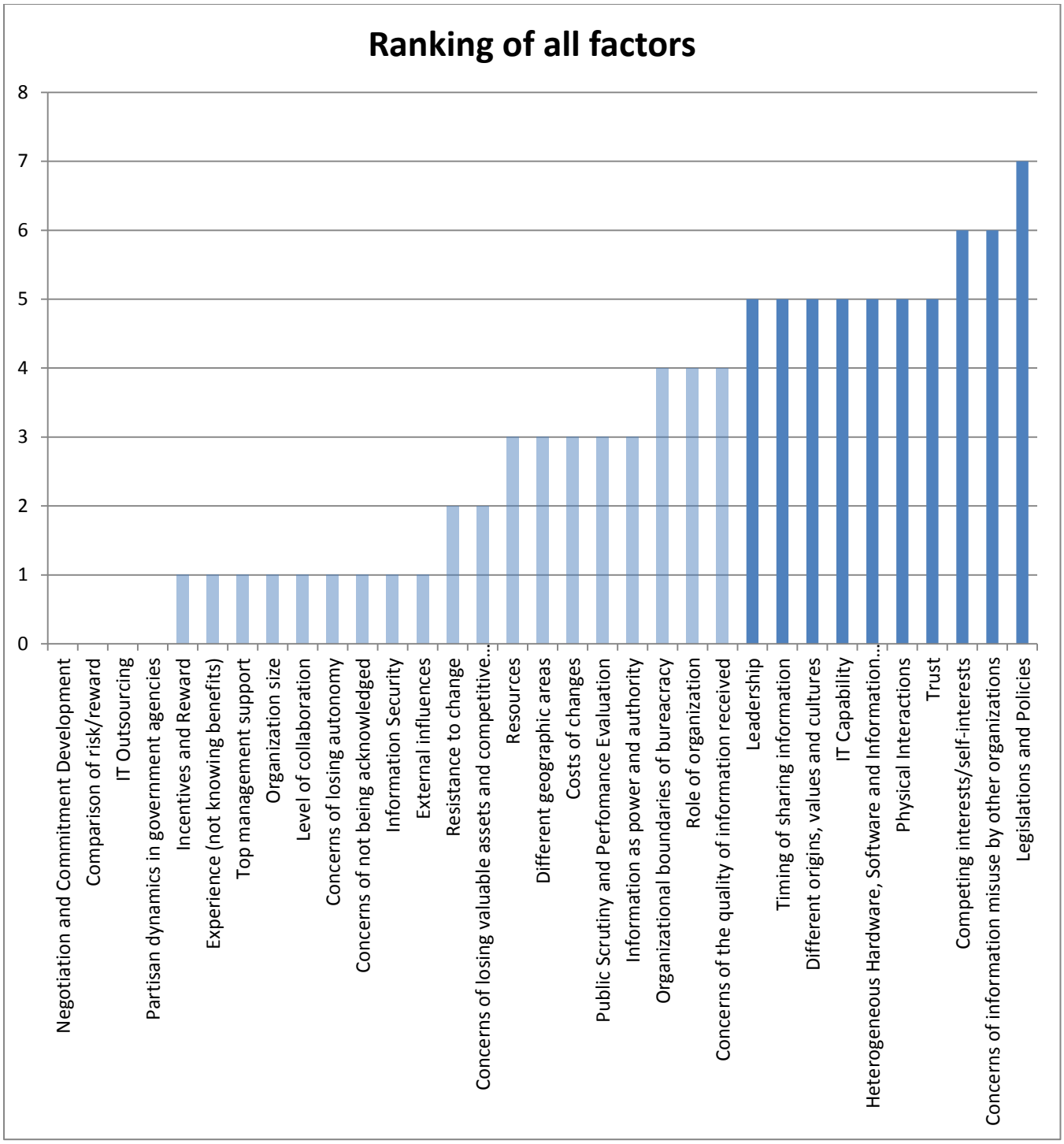


Figure 25 Bar chart showing the ranking of the mentioned factors

From the slightly revised framework of Yang and Maxwell, the following 4 factors were not mentioned: negotiation and commitment development, comparison of risk and reward, IT outsourcing and partisan dynamics in government institutions. The rest of the factors were all mentioned at least 1 time or more. This simple counting of factors does however not tell much

in terms of the factors influences, but gives a primary indication as to which factors are seen as important. As it is not practical to elaborate in detail on all the factors, a threshold is used. Factors that are mentioned 5 times or more (dark blue bars in figure 25) are discussed in the next subparagraphs. Even within the factors that are considered as a result of the threshold, further distinctions could be made. Interviewees have for example paid more attention to some factors than other ones. Therefore the factors that have been mentioned more than 5 times are sometimes discussed in relation with some of the other factors. Apart from the elaboration, some factors/causal relations are sketched between factors. Examples and some quotes from the interviewees are gives, as well the interpretation through theory .

5.3 Interpretation of case-results through theory

Researching potential relationships between these factors has been identified by Yang and Maxwell as an important area for further research (Yang & Maxwell, 2011). Interviewees have more than often mentioned some interesting relations between factors and the information sharing levels. An overview of all the relations that have been mentioned during the interviews is found in tab 22 of appendix 8. Not all the relations have been elaborated on by interviewees, therefore this paragraph pays attention to some of the relations that were more central during the interviews. Relations between trust, legislations & policies and competing interests/self-interests, as well as their relations with other factors are discussed in the first 2 sub-paragraph. In sub-paragraph 5.3.3 the interrelation between information sharing levels is discussed. Apart from these insightful relations, some other case results were also worth mentioning. Three of these are therefore also shown in the last sub paragraph (5.3.4).

It should be noted that these analysis are not based on statistical analysis: to say for sure that there are causal links, more data would be needed, and thorough statistical analysis should be done. It is however a first step into the research area that requires further studies and understanding within the concept of inter-organizational information sharing.

5.3.1 The role of trust and legislations & policies in inter-organizational information sharing

Five out of seven interviewees spoke about trust as if this was one of the essential building blocks that facilitate information sharing. *“If you cannot look each other in the eye trustfully, we will also not reach a deal”*, one interviewee stated. This is the case for both the organization sharing information, as the organization receiving information. During the interviews it was made clear that an optimal level of trust between organizations is one of the, if not, the first box that has to be ticked off in order to start an information sharing process. Building and maintaining a trustworthy relationship can sometimes cost time and resources. It is further dependent on many other personal characteristics of the representatives of the organizations involved, making it a rather complex factor to deal with. Respondents further point out that if there is trust between organizations, there is less concern about the quality of information, as well as the misuse of information.

Trust in the setting of information sharing is extensively studied in the literature. Trust has a direct effect on efficiency or level of information sharing (Abrams, Cross, Lesser, & Levin, 2003; Ardichvili, Page, & Wentling, 2002; Willem & Buelens, 2007; Zhang & Dawes, 2006). In the context of critical infrastructures with many social and economic interfaces, organizations can deal with sensitive information, making trust indeed one of the important factors for these actors to share or not share information. The way and manner trust is perceived is obviously dependent on the setting in which it is required: this could be related to the factor different origins, values and cultures. Trust is also related to other factors within the framework, shown in literature but also through the findings of the interviews.

Factor/Causal relations from interviews

Trust and inter-organizational information sharing

Text Box 8 Professional Relationships

Professional Relationship

A professional relationship between the organizations, apart from trust can work both ways when sharing information. Apart from this, this professional relationship must be maintained: *"doing something without expecting anything back can sometimes pay off in the future",* as one of the interviewees stated.

The existence of trust between organizations facilitates information sharing. This can be clearly induced from the interviews talks, as well as the data. This positive causal relationship has also been shown in the literature (Abrams et al., 2003; Ardichvili et al., 2002; Willem & Buelens, 2007; Zhang & Dawes, 2006). However, trust-building first requires the existence of a professional relationship between employees of organizations. *"Not only should this relationship exist, it should also be maintained"*, were words of 1 interviewee. Literature has also argued that having a professional relationship helps in facilitating trust building. Following causal relation is then sketched (figure 26), in which professional relationships influence trust positively/negatively (vice-versa), and trust in turn positively/negatively influence information sharing.

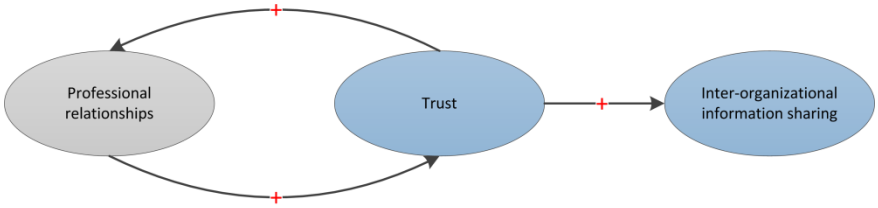


Figure 26 Trust and Inter-organizational information sharing

Trust and concerns of information misuse

"ROBAMCI deals with critical infrastructures, and the information can certainly be used in a negative way. Trust between organizations helps to counter this fear", one respondent showed. Research shows that the level of trust decreases if organizations are afraid of

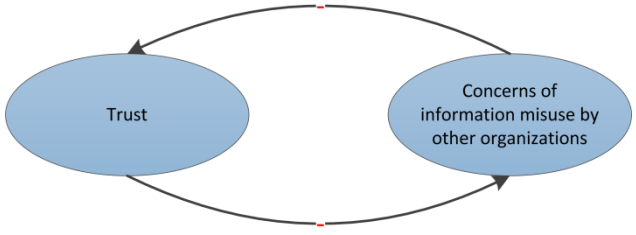


Figure 27 Trust and Concerns of Information Misuse

information misuse (Chau, Atabakhsh, Zeng, & Chen, 2001) . The higher the concern for misuse, the lower the level of trust, and vice versa. Another interviewee stated: *"information is always within a certain context, you must explain this context, otherwise the information can be used for other unintended purposes"*. The relation is therefore negative: a higher level of trust leads to a lower concern of information misuse by other organizations. The misuse of information can not only have legal consequences for the organizations involved in sharing, but in this particular case-study, asset information from critical infrastructures can for example be negatively used, resulting in devastating effects for society and economy On the other hand it can also be argued though that a low level of trust increases the concern of information misuse, hence figure 27.

Legislations & policies through trust and inter-organizational information sharing

A survey by Dawes, provided to 173 public managers had already illustrated the need for legislative frameworks that should anchor inter-organizational information sharing processes (S. Dawes, 1996). In the public sector legislations and policies can have severe impacts on the information sharing across agencies as many authors show (S. Dawes, 1996; Landsbergen & Wolken, 2001; Zhang & Dawes, 2006). During the interviews the transparency principle was twice referred to: *"As governmental organizations in the public sector we are obliged to be transparent with information and information sharing, under the Wet Openbaarheid van Bestuur",* the 2 respondents stated. ROBAMCI operates in the public sector, and these legislations and policies also apply for this project and its users. External influences from for example politicians with certain political agendas can also affect the sharing of information of certain governmental institutions, another respondent showed, also shown by Gil-Garcia in literature (Gil-Garcia et al., 2005).

Literature shows that there is an indirect link between trust and legislations and policies. Yang and Maxwell argue that through trust, legislations and policies can influence information sharing. The data set also shows this relation. Legislations and policies can increase trust building, but on the other hand it can also impede information sharing, as a result of certain legislations which prevent or hinder information sharing. As a result of this double relation, there is no clear causal relation (figure 28). However, the importance of these 2 factors together was clearly shown by one interviewee, who stated that: *"an ideal situation for information sharing is to have a trustworthy relationship with the organization that shares/receives the information, as well as having a sound and correct legal basis, often in the form of contracts".*

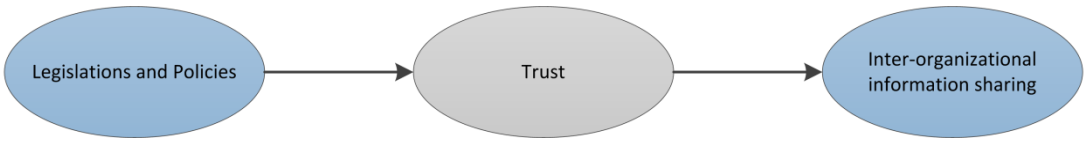


Figure 28 Legislations & Policies and Inter-organizational information sharing

Trust and concerns of the quality of information received

Organizations are concerned with the quality of received information: *"shared information must be based on for example scientific research"*, a respondent stated. Another respondent for example had his *"concerns of the quality of the results from the Social Cost Benefit Analysis conducted for this expansion of the sea lock*".

One interviewee provided a relation between this factor and trust: *"A trustworthy relationship between organizations, takes away concerns of the quality of the information. It also enables us to work together and take away potential differences in the case of not correctly understanding the information"*. This indicates a negative causal relationship between trust and concerns of quality of the received information (figure 29). The higher the trust between organizations, the less concern regarding the quality of information received.

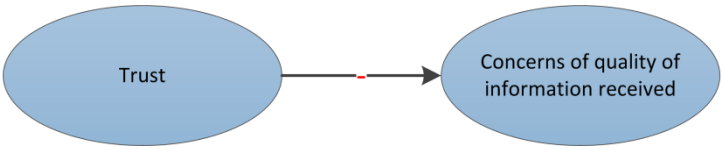


Figure 29 Trust and Concerns of quality of information received

5.3.2 Competing interests/Self-interests and inter-organizational information sharing

Representatives of the organizations responsible for the management and maintenance plans of the sea locks stated that in general interests of other actors in the asset are taken into account: this will however occur when there is evidence that the main function of the sea-locks (facilitating maritime traffic) requires adjustments. Another interviewee mentioned that in *"the case of administrative situations"* it is more likely that competing interests/self-interests will have a prominent role. This is of a lesser extent when information is for example shared in the context of a research project. Even in the public sector organizations can have competing interests. However, 1 respondent *showed "that as a result of the legislative framework the government operates in, information will have to be made public in the long run".* These competing interests or self-interests can severely impact the level of information sharing (Akbulut, Kelle, Pawlowski, Schneider, & Looney, 2009; Chau et al., 2001; S. Dawes, 1996) . Placing this finding in the perspective of the asset management of the sea lock it can make sense: not all the actors have the same interests, as was seen in the actor-analysis (appendix 5). Rijkswaterstaat for example does not have the same interests as the province of Groningen. The latter actor has several economic, environmental and transport related ambitions for the region, while Rijkswaterstaat is

Text Box 9 Commercial Interests

Commercial Interests

Even though public organizations have less commercial interests, this factor most definitely affects the sharing of information. Many interviewees state that in the case of commercial interests, for example the sale of a property, the commercial territory of an organization or the establishment of a new company, information sharing between organizations is often limited. An interesting example was given: Google bought a lot in operational boundary of Groningen Seaports to set up a new data center. During the preliminary talks, no one, not even the province and the municipality had the information that the company interested in the lot was Google. This was due to high commercial interests and the companies edge over its competitors

concerned with the safety and operational status of the asset, mostly with regards to its function for maritime traffic.

Factor/Causal relations from interviews

Competing interests/self-interests, trust and information sharing

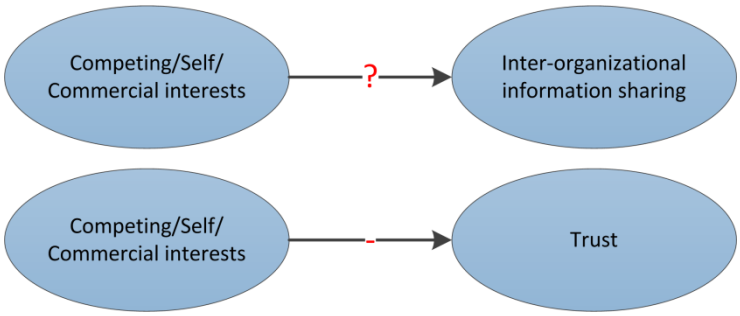


Figure 30 Competing Interests/Self-Interests, trust and Inter-organizational information sharing

It is clear from literature that information sharing is impacted when organizations have competing interests, or one of the organizations acts out of self-interest (Constant et al., 1994). However, the nature of this relation is difficult to classify: on one hand the information sharing activities can decrease, on the other hand, an organization can also increasingly share information out of self-interests, to for example mislead the recipient of the information (figure 30). Literature argues that it is important that managers within organizations actively promote and understand the benefits of inter-agency information sharing, as it is almost inevitable that there are competing interests between participating organizations, which will then not only affect the information sharing process, but also potentially the quality of the information received (Fedorowicz, Gogan, & Williams, 2007; S. Li & Lin, 2006). Literature also shows that through the existence of a trustworthy professional relationships between organizations conflicting interests can be minimized. This enables organizations to optimally benefit from inter-organizational information sharing (Cheng, Yeh, & Tu, 2008). If one organization for example knows that the other organization has shared information that is a result of their self-interests, it could potentially also have an impact on the mutual trust between these organizations. A recent example is the mutual distrust between managers of KLM and Air France: these individuals have a low level of trust in each other, as they accuse their counterparts of self-interests (NU.nl, 2017).

Although these relations are not mentioned by the interviewees, when looking at the factors in the framework, it can further be argued that competing interests/self-interests can then also lead to influences on the level of collaboration between organizations (Fukuyama, 2000), again through trust, or on the concerns of the quality of information received and concerns of losing competitive advantage or valuable assets.

5.3.3 Relations between information sharing levels

The case-study clearly illustrated the existence of an interrelation between the different levels of information sharing, inter-personal, intra-organizational and inter-organizational. This was also shown by Yang and Maxwell in their literature review: the different levels of information sharing

are embedded in each other (Yang & Maxwell, 2011). 5 out of the 7 respondents explicitly mentioned at least one of the 2 levels not in the context of this study. Interviewees made it known that in order to efficiently and effectively transfer information to the outside, they should be first able to do that within their own organization without problems. Trust between departments within an organization and physical interactions between employees of different departments of 1 organization were intra-organizational examples. Management encouragement, as well as the existence of physical interactions within a department were inter-personal examples.

These are all valid arguments, because it is completely logical that information shared between organizations, must further find its way to the right department, triggering intra-organizational information sharing, Within that department, the information must then be shared with the right person, at last triggering the context of inter-personal information sharing. However, taking into account all the levels is often not done, leading to for example information loss down the road. This was illustrated with an example by one respondent: *"even though our organization was involved in the ROBAMCI project for this sea lock, this information reached my department too late, possibly limiting our contribution in the project, leading to the fact that our interests have possibly not be taken into account sufficiently".*

Even though the 2 more embedded levels of information sharing were out of the scope of this study, they are still seen as a stepping stone to inter-organizational information sharing and should be taken into account. Yang and Maxwell also made clear that all three are needed in an ideal information sharing environment (Yang & Maxwell, 2011).

5.3.4 Other case-study outcomes

Apart from the insights in the previous paragraph there were also some other interesting research results, some of which are not explicitly based on the ranking of the factors.

Inter-organizational information sharing and decision making processes

The general agreement (5 interviewees out of 7) was that inter-organizational information sharing is beneficial for decision making processes. That was to be expected, as usually more information, that is, the right amount of high quality information on the right time, the better a decision can be substantiated. After all, information overload can lead to a gridlock in decision making processes. The positive influence of information sharing on decision making is conform the findings in the literature, as it is argued that inter-organizational information sharing at least improves efficiency and interoperability of

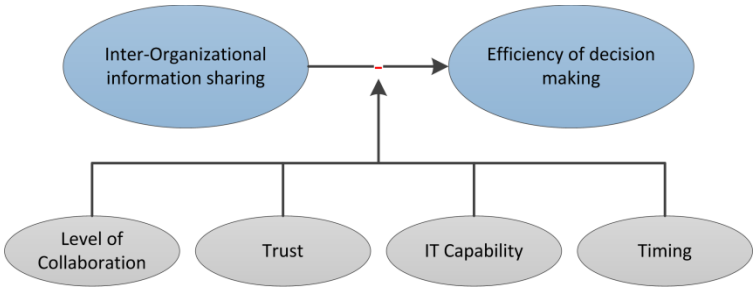


Figure 31 Inter-organizational information sharing and decision making

and within governments (Pardo et al., 2004). Research by Dawes also showed this positive influence of inter-agency information sharing on decision making, planning processes as well as policy development (S. Dawes, 1996).

However, this opens up relations with other factors. Sahin and Robinson argue that even in the case of full and correct information existence, decisions making does not have to be optimal, as organizations can act out of self-interests or competing interests (Sahin & Robinson, 2002). One respondent also stated that *" even in the case of no or sometimes less information that we would like to have had, decisions are still made"*. The right level of collaboration between organizations, their mutual trust, information technologies and the existence of heterogeneous hardware/software are all factors that could be of an influence (among many), in order to have the positive effect of information sharing on the decision making processes, making this relation not one-on-one (figure 31). Timing of shared information is also important, a factor frequently mentioned by interviewees. Inter-organizational information sharing through its effect on decision making can however also be a barrier. As a result of sharing information between public actors, there is a constant web of influence on the decision making process, which organizations have to take into account (S. Dawes, 1996).

The systematic perspective of the intermediary

At least 2 interviewees stated that the existence of an independent intermediary, in the form of a representative of organization De Laar (hired by the municipality of Delfzijl) benefitted the process of information sharing: *"Individual x did a good job of managing and facilitating the plenary sessions where multiple actors shared their insights".* Apart from the management, this particular individual also had to know where and when which type of information was required. The importance of such a "process manager" is extensively described by De Bruijn et al. , who identify this as one of the core elements of multi-actor oriented decision making processes. These authors argue that a good process manager should have knowledge about certain aspects, but on the other hand should be able to use this excessive knowledge, in order to not harm the process (De Bruijn, ten Heuvelhof, & in 't Veld, 2010). This intermediary could also retain a systematic perspective before and through the process. This was important, as 2 interviews showed that this is sometimes still lacking. An example from the case-study: *"there is a clear lack of systematic perspective in one of the organizations, this is a result of their culture, and this shows for example that they are much more reserved in sharing information"***.** This particular insight can for example have negative consequences for the ROBAMCI setting, as the core of the program is to have this "systematic perspective". This lack of systematic perspective at this particular organization could also be concluded from the following insight from the organization itself: "*"our organization is not concerned by for example tourism/recreation, for us it is important to maintain the primary functionality of the sea lock".* This is disturbing insight, as this organization is known to use the RBAM methodology for other assets (see Maeslandkering in chapter 1), and actively encourages organizations in the ground, road and water sector to also make use of this methodology (Van den Bogaard & Van Akkeren, 2011).

Different origins, values & cultures, leadership and resistance to change

Figure 32 Different origins, values and cultures and resistance to change

The lack of a systematic perspective within certain organizations already showed that this could be related to the factor different origins, values and cultures within organizations. An organizations culture was already shown to be an important aspect in risk based asset management (Harner, 2010). In most of the cases these values, origins and cultures have been embedded in the organization for some time, potentially hindering changes: often these old organizations with their embedded cultures and values are not open to changes (figure 32). This resistance to change was also identified as one of the barriers of risk based asset management (chapter 2) (Stillman, 2015). This is the core concept of change management. Introducing incentives, modification of formal structures and procedures by leaders (leadership) followed by continuous evaluation and monitoring are some of the "nudges" to initiate potential institutional change, as defined by the literature (Fernandez & Rainey, 2006; Kriege & Vlok, 2015).

Information Technology 'Paradox'

The frequent appearance of the factors heterogeneous hardware, software and information systems and IT capability are logical. Information is mostly shared via internet or intranet through different media such as email, clouds and even social media platforms, making personal interactions less necessary. Organizations are getting more and more dependent on the functioning of such critical IT infrastructures to share information mutually. Interviewees were not of opinion that these factors cause issues, and even if there is a sporadic case in which data is unreadable, this *"can be easily solved through some communication".*

Nevertheless, despite the dependence on IT the responses showed that having occasional personal meetings and/or informal talks (factor physical interactions) is definitely important for knowledge exchange: *"seeing each other often, opens up possibilities of sharing information between our different organizations"*, one respondent said. This does not necessarily have to do with trust building or a professional relationship. It is felt to be an important self-standing factor and this was illustrated perfectly during the plenary workshop where a legislator of the municipality of Delfzijl was absent. This individual had the ability to provide quality information regarding some questions from other organizations. "*This had a definite negative effect on the process"*, as one interviewee stated later. This factor is however not sufficiently discussed in literature within the context of inter-organizational information sharing. Barua et al., however have shown that there is more to information sharing than only information technology (Barua et al., 1997). This study however focuses on intra-organizational information sharing.

5.4 Discussion of the results

The research results showed that inter-organizational information sharing is mostly influenced by factors such as mutual trust, competing interests/self-interests from organizations and legislations and policies to which these organizations have to comply. Information sharing was studied in a specific context: it is a critical activity within the maintenance and management of assets of critical infrastructures, especially if governments want to maximally use the remaining technical lifespan of these infrastructures through innovative management methods. Previous research had also shown that information sharing is somewhat lacking in the current management and maintenance practices. Further understanding of information sharing was first needed in order to propose solutions to address this lack.

On the basis of the literature review (risk based asset management and information sharing) it was already expected that factors such as trust, competing interests/self-interests and legislations & policies would be important in this context. Other factors such as adequate IT Capability and leadership from management were also expected to be of an important influence. The introduction also showed the changing institutions in infrastructure management, leading to the outsourcing of activities (Coutard, 1999). IT outsourcing however was one of the factors that were not mentioned by respondents. It was however not expected that the factors concerns for information misuse by other organizations and different origins, values and cultures would be of such an importance. These 2 factors could also be related to each other: Hansen & Järvelin showed that uncertainties can occur due to misinterpretations by actors with different backgrounds (Hansen & Järvelin, 2005). The fact that organizations have a concern for information misuse can very well be one of the barriers for information sharing, leading to lack of information asymmetry and the inefficient decision making. That an organizations values and cultures has an influence on their operations is a given and trying to change this is also a known issue. These 2 factors in this case, form negative causal relations with information sharing. An interesting result was the importance of the factor “physical interactions”: even though in current times organizations (and people) tend to mostly communicate through different electronic media, it is still seen as an important factor to exchange knowledge, even on the level of inter-organizational.

Studied literature has however not sufficiently made mention of the importance of physical interactions for inter-organizational information sharing. It is probably implicitly linked to professional relationship and trust building, factors that are extensively studied in the existing information sharing literature. This is also the case for the other factors such as competing interest/self-interests and legislations & policies, be it in other contexts. There is not sufficient literature addressing inter-organizational information sharing in the specific context of risk based asset management. But this is important, especially when this method is used to manage and maintain complete infrastructures, a highly multi-actor environment with many interdependencies. This study can possibly create some support for the importance of information sharing in the context of risk based asset management, by linking these 2 concepts.

5.5 Conclusions of case-study

This chapter has presented the research findings, resulting from the case-analysis and the in-depth interviews. Coding rounds have helped to filter the factors through the analytical frameworks, resulting in the ranking of factors that have been mentioned the most by interviewees.

This chapter elaborated on some of important factors through examples from the case-study interviews and theoretical insights. The role of trust and legislations & policies as well as the influences of conflicting interests/self-interests are discussed. In light of these factors, some inductive relations between factors are presented, actively contributing to one of the scientific research gaps that were identified for the topic of information sharing. Furthermore, the case-study also showed evidence of the interrelation of information sharing levels. Lastly, this chapter also placed the results back in the context of the studied literature by providing a brief discussion.

The next chapter provides, based on the case-study results, two important general fundamentals that can help to further understand inter-organizational information sharing.

6 Fundamental principles for understanding inter-organizational information sharing

Based on the research results and their interpretation through theory 2 important aspects of inter-organizational information sharing are proposed (paragraphs 6.1 and 6.2). It is hoped that these fundamental insights can positively contribute to both research and practice in further understanding the concept of inter-organizational information sharing. These insights, together with the research results are also placed back in the context of ROBAMCI: their usefulness is shown in paragraph 6.3.

Although these insights are based on a research done in a specific engineering field, they have a very generic character. Through theory it is shown that these fundamentals do not specifically apply to the context of ROBAMCI and its sector. It can then cautiously be said that they can be applied in other settings, sectors and organizations.

6.1 Trustworthiness & Legislations

A trustworthy professional relationship anchored in a legal basis were mentioned to be the ideal combination to share information, as chapter 5 showed. Trust seems to be important in every sector. Literature also shows that this is the case for contexts beyond risk and opportunity based asset management. Liu and Chetal for example show the importance of trust between federal government agencies in the US (Liu & Chetal, 2005). Trust also plays a critical role in disaster management in for example the oil industry (Hassan Ibrahim & Allen, 2012). It is also related to many other factors: without trust, almost all the “concern factors” in the uncertainties category of Yang and Maxwell’s slightly revised framework are negatively influenced. Trust even plays an indirect role between legislations & policies and inter-organizational information sharing. These legislations and policies can however be sector specific and should always be taken into account, especially when the content to be shared is seen as sensitive and/or confidential. These 2 factors create an important context for information sharing: they not only stand apart, but are also related. Therefore they are proposed to be one of the first important foundations to be considered when trying to understand how inter-organizational information sharing must function.

A comparison of the studied inter-organizational frameworks in appendix 3, revealed that each of them pays attention to trust (Akbulut, 2003; Cresswell et al., 2004; Gil-Garcia et al., 2005). Gil-Garcia et al. show that according to participants in their study, the success of information sharing between organizations is very much dependent on trust building instead of for example the use of certain hardware and software (Gil-Garcia et al., 2005). However, Akbulut statistically

partly contradicts the importance of trust: further research shows that the hypotheses “trust improves electronic information sharing” is not supported (p=0.578, 95% confidence interval) (Akbulut, 2003). A possible explanation could be the fact that the hypotheses focuses on the “improvement” of information sharing and not the “facilitation” of information sharing.

The data also showed a relation between trust and the existence of professional relationships between organizations. This relation is also shown in various literature, and also re-appears in the studied frameworks: Cresswell et al. argue that, similar to the results of the case-study, not only the development, but also the maintenance of a professional relationship is critically dependent on trust (Cresswell et al., 2004). Akbulut also provides this exact finding, though in another study (Akbulut et al., 2009). Yang and Maxwell also show this in their literature review, as well as further linking the level of trust to the culture of the organization and concerns of autonomy loss (Yang & Maxwell, 2011).

The theoretical insight that trust is an important factor was also shown by the empirical data of the case-study, and as shown above also in various sources of literature. The data has also shown that there are multiple possible relations between the factor trust and other factors, making it one of the central elements facilitating information sharing.

Data also showed that legislations and policies are also important factors for information sharing, as organizations in the public sector have to take other principles such as transparency into account. In the Netherlands this legislation is anchored in the “wet openbaarheid van bestuur”, which regulates the information sharing for ministries, provinces, municipalities and other governmental bodies (“Wet openbaarheid van bestuur - BWBR0005252,” n.d.). Various authors show the importance of legislations in the public sector, and their influence on other factors (S. Dawes, 1996; Landsbergen & Wolken, 2001; Zhang & Dawes, 2006). Cresswell et al. and Akbulut explicitly state the importance of inter-organizational policies in their framework (Akbulut, 2003; Cresswell et al., 2004). On one hand the existence of such regulations facilitate professional relationships and trust building, on the other hand, lack of e.g. privacy legislations can negatively affect information sharing, in turn affecting transparency (Atabakhsh, Larson, Petersen, Violette, & Chen, 2004; Gil-Garcia & Pardo, 2005). Most actors involved in the management and maintenance of the sea lock (municipality of Delfzijl, Province of Groningen, Rijkswaterstaat, Water Authority Hunze en Aa’s) are public actors, and thus have to take into account transparency legislations.

Without mutual trust between organizations, as well as without the proper legal basis, information sharing is expected to be on a lower level than desired. These 2 factors do not cancel each other out: even though it seems simple to for example facilitate and promote a trust friendly environment between organizations, information sharing can still not take place as a result of legislations and policies. Although there are more factors and principles to consider, it is recommended to take the combination of these 2 factors as one of the first aspects when trying to understand inter-organizational information sharing.

6.2 Embeddedness of information sharing levels

That the information sharing levels introduced in this report (inter-personal, intra-organizational and inter-organizational) are related with each other was already shown in the literature review. Yang and Maxwell made it explicitly clear that the levels are interrelated with each other: inter-personal information sharing is needed for intra-organizational information sharing, and this in turn is needed for inter-organizational information sharing (Yang & Maxwell, 2011).

It was felt by the interviewees that in order to successfully share knowledge or information between organizations, it must first be successfully transferred within an organization itself. Literature shows that this is also the other way around: Yang and Maxwell argued that information that is shared between organization, must further finds its way to the right department within that organization (intra-organizational), and finally to the right person within that department (inter-personal).

Also by looking at the factors influencing information sharing this interrelation between levels is noticeable. Trust for example appears in literature and frameworks across all levels of information sharing and has its basis in inter-personal information sharing. For inter-personal information sharing, Abrams et al. show that this is a complex issue, as just simply providing time and space and more effective means of communication between employees does not increase their level of trust. This complexity is shown through the existence of two dimensions of trust: benevolence-based trust and competence based trust. Both these dimensions have been shown that not only they can have a positive influence on knowledge sharing, but they also, as was already established, promote the development of professional relationships (Abrams et al., 2003). For intra-organizational information sharing, Yang and Maxwell name trust as part of the second layer of their framework, which together with the other factors of this layer, can be influenced by the organization culture and structure (Yang & Maxwell, 2011). Several researchers say that a lack of trust results in reduced intra-organizational information sharing (Ardichvili et al., 2002; Willem & Buelens, 2007). This is the same for inter-organizational trust, as Gil-Garcia showed (Gil-Garcia et al., 2005).

Competing interests/self-interests is also a factor that is present in all three levels of information sharing. On the inter-personal level an individual can share or not share specific information based on their self-interests. Also on intra-organizational level this factor can present some social dilemmas, triggering conflicts between personal and collective interests (R. . Dawes, 1980). Departments sometimes also have to compete for budget allocations, and thus out of self-interests choose to share/not share specific information. Apart from the above organizational factors, there are also information technology related factors that find their way as an influential factor for all three levels to successfully share information.

Comprehending why some of the factors are so important for inter-organizational information sharing often asks to have some understanding of their role in the lower levels of information sharing. And as this embeddedness of levels and factors also surfaces from the data, showing its existence in practice, this is proposed as an important fundamental principle of inter-

organizational information sharing. Taking the other levels into account can actively contribute to explain certain influences or situations.

6.3 Usefulness of research insights for ROBAMCI

The above fundamentals could, as said earlier, be applicable to other sectors and environments. It is however also interesting to mention the meaning of the results and the fundamental principles for the ROBAMCI project, thus from general to specific. This is briefly done in this paragraph. The research has thus identified some important factors for organizations to consider when they are involved in sharing information related to the management and maintenance of assets of critical infrastructures. Effectively and efficiently maintaining the assets requires sound, qualitative information that is shared on time with organizations that require it. This information is shared within specific legal frameworks. Successful adoption of the RBAM methodology to maintain critical infrastructure sector-wide is very much dependent on this information sharing. This is a result of the large multi-actor environment and the continuous developments in this sector. Still, organizations need to have a trustworthy relation with each other, as research showed. Some of the important factors (trust, legislations and policies and competing/self-interests) were already shown to be of some importance during the literature review (chapter 3, subparagraph 3.1.5). But how bad/good is the level of trust between these organizations? And do the organizations involved in this sector and with this methodology actually have competing/self-interests, in turn influencing the level of information shared?

The results of this study can serve as the data for the follow up step in the ROBAMCI project: determining the current situation and level regarding the important factors within the organizations involved in this case-study or other case-studies. This, with the help of some of the shown relations, can analytically help to pinpoint where potential improvement areas are.

Such an analysis can be done through for example a maturity assessment. By employing this maturity concept the level of certain technological, cultural and social processes or factors is assessed. This enables the organization to determine how “mature” it is (based on 5 levels) on these factors or processes and thus to specifically identify on which factors the organization should focus. If such an analysis for example shows that a certain organization has a low maturity on its ability to develop and maintain trustful relationships with other organizations, it can then focus its improvements on these factors, in order to optimally benefit from information sharing practices.

Volker et al. have recently developed such a maturity model especially for infrastructure asset management (Volker, Lei, & Ligtvoet, 2011). This IM^3 (Infrastructure Management Maturity Matrix) could be a suitable basis for determining the current situation and level of the important identified factors within organizations: apart from also assessing the level of risk management, the model also pays explicit attention to information management and other dimensions such as culture, leadership and roles. The important factors identified by this research can then be used in this maturity analysis by for example focusing on the dimension of information management.

7 Conclusions & Recommendations

In this chapter the work is synthesized: in the first paragraph conclusions are drawn, followed by recommendations for further research and for the ROBAMCI project (paragraph 7.2). In the last paragraph, 7.3, various parts of this research are reflected on.

7.1 Conclusions

Gathering a deeper understanding of how information sharing in a multi-actor setting is influenced was the main goal of this research. This was done through both theory and practice by means of a case-study. The following research question was central:

"How is information sharing between actors involved in risk and opportunity based asset management decision making being influenced?

Following paragraphs first summarize the answers to some sub-questions:

Sub-question 1 focused on the *underlying concepts of risk and opportunity based asset management*. It is a very systematic oriented practice, taking into account various disciplines. The method has clear benefits, however, there are some challenges: people with various skills are needed and high quality information should not only be available, but also shared between departments and organizations.

In sub-question 2 the *theory of information sharing* was studied. Information sharing is classified in three interrelated levels (inter-personal, intra-organizational and inter-organizational). All three are being influenced by a vast array of factors. For ROBAMCI, the focus was set on the level of inter-organizational information sharing, due to its highly multi-actor and systematic environment. Studying and comparing existing frameworks has led to the use of a slightly revised framework that served as the analytical lens for the rest of the research.

Sub-question 3 focused on *inter-organizational information sharing in practice* through a case-study. The case-analysis identified the asset, its functions, the actors involved and the information subjected to sharing. In-depth interviews were conducted, data was coded and analyzed and results show that trust, competing interests/self-interests and legislations & policies are among some of the important factors influencing inter-organizational information sharing. Further analysis of the data also revealed some causal relations between the important factors.

For the last sub-question, 4 , two *fundamental principles* for understanding inter-organizational information sharing were proposed. The first focused on trust and legislations, while the second focuses on the embeddedness of the different levels of information sharing. These important fundaments are *generally* applicable and find their basis in both the literature as empirical findings of the data.

The following conclusions can then be drawn from this research:

1. Information sharing between actors involved in ROBAM decision making is influenced by many factors, ranging from information technology capabilities to the organizations culture and values. From the analytical framework used in this study, respondents have found trust, legislations & policies and competing interests/self-interests among some of the most important factors influencing inter-organizational information sharing. Respondents have also found that, even though they are mostly dependent on information technology to exchange information, seeing and speaking each other physically is also an important factor influencing information sharing. The framework used did not pay explicit attention to the influence of this factor on this level of information sharing.
2. The factors in the framework form different causal relations with each other. Organizations involved in information sharing should take notice of these relations, as they can help to pinpoint potential improvement areas. Trust for example has a positive and direct causal relationship with inter-organizational information sharing, but has a negative causal relationship with concerns of information misuse by other actors. Organizations should also be aware of the interrelation and embeddedness of information sharing levels. Inter-organizational information sharing is only successful if both intra-organizational and inter-personal information sharing is involved.
3. Organizations are not always taking a systems perspective within their operations. This could be related to the organizations values, origins and culture. This has not only a negative effect on information sharing, but also on the adoption of the RBAM practice in general.
4. Based on the most important empirical findings and backed by theory and literature, two fundamental principles are proposed to help further understand information sharing. The first fundamental concept is related to the importance of trust and its relation with legislations and policies. Together they both form the context in which (and if) information sharing will take place. Fundament two is proposed to make it clearly understandable that when trying to study inter-organizational information sharing, one cannot neglect the importance of the other 2 levels. After all, information shared between organizations, has to find its way to the right department, and then to the right person within that department. Both fundamentals are not ROBAMCI specific and can be important when studying information sharing in other cases or sectors.

7.2 Recommendations

The following recommendations can be made to improve on the scientific relevance of this study:

- Further research that focuses on relations between factors. This research has already addressed some relations, but this is nearly not enough: many other relations between factors are possible and deserve further attention. The studying of factor relations can

also help to drastically reduce the number of factors that are listed in the literature, by determining they importance.

- A study that focuses on the role of physical interactions in inter-organizational information sharing practices. Was this a result by chance, or is there seriously something to say regarding this factor?
- Further studying the seemingly importance of trust on information sharing, specifically for the public sector. Literature showed that trusted social networks in public environments are one of the four components in the conceptualization of information integration (Yang & Maxwell, 2011). In the private sector it is understandable that trust is needed in order to collaborate or share specific information, however, most public organizations are legally required to share or collaborate with other organizations, hence the importance of legislations and policies in the form of the “wet openbaarheid van bestuur”.
- Additional research to study the interrelation between the levels of information sharing. Even though the interrelation is made clear, and verified by this case-study, there is not enough literature explicitly paying attention as to this interrelation and embeddedness. Further understanding on this aspect is needed.
- Further research that links inter-organizational information sharing with asset management practices. Current research mostly focuses on information sharing between departments of 1 organization involved in asset management. Research has shown that the sharing of data is often limiting the successes of asset management (Arunraj & Maiti, 2007; Stillman, 2015; U.S. Department of Transportation, 2015) , and with the insight that levels of information sharing are interrelated, this area deservers some further attention. It is hoped that this research, by studying and linking these 2 concepts, can provide a basis for further research.

For the ROBAMCI project and its users, the following recommendations are made:

- Researching what the current level of the identified important factors are within organizations. This can, as was more extensively shown in paragraph 6.3 done by means of a maturity analysis.
- Organizations involved in ROBAMCI case-studies could be provided an “asset information sharing framework”, in which it is clearly shown what information is needed from whom and when (similar to the information needs template from the general case-methodology, see figure 33, which then resulted in figure 24). Adopting and operating ROBAMCI practices will after all always involve information sharing between organizations due to the multi-actor environment of the sector and the systematic approach of the practice. This enables the organizations to provide additional contributions on time and simultaneously increases the transparency of the process. This however asks for through system and information analysis. Other parts of the designed methodology, such as the system analysis can also be used, as a result of its general character.

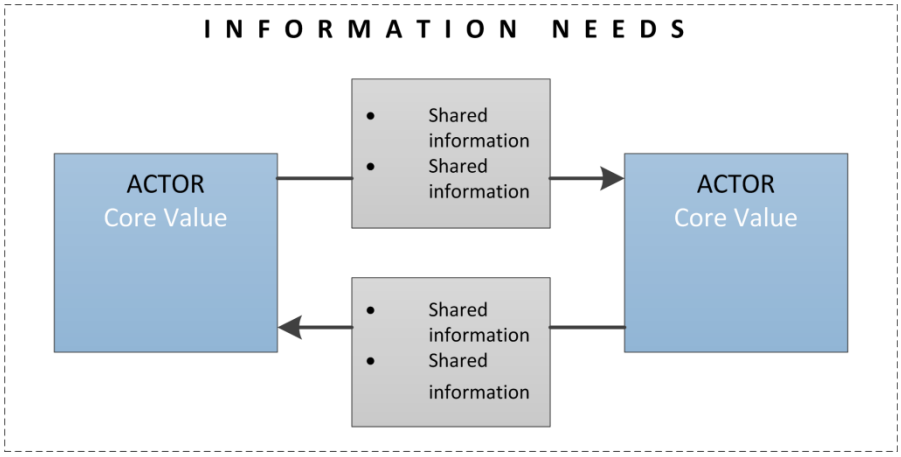


Figure 33 Information Needs Template

- Addressing the sometimes lack of systematic perspective in some organizations. Organizations need to be made aware that in current times almost every asset or process evolves in a socio-technical environment. Change is always difficult, but through for example incentives or other forms of nudging this resistance to change and institutional lock-in can be countered. This change will not happen overtime, but it is extremely important that organizations not only focus on their own interests, but see their asset in relation with other public and private organizations. After all, this is the basis of ROBAMCI. In this case-study the role of the intermediary helped to counter this potential lack of a systematic perspective, but this will not always be financially and logistically possible to organize.

7.3 Reflection

This paragraph briefly reflects back on the content and process of this research, as well as its benefits for science and society.

The use of Yang and Maxwell's analytical framework

The analytical basis used was a slightly revised version of Yang and Maxwell's inter-organizational information sharing framework. The original framework consists of 25 factors grouped in three categories (the revised version had 2 additional factors). A negative consequence of using such a framework with many different factors is that respondents will mostly provide answers out of this pool of factors, be it sometimes under different words or concepts. Furthermore, Yang and Maxwell are for example not consistent with the factors in the framework e.g. for some factors they have added a direction and for some not ("lack" of resources and "lack" of experience). Even though this has been corrected for in the revised framework, it shows that this model could be improved on. The authors have also grouped most of the factors in the category "organization and management", while a more specific and deeper categorization is certainly possible.

The developed methodology to analyse case-studies

The case was analysed through methodology designed based on SEPAM techniques. It is found that this was a critical step, because it created structure in how to address the case. The methodology was developed in an iterative way, and can still be improved: more thought could be given as to how to distinguish between factors influencing maintenance activities and functions that are influenced by maintenance activities on the asset (see figure 13). The way it is shown currently can create some confusion: there is a thin line between the “factors” and the “functions” for the asset in this case.

Research Design

Although having so many influential factors available can be beneficial, it not only limits the focusing possibilities, but also negatively affects the data-collection phase, especially if the method as part of the research design is an in-depth interview. In an in-depth interview respondents often do not use the same words, making the coding process that follows extremely difficult. The results of such qualitative interviews are subjectively interpreted, which means that it could be possible that someone else attaches another meaning to something, or categorizes factors in a different way. This is known as the concept of Verstehen, which refers to the fact that human actors have their own understanding of certain things and they give it their own meaning (Weber, 2009). To minimize this, scripts of the interviews were sent back to interviewees for verification. The used framework would I think function better in a survey, where each factor would be part of a question, in such a way that uniformity is preserved.

Having results from one case-study alone and on top of that in-depth interviews as the data collection method can provide limitations to generalize findings. On the other hand, the value of one example does not necessarily have to be low (Flyvbjerg, 2006). Doing one case-study did provide opportunity to focus extensively on the system analysis and the information needs analysis, but as the research is done in a specific context and there is not yet that much literature focusing on inter-organizational information sharing in this context, it is felt that the research findings would be better supported had they been the results of more than one case-study.

Research process

Non-responsiveness of candidates did play a role in the process, as well as my lack of experience in interviewing. Through trial and error this improved per interview. The same can be said for the coding process of the interview results.

Research objective

As shown in paragraph 1.4.4 the objective of the research was to understand inter-organizational information sharing. This objective has been achieved: both the extensive literature review and the exploratory case research have contributed to understanding how this concept functions.

The social and scientific relevance of this research project

Information plays a big role in our current society. Both private and public sectors can only function if they have information. Governments are increasingly dependent on information from other governments related to enforcement of laws and legislations, terrorism and other important aspects that have big influences on societies and their citizens. This was seen during the case-study: the asset performed many functions that are critical to not only companies and recreational shippers, but also flora and fauna. Gained understandings of the concept of information sharing can thus improve certain qualities of life for people. In the context of critical infrastructures, the knowledge can help relevant organizations to systematically increase the efficiency of their assets, by knowing how to identify where, when and from whom information is needed, as well as how this sharing of information is influenced. This can help the organization to for example focus on these specific factors to improve the sharing of information, making infrastructural functions better for citizens and/or anticipating on certain situations. Apart from the focus on this sector, the results can also help to address inter-organizational information sharing issues in other fields and sectors, as this can, to date be improved, illustrated by a recent example in which investigation showed that due to a lack of information sharing between relevant organizations, not enough attention was paid to the situation of a bullied child, ultimately leading to this individual committing suicide (ANP, 2017).

Yang and Maxwell's literature review addressed the need to further identify relations between factors in their inter-organizational information sharing framework. They also made it clear that this is needed in order to identify which factors are considered to be more important than others. By addressing some of these relations, it is hoped that this research can provide a modest contribution to the science of information sharing in general and more specifically the science behind inter-organizational information sharing. Furthermore, this research has created the link between this level of information sharing and asset management in general. It is also hoped that through this can be used as a platform for further studies between these 2 concepts.

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Appendix 1 Other ROBAMCI Case-studies

Within the ROBAMCI project a number of case-studies are done to test the applicability of risk and opportunity based asset management methods and identify aspects to improve the adoption possibilities in practice. In this appendix descriptions are given of the case-studies, identifying their specific characteristics, their objectives, the actor's and their relations. The case used in this research (Sea Locks Farmsum) is not included in this appendix, as it has been extensively discussed in the main body of this report). The reason for doing this exploratory research was primarily to identify a case-study that suited the objectives of this research. It also shows the different areas in which ROBAMCI is active and provides some more background information.

The ROBAMCI project encourages actors in the ground, road and water sector to adopt a systems-oriented approach as part of the risk and opportunity based asset management practices. This means that organizations responsible for asset maintenance of the infrastructures must also take into account decisions, policies, plans and objectives of other actors. After all, many of these assets usually have multiple functions, affecting multiple stakeholders. For example the Afsluitdijk, a flood defense system between the provinces of North Holland and Friesland. This colossal asset is not only a critical system protecting the Netherlands from floods, but also connects 2 provinces of the Netherlands with each other: North Holland and Friesland, by means of a highway. Furthermore the system is important for recreational aspects, shipping and it also performs an ecological function.

This wide array of social, economic and technical functions already shows that multiple sources of data and information are needed to adopt risk based asset management strategies to maintain such an asset. Performing maintenance, improving or removing assets can have both positive and negative effects on the rest of the system. This was the case when sluices in the Afsluitdijk were replaced in 2003. This could negatively impact the distribution of fresh and salt water, affecting birds and other animals (Smit et al., 2003). Rijkswaterstaat however, the organization responsible for maintaining the system, does not collect, analyze and processes data from every parameter. The organization is dependent on information of other actors to devise their maintenance plans. This is generally the case for many of the assets in the sector. This system perspective is exactly what the ROBAMCI project is aiming for, be it with multiple other assets as the focus, as can be seen in the following case descriptions.

Case-study: Dredging in the municipality of Spijkenisse

Dredging in water systems not only results in the maintenance of discharge of the waterways, but also maintains the quality of the water. Not only is the waterway critical for shipping activities, it also has other economic and ecological functions for the municipality, its citizens

and the surrounding natural systems. In Spijkenisse the dredging activities are being performed by the Waterschap Hollandse Delta (WSHD). Dredging takes place on cyclic basis, which means that the activities take place after *n* period, in this case every six years. Within two years, the WSHD wants to replace this cyclic process with risk based dredging, in other words: the maintenance activities of the assets within waterways will take place based on risk and opportunity based practices. The hypothesis is that this switch in operational processes will result in efficiency gains (Deltares, 2016).

In this case-study two alternatives are considered, apart from the current strategy the WSHD employs (cyclic dredging):

- Risk based maintenance on the basis of monitoring and inspections of assets. Dredging would then take place if one or more specific parameters reach critical values.
- Incident based maintenance. This means that dredging would only take place when there are for example complaints by users/citizens about the depth of the waterway.

In this case-study a number of organizations are involved, creating a multi-actor environment with the inclusion of public and private organizations (Deltares, Waterschap Hollandse Delta, Witteveen+Bos, HKV, BZIM and Intech). However, apart from the WSHD, all other actors involved are consultancy's and/or research institutes. This makes this case not suitable for doing research based on the previously defined unit of analysis and the scope limitation to inter-organizational information sharing, as there is only one public organization.

Case-study: Sewerage cleaning Almere

Flooding, as a negative consequence of climate change is expected to increase in the urban area of Almere. Higher volumes of water means that the drainage systems of the city have to be able to physically drain more water. Not only is this increased risk of flooding putting more strain on the system, the system itself is also reaching the end of its technical lifespan as a result of corrosion of the materials, blockages by sediments and other substances. Correct and efficient maintenance of this system can thus help to increase its life-span significantly. Current maintenance strategies by the province of Almere are incident as well as cyclic based with fixed frequencies.

The city of Almere wants to develop a risk based maintenance strategy for their sewerage system: locations that have a high chance of blockages would then be identified and maintenance activities would then be coordinated based on those risks and chances of failures. Effects of ground occupation on specific locations and flooding as an effect of climate change are also studied in this case. Participation in the ROBAMCI project was therefore a straight forward decision, as the objectives of the this project coincided with the ambition of the city. The change in maintenance strategy is expected to lead to effectivity and efficiency gains for both personnel and equipment. As the effects of sewerage blockages are difficult to quantify, a complete risk and opportunity based asset management strategy is not possible in this case (Deltares, 2016).

The scope of this case-study is limited to only the sewerage system that is being managed and maintained by the province of Almere. This means that similar to the dredging in the municipality of Spijkenisse case-study there is only one public actor involved, apart from the other research institutes (Deltares, Fugro, HKV and BZIM). This also makes the sewerage cleaning Almere case-study less suitable for doing research in information-sharing on inter-organizational level.

Case-study: Regional barriers North Holland

The regional water defence barriers in the North Holland region are being maintained and managed by the Hoogheemraadschap Hollands Noorderkwartier (HHNK). Currently, only for half of the barriers (amounting to 1000 km) the budget for maintenance activities has been estimated. However, these estimates are usually to low, or to high, which is not considered efficient planning (Deltares, n.d.).

In the ROBAMCI context this case-study aims to research the investments that are needed to maintain the regional barriers that are under the management of HHNK by looking if a risk based strategy can be used to efficiently predict the maintenance budget.

In this case-study there is also only one actor that is responsible for the maintenance activities, and is thus not suitable for doing research in the context of inter-organizational information sharing. Furthermore, data on this case-study is fairly limited.

Case-study: Hydraulic structures Ijmuiden

The asset that is defining this case is the pumping station Ijmuiden. The pumping station is a key structure in the water system of the North Western Netherlands, as well as being an important tool for 4 regional water boards (Van der Wiel et al., 2016). This pumping station is the biggest of its kind in Europe, as well as the most energy efficient (Rijkswaterstaat & SenterNovem, 2004). Apart from this pumping station the water system also consists of a number of other hydraulic structures that have the ability to discharge water. Expansion or renewal of the station to keep the water system functioning were identified in this case-study, as well as uncertainties in future climate scenario’s.

Its inclusion in the ROBAMCI project is to determine adaption pathways on a system wide level, instead of only looking at the asset (the pumping station) itself. This corresponds with the integrated objectives of the ROBAMCI practice which can then lead to reduced maintenance and replacement costs. This increases the solution space, but on the other hand requires information to support the decisions that can potentially increase efficiency.

The structure is owned by Rijkswaterstaat, but as said before provides policy tools for a number of water boards. The municipality of Velsen, in which the structure is located is also one of the actors involved. This case, due to its inclusion of multiple actors could also be a candidate to focus the research on, however, limited data and non-involvement of many of the public actors in the ROBAMCI setting make it problematic.

Appendix 2 Benefits of Information Sharing

The benefits of sharing information have been studied intensively in different sectors and fields, from supply chain management to the criminal justice enterprise. The consequences of not sharing information have sometimes been devastating. Kobach shows that as a result of not sharing information between agencies, one of the terrorists responsible for the September 11, 2011 attacks, was able to escape earlier arrests by authorities (Kobach, 2006). In the following sections some benefits of information sharing, as presented in examples of various literature are discussed.

Collaboration

Sadoff and Grey argue that uncoordinated activities in transboundary rivers may can significantly diminish water flow, as well as degrade water quality for all other countries involved. The authors further state that the cooperation and coordination between these countries is in some cases an extreme, in opposition to "water wars" (Sadoff & Grey, 2005). These authors identify numerous benefits for the countries involved in the case of cooperation. Better forecasting of river flows, better preparedness for floods and droughts and avoidance of conflicting projects are all benefits that can have positive impacts on the societies of the countries involved. However, economic, social, environmental and political benefits from collaborating can only be achieved through the exchange of information. Information sharing, together with communication and notification are the first steps on a cooperative continuum.

This need for information sharing as a basis for international transboundary water management is also recognized by the international community as was shown in the in the text of the Dublin Statement, the product of the International Conference on Water and Environment in 1992 and the United Nations Convention on the Law of the Non-Navigational Uses of International Watercourses in 1997 (Giordano & Wolf, 2003).

A more recent study illustrated how information sharing resulted in collaboration and cooperation between countries regarding international water management. Over 100 commitments to develop the water sector between countries and organizations were made as a result of a multi-stakeholder dialogue session with water ministers and other stakeholders, where information was shared and cooperation was promoted (Rahaman & Varis, 2005). However, there is still room to improve information exchange in this field. Mitchell argues that, through a review of 15 case studies in Australia that greater integration of water related activities can be achieved if the information sharing is improved, among some other factors (Mitchell, 2006).

Cost savings

Byrne and Heavy have modelled and analyzed the effect of information sharing of an actual industrial supply chain which consisted of Small-To-Medium sized enterprises. The results were positive: significant cost savings of up to 9.7% were shown as a result of the use of improved information sharing between some of the supply chain performance parameters. Furthermore, according to the model, as a result of collaboration between the partners, other gains were achievable by these (Byrne & Heavey, 2006).These cost savings have also been shown by Lee et al., using a complex mathematical model to try and quantify the benefits of information sharing in a simple two level supply chain (Lee, So, & Tang, 2000). These authors conclude that information sharing will surely improve the efficiency of the supply chain, more specifically for the manufacturer in the area of larger reductions in average inventory and costs.

To show the benefits of inter-organizational information sharing on system wide level, Li et al. have made use of a supply chain system (J. Li, Sikora, Shaw, & Woo Tan, 2006). Depending on the type of information shared and the areas where the information flows are conducted a reduction of transaction costs and inventory costs are achievable. Boeing has shown that by means of information sharing, they were able to cut their cycle times in half and achieve a reduction in defect parts of 56%, illustrating that not only can information sharing lead to cost savings itself, but also to increasing efficiency.

Improved decision making

Literature also identifies information sharing across organizations as a key strategic activity for organizations both in the public and private sector (Yang & Maxwell, 2011). Clear and comprehensive understandings of the diverse factors that either support or constrain the design and development of effective information exchange systems can increase policy makers and practitioner's confidence in their outcomes and in their accuracy and timeliness of their decisions. This improves the quality of decision making processes (Yang & Maxwell, 2011). Lacking decision making processes by not considering alternatives or constraints are often the result of other actors not sharing ideas or important information (Devine, 1999).

Information sharing has been identified as a prerequisite by Charles et al. in shared decision making processes in the medical encounter. Important decisions at important points in the disease process and the existence and choice of several treatment options with their different positive and negative effects are decisions that a medical professional and the patient can take together, but only if the correct and complete information has been provided by both parties. Information coming from the patient can for example be used by the medical professional to suggest treatment options. The value of information for the patient can both be in its aid for the decision making process, as well as reducing uncertainties or other positive psychological effects (Charles, Gafni, & Whelan, 1997). Dawes argues that information sharing aids in improved problem solving between agencies as a result of improved availability, quality and quantity of data. In that way the agency can make better founded decisions (S. Dawes, 1996).

Transparency

Sharing information increases the level of transparency between the public and the government. Providing details and other information about particular program's then requires the government to account in a better way for their decisions. Maier and Ottaviani have studied the effect of transparency resulting from sharing information in the field of new institutional economics. They have shown that within the principal-agent theory information sharing always increases total expected welfare, if the principal cares about the agent's output. Vice versa this works the opposite way: if the principal does not care about the agent's output level, the transparency as a result of information sharing decreases total expected welfare (Maier & Ottaviani, 2009).

Other Benefits

Apart from the benefits of information sharing elaborated on above, there are also other advantages (Akbulut, 2003; S. Dawes, 1996; Gil-Garcia & Pardo, 2005; Landsbergen & Wolken, 2001):

- Having efficient data management practices: as a result of information sharing duplicate data collection and analysis can be prevented. This reduces costs and can improve productivity by not having duplicate information handling. Paperwork for the citizen is reduced, work processes and the formulation, implementation and evaluation of policies is being streamlined.
- Presence of an information infrastructure: sharing information requires technical artefacts. It also encourages innovative solutions to be able to facilitate the ever growing need for sustainable data-centers and communication networks on the ground and in the air. This in turn helps to create information infrastructures which can be used for other purposes.
- Networks of professionals: sharing information creates and reinforces professional working relationships, opening up opportunities to collaborate on certain aspects. In turn if further encourages the sharing of information between these professionals.
- Broader contexts for programs: having information of other actors can help governments and agencies to understand economic and demographic trends more effectively, leading to budget improvements and legislative deliberations for resource allocations
- Integrated plans and integrated public services: as a result of information sharing programs and projects can be planned in a systematic, multidisciplinary and integrated way. It further enables organizations to use their resources in other ways, as the burden of information on these organizations is reduced.

Appendix 3 Inter-organizational information sharing frameworks

In table 8 an extensive overview is provided of factors in the studied inter-organizational information sharing frameworks. This overview has resulted in the choice to use a slightly revised version of Yang and Maxwell's framework as the follow-up for this research. This has been elaborated on in chapter 3.

Table 8 Categories and Factors Inter-Organizational Information Sharing Frameworks

(Gil-Garcia et al., 2005)		(Cresswell et al., 2004)		(Akbulut, 2003)		(Yang & Maxwell, 2011)	
CATEGORY	**FACTORS**	**CATEGORY**	**FACTORS**	**CATEGORY**	**FACTORS**	**CATEGORY**	**FACTORS**
Turf and Resistance to Change	• Integration experience • Technology acceptance • Costs of change • Reduction or control of risk(s) • Preserving Autonomy • Defense of status and Power	**Social Processes**	• Collaboration in work processes • Trust building • Negotiation • Decision Making	**Characteristics of Electronic Information Sharing**	• Benefits • Costs • Risks • Compatibility • Complexity	**Organizational and Managerial Perspective**	• Organizational boundaries of bureaucracy • Different geographic areas • Different origins, values and cultures • Different operation procedures, control mechanisms and work flows • Lack of experience • Lack of resource • Competing interests/self-interests • Resistance to change • Concerns of losing autonomy

							• Concerns of losing valuable assets and competitive advantage • Concerns of misuse by other organizations • Concerns of the quality of information received • Incentives and reward • Comparison of risk and reward • Trust • Leadership • Negotiation and commitment development
IT and Data	• Incompatible hardware • Incompatible software • Incompatible telecommunication systems • Mismatching data structures • Incompatible database designs • Conflicting data definitions • Reliability of data • Compatibility of data	**Resources**	• Leadership • Authority • Skills • Materials • Facilities • Inter-organizational policies • Resource allocation mechanisms • Political will	**Agency Characteristics**	• IT Capability • Top Management Support • Agency Championship • Size	**Technological Perspective**	• Heterogeneous hardware, software and information systems • Information security • IT outsourcing • IT Capability
Organizational Diversity and Multiple Goals	• Internal Benefits • Improvement of public image • Expanding influence • Trust • Collaboration • Organizational culture	**Organizational Artefacts**	• Goal alignment • Policies • Management structures and decisions • Interpersonal relationships • Contracts and Agreements • Trust • Incentives • Norms	**Environmental Characteristics**	• External influence • Policies • Legislations • Interagency trust • Critical Mass • System-Wide Championship	**Political and Policy Perspective**	• Legislations and Policies • Information as Power and Authority • Partisan Dynamics in Government Agencies • Public Scrutiny and Performance Evaluation

			• Social translation techniques • Shared understandings • Life-cycle/budget-cycle alignment • Integrated work rules and procedures				
Environmental and Institutional Complexity	• Political complexity • External influences such as legislative committees and civil servants • Agency discretion • Primacy of programs	**Technology Artefacts**	• Physical networks • Integrated system architecture • Interoperable hardware • Protocols • Standards and data definition • Integrated applications • Process maps and models • Integrated databases and data warehouses • Analytical and decision support tools • Technical reports and analysis				

Appendix 4 Factors of the revised inter-organizational information sharing framework

In this appendix the different factors of the analytical lens of this research are elaborated on. As already stated, this framework is a slightly revised version of Yang and Maxwell's inter-organizational information sharing framework.

Comparison of available frameworks related to inter-organizational information sharing and contextual research have led to the inclusion of three other factors in this framework (collaboration, size of the organization and costs of potential changes), as well the removing of one factor (different operation procedures, control mechanisms and work flows). Respectively the technological, political + policy, organizational, managerial and uncertainties factors are presented in the following subsections.

It has to be made explicitly clear that the identification of the factors (minus the three added factors), have been done in the literature review by Yang and Maxwell. Scientific sources that have been used by these authors related to these factors have been used to get further knowledge on these factors, supplemented by scientific literature that has been found by searching the respective factor in scientific databases such as Google Scholar, Scopus and Web of Science.

Technological factors

The revised framework list the following factors from a technical perspective that can potentially influence inter-organizational information sharing.

- *IT Capability*: a case-study done to examine the factors that influence electronic information sharing within the State of Louisiana Uniform Motor Vehicle Crash Reporting System listed the availability of IT resources and expertise within agencies as a key aspect . A lack of equipment required to share information was found in agencies that were not engaging in information sharing. Lack of an inadequate infrastructure and IT skills of employees impede inter-organizational information sharing (Akbulut et al., 2009).
- *Heterogeneous Hardware, Software and Information Systems:* Lam, while studying barriers for e-government integration also stated that an interoperable IT infrastructure between agencies is a key component for information sharing (Lam, 2006). Lack of application integration as a result of different technology platforms and different

programming frameworks result in great technical challenges for departments to share information.

- *Information Security:* in a time of growing number of cybercrime incidents security and confidentiality are important constraints when information sharing systems are being designed. The year 2016 showed an increase of 38% for cybersecurity incidents, compared to 2015. Security breaches in financial, government, health care and education sectors were detected, exposing more than 29 million records (Laberis, 2016). Depending on the information that is being shared and the organizations that are sharing it, security and confidentiality of the information is a key factor that can either enable or disable information sharing (Chau et al., 2001).
- *IT Outsourcing:* As more and more governments and other organizations are outsourcing their IT related activities to cut costs, this also proposes some new challenges. Lacking system design specifications, competition between contractors, failure to support the maintenance activities and upgrades by contractors are some of the issues related to IT outsourcing that can influence information sharing (Yang & Maxwell, 2011).

Above technical factors are however not the major challenges that organizations face when trying to realize information sharing. Researchers have argued that although these technical factors are key components to realize information sharing systems, it is often the organizational and policy complexities that need to be addressed in order to successfully share information (Yang & Maxwell, 2011).

Political and Policy Factors

Yang and Maxwell list the following factors from a political and policy perspective that can potentially influence inter-organizational information sharing.

- *Legislations and Policies:* laws and regulations can have varying effects on information sharing. On one side they can be barriers that prevent inter-organizational information sharing. Governmental policies often prevent the sharing of sensitive information (S. Dawes, 1996; Pardo & Tayi, 2007). On the other hand legislations and policies can be enablers of relationship building, trust development and risk reduction. To encourage public organizations to share information and increase public support of governments information sharing projects legislative support and privacy and confidentiality policies must be in place (Yang & Maxwell, 2011).
- *Public Scrutiny and Performance Evaluation:* sharing information increases the possibility that agencies can be subjected to public scrutiny or performance evaluation audits. An increase of public requests for information and a higher level of micromanagement of the organizations policies and decisions can lead to this public scrutiny (Landsbergen & Wolken, 2001).
- *Information as power and authority:* having information and expert knowledge is sometimes seen as a source of power and a symbol of an organizations authority for

decision making (S. Dawes, 1996; De Bruijn & Ten Heuvelhof, 2008). As a result of this, agencies often do not share or are reluctant to share information.

- *Partisan Dynamics in Government Agencies*: loss of power and strategic use of the shared information can also give organizations a cautious attitude to engage in information sharing. This strategic behaviour of organizations can include the monopolization, distortion or selective communication of information (De Bruijn & Ten Heuvelhof, 2008).

Organizational factors

The revised framework in shows the following factors.

- *Competing Interests/Self Interests:* as is usually the case in multi-actor environments, actors have different interests, which as was shown earlier can lead to the strategic (mis)use of information (De Bruijn & Ten Heuvelhof, 2008). This gets even more complex, as often these actors are dependent on each other.
- *Trust:* many authors list trust as one of the essential factors that can encourage or discourage inter-organizational information sharing (Chau et al., 2001; S. Dawes, 1996; Gil-Garcia et al., 2005; Landsbergen & Wolken, 2001) . In this context 3 distinctions of trust are identified: calculus based trust (the ability of the trustor to assess the trustworthiness of the trustee), identity-based trust (the long term established personal relationship between trustor and trustee) and institution-based trust (institutional structures, societal norms, legal systems and organizational cultures). To positively impact the level of trust, Pardo et al. identify the clarity of responsibilities and roles, respect for autonomy and authority as key factors (Pardo, Gil-Garcia, & Burke, 2006).
- *Comparison of Risk and Reward:* Organizations are therefore weighing the risks such as losing competitive advantage or misuse of the shared information with these incentives.
- *Different Origins, Values and Cultures*: as with the factor trust, many authors state the different values and cultures of organizations as the reason for the complex interactions when trying to share information (Pardo et al., 2004; Pardo & Tayi, 2007; Ramon Gil-Garcia et al., 2007).
- *Organizational Boundaries of Bureaucracy*: Furthermore, as a result of boundaries between these organizations, actors often also do not know what information actually can be shared and used. And if they do not know this, the information will also not reach them (Landsbergen & Wolken, 2001).
- *Level of Collaboration*: collaboration across agencies is critical to reach integrated policies or decision making (Cresswell et al., 2004). In a situation where there is a high level of collaboration, sharing of information between agencies is then seen as a normal procedure. However, this is still one of the challenges that organizations in multiple sectors face (Gil-Garcia et al., 2005)
- *Resources*: a lack of financial and technical resources can have a negative impact on inter-organizational information sharing (Landsbergen & Wolken, 2001). Coupled

with not knowing the benefits of information sharing, this leads organizations to focus on for example collecting their own data and information.

- *Costs of potential changes*: resistance to change is often related to the costs that these potential changes bring with them (Gil-Garcia et al., 2005). Not only is it likely that new technology systems have to be installed, but inter-agency policies and other institutional aspects have to be dealt with (contract development, rules and KPI's)
- *Size of the organization*: in bigger organizations it is likely to be more difficult to facilitate information-sharing processes with other agencies. This in turn is then connected to the resources, the finances and the IT capability of such organizations, as well as the organizational structure (Chengalur-Smith & Duchessi, 1999).
- *Resistance to change*: not only individuals, but also complete organizations can be resistant to change, especially if they have been doing certain things for years. Through the complexity of all the categories of factors, radical organizational change has become a research issue (Greenwood & Hinings, 1996).
- *Different geographic areas*: an example of how this factor can affect information sharing is the metric system and the US customary units. Sharing information internationally can then have an effect on the interpretation or the use of the information.

Managerial factors

- *Leadership:* top management can encourage information sharing by showcasing vision and guidance, as well as providing the appropriate resources. Executive involvement, formal authority and informal leadership qualities can lead to agreements, the creation of process arena's and increased trust and interactions between organizations, as identified by Gil-Garcia et al. (Gil-Garcia et al., 2007).
- *Negotiation and Commitment Development*: showing commitment to share information increases trust between organizations. This can also be said for participating in negotiations, however, this process can be characterized by strategic behaviour, leading to a negative impact on trust (De Bruijn & Ten Heuvelhof, 2008).
- *Incentives and Reward*: having the appropriate incentives in place, either financial or other forms of compensation, can encourage organizations to share information. This is perceived to be logical, as organizations have allocated their own resources to collect, analyse and transform data to information (Yang & Maxwell, 2011).
- *Experience (Don't Know The Benefits)*: as was shown in chapter 3.2 and appendix 2 inter-organizational information sharing can lead to a number of benefits, however, if these benefits are not known and with no prior experience with information sharing, organizations are not encouraged to share information

Uncertainties factors

- *Concerns of Losing Valuable Assets and Competitive Advantage*: sharing information can either increase or decrease the competitive advantage organizations have over their competitor. Lin argues that in the field of supply chain management

taking and sharing available data with other actors in the supply chain, a competitive advantage is gained (S. Li, Ragu-Nathan, Ragu-Nathan, & Subba Rao, 2006). On the other hand, sharing information can also enable the competitor to gain an advantage, e.g. the Coca-Cola Company whom will lose valuable assets and its competitive advantage if its Coke recipe would be shared with other organizations.

- *Concerns of Information Misuse by Other Organizations and Concerns of Losing Autonomy:* information misuse can have devastating effects for the organization that is sharing, from losing its competitive advantage to losing autonomy. This automatically leads to a loss of trust between the sharing organizations (Chau et al., 2001). However, not only the organization that has shared can be affected: depending on the information that is being misused, entire societies can feel the mostly negative effects.
- *Concerns of the Quality of Information Received:* Different backgrounds of actors in the public sector, such as politicians, bureaucrats and scientists, make it difficult to assess the quality of information that is being shared between the three subcultures (Drake, Steckler, & Koch, 2004). Low quality information is not only unusable, it is also a waste of resources.

Appendix 5 Relevant case-study content

In this appendix some relevant case-study information is shown. The factors and functions concerning the sea lock are listed, as well as the different ambitions and interests of many of the actors in relation to the asset.

Factors and corresponding actors influencing maintenance activities of the asset

In table 9 below an overview is given of the factors that can potentially influence the maintenance strategy and planning from the asset owner, Rijkswaterstaat. The second column also indicates if and which actor(s) is (are) involved in or with these factors.

Table 9 Factors influencing maintenance activities sea-lock

Factor	Actor(s)
Water quality and quantity	Water Authorities Hunze en Aa and Noorderzijlvest
Commercial and recreational shipping activities	Shippers, Groningen Seaport, Companies
Ecology	Het Groninger Landschap, Ministry of Infrastructure and the Environment, RIjkswaterstaat

Functions of the asset and their influence

The sea-locks not only allow ships to pass between the 2 water systems, they also perform other functions, when looking at the assets from a system-oriented view. Table 10 summarizes these functions, as well as the factors and actors they can potentially influence.

Table 10 Functions of the asset and involved actor(s)

Function	Function influences following factors	Actor(s)
Shipping accommodation	Shipping route and schedules. Economic and commercial activities	Shippers, Groningen Seaport, Companies, Municipality of Delfzijl, Province of Groningen
Water Management	Drainage of excess water, water quality and quantity	Municipality of Delfzijl, Province of Groningen, Rijkswaterstaat, Ministry of Infrastructure and Environment, citizens, Water Authorities Hunze en Aa and Noorderzijlvest
Nature	Ecology, flora and fauna	Het Groninger Landschap, Ministry of Infrastructure and Environment, citizens
Safety	Flooding, Policies, water quality and quantity	Municipality of Delfzijl, Province of Groningen, Ministry of Infrastructure and Environment, Rijkswaterstaat, citizens, Groningen Seaport

The table above shows the actors involved. Rijkswaterstaat as the owner of the sea-locks, the province of Delfzijl who is responsible for a number of economic and social activities as a result of the functions of the sea-lock and Groningen Seaports who is dependent on the sea locks to facilitate ships are some of these (Groningen Seaports, 2013). The sea-lock at Farmsum which is sometimes used in combination with a bigger sluice in the Oude Eems channel to drain excess water. This combination produces nautical risks for the ships, therefore affecting the operations of Seaport Groningen (Projectgroep Marconi, 2014). Furthermore there are the water authorities Noorderzijlvest and Hunze en Aa's responsible for various water management related activities (water quality, water quantity, water safety, water level, etc.) in their respective regions. Expansion plans, policies and data of for example Rijkswaterstaat as the owner of the sea-locks can have impacts on the functioning of the water authorities or Groningen Seaports.

Chapter 5 showed a formal chart in which the different relationships the actors have with each other are conceptually sketched as well as the core values of the actors (figure 23) . Table 11 shows more in depth for this specific case the actors interests and future ambitions.

Table 11 Interests and ambitions of Actors

Actor	Interests and ambitions
Province of Groningen	Source(s): (Provincie Groningen, 2016) • Based on the European Water Framework Directive (2000/60/EC) as its legal basis, the province, together with the water authorities want to improve the quality of water, as well as creating space for flora and fauna. • Apart from clean water, the province also wants to ensure that there is enough water for not only agriculture, but also nature • Protection against floods and other water related nuisance • Increasing flexibility of service times for shipping by enabling operations of bridges and sea-locks from a distance
Municipality of Delfzijl	Source(s): (Kok et al., 2017; Provincie Groningen et al., 2012) • Facilitating and increasing commercial shipping • Replacement of the sea-lock, as it currently does not satisfy the design criteria of a class Va-waterway and does not allow two barges to pass • Potential replacement of the sea lock then requires the relocation of the smaller sea lock, mainly used for recreational shipping • Decreasing salt intake of the Eems channel • Increasing commercial shipping closer to the centrum of Delfzijl, thus boosting tourism
Citizens of Farmsum and surroundings	• No hinder from commercial shipping for recreational shippers • Sea-lock fulfilling its safety and water quality and quantity
Rijkswaterstaat	Source(s): (Maritiemnieuws, 2015; Rijkswaterstaat, n.d.-b) • Innovative, safe, environmental friendly and sustainable maintenance of the sea-lock • Sluicing in case of surplus water in the area of the Eems channel
Water Authority Noorderzijlvest	Source(s): (Waterschap Noorderzijlvest, n.d.) • Responsible for safety, quality, quantity and clean surface water (for flora, fauna and citizens)

	• Managing waterways
Water Authority Hunze en Aa's	Source(s): (Waterschap Hunze en Aa's, 2017) • Responsible for safety, quality, quantity and clean surface water (for flora, fauna and citizens) • Managing waterways • In collaboration with Rijkswaterstaat, the smaller sea-lock is sometimes used to sluice surplus water
Het Groninger Landschap	Source(s): (Het Groninger Landschap, n.d.) • As a foundation the organization is concerned with the protection of the nature and habitats, as well as cultural heritage in the province • Increasing public awareness of above mentioned aspects
Groningen Seaports	Source(s): (Groningen Seaports, n.d.) • Exploiting and managing the seaports of Delfzijl and Eems, as well as the smaller inner ports Farmersum and Oosterhorn located in the province of Delfzijl • Facilitating safe and smooth mooring of vessels
Ministry of Infrastructure and Environment	Source(s): (Ministerie van Infrastructuur & Milieu, 2017) • Developing policies for organizations such as Rijkswaterstaat • Improving and facilitating shipping connections in a sustainable, economically feasible and environmental friendly way • High level policy development related to protection from negative effects of sea level rise
Shippers and companies	• The ability of the sea-lock to accommodate vessels to transport their goods • Expansion of sea lock to facilitate growth • Safety of sea-lock

Appendix 6 In-depth Interviews Protocol

Interviewees

From the organizations identified in chapter 4, a request to be interviewed was sent to the following individuals. This table (12) also shows the logistic actions related to the requests.

Table 12 Overview Interviewees

Organization	Name	Function	Request sent?	Date sent	Reaction received?	Date of interview	Comments
Rijkswaterstaat	Jan Maarten Bakker	Senior Adviseur netwerkontwikkeling en visievorming	Yes	1-5-2017	Yes	16-5-2017	
Rijkswaterstaat	Rick Hoeksema		Yes	1-5-2017	No		
Rijkswaterstaat	Dick As	Adviseur Eems	Yes	2-5-2017	Yes	16-5-2017	
Rijkswaterstaat	Jan Theo Ijnsen	Senior Adviseur netwerkontwikkeling en visievorming	NEE	1-5-2017	Yes	16-5-2017	
Groningen Seaports	Tjaard kuiper	Senior projectleider Port Technology	Yes	1-5-2017	Yes	22-5-2017	
Groningen Seaports	Theo Smit		Yes	1-5-2017	Yes	-	Request sent to colleague who is more involved
Gemeente Delfzijl	Jornand Veldman		Yes	1-5-2017	Yes	-	Promised to react during workshop, reacti

							on not receiv ed after that
Gemeente Delfzijl	Rob Menkveld		Yes	1-5-2017	Yes	-	Reque st sent to Jorna nd Veldm an
Gemeente Delfzijl	Sacha Schram	Stedenbouwk undige	Yes	1-5-2017	Yes	17-5-2017	
Provincie Groningen	Klaas Klaasens		Yes	1-5-2017	No		
Provincie Groningen	Peter van der Wal	Coördinerend projectleider en omgevingsma nager	Yes	1-5-2017	Yes	17-5-2017	
Waterschap Noorderzijlvest	Gerwin Zantingh		Yes	1-5-2017	No	-	
Waterschap Hunze en Aa's	Erik Jolink	Projectmanag er Brede Groene Dijk	Yes	1-5-2017	Yes	16-5-2017	
Waterschap Hunze en Aa's	Jan den Besten		Yes	1-5-2017	Yes	-	Reque st sent to Erik Jolink
Project Facilitator	Arjen Bosch	Strategisch adviseur	Yes	16-5-2017	Yes	22-5-2017	
Stedin	Lion van der Heijden	Manager Risk, netstrategie, & Asset informatiema nagement	Yes	9-5-2017	Yes	6-6-2017	

From Deltares, informal talks were held with the following people:

Table 13 Overview of informal talks Deltares

Name	Function
Frank Den Heijer	ROBAMCI Program leader
Sien Kok	Resource Economist
Mark de Bel	Case leader Sea Locks Farmsum
Gerald Jan Ellen	Sr. Advisor Governance and Spatial Planning

Assumptions and Limitations of conducting in-depth interviews

Conducting in-depth interviews are not without pitfalls: the interview responses might be prone to biases, time sensitivity plays a role and the content of the interviews are usually not generalizable (Boyce & Neale, 2006) . Furthermore, when doing these interviews or sending out invitations for participating in focus sessions, non-responsiveness could be an issue, which in turn has an effect on the data and its analysis.

Interview Guide

Table 14 shows the administrative script of the introduction and the closing section of the in-depth interviews.

Table 14 Administrative Script (English)

Introduction	I want to start this interview by thanking you for your time and effort to meet with me today. As I illustrated in the email I sent, my research focuses on what aspects influence inter-organizational information sharing between actors involved in the risk and opportunity based asset management of critical infrastructures. Your organization, as part of the Delfzijl case-study, has a significant influence in determining the replacement and/or maintenance of the sea locks. These assets perform multiple functions, so a system oriented perspective is needed, to make decisions. The interview should take less than an hour, and if you are OK with this, I would like to tape our conversation.

	If there are any issues regarding confidentiality, please let this know. Remember, you do not have to talk about anything you do not want and you may end this interview at any time. Do u have questions for me and are you willing to participate in this interview?
Closing Section	In closing this interview, is there anything you want to add? I would like to thank you for your time. I will be analyzing the information you and the other interviewees have provided me with. If you are interested, I will be happy to send a copy of my report.

Interview Script

The following table (15) shows the script that has been used to structure the in-depth interviews. The questions related to the statements are general guidelines and serve as a trigger to ask further questions. This could then provide further examples and details.

Table 15 Interview Script

Section	Number	Statement Category	Questions
Administrative Procedures			-
Interview	**1**	**Awareness and dependency**	**The organization actively shares information with other actors related to maintenance strategies of the sea lock**
			To what extent does your organization currently shares information with other's organizations? What information can be added to shown figure?
			Do you think that your organizations view and objectives (the information that you share) have been sufficiently used in the decision making processes of potential operations and planning activities? Please

			elaborate.
	2	**Uncertainties**	**Sharing information can possibly weaken our strategic position due misuse**
			What concerns do you have when sharing information, if any, and how can these be overcome?
	3	**Management**	**Sharing information with other agencies is encouraged by our organization**
			What is (not going) well, and thus can be improved by management to encourage information sharing between organizations?
	4	**Organization**	**Inter-organizational information sharing overall improves efficiency and effectiveness of decision making**
			Within your organization, what possible factors do u find that facilitate the sharing of information with other organizations?
	5	**Laws, Politics and Regulation**	**Legislative and regulative procedures influence inter-organizational information sharing**
			What legislations/regulations possibly discourage/encourage information sharing? How can this be improved?
	6	**Information Technology**	**Different IT related factors influence our ability to share information**
			What aspects related to information technology are critical to facilitate information sharing?
Closing Component			-

As most of the interviewees are Dutch speaking, the interviews will be held in Dutch. To maintain transparency in the research, the Dutch version of above questions and statements is presented in table 16.

Table 16 Interview Script (Dutch)

Categorie	Stellingen	Vragen
Achtergrond en huidige situatie	De organisatie deelt onderhoudsinformatie over de zeesluis met andere actoren	1. In hoeverre deelt de organisatie deze informatie? Komt dit overeen met de geschetste situatie in onderstaande figuur en tabel? 2. Bent u van mening dat de informatie die de organisatie deelt ook daadwerkelijk gebruikt wordt om onderhoudswerkzaamheden aan de zeesluis te plannen?
Onzekerheden	Het delen van informatie kan de strategische positie van de organisatie in gedrang brengen als gevolg van misbruik van deze informatie	Welke potentiele bezorgheden zijn er wanneer de organisatie informatie deelt, en hoe kunnen deze overwonnen worden?
Management	Het delen van informatie met andere organisaties actief aangemoedigd binnen onze organisatie	Wat gaat er mis, en hoe kan dit verbeterd worden door de leiding van de organisatie, om werknemers aan te sporen informatie te willen delen?
Organisatie	Informatiedeling tussen organisaties zorgt ervoor dat besluitvorming effectiever en efficiënter verloopt	Welke factoren, binnen de organisatie, dragen bij aan de deling van informatie?
Regels, beleid en wetten	Wetten, regels en procedures beïnvloeden de deling van informatie tussen organisaties	Welke regels/wetten/procedures beletten/faciliteren de deling van informatie tussen organisaties? Hoe kan dit verbeterd worden?
Informatie technologie	Informatietechnologie speelt een rol in onze capaciteiten om informatie te delen	Welke aspecten gerelateerd tot informatietechnologie in uw organisatie zijn absoluut noodzakelijk voor het delen van informatie?

Inter-Organizational Information Sharing Needs as identified by Analysis

Following table (17) shows the type of information that flows between organizations. A distinction is made between need to know and nice to know information, to not overflow the system with information, because, having too much information can sometimes work in a reversed way. This information has been presented to the interviewees.

Table 17 Inter-Organizational Information Sharing Needs as identified by analysis

From Organization	Receiving Organization	Type of shared information	Need to know/Nice to know (from perspective of receiving organization)
Rijkswaterstaat	Ministry of Infrastructure and the Environment	Operational results (technical status of asset, replacement trajects, traffic volume)	Need to know
Ministry of Infrastructure and the Environment	Rijkswaterstaat	KPI's	Need to know
		Policy goals related to safety, livability, shipping and the environment	Need to know
Rijkswaterstaat	Groningen Seaports	Maintenance plans	Need to know
		Safety status and operational status of asset	Need to know
Groningen Seaports	Rijkswaterstaat	Marine traffic numbers	Need to know
Rijkswaterstaat	Municipality Delfzijl	Maintenance plans	Need to know
		Safety status and operational status of asset	Need to know
Municipality Delfzijl	Rijkswaterstaat	Plans and ambitions related to different aspects for the municipality and its citizens	Nice to know
		Environmental goals	Nice to know

Rijkswaterstaat	Water authorities Noorderzijlvest en Waterschap Hunze en Aa's	Maintenance plans	Nice to know
		Safety status and operational status of asset	Need to know
Water authorities Noorderzijlvest en Waterschap Hunze en Aa's	Rijkswaterstaat	Water quantity data	Need to know
		Water quality data	Nice to know
		Water depth data	Need to know
Rijkswaterstaat	Province of Groningen	Maintenance plans	Nice to know
		Design plans of asset	Need to know
Province of Groningen	Rijkswaterstaat	Regional policies and ambitions, related to infrastructure and subsurface	Need to know
		Expansion plans related to asset	Need to know
Water authorities Noorderzijlvest en Waterschap Hunze en Aa's	Province of Groningen	Water quantity data	Need to know
		Water quality data	Need to know
		Water depth data	Need to know
Province of Groningen	Water authorities Noorderzijlvest en Waterschap Hunze en Aa's	Regional policies and ambitions, especially related to the water and its surrounding systems	Need to know

		Expansion plans	Nice to know
Water authorities Noorderzijlvest en Waterschap Hunze en Aa's	Het Groninger Landschap	Policies and plans, especially related to the nature and its environment	Need to know
Het Groninger Landschap	Water authorities Noorderzijlvest en Waterschap Hunze en Aa's	Various environmental data	Need to know
		Flora & Fauna data	Need to know
Ministry of Infrastructure and the Environment	Province of Groningen	National policies, ambitions, rules and regulations	Need to know
Province of Groningen	Ministry of Infrastructure and the Environment	Regional ambitions and plans, related to economy, demography, accessibility, the environment and transport	Nice to know
Municipality Delfzijl	Het Groninger Landschap	Ambitions for the surrounding areas	Need to know
		Ambitions that affect the surrounding nature	Need to know
Het Groninger Landschap	Municipality Delfzijl	Environmental data	Nice to know
		Flora & Fauna data	Nice to know
Municipality Delfzijl	Citizens	Maintenance plans and status sea lock	Need to know
Citizens	Municipality Delfzijl	General observations	Nice to know

Groningen Seaports	Shippers and companies	Various port activities	Need to know
		Timetables	Need to know
Shippers and companies	Groningen Seaports	Logistical data	Need to know

Appendix 7 Interview transcripts

The transcript of the interviews, both in audio and textual versions, are, as a result of respecting the confidentiality of interviewees, available and can be provided on request. The talks with the experts of Deltares are also attached to this confidential appendix. This request can be sent to the author of this thesis on the following email address: N.V.Sardjoe-1@student.tudelft.nl

Appendix 8 Interview results and other analysis

In this appendix, attached as a separate excel workbook, the data has been ordered, coded and analysed. On each tab of the excel workbook it is explained what is done and how the results should be interpreted.