



Improving risk identification on large infrastructure projects

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PREFACE

Before you lies a report on the research into the risk identification process on large infrastructure projects. The research has been executed on behalf of VolkerInfra and SAAone. It serves two purposes: on the one hand to answer the initiated research question and on the other hand to conclude my master Construction Management and Engineering at the University of Twente.

The motivation for this research is the recent attention for risk management in the construction industry due to some extreme examples the past year. This led to the goal of VolkerInfra to further develop their risk management expertise and knowledge. This research will contribute to that goal by analyzing the risk identification process and provide recommendations for further development.

I would like to take this opportunity to thank VolkerInfra for giving me the opportunity to execute my graduation research for their company. I would like to personally thank Hans Hulst for his daily guidance, advice and substantive input. Furthermore, Jan Ruitenberg, Joop Halman and Saad Al-Jibouri for their guidance, substantive input and constructive criticism. Furthermore, I would like to thank the interviewed risk managers and colleagues of VolkerInfra and SAAone for their time and input where necessary.

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N.B.: This version of the report is the public version. This means that some values in tables and figures are confidential and therefore removed from this version and marked with 'confidential'. The essence of the report remains the same.

MANAGEMENT SUMMARY

Due to government austerity, governmental agencies are downsizing and the contractors in the construction industry are increasingly responsible for more phases and tasks within construction projects. Not only have they become responsible for the construction phase itself, but also for design, maintenance and in some cases even finance. Furthermore, they are required to provide complete services, which means the combining of different disciplines in a single contract. These increased responsibilities also lead to an increase in risks for which the contractor is responsible. Together with the pressure on turnover in the infrastructure sector specifically, these cause contractors to improve their project management expertise and all relating processes. Recent examples in the industry illustrate the need for a high level of expertise of risk management. These developments led to the goal of VolkerInfra to improve their risk management expertise and knowledge.

The research is based around six case studies. These concern six large infrastructure projects of VolkerInfra, of which two are still in construction and four have been recently completed. This approach was chosen because of to the strong project focus of VolkerInfra. To measure success on these projects, usually a set of objectives is developed that the project hopes to accomplish. Part of these objectives are the traditional operational objectives of cost, time and quality. Of these three, cost is the most obvious and consistent measure of project success and therefore this measure is chosen as initial assessment parameter for the effectiveness of risk management.

However, an initial review of the cases revealed that there is limited data available on the cases. The data that is available on all cases however, is the amount of identified risks, in both the tender phase and the execution phases of the cases. These revealed that most risks are identified after tender, while ideally they should be identified during the tender phase to prevent surprises when going down the project life-cycle. Due to the limited available other data, a further analysis of cost data was only limited possible. Furthermore, a literature revealed that there was limited attention for the risk identification part of the risk management process. For these reasons it was decided to focus on risk identification. This led to the following objective in the research: *"Develop recommendations for the further development of the risk identification process and identify and classify top risks on VolkerInfra projects to enable generic oversight to assist in risk identification on future VolkerInfra projects."*

Interviews were held with the six risk managers of the six cases to determine their preferred risk identification approaches. These interviews revealed that each risk manager has their own preferred approach to risk identification and that this approach developed little over time. It also revealed that there is no company guideline on how to perform risk identification. The approaches of the risk managers were divided in the tender phase and the execution phase. During the tender phase, personal interviews, brainstorm sessions and work groups led by the risk manager were the preferred methods for risk identification. During the execution phase, only the personal interviews were preferred, while few other methods were applied.

The literature review also revealed that there are multiple other tools that can be developed to help during the risk identification. These are mainly historic records and checklists, both of which were little used by the risk managers. Historic records are a valuable source of information for risk identification. These historic records are currently unavailable and therefore the goal was to develop the starting point for a database of historic records. The

focus lies on occurred risks for the starting point, as these are considered to contain the most valuable information to enable reflective learning from these records. These are however only available on three of the six cases.

To be able to maintain an overview of these records, a classification has been developed. This classification consists of a number of criteria, each with a number of underlying categories. Each risk is assigned a category per criterion. The classification will then enable oversight over the projects of the most prevalent classes of risk and thus the identification of the most important points of improvement. Due to the time consuming process of categorizing risks, only the most important occurred risks have been classified. The top fifteen (based on the calculated value, which is an estimate of the financial consequences) occurred risks of the three available cases is classified, giving a total dataset of 45 risks.

The most important criteria are the phase identified, nature of the risk and the source of origin criteria. The classification revealed that 27 of the 45 risks was identified after tender. However, further analysis revealed that 15 of these 45 are due to an insufficient risk identification process. The other 12 were attributable to unforeseen scope changes, overarching risks that were identified sooner (so called container risks) and a force majeure and therefore not culpable to a faulty risk identification process. Further it revealed that most risks are of a technical nature, with process and managerial having a lot less risks in the top fifteen occurred. The source of origin criterion revealed that there are a number of risks present due to opportunistic behavior in the form of commercial decisions and a number of risks occurred as a consequence of another risk occurring. Based upon this research it can be concluded that there is a lack of guidelines for risk identification. Furthermore, a lack of data prevents further analysis of the effectiveness of the risk management process. There is also some ambiguity regarding the definition of certain concepts relating to risk management.

Based upon this research, ten recommendations are being made to VolkerInfra to develop their risk identification process. First of all it is recommended that more data is recorded of risks, this data should at least consist of: the occurrence of the risk, cost data relating to the risk and a classification in the following criteria: main- and sub-object, nature of the risk and source of origin. When this data is recorded, this will allow for benchmarking of future projects and the setting of goals for improvement. Furthermore, relevant concepts and the exact purpose of risk management have to be clearly defined in order to prevent confusion and differences of approaches between the different risk managers. Fourthly, opportunism due to commercial decision should be prevented and be included as opportunities and not as risks. Due to the revealed link between different occurring top risks, a conditional probability class should be added to the RISMAN categories to define this relation. Guidelines for the risk identification process are formulated in order to develop and improve that process. This guideline makes use of all information gathered from the literature and empirical research parts and proposes the following sequence: Start by collecting all relevant documents and data, this includes tender documents, flowcharts and breakdown structures. If the first recommendation is followed, more data is recorded on the projects that can be used as historic records on future projects, which should be the second step. Then a combination of identification methods should be applied to prevent bias from either ones. This should be followed by a check for opportunism, check for conditional probabilities and then a full risk assessment of the consequences and probabilities. These can then be mutually compared to come to the final risk database for tender. This is a structured approach that is recommended to VolkerInfra as development of their risk identification process.

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ABBREVIATIONS

B&U	-	Building & Utility construction sector
CBS	-	Centraal Bureau voor de Statistiek
COSO	-	Committee of Sponsoring Organizations of the Treadway Commission
DBFM	-	Design-, Build-, Finance-, Maintain-
DBFMO	-	Design-, Build-, Finance-, Maintain-, Operate-
D&C	-	Design & Construct
EMVI	-	Economisch Meest Voordelige Inschrijving, see MEAT
EPC	-	Engineering, Procurement and Construction
EPCM	-	Engineering, Procurement, Construction and Maintenance
ERM	-	Enterprise Risk Management
GWR	-	Ground-, Water- and Road construction sector
HRO	-	High Reliability Organization
IF	-	Integrated Framework
ISO	-	International Organization for Standardization
MEAT	-	Most Economically Advantageous Tender
N/A	-	Not Available
RISMAN-method	-	RISk MANagement-method
RMM	-	Risk Maturity Method
RWS	-	Rijkswaterstaat
SAA	-	Schiphol Amsterdam Almere
SPC	-	Special Purpose Company
SPV	-	Special Purpose Vehicle
WISE	-	VolkerInfra Systems Engineering
VOF	-	Vennootschap Onder Firma, a General Partnership
VVU	-	Voertuig Verlies Uur, Lost Vehicle Hour
WBS	-	Work Breakdown Structure
WRR	-	Weekly Risk Report

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1. INTRODUCTION

The Dutch government is the most important client for large infrastructure projects in the Netherlands. Within this market, Rijkswaterstaat (RWS, Directorate-General of Public Works), is a large actor as they are a large direct client for construction companies for putting large infrastructure projects on the market. Due to governmental austerity these organizations have been downsizing and therefore required the market to take over certain tasks, such as design, asset management, risk management etc. The role of the construction companies therefore changed to provide more services for a smaller governmental client than solely providing the execution of the work itself for which they were traditionally only responsible. Pressure on rates and prices, a slow recovery of the financial crisis and a decreased workload have increased pressure on the market further and increased competition. These developments increase complexity for the contractors and requires them to ensure a greater variety of in-house expertise and knowledge. This means a shift in their attention from traditional execution work to gaining a higher level of proficiency in these other fields. More clients in the construction industry also require contractors to engage in long term, integrated contracts, for example Design- Build- Finance- Maintain (DBFM) contracts, which also put a larger share of involved risks with contractors. These factors combined cause contractors to think differently about their risk management processes. That is why risk management needs to be an important and integral part of core business processes and culture of modern construction companies.

These developments have led to the demand of VolkerInfra to investigate their current risk management practices and design strategies for improvements and has subsequently led to the motivation for this research project. This report describes the research project, which will serve as Master Thesis project and conclusion of my Construction Management & Engineering Master at the University of Twente.

1.1. VOLKERINFRA

VolkerInfra is a relatively young organization, founded by four operating companies of the VolkerWessels concern: KWS Infra, Van Hattum en Blankevoort, Vialis and VolkerRail. VolkerWessels is the parent company of a large network of international construction companies that design, develop, build, manage and operate construction projects in the Netherlands, Belgium, the United Kingdom, the United States and Canada. They employ over 15.000 employees worldwide. The concern is active in the construction-, mobility-, energy- and communications- industries. The concern is mainly characterized by the amount of, mostly independently working, operating companies. These companies are managed locally as much as possible, each with their own responsibilities.

VolkerInfra was specifically founded for the purpose of managing large, multidisciplinary infrastructure projects. Their activities consist of integrating knowledge from all disciplines, from preparation of tenders to guidance and control during the project construction phase and operation/maintenance phases thereafter. Core aspects in their work are project management, asset management and all relating activities. These activities are organized in four departments: one process management department (Integrated Process Control) and two operational departments (Design & Build, and VolkerInfra Asset management). These departments cater to the needs of DBFM-, Design & Construct- (D&C) and long-term maintenance- contracts, which are currently the main parts of their target market.

1.2. SAA & SAAONE

SAA stands for Schiphol-Amsterdam-Almere and is a major road expansion program of Rijkswaterstaat. This program is intended to improve the traffic flow, travel time and quality of life between the aforementioned three major centers in the northern part of the urban agglomeration 'de Randstad'. This program consists of five projects:

- A10/A1 highway between junctions Amstel – Watergraafsmeer and Diemen, which was completed in 2014
- A1/A6 highway between junctions Diemen – Muiderberg and A6 exit Almere Havendreef, which is currently under construction
- A9 highway between junctions Diemen and Holendrecht, which is currently under construction
- A6 highway between exit Almere Havendreef to exit Almere Buiten-Oost, which has recently been tendered
- A9 highway between junctions Holendrecht and Badhoevedorp

The second, the trajectory between the junction 'Diemen' of the A1/A9 highways and the new A6 exit 'Almere Havendreef', was awarded to the SAAone consortium in 2012. SAAone consists of VolkerWessels, Hochtief, Boskalis and DIF. For a more detailed description of the project see chapter 3 and appendix B. SAAone is an organization in itself and its four partners have entered into a general partnership (VOF). The project is organized in a DBFM- construction organization, meaning the consortium is responsible for four project phases. From design to build and maintain for 25 years. It also includes the financing of the project. SAAone is used by VolkerInfra as example project to invest in innovations and test them. These innovations mostly concern organizational processes and systems and is therefore in that capacity also a client for this research project.

1.3. THE RESEARCH

This research project is aimed at exploring the risk management practice of VolkerInfra and specifically at providing insight into their risk identification process. Due to the project focus of VolkerInfra, the research is done via six case studies, which will provide insight into their risk management practice. Furthermore, an extensive literature review revealed that risk identification itself receives little attention in research but is considered one of the most important aspects of the risk management process. An initial exploration via preliminary interviews and a review of available case-data indicated a high increase in identified risks after the project was won in tender. For these reasons it was decided to focus on the risk identification aspect of risk management. These concepts and the research design itself will be further explained in this report. It will contribute to the risk management, and specifically risk identification, expertise of VolkerInfra. Furthermore, it will provide a basis for further expanding the knowledge on risk identification.

This research report is divided into five parts. The first part contains two chapters. The first focuses on a general exploration of the current dynamics in the construction industry and will continue where the introduction stopped. The second outlines the research design. This will start by delineating the research scope. Subsequently the problem definition, research objective and research questions are formulated, as well as explaining the research methodology. The second part focuses on the theoretical part of the research, consisting of an extensive literature review and identifying the theoretical ideals. This part contains four chapters. Chapter 4 focuses on definitions relating to risk management. Chapter 5

discusses three prevalent risk management frameworks. Chapter 6 discusses common risk identification methods and techniques. Chapter 7 discusses four manners of classifying risks that were derived from the literature review. The third part provides the results of the empirical research part of the research. This part contains three chapters. Chapter 8 contains an overview of the initial findings on the six case studies, resulting from an exploration of available data on the case studies. These mainly relate to occurred risks and actual costs. Chapter 9 discusses the empirical results of the interviews that were held in relation to risk identification, which explore the applied risk identification methods by risk managers of VolkerInfra. Chapter 10 follows with empirical results on the risk classification that was made for a number of high-profile risks on the case studies. The fourth part of the research consists of three chapters. Chapter 11 provides an overview of the conclusions that can be made based upon this research. These lead to a number of recommendations that can be made towards VolkerInfra, which are given in chapter 12. The last chapter discusses the limitations of the research, which lead to an advice for follow-up research. The final part contains the appendices, which are numbered A through H. An overview of these chapters is shown in Figure 1.1.

	<i>Part I Research Approach</i>	<i>Part II Theoretical background</i>	<i>Part III Empirical results</i>	<i>Part IV Synthesis</i>	<i>Part V Appendices</i>
Chapter 1 Introduction	Chapter 2 Industry Dynamics	Chapter 4 Risk Management	Chapter 8 Initial results: available data	Chapter 11 Conclusions	Appendices A through H
	Chapter 3 Research Design	Chapter 5 Frameworks	Chapter 9 Results risk identification	Chapter 12 Recommendations	
		Chapter 6 Risk Identification	Chapter 10 Results risk classification	Chapter 13 Limitations and follow- up research	
		Chapter 7 Risk Classification			

Figure 1.1 - Reading guide: chapter overview

Part I - Research Approach

This part contains a description of all aspects belonging to the research setup; a chapter explaining the current industry dynamics leading to the motive for this research. This is followed by a chapter defining the scope, research problem research objective and research questions as well as the methodology.

2. INDUSTRY DYNAMICS

This chapter describes the developments and current dynamics in the construction industry that have indirectly led to this research project. It is divided into two sections. The first section describes the external developments in the market, which have an effect on all organizations in the construction industry and specifically for risk management with contractors. The second section describes the subsequent consequences for VolkerWessels and how the external changes have affected their organization and led to the demand of VolkerInfra for an increased focus on risk management.

2.1. EXTERNAL DEVELOPMENTS

The latest quarterly report (Q4, 2015) from the 'Centraal Bureau voor de Statistiek' (Central Bureau for Statistics, CBS) about the 'Kwartaalmonitor bouw' (Quarter monitor of the construction sector) shows a fifth consecutive quarter with increased production in the construction industry as a whole. It also shows an increase in turnover of more than 5% average compared to a year earlier (Centraal Bureau voor de Statistiek, 2016). However, the prospects in the infrastructure sector specifically are much worse. They have an expected decrease in workload of 17%, even up to 55% in the province of Drenthe (Zwaga, 2015). At the same time prices in the ground- water- and road construction (GWR) sector are decreasing, which pressures the, already low, pricing in that sector. The prices have practically been stable since the beginning of 2012 and current prices are even slightly below that price level (Centraal Bureau voor de Statistiek, 2015). This puts even more pressure on the turnover of companies in that sector and increases competition. This resulted in more bankruptcies and less jobs in the sector and a decrease in turnover in the GWR-sector of 9% (Centraal Bureau voor de Statistiek, 2016). It also resulted in a workload decrease of GWR-companies of 27% compared to a year earlier (Doodeman, 2016). This is partly due to the slow recovery of the financial crisis in the construction industry and due to budget cuts in all layers of the government and the following decrease in governmental investments in infrastructure.

Another development in the construction industry entails the increasing transfer of risks from clients to the contractors. The largest governmental client in the construction industry in the Netherlands, Rijkswaterstaat, is facing budget cuts and has to slim down their organization. Due to these budget cuts and the ambition to better respond to the market, Rijkswaterstaat has introduced the 'Markt tenzij' ('Market unless') - principle, by which they increasingly transfer tasks and responsibilities, and thus corresponding risks to the market (Rijkswaterstaat, 2015). Anything that can be done by the market, should be done by the market is the philosophy, resulting in the phrase 'the market is responsible unless...'. Another large public client, ProRail, is increasingly working with long-term maintenance contracts that also transfer most risks and responsibilities to the market for a longer period of time, 10 years in the latest performance-based maintenance contracts (SpoorPro.nl, 2014).

Not only the length of the contract increases, but there are more different phases integrated in a single construction organization and contract, see chapter 3 for a more detailed description. Large (infrastructure) projects, again by governmental clients, increasingly integrate the design and construction phases in a single contract. Even the maintenance, finance and exploitation phases are sometimes included in these contracts (see section 3.1). Apart from the different project phases that are integrated in large projects, the work itself is also more diversely integrated in large contracts. Contractors

are required to deliver complete products, not only the road itself, but a complete product in the form of the road, road markings, installations, lightning, roadsides etc. This requires the integration of multiple disciplines. For the large projects that VolkerInfra manages even more so, these are often combinations of large GWR works and civil constructions. Many of the specific tasks included in large projects (for example piling and braiding of reinforcements) are executed by sub-contractors, adding an extra layer in the organization and increasing the management tasks and responsibilities and thus the risks.

The increased contract durations and integration of project phases and work in large construction organizations motivate contractors to make specific investments for projects to reduce overall costs. It also offers opportunities for the contractors to develop innovative solutions in early stages of the project, since the longer project duration makes that worth it. This increased duration and complexity however, also means that risks are increasingly transferred to the market as well, which is not necessarily a good thing. It requires more knowledge with contractors and close monitoring of project progress in order to successfully manage projects. It is not guaranteed that contractors are ready for these changing market conditions in the short-term. When unforeseen events do happen, the consequences are often costly and will require long-term experience to manage effectively. There is a recent example in the construction industry that illustrates the possible negative consequences. Contracting company Ballast Nedam got into deep financial problems, mainly due to unexpected cost overruns on two large infrastructure projects, the A2 Passage Maastricht (Design & Construct) and the A15 Maasvlakte-Vaanplein (DBFM) (ANP, 2015). The A-Lanes-A15 consortium only recently reached agreement on a settlement between them and Rijkswaterstaat after a lengthy discussion on the matter (Battes, 2016). Ballast Nedam had to resort to an international takeover by the Turkish construction company Renaissance. They were forced to accept an extremely low offer of only € 6 million for 95% of the company's shares in order to survive, penalizing other shareholders that saw the value of their shares decrease by over 91% (Dobber, 2015).

These problems go hand in hand with the pressure on prices in the industry and the financial crisis from which the construction industry has only recently started to recover. Construction companies currently often tender below the normal market prices in order to sustain enough turnover to survive in the first place (Profnews, 2015), while at the same time they have to bear increased risks and responsibilities (Battes, Staat speelt bouwsector genadeloos uiteen, 2015).

The developments mentioned above raise questions in the current market whether contractors are currently capable of bearing the risks that accompany such large projects. Other options in future contracts are being considered, for example sharing the risks with the client. They also generated criticism on the Rijkswaterstaat policy. Rijkswaterstaat themselves have recently experienced the consequences of these problems on large infrastructure projects: only two consortia were interested in tendering for the A10 Zuidasdok project, one of the largest upcoming infrastructure projects with a total cost of around € 1.9 billion (+/- €1 billion contract value). Furthermore, there was very limited interest from construction companies in tendering for the new sea lock at IJmuiden, with a contract value of around € 800 million. The conclusion is simple: the risks are simply too big and construction companies are not willing to bear these risks after the recent problems (Houtekamer, 2015). This made Rijkswaterstaat realize they had to act differently towards the construction companies and resulted in them taking over part of the risks for the Zuidasdok project. Among others, the obtaining of the permits, the setting of a bottom tender price and monthly payments for the contracting party were measures implemented

by RWS (Battes, Rijkswaterstaat maakt knieval voor bouwers, 2015). Furthermore, to prevent future conflicts between contractors and Rijkswaterstaat on large infrastructure projects, a common 'market vision' has been developed by Rijkswaterstaat and their most important contractors. This market vision contains a number of principles to improve relations between the client and the contractors and increase transparency on risks and problems (Clahsen, Rijkswaterstaat en bouwsector lanceren nieuwe werkwijze om 'vechtcontracten' uit te bannen, 2016). This means for example that the price is subordinate to quality, meaning that contractors are involved in the entire preparation phase of projects and potential candidates are selected based on their added value to the project and not on price. For example, for the Nijkerkerbrug renovation, the price was not determined until only one candidate was left for the tendering of the project, indicating a focus on quality and added value (Clahsen, Nieuwe werkwijze Rijkswaterstaat wordt langzaam tastbaar, 2016).

These market developments show that the modern construction industry requires a high level of proficiency of, among others, risk management. It also shows that effectively managing and monitoring these risks is more important than ever.

2.2. *INTERNAL RESPONSE*

As stated in the introduction, VolkerInfra is a relatively young project management company, founded in 2006. The company was founded in part due to the changing demands from the market and the increased use of large, integrated contracts by important clients. Due to the historically fragmented and independent nature of the operating companies of VolkerWessels, some of the operating companies struggled with the relatively new and large integrated contracts in the industry. The need arose for some of the operating companies to combine their knowledge and expertise in project management, in order to enable them to deal with larger, integrated contracts.

VolkerInfra was set up to bring the different disciplines of the operating companies together and to ensure and tune a transparent work environment when the disciplines of VolkerWessels need to work together in large, integrated projects. Furthermore this would strengthen the individual project management capabilities of- and the cooperation between- the operating companies of VolkerWessels. A special company with the purpose of managing and controlling large projects and integrating the disciplines of VolkerWessels was founded. VolkerInfra employs a 'Best for Project'-policy to ensure that the project objectives are the main objectives during the execution and not the individual objectives of the operating companies or consortium partners. This is for example reflected when budgets need to be redistributed, which VolkerInfra ensures to happen according to the 'best for project' principle and not to the operating company which has the best claim on them. These tasks have required VolkerInfra to expand their knowledge in the relevant disciplines and they continue to do so in response to external developments and internal ambitions.

2.3. OVERVIEW

Figure 2.1 shows a schematic overview of the previously described external and internal developments, in sections 2.1 and 2.2, and the resulting objective of VolkerInfra.

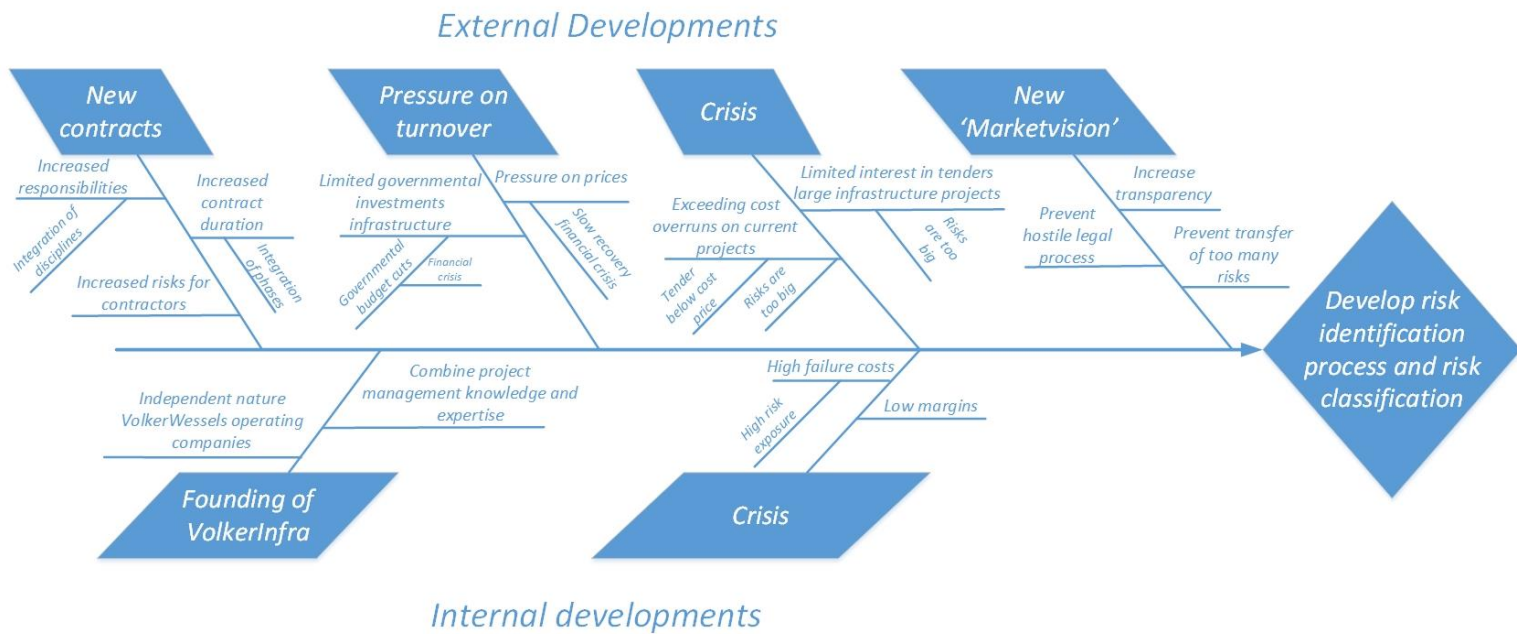


Figure 2.1 - Diagram external and internal developments in time

3. RESEARCH DESIGN

This chapter describes the research design for the master thesis project. It starts by delimiting the scope of the research, after which the specific research problem is defined. Furthermore the research objective and research questions are stated. Finally the applied research methodology is described.

3.1. SCOPE

This section defines the research in terms of its intended scope. The delimitation of the scope is done in a comprehensive manner, step-by-step in the subsequent sub-sections. It is the result of an extensive preparation period, which was required since the specific research focus and scope was not yet clearly defined at the start of this research. The preparation period consisted of gathering preliminary case-data and a series of exploratory interviews with experts within VolkerInfra. This exploratory process is further described in the research methodology in section 3.5. The research is done for VolkerInfra and their scope as a company is the starting point of this research.

VolkerInfra's task within the VolkerWessels concern consists of project- and process-management and related tasks on large infrastructure projects. Their target market within the construction industry consists of two focuses. The first lies with large-scale integrated construction projects, in which the integral aspect is the central characteristic. Either or both different disciplines (e.g. GWR and Civil) or project phases (e.g. design and construct) have to be integrated in a single project for VolkerInfra to become involved. These projects are therefore generally long-term and high value. They generally concern the initial preparations of the tender until the end of the execution or even longer when a maintenance phase for the project is included. The second lies with long-term maintenance only projects, in which VolkerInfra is responsible for the maintenance of infrastructure objects or assets for a longer period of time. These projects are mainly related to the asset management activities of VolkerInfra.

As was made clear in the previous chapter, the construction industry currently struggles with the responsibilities that accompany the execution of large-scale infrastructure projects. The focus of this research is therefore not on the maintenance projects of VolkerInfra, but on their integrated, large-scale execution projects. There are a number of integrated disciplines and objects present in each of these projects, which will be described in the subsequent sub-sections in order to further limit the scope of this research. Firstly however, the project focus will be further illustrated in the first sub-section.

3.1.1. VOLKERINFRA: A PROJECT FOCUS

The strong project focus of VolkerInfra also means the majority of their employees are stationed directly on the projects. Improvements to the organizational processes of VolkerInfra are derived from their projects. For example: out of the 10 projects that VolkerInfra carries out at any given point in time, the best performing project is chosen and used as basis on which future processes in projects and the organization are based. This obviously doesn't happen overnight, but has a learning curve and improvements are implemented gradually. Due to that focus and organization this research will be grafted on projects, which will be done via case studies.

In consultation with VolkerInfra, six projects, either recently completed or still in the execution phase, have been selected to serve as case studies for this research. These have been used to obtain relevant data and make comparisons between them. An overview of the selected case studies is shown in Table 3.1.

Table 3.1 - Overview of selected case studies

ID	Project/ combination	Contract	Approx. contract value	Tender date	Approx. completion date
1	SAAone	DBFM	Confidential ¹	12-12-2012	2020
2	A4All	D&C	Confidential	Sept. 2011	End of 2015
3	Combinatie Badhoever Bogen (CBB)	D&C	Confidential	End of 2012	Mid 2017
4	Utrechtse Tulp	D&C	Confidential	End of 2009	2013
5	Galecom	D&C	Confidential	April 2013	End of 2015
6	Willems Unie	D&C	Confidential	Mid 2010	Beginning of 2015

More details on each of the six cases included in this research are given in appendix B. The central case study in this research is the SAAone project. The SAAone project has its own organizational structure, a VOF, as shortly introduced in the introduction. SAAone is being used by VolkerInfra as a pilot project, where innovations can be invested in and tested and in that capacity SAAone is also client for this research. Rijkswaterstaat is, or has been the client for all of these projects. All of them are executed by a combination of multiple contractors, in which VolkerInfra also participates. These combinations are organized in specific integrated construction organizations, which are discussed in the following subsection.

3.1.2. INTEGRATED CONSTRUCTION ORGANIZATIONS

The third column in the overview of case studies in Table 3.1 shows that VolkerInfra provides its services in different contracts. These contracts relate to the form in which the project is organized and is called construction organization forms. These are organizational structures that establish the responsibilities of the contractor. The organizational forms that VolkerInfra is involved in are integrated construction organizations. These are construction organizations in which the contracting party is responsible for multiple phases of the project, which is subsequently legally established, hence the term 'contract'². These construction organizations are embedded in fully operational organizational structures, in the form of separate companies or combinations. These construction organizations are often also responsible for combining multiple disciplines, e.g. GWR and civil (concrete construction), in one project, which adds an additional dimension of interfaces and responsibilities. Traditional construction organizations consisted of a specification of the entire project in detail and there were separate contracts for design and construction phases of a project. Integrated construction organizations combine these phases and responsibilities in a single organization and contract for a single contracting party or combination of parties.

There are a number of different integrated construction organization forms, with increasing integration of project phases and responsibilities. This research focuses on Design & Construct (D&C)³ and DBFM construction organization forms, since these currently are the

¹ Confidential values

² Construction organization forms and contract forms are often confused and therefore discussed here.

³ The concepts Design & Construct (D&C) and Design & Build (D&B) are interchangeable, but in practice used for the GWR-sector and the Building & Utility (B&U)-sectors respectively (Jansen, 2009).

main focus of VolkerInfra and are the organizational forms used in the chosen case studies. Design-, Build- and Maintain- (DBM) projects are not very common in infrastructure projects in the Netherlands, but some examples can be found, e.g. the older Westerscheldetunnel construction project. These are not part of the scope of this research.

There are also Design-, Build-, Finance-, Maintain-, and Operate- (DBFMO) – construction organizations. In these organizations, the 'operation' part means that the contractor is also responsible for exploiting the network through network management to generate income to earn back the initial investment. This means that the contractor is given a concession to exploit the network to generate income, which is the main difference with DBFM-organizations (Vlaams Kenniscentrum PPS, 2009). In the Netherlands this is generally only applied for some building & utility projects, e.g. the National Military Museum in Soest. This type of construction organization is generally not applied for infrastructure projects in the Netherlands. This is because the operation of infrastructure is more of a public service and because it is part of a larger network and is therefore difficult to split up. For example, the traffic service operation, which guides the matrix signs above the highway, need to be operated from a central location, since decisions on one part of the road influence the others in the network. Operating buildings for example is more separable than part of a road. In Dutch infrastructure projects, the operation task therefore generally remains a strictly public responsibility. Income for the private partners is generated by the public body and the private partners earn back their investment through availability payments during the projects' life-cycle, depending on availability of the infrastructure facility (Lenferink, Tillema, & Arts, 2013) (Jansen, 2009). Initial funding usually comes from a combination of banks, private investors and the contractors themselves, which is then earned back over time.

In other countries there are some other organizational forms that are commonly used, that are comparable to DBFMO. Examples are Build-Operate-Transfer (BOT) projects, Build-Own-Operate-Transfer (BOOT) projects and Build-Own-Operate (BOO) projects. Aside from the concession to generate income from the network, these differ from DBFM in that they also transfer ownership of the network to the contractor for the duration of the contract (Kenniscentrum PPS, 2008). This transfer of ownership is not used in the Netherlands, since the government wants to have unrestricted control over the object in the event of bankruptcy of the contractor (Kenniscentrum PPS, 2008). These are therefore not part of the research scope since they are not applied in the Netherlands and thus not part of the target market of VolkerInfra.

Some of the construction organizations discussed above can be grouped under the heading Public-Private-Partnership (PPP). For the Dutch national government, PPP projects are the DBFM and DBFMO projects (Rijksoverheid, sd). These will be applied when the contract value of infrastructure projects is above € 60 million and the two tools Public-Private-Comparator and Public-Sector-Comparator indicate that a form of PPP is more effective than traditional procurement methods. Sometimes also DBM projects are considered under the PPP-heading as a 'light' variant (PPS Netwerk Nederland, sd). Generally speaking the PPP-heading indicates a high level of transparency between the client and the contractor and a close cooperation between them.

An overview of these organizational forms is shown in Figure 3.1. Both, for this research, relevant forms (D&C and DBFM) will be discussed in more detail in the following two paragraphs. Thereafter, the relevant project phases are discussed.

DBFM

DBFM, as integrated construction organization forms, are part of the target market of VolkerInfra and will therefore be an important type of organizational form in their activities. DBFM is an integrated construction organization in which a private party (or combination of private parties) is responsible for design, construction⁴, financing and maintenance of a project and in this research relevant: for an infrastructure project. A DBFM construction organization is mainly different from other types of integrated construction organization forms because the 'finance' and 'maintenance' phases are included in the contract. This can be a good solution when the client itself does not have enough initial capital available, while private funding still ensures that the project can be executed (Jansen, 2009). It also reduces the number of involved parties and therefore the number of interfaces and corresponding complexities and risks. Furthermore it is characterized by the transfer of risks and responsibilities to the party that is the most able to control and bear these risks, which generally means the contractor, combination or consortium responsible for the project. Some specific risks may however remain with the client, depending on the specific arrangements made. The combination or consortium usually sets up a Special Purpose Vehicle (SPV) or Special Purpose Company (SPC), in which the participating companies are the shareholders and which is specifically designed as a separate legal entity for the project. The SPC has the task of handling the financing of the project, but is usually only used as a service-hatch that transfers the other phases of the project to an Engineering, Procurement and Construction (EPC) or Engineering, Procurement, Construction and Maintenance (EPCM) company, designated for the execution of the project. This, in theory, keeps the SPC itself free of project execution risks.

D&C

The second type of integrated construction organization form that VolkerInfra mainly deals with is D&C. In a D&C construction organization, the contracting party is responsible for the design and construction phases of a project. Because of its integrated form, there is also only one party responsible for the design and construction phase of the project. This gives the same interface advantages as for the DBFM construction organization described above and improves the alignment of the design and construction phases. However, maintenance and finance are not part of the agreement, which has advantages for the contracting party. In a D&C construction organization, risks are not all transferred to the contracting party and the client usually specifies the object that is to be built in a functional way. This leaves room for innovations by the contracting party, while still ensuring that the project meets the functional requirements set by the client. Additional advantage for the contractor is that payment for the project does not depend on availability of the project, as is the case with DBFM construction organizations in the Netherlands. The D&C agreement still transfers the design responsibilities to the contracting party, whom therefore still is legally responsible for those and the project keeps its integrated character.

⁴ In this research the term 'construction phase' will apply for the build phase of a DBFM. This is done to prevent confusion with the construction phase in a D&C, which are considered to be the same.

Project phases

As well as differing responsibilities in integrated construction organizations, a number of corresponding phases can be identified in these projects. The research focuses on specific phases of construction projects, which are described below and shown in Figure 3.1.

- The first part consists of the tender preparation phase, which considers the internal preparation of the contractor for a tender bid. This part also considers the link between the tender- and execution-phase (the design and construct phases combined⁵). With the link between the tender phase and the execution phase, it is meant, how the tender phase influences the execution phase. This link is valuable for this research since errors in the transition between both phases can have severe consequences for the project objectives and thus for the 'best for project' philosophy of VolkerInfra. For example when risks are incorrectly transferred from the initial risk register (tender phase) to the final risk database in the execution phase (for further information, see sub-section 3.1.6). This phase also sets the basis on which the rest of the project is carried out, see chapter 6 on the importance of early risk management.
- The second part consists of the execution phase itself. The focus lies on the execution phase itself, because that phase usually has the highest turnover (the phase in which the money is spent) and has the highest failure costs. This phase determines the final quality of the end-product and therefore also determines the corresponding required maintenance strategy. This phase relates to the actual execution and control of the project, which needs to comply with decisions made during the tender phase.

The phase that is not included in this research is the maintenance phase:

- The maintenance phase of the long-term projects is not included in the scope of this research. This is because the first DBFM infrastructure projects have only recently been completed and there is little experience with that phase of projects in the Netherlands. Furthermore, during long-term maintenance phases, there is a cycle that is repeated every year or every few years, with a corresponding recurring cycle in budget and a learning curve over time. Therefore the maintenance phase is substantially different from the rest of the project execution. The quality of work during the execution phase partly determines the required work during the maintenance phase. Furthermore, the interest generated over the longer time period during the maintenance phase generates a different type of turnover, requiring different management strategies and is therefore not included.

⁵ The design and construction phases in large contracts often partly run parallel, as well as part of the design happens in the preceding tender preparation phase and therefore both put under the 'execution' denominator.

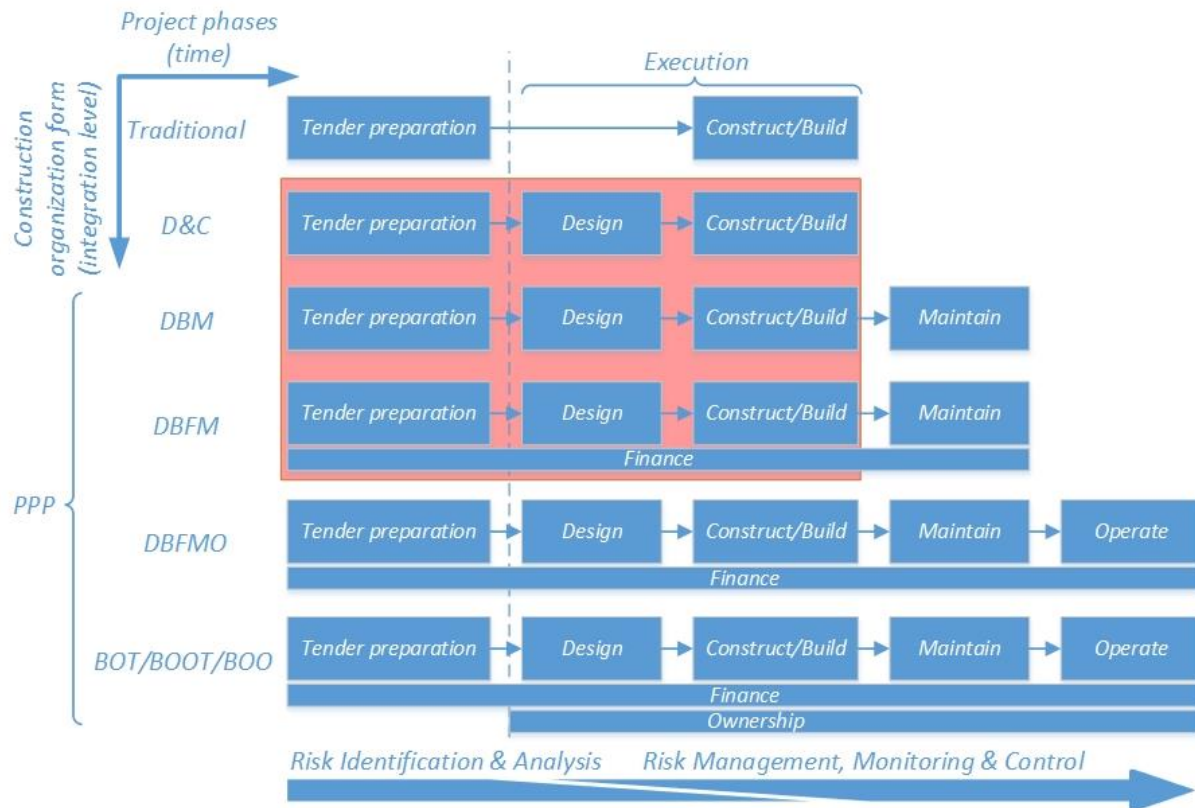


Figure 3.1 - Project phases and construction organization forms, with the scope highlighted in red

Advantages & Disadvantages

One of the major theoretical advantages of these large integrated construction organizations is that they offer room for the client to profit from the innovation capabilities of the market. Because the contractor is involved from the beginning of the project, it is possible to make use of the innovation capability of the market. The contractor is able to invest in innovations and thus provide better solutions, since he has a better understanding and a longer connection to the project. For example, innovative design solutions can save money during the execution phase of the project. It becomes possible to profit from these investments in the long run since the longer contract durations allow for an improved cost recovery model. These innovations may be costly in the beginning, but because of improved future prospects these can be profitable, thereby providing an incentive for the contractors. This should give a boost to the innovation capacity of the construction industry, promote the distinctiveness of construction companies and lead to cheaper solutions for large infrastructure projects. However, whether this goal is achieved, is difficult to say. Because of increased risks with contractors due to increased responsibilities and complexities, the projects not always turn out to be cheaper. Increased complexity is the main disadvantage of these organizations. It emphasizes the importance of proper management on these projects.

Another advantage includes that the client only has to deal with one contracting party, which is responsible for the entire project. This reduces interface risks between traditionally separated project phases and disciplines since only one party is responsible. It also reduces coordination tasks and thus costs. Furthermore combining project phases in one construction organization usually results in a shorter overall project duration. Risks are for the most part transferred to the contracting party as well. Exceptions can be made for specific subtasks in the contract itself, but these are not part of the scope of this research,

since they are too specific. Major disadvantage of these integrated construction organizations is the high increase in transaction costs when the contractor is found inadequate and another has to be selected.

3.1.3. PROJECT SUCCESS

Generally a project is designed to achieve a strategic objective, which in the construction industry is mostly developed by the client, for example 'improve the traffic flow between A and B'. These objectives tend to be politically tinted, e.g. when the Secretary of Infrastructure promises the public to 'tackle congestion'. Operational objectives are often represented by a certain budget and time frame within which the project needs to be completed. The operational objectives are more prone to influence from the contractor as they can have direct influence on it by expenditure and quality of the executed work etc. These operational objectives will therefore serve as the set of project objectives relevant for this research, while the strategic objective is not part of the research scope.

Research presented by B. Flyvbjerg, M.K.S. Holm and S.L. Buhl over the last decade has shown significant cost escalation on large infrastructure transportation projects. Their initial publication (Flyvbjerg et al., 2003) analyzed a sample of 258 projects divided over 20 nations and five continents, with an approximate total value of \$ 90 billion. Their statistical analysis showed substantial cost escalation for rail projects (45%), fixed links (34%) and roads (20%). Furthermore, a separate study showed that delays on these large infrastructure projects are very costly, on average leading to 4,64% cost increase per year of delay, after the decision to build (Flyvbjerg et al., 2004). In terms of operational objectives, this indicates a structural tendency for large infrastructure projects to overrun on their operational objectives of budget, time and performance (Flyvbjerg et al., 2009). Flyvbjerg focuses his research on the governance aspect, policy making and planning of large infrastructure projects, which is oriented towards the client side to get approval for funding. His identified causes lie with strategic misrepresentation and optimism bias regarding misinformation about costs, benefits and risks of large infrastructure projects (Flyvbjerg, 2007). But while the client side of project promoting is also important, it doesn't fully explain the extent to which these objectives are overrun. Therefore, research into the contractor side is needed, to which this research will contribute.

The operational objectives on projects often refer to specific achievements in what is known traditionally as 'the iron triangle' (Winch, 2010; Atkinson, 1999). This consists of quality (can also referred to as 'meeting the scope', which comes down to conforming to specifications set beforehand (Winch, 2010, p. 207)), time (schedule) and cost (budget). From the point of view of the contractor, his own commercial performance as in: "Did those who provided a service for the project benefit commercially?", is also important (Morris & Hough, 1987). But this last aspect is of less relevance to this research as it is mostly covered by the cost aspect and profits for the contractor are difficult to estimate and track in large, integrated contracts. In order to assess project performance, often the degree to which these objectives have been met determines the success or failure of a project (De Wit, 1988). Thus, a project needs to be delivered according to specifications, on time and within budget to be considered successful. Recent projects often have a focus beyond the traditional iron triangle of project objectives and also include aspects such as safety, impact on the environment, sustainability/life cycle, meeting stakeholder demands and image. Many research efforts argue that the traditional approach is too narrow and project success will depend on more factors than the traditional triangle, e.g. Winch (2010) refers to minimizing client surprise as an important aspect and De Wit (1988) distinguishes project success from project management success and thus different corresponding factors. As the

projects that are used as case studies in this research are integrated contracts, these also look towards a more complete life-cycle analysis of the infrastructure and therefore not only the traditional triangle of project objectives applies, but also other objectives of stakeholder satisfaction, safety, environment and sustainability. Winch places the project mission at the heart of the definition of success and combines the traditional iron triangle with a second triangle. The first triangle stands for product integrity, meaning managing the entire project life cycle with appropriate intent. The three points are the quality of conception, concerning the adding of value in the life cycle, the quality of specification concerns the fitness for purpose of the product and the quality of realization, which refers to a second triangle. The second triangle captures the traditional operational objectives of the project, and stands for process integrity which includes management of the process of realization within the project constraints. These are represented by the objectives for time, budget and conformance. Conformance then includes conformance to safety, quality and environmental impact. Achieving both triangles minimizes client surprise and achieves project success. The triangles are shown in Figure 3.2.

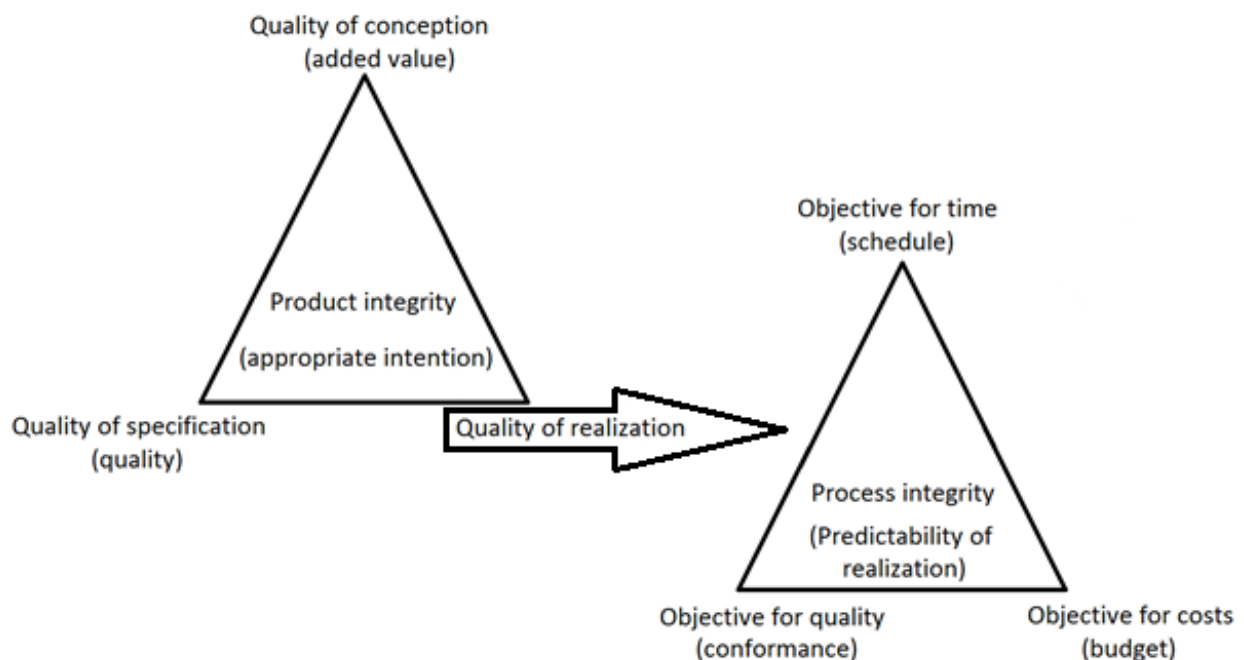


Figure 3.2 - Double triangle project success, derived from Winch (2010)

3.1.4. THE RELEVANCE OF RISK MANAGEMENT

Based on the literature review in section 4.1, risk in a project management context is, in this research, defined as:

"Risk is the positive or negative effect of uncertainty on one or more objectives, as determined by its likelihood, consequence and strength of knowledge".

This relation to objectives on projects is also reflected in the different risk management frameworks available in literature, as discussed in chapter 5. Therefore, risk management partly determines the extent to which objectives on projects are met and thus the extent to which project success is achieved. Consequently, this research also needs to assess the effect of risk management on objectives to be able to critically evaluate it.

According to the Project Work Instructions (PWI) of six case studies (case documents), the criteria for the inclusion of risks of the projects in the risk database for the most part

depends on their influence on the project objectives, their relationship with the client or whether it requires an integral approach. Furthermore, VolkerInfra uses the RISMAN (RISK MANagement)-method in their projects to enable quantification of risks by categorization in terms of effects on the project objectives of cost, time and quality and in some projects the additional ones of safety and/or environment and/or image/stakeholder satisfaction that are also mentioned above. The RISMAN-method itself is explained from a theoretical point of view in chapter 5. The way to assess risk management logically relates to all the objectives that are actually used on the projects. This way, risk management can be made tangible and the associating numbers enable the building of a foundation on which conclusions and further research can be based.

However, after initial interviews and an initial analysis of the obtained documents and risk registers from the cases, it is clear that some of the quantified objectives in the RISMAN method differ per project and some are not used consistently for each risk, while they are included in the analysis. The only metrics that are consistently being used for each risk are the probability of the risk occurring, and a quantification of the cost and time for the consequences of that risk. The other objectives are often blank or are covered by other project management aspects:

- Safety is a separate process in its own right in most of the projects and has multiple concern-wide campaigns. For example: Wees Alert! Veiligheid Eerst! (WAVE, meaning Be alert! Safety first!) and: No Injuries, No Accidents (NINA). Specific safety risks have their own database on the projects and are therefore not included in the scope of this research.
- Stakeholder satisfaction is achieved by short communication lines with the stakeholders, including them early in the project, information evenings/letters and, as for the client, including them in the entire process through specific requirements of auditing, improvement management, systems engineering and regular meetings. Furthermore stakeholder management is, as is safety, a separate process in its own right with dedicated stakeholder managers employed on all of the projects and not included in the scope of this research.
- Environmental impact is accommodated in the Milieu Effect Rapportage (MER, meaning Environmental impact study) in early phases of the project and, when applicable, stated in the Economisch Meest Voordelige Inschrijvings –criteria (EMVI, meaning Most Economically Advantageous Tender, MEAT-criteria) during the tender. This usually contains requirements for the CO²-performance-ladder and life cycle analysis. However, this currently has no further role in the risk management process and is therefore not included in the scope of this research.

As for the objective of time; the case studies themselves concern relatively large infrastructure projects, with a total time period that spans multiple years. Therefore, many of the risks have no impact on the final date of completion. Most risks can be corrected by changes in the critical path of the projects and by employing more people to enable the project to get back on schedule. This will result in higher costs, but has no effect on the planning and is therefore not traceable. The only metric that can consistently show the actual impact of risks are associated costs and therefore that metric is chosen to assess the risk management with. This is not to say other metrics are not important and soft influences like organizational culture do not apply or are not important, it is simply an argument to be able to categorize risks and assess their impact as a starting point for this research. Costs are probably best known in the projects themselves and best suited to identify the specific problem. Last relevant point is that using cost as measuring tool for

the performance of risk management has the support of risk managers across VolkerInfra, as it was conceived in joint discussions. It will allow for increased insightfulness of the consequences and thus enable them to convince others of importance of risk management and thus attitude towards risk.

3.1.5. THE RISK MANAGEMENT PROCESS

To define risk management, first management itself is defined. Winch (2010) has based his definition on the context of the management of construction projects and is therefore applicable to this research. He defines management in a project context as: *"...moving through the project life cycle is essentially structured sense making"*. This is derived from his perception of the main challenge for managers, which he essentially defines as the management of information in the face of uncertainty and in which uncertainty is defined similar as in section 4.1.1. (a state of deficiency of information). Applied to projects, this entails that project managers make decisions in response to the availability of information, while trying to achieve the project objectives. These decisions then yield further information on which future decisions can be made and progressively reduce uncertainty during the project life cycle. The progressive reduction of uncertainty is shown in Figure 3.3. This effect is limited in organizations, as they are not subjective to a life-cycle and is therefore an additional challenge in projects.

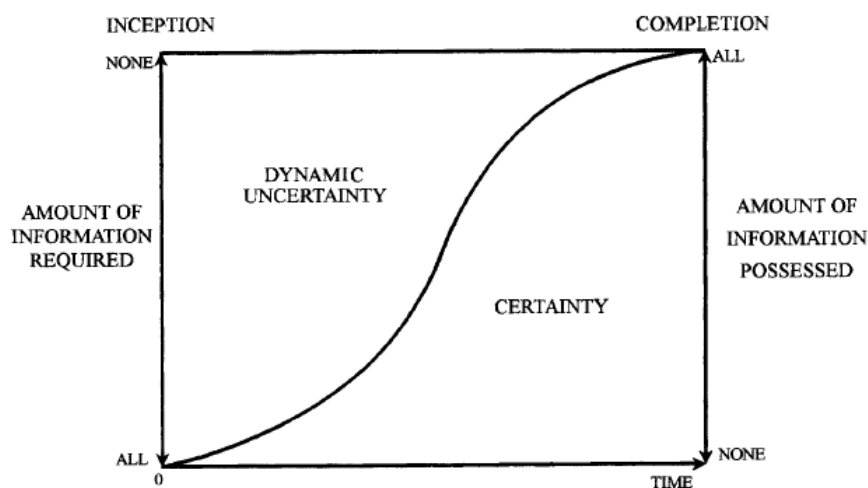


Figure 3.3 - Information and uncertainty in the project life-cycle (Winch et al., 1998)

There are a number of readily available definitions for risk management from differing viewpoints. For example, the ISO 31000:2009 standard defines risk management from an organizational viewpoint: *"coordinated activities to direct and control an organization with regard to risk"* (Dali & Lajtha, 2012, p. 8). From the viewpoint of decision makers in organizations, risk management may be termed as: *"...a comprehensive, systematic process that assists decision-makers in identifying, analyzing, evaluating and treating all types of risks, both internal and external to the organization."* (Shortreed et al., 2000, p. 14). From the project management viewpoint, risk management can be defined as: *"the entire set of activities and measures that are aimed at dealing with risks in order to maintain control over a project."* (Van Well-Stam et al., 2004, p. 1). The two recurring aspects are: coordinated and well thought out *activities* and maintaining *control*. Thus, risk management comes down to giving thought beforehand on events that might occur, so that decisions can be made to take early action and develop control measures, while monitoring this process to reduce negative impacts or exploit positive opportunities.

'Structured' is used to indicate that sense making is facilitated through structured routines, e.g. standard frameworks and processes. These processes generally consist of the following generic aspects:

- Risk identification
- Risk analysis (in some works referred to as risk assessment)
- Risk response
- Monitoring and control

They are often applied in a cyclical manner during the project execution, as is shown in Figure 3.4. These aspects are also mentioned in a similar way by many researchers in this field, e.g.: Bandyopadhyay et al. (1990), Al-Bahar & Crandall (1999), Shortreed et al. (2000), Pipattanapiwong (2004) and Winch (2010). Furthermore, they appear similarly in the frameworks that are reviewed in chapter 5. The generic aspects will be further explained in the following few paragraphs.

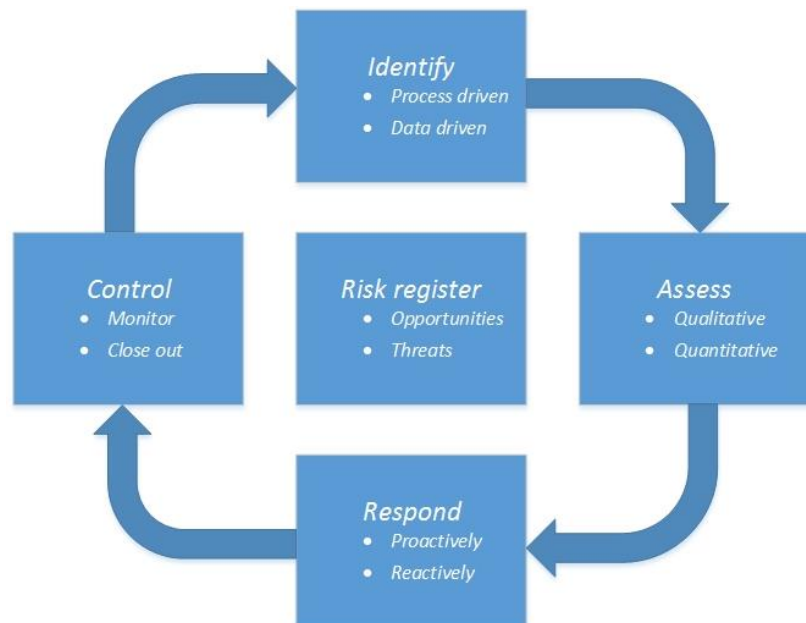


Figure 3.4 - Generic risk management process (Winch G. M., 2010)

Risk identification

This is usually the first step in the risk management process after the project context itself has been established. Risks are identified in relation to the project objectives. This aspect is usually performed by the risk manager, for which several methods and tools can be applied to help this step. These are discussed in more detail chapter 6. This risk identification step results in a risk dossier in which all identified risks are recorded.

Risk analysis

After a risk is identified, it is analyzed. This usually means a probability of occurrence, the consequences and other required knowledge are estimated. Consequences are usually divided on the effect on different objectives, depending on which objectives are required on that specific project. As indicated in the previous sub-section, these are usually expressed in time and cost, but some additional objectives may be defined. The analysis can be made quantitative or qualitative, but it is argued that a semi-quantitative approach is most applicable to the construction industry. This is reflected in the proposed approach to risk in the theoretical review in section 4.1 and for example also suggested by Winch (2010) and Chapman (2001). The data that is required for an objective quantitative approach is simply not available, especially in the early stages of a project when the analysis is initially required and available information is limited and uncertainty is high. Therefore a mixed approach is often used, in which data is solicited from experts and therefore subjective. After the subjective data has been obtained for each risk, a probability analysis is done, for example through a Monte Carlo simulation, in which the overall risk profile for the project is established.

Risk response

After the risks have been analyzed, a response can be determined. It will depend on the severity of the risk what kind of action is required and how much will be invested to implement control measures to reduce that risk. The proposed measure needs to reduce the risk with more in terms of costs, than it costs to implement the control measures. I.e.: if a measure is too expensive in relation to the value of the risk itself, it isn't worth it to implement the control measure. These control measures are aimed at reducing the overall risk profile.

Monitoring and control

After the risk response has been determined and the control measures have been established, the risks need to be monitored and controlled. This mostly means that the project will be monitored by the risk managers. New risks need to be identified when applicable and they need to be added to the risk database. In that case, the identification and analysis steps are repeated. Similarly, when risks can no longer occur, they need to be eliminated from the actual risk profile. The risk manager then needs to keep higher management informed on the actual risk exposure of the project. Furthermore, risks that are being monitored are controlled and the right people need to be informed on the risk exposure.

3.1.6. INITIAL FINDINGS: POINT OF DEPARTURE

As was stated in sub-section 3.1.3, VolkerInfra applies the RISMAN method as main guideline for their risk management practice. However, the complete process per project is more extensive and complex than just the RISMAN method. A generic process has been developed by VolkerInfra, which, theoretically speaking, serves as guideline for the risk management process that is done on projects. This process is schematically shown in appendix C. It contains elements of the generic aspects discussed in the previous sub-section. Details of this process can be changed to comply with specific client demands on different projects. This process is used by different risk managers of VolkerInfra, who are free to interpret this process in a way they see fit on different projects. For example, the exact manner in which the process step 'identifying risks' is executed can differ per project and per risk manager, according to client demands and/or preferences of the responsible risk manager.

The generic process more or less prescribes the tasks and/or responsibilities of the risk manager and the interfaces with other main processes step by step. This process can be related to the concept of total project risk. After the preliminary analysis of the six case studies, the process that is used in practice, in the tender and execution phase, can be related to the concept of total project risk. This is shown in Figure 3.5, which shows the relation between the most important aspects of the risk management process and the total project risk and the relative unidentified and identified parts, during the two consecutive project phases. This process in practice is very dynamic, but the figure suffices as an initial, general overview. A few notions on this figure will be made below, based on the analysis of case study data so far, which will be the point of departure for this research.

The total project risk is divided in unidentified risks and identified risks. Identified risks are identified in the risk management process, through the risk identification step. They are subsequently included in the risk analysis, in which the consequences and probability of occurrence are assessed. Unidentified risks are unknown to the project team, as they have not (yet) been identified. It is important to note that both unidentified and identified risks can occur, for identification is not a prerequisite for occurrence.

- Unidentified risks can occur, in which case they are surprises, since they were unknown up to that point. They can also not occur, in which case any knowledge that could have been achieved remains unknown. Unidentified need to be divided further, in order to analyze the effectiveness of the risk identification process. Because risks can be unidentified for varying reasons, they are not always the fault of an insufficient risk identification process:
 - Risks that could have been identified, but for varying reasons it was not identified, e.g. a lack of knowledge, a lack of resources dedicated to identification, or an insufficient risk identification process. In these cases, the fact that the risk remains unidentified is usually attributable to the contractor.
 - Risks that were not identified but resulted from a change of the project scope, e.g. because of changing client demands. These are therefore unable to be identified sooner, in which case they are not attributable to the contractor.
- Identified risks can occur, in which case the estimation of the consequences can either be right or wrong. The reserved budget can therefore be sufficient or insufficient. They can also not occur, in which case they are well managed or controlled.

During both relevant phases, the unidentified risks gradually decrease and the identified risks gradually increase. This is represented by the white line that runs through Figure 3.5. The identified risks generally increase faster right after the project has been won in tender than during the tender phase itself, which results in more risks being identified during the execution phase than during the tender phase. This was identified during the preliminary analysis of the case studies and the corresponding results are discussed in chapter 8.

After the risks are identified during tender, they are analyzed. This means that specific numbers in the RISMAN categories (cost, time and sometimes environmental, safety and quality, as discussed in sub-section 3.1.3) are assigned to the risks. These numbers represent the consequences of that risk, if that risk were to occur. For the probability of occurrence, a number is assigned as well. These numbers represent corresponding categories, usually one to five, one being the lowest and five being the highest. Each corresponding category represents a value or range that enables the quantification of the risk. An example of these numbers and their corresponding value ranges is shown in appendix D.

After the identified risks are initially classified via the RISMAN categories, the probability and consequence numbers of the RISMAN categories are multiplied. When the resulting value crosses a certain threshold, the risk requires control measures. The threshold value is determined by VolkerInfra themselves and an example is shown in table D.2 in appendix D. For example, if a risk X scores 3 on financial consequences, 2 on probability, 3 on time consequences and the other categories do not apply, the total value of the risk is: $3 \times 2 \times 3 = 18$. That would mean that the risk requires control measures, as it is higher than the threshold value of 8, determined by VolkerInfra, shown in table D.2. Control measures are developed to reduce these numbers and thus the category and total value of the risk. These can be aimed at lowering the probability of occurrence or lowering the consequences of the risk in any or more of the RISMAN-categories. Each measure is weighed via a cost-benefit analysis to determine if they are worth implementing. After all identified risks have been analyzed and control measures have been developed to sufficiently reduce them, the residual risk is determined. This residual risks and their probabilities are put into a Monte-

Carlo simulation. This simulation is used to calculate the final risk budget that will be added to the tender bid price, based on a statistical analysis of the input variables of every identified risk. This statistical analysis is based around two values:

- The calculated value, which is the value that is derived from the RISMAN categories. So in the example above, risk X scored 3 on financial consequences, which means that the calculated value is in the € 250,000 - € 500,000 range, see appendix D. For statistical analysis, a specific value or distribution may be required. In practice, this means that either the average value, top value or a triangulation between bottom, mid and top values is used as input. A complete distribution is usually not available and is considered unreliable to use in practice, due to the inherent uncertainty of the assessment. The choice between which specific value is applied, depends on the preference of the risk manager or the requirements on the specific project. This means that either € 375,000 or € 500,000 or a triangulation can be used for risk X.
- The expected value, which is the value that is obtained by multiplying the calculated value with the probability of occurrence. So for risk X, it would mean that, if the mid values are used, the expected value is: $\text{€ } 375,000 \times 7.5\% = \text{€ } 28,125$.

In theory, if a risk occurs, the costs of that risk will equal the calculated value. The expected value is required to generate an indication of the required risk budget. If for each risk the expected value is determined and added together, this should translate into an indication of the budget that covers the likely risks to occur. Because a number of risks will occur and a number of risks will not occur, the combined expected values should in theory be sufficient in most scenarios. However, if any of the input variables are wrong or more of the major risks occur than expected, it can lead to a budget shortfall. This can be caused by the inherent uncertainty that is present when assessing the risks. Therefore, on projects of VolkerInfra, a Monte Carlo simulation is applied. This means that every risk that was identified and assessed is entered. The Monte Carlo simulation then performs a number of runs, for example 10,000. In each run, each risk that was entered has a chance to occur, equal to its probability of occurrence. Each run then has a number of risk occurring and a number of risks not occurring. Because this is done 10,000 times, an indication can be made of the statistical likeliness of different scenarios in which different combinations of risk can occur. Depending on the specific requirements of the project, the final risk budget is determined to be sufficient for anywhere between 70 % and 80 % of the runs that were generated by the Monte Carlo analysis. I.e.: the reserved budget is sufficient for 70%-80% of the runs that were generated by the Monte Carlo analysis. This value is generally higher than the sum of the expected values and therefore a safer and better informed solution.

During tender, the risks are maintained in a risk register, usually in an Excel file. If the tender is won, this register is converted to an online database, in the program VISE (Volker Infra Systems Engineering, which is a Relatics application). In this database the risks are allocated to work packages and corresponding operational managers, who are in practice responsible for the risk and corresponding control measures. This database also allows the risk manager track changes to each aspect, e.g. the RISMAN scores or add supporting documents to specific risks or control measures. The RISMAN method is continuously used to identify and analyze new risks and to develop control measures for these. It can also be used to develop new control measures for existing risks, when the residual risk is found to be unacceptable. During the execution phase, risks and their control measures are thus continuously monitored and controlled in the database. As more information becomes available, risks can be reassessed. Ultimately the conditions under which a risk can occur

pass and then the risk can be removed from the active database, or the risk can occur. This database is not cross-project and is set up for each project individually and to the specification of the responsible risk manager and/or client requirements.

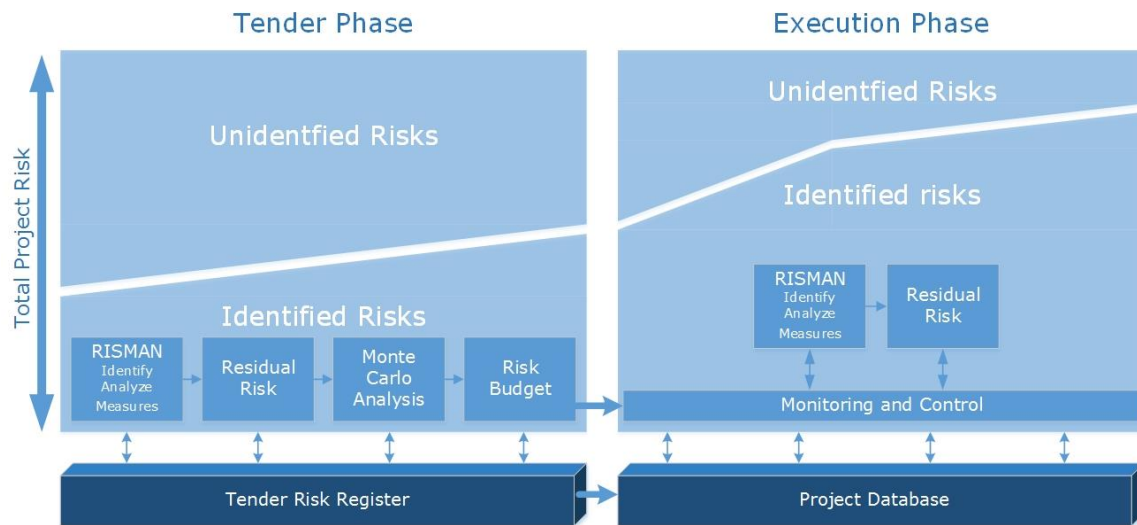


Figure 3.5 - General overview of risk management process and unidentified risks relating to total project risk through tender and execution phases

3.2. PROBLEM DEFINITION

The risk management processes as described in the previous section and as can be viewed in appendix C, have been developed over time. After the preliminary analysis on them in the previous section, the identified problems are stated in this section. They are shown in the causality diagram in Figure 3.6. This is further elaborated in the section below.

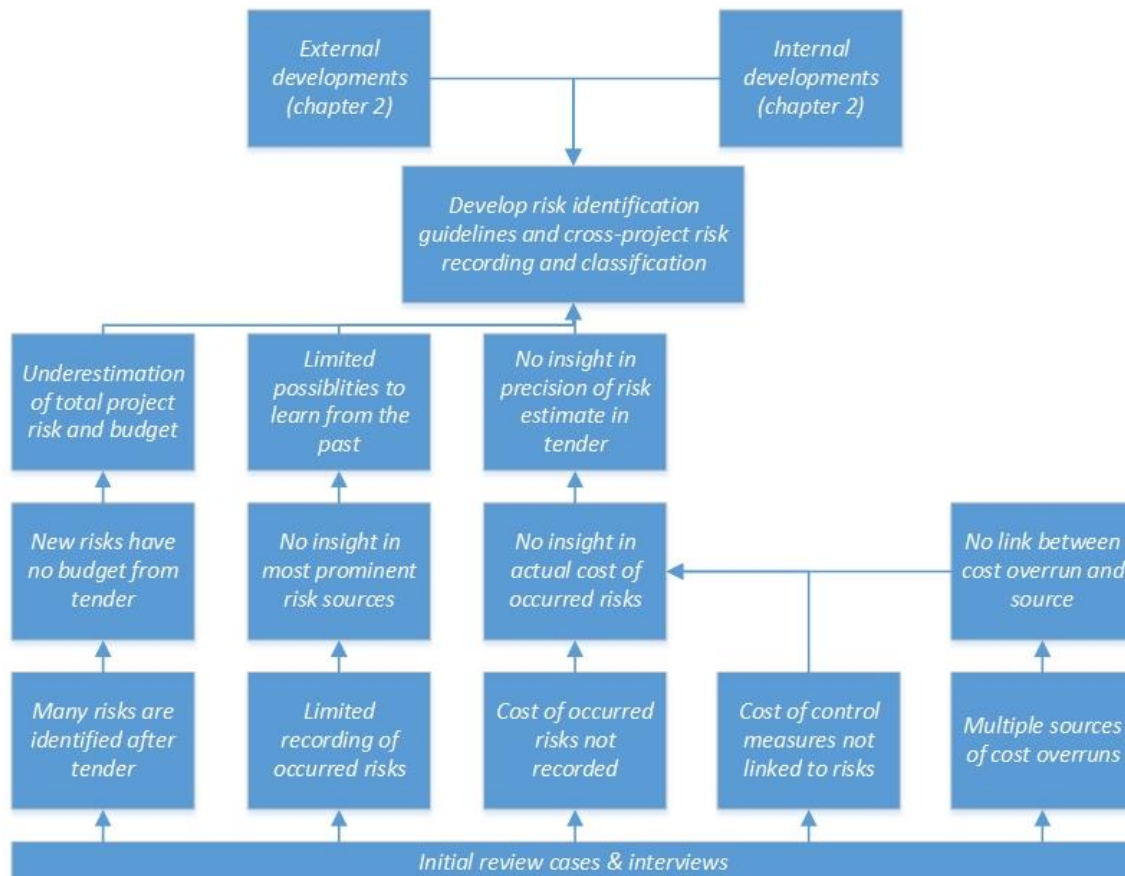


Figure 3.6 - Causality diagram of problem definition

1. Risk identification, the first aspect in the risk management process, does not function as well as it should. The majority of risks is identified during the execution phase of the project, while under ideal circumstances identification happens during the tender phase. On average over the six selected cases for this research, there are six times as many risks identified during the execution phase than during the tender phase. Even when the Willems Unie case (case 6 in table 3.1) is, for the sake of example, omitted as outlier, there are on average still three times as many risks identified during the execution phase than during the tender phase. See chapter 8 for an overview of these identified risks and why Willems Unie may be considered an outlier.
 - a. A side note has to be placed here however. As was previously explained in sub-section 3.1.6, unidentified risks cannot always be attributed to the contractor. They can only partly be attributed to a lack of guidelines on the risk identification process. Some later identified risks are a result of scope changes in the project.
 - b. Furthermore, some risks are only fully developed when that specific part of the project is underway but are, until that time, placed in a 'container risk'. This container risk is often set up during the tender phase and consists of a more general description, such as 'geotechnical risks'. The container risk can later on be separated into more specific risks. They are usually created because there is limited information available in the tender phase, see also figure 3.3. The container risk is then calculated sufficiently to cover all potential underlying risks. Reasons for this limited amount of information available are the lack of resources that are spent on the preparation of the tender in order to stay competitive and not lose too much when the tender is not won. Another reason is that during the tender phase it is not allowed to communicate directly with stakeholders, all communication runs through the client. This can result in a lack of information regarding risks relating to them and insufficient identification. The link between the original container risks and underlying risks (which are newly formulated during a later stage of the project) is missing however. That can lead to ambiguity in the assignment of budget or the traceability of the risks.
2. Insufficient identification leads to problems in the allocated risk budget, which is only calculated to be sufficient for the identified residual risk during the tender phase. Due to so many risks being identified in later stages of the project, there is no budget left to allocate to them, since the budget is fixed when the project was awarded. This causes the risk budget to overrun quickly as more risks are identified after tender and the value of occurred risks is several times higher than the budget allocated to them (see chapter 8). Even though the client is in some cases benevolent and concedes to payment for (part of) the risk, for example when the risk results for a change in the project scope, the budget is still not sufficient when many risks are identified after tender. This reduces profitability for the contractor and can cause friction in the client-contractor relationship as conflicts can arise over the responsibility of the risk.
3. Occurred risks are only recorded on three of the six cases, while they are considered to contain valuable information for future projects. This limits insight in the most common risks or the most prominent risks that occur on these projects and thus limits opportunities to learn from them or account for them in future projects. These are only transferred through the experience of the responsible risk manager at that time, but these can change during the course of the project.

4. In none of the six cases are the actual costs of occurred risks tracked, only after significant effort and inquiries have the actual costs of occurred risks been uncovered for the SAAone project. During this effort it was found that costs of these risks are hard to identify or assess accurately, because of multiple additional reasons that complicate the process:
 - a. Some risks have multiple control measures that were costly. Costs of initial control measures are not linked to risks and are difficult to trace as they are included in other parts of the budget, for example design changes due to control measures are allocated in the design budget. They can also have an effect on multiple risks, or can be repeated for other risks. Furthermore some risks are given additional control measures with additional costs after tender, which have no initial allocated budget and the costs of these are not linked to risks.
 - b. Risks are not the only source of cost overruns, they can also be attributed to quality management, bandwidth in product prices, interface management, product failures, etc. Therefore it is difficult to say which specific cost overruns can be attributed to risks as these are not specifically linked.
 - c. Some cost overruns lead to the formulation of a new risk, but the initial overrun is not traceable to that new risk.
5. Due to the limited insight in actual costs of occurred risks, possibilities to determine the accuracy of initial cost estimates during tender are also limited. This also prevents improvement of estimation of the risk budget in new tenders.

The following problem definition can be distilled:

"Risk identification during the tender phase is insufficient and leads to an underestimation of the project risk and available budget and there is no cross-project insight in the main sources of costs due to risks on projects of VolkerInfra."

3.3. RESEARCH OBJECTIVE

Two different objectives are identified for this research project. Based on Verschuren & Doorewaard (2000), an objective *of* the research and an objective *in* the research can be identified. The objective *in* the research serves as the endpoint of the delimited scope of this research (see section 3.1). The objective *of* the research can be seen as a wider objective for VolkerInfra and serves as a more external part of the scope of the research, which will be brought closer through the objective *in* this research.

The objective *of* risk management research for VolkerInfra reads as follows:

"Improve the risk management proficiency of VolkerInfra."

The objective *in* this research reads as follows:

"Develop recommendations for the further development of the risk identification process and identify and classify top risks on VolkerInfra projects to enable generic oversight to assist in risk identification on future VolkerInfra projects."

3.4. RESEARCH QUESTIONS

Following the delimitation of the scope and definition of the problem definition and research objective of the research, the research questions can be formulated. The research is divided into two parts, a theoretical part and an empirical part, which corresponds with the division of the research questions listed below. These are formulated in order to answer the main research question, also given below. Most of the theory for the theoretical research questions will be discussed in part 2 of this report, after which some of these questions can be answered. The empirical research questions will be answered after the empirical research itself. The details about the methodology and strategy for answering the research questions will be discussed in section 3.5.

Main question

How can the current risk identification process be further developed and how can data be used to enable generic oversight on projects and to assist in risk identification on future VolkerInfra projects?

Theoretical

1. *What is project risk management?*
 - a. *What recent developments can be identified in risk management literature?*
 - b. *How can project risk management be defined and measured?*
2. *Which frameworks are available for risk management on infrastructure projects and what are their advantages and disadvantages?*
3. *What risk identification methods are available in current research and what are their advantages and disadvantages?*
4. *What risk classification methods are available in current research and how can they be applied to risks?*

Empirical

5. *What data is currently available on risks and risk management on VolkerInfra projects and what follow up research is recommended based on that?*
6. *What risk identification methods are currently applied within VolkerInfra and how can they be further developed?*
 - a. *What risk identification methods are currently applied within VolkerInfra?*
 - b. *What are the main differences between the approaches applied and how do they compare to the literature?*
 - c. *How can the risk identification process of VolkerInfra be further developed?*
7. *In what way can risks be classified in order to reveal key aspects and enable generic oversight on VolkerInfra projects and how can this oversight assist in risk identification?*

3.5. METHODOLOGY & STRATEGY

This section describes the methodology and strategy for the research and the answering of the main research question. Several methods will be used in this research for answering the different research questions. The whole process is divided among five different phases (the strategy), which are discussed below. A schematic overview of this process is given in Figure 3.7. After the visualization of the strategy, the individual research methods within this research will be shortly described.

PHASE I – SET UP

Since the research had no clear starting point or initial goal, the start concerned exploratory and unstructured interviews with stakeholders. Among these were supervisors to this research, process managers and risk managers of other VolkerInfra,- Van Hattum en Blankevoort- and VolkerRail- projects. Initial problem definition, objective and research questions were formulated. Furthermore, it contained an exploration of risk management literature. During this step the case studies themselves were selected and, as introduced in section 3.1, narrowed down to six recent infrastructure projects.

PHASE II – INITIAL DATA COLLECTION

A preliminary literature review was done on risk management in general (chapter 4) and three prevalent risk management frameworks (chapter 5). Furthermore, after the selection of the case studies, initial data was collected. The responsible risk managers on each of the six projects were approached and inquired to specific aspects of risk management on their projects, concerning documents and other information, namely:

- Process overviews
- Access to the online database in VISE
- Management plans
- Occurred risks
- Cost data relating to risks
- Insight in calculation of initial risk budget during tender

All this information, together with clarifications where needed from the risk managers, has been preliminary analyzed and used to determine the final scope of the research project. This led to a revised problem definition, revised objective and for the most part revised research questions that are stated in the previous sections. Due to this extensive initial analysis, there was an initial empirical research question formulated, relating to this preliminary exploration of the cases and available data (research question 5), which is discussed in chapter 8. This question forms the basis for the following focus of the research on risk identification and risk classification as the exploration revealed that those two areas would be the most suitable focus for further development through research

Phase III – Analysis

Based on the extensive preliminary analysis in the previous phase, it was decided to focus on two aspects in the following parts of the research, since these aspects show room for improvement. This enables reflective learning and thus reduce uncertainty in future projects, see section 4.1. The following aspects are the further focus of this research:

1. The risk identification process
2. Analysis of top fifteen occurred risks on three of six available cases, via a risk classification

Both aspects consist of a literature review (chapters 6 and 7 respectively) and an empirical research part (chapters 9 and 10 respectively). The literature review on risk identification concerns a review of identification methods and tools. Furthermore, for the empirical part, six risk managers of the six case-studies have been interviewed to determine their preferred risk identification methods and tools. The second aspect concerns the top 15 occurred risks of three of the six cases. Only three cases had occurred risks available, which is why this is not done for all six cases. These are only available for the SAAone, A4All and Galecom cases. The occurred risks will be analyzed as follows: Since actual costs for occurred risks are only available for the SAAone case, the top fifteen ranking will be based on the fifteen highest calculated values of occurred risks *on the latest update in VISE*. This is a value in €, which, in most cases, represents a value depending on the classification that is made for that project with the RISMAN method (see sub-section 3.1.6 and the classes in appendix D). After the top fifteen has been determined, they will be further analyzed. This will be done via a classification that is assigned to each risk. This classification is based on four criteria that were derived from the literature review in chapter 7. Furthermore, 5 additional criteria will be assigned to the risks to classify them further and present a detailed overview of the most important occurring risks on the three available cases. This will result in most critical and underexposed risk categories in infrastructure projects that can be used by VolkerInfra to help identify risks on future projects.

Phase IV – Synthesis & Design

The fourth phase consist of synthesis of the results and using it to develop recommendations improvement of both, the risk identification process and determine critical risk categories. Combined results from the analysis above will be used to determine targets for improvement, which will be presented in the final part of this report.

Phase V – Finish

The last phase of the research will consist of finalizing the research. Conclusions will be drawn from the performed analysis and data, which will answer the main research question. Recommendations will be made to address what specific steps should be made by VolkerInfra to apply the results from this research.

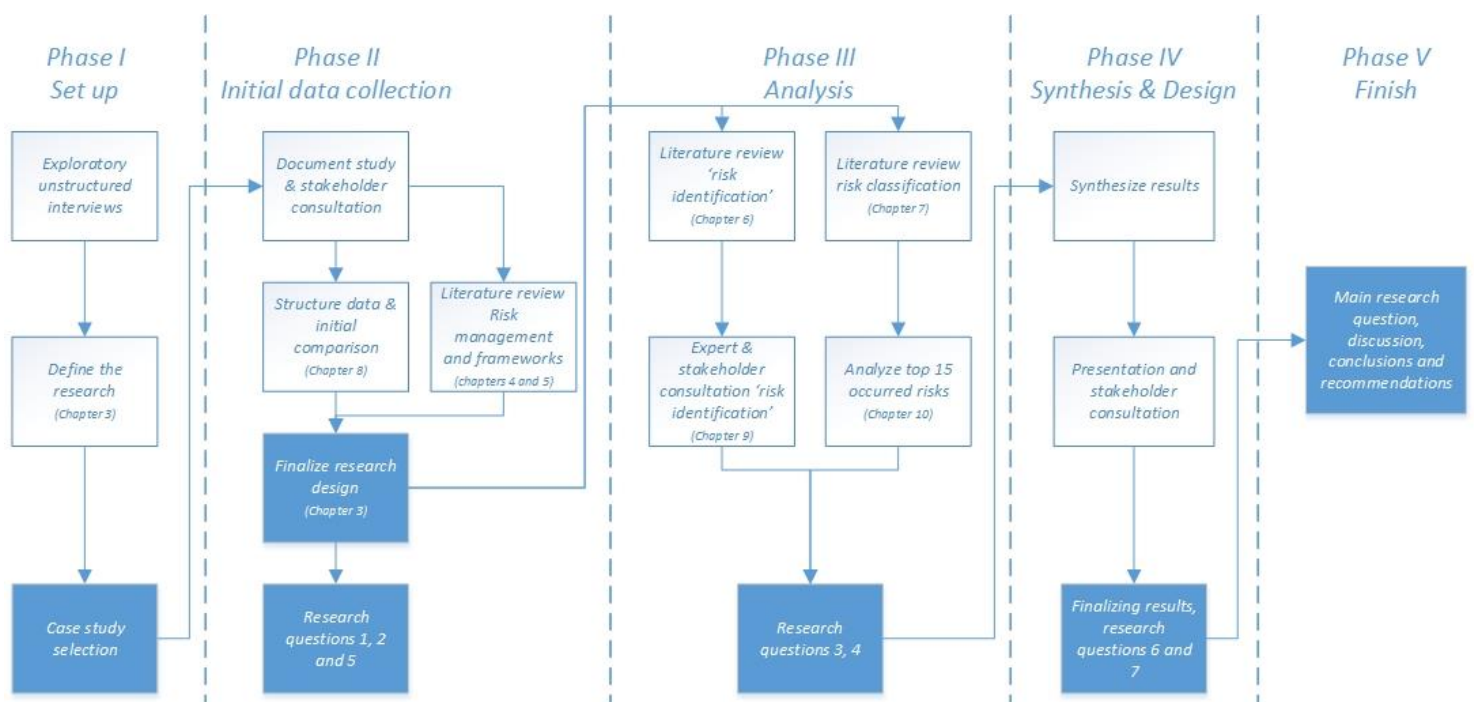


Figure 3.7 - Overview of research strategy

3.5.1. RESEARCH METHODS

The applied research methods are listed and described below.

a) Literature review

The literature review or theoretical analysis contains a description and analysis of existing literature on relevant topics and how they relate and are applied to this research. It is used to familiarize with concepts regarding relevant risk management aspects and describes current discussions and developments. The search process itself is described in chapter 5, which will ensure reliability in the research. Furthermore, the results from the literature review are used to answer the theoretical research questions. Relevant topics are:

- Defining risk and risk management
- Measuring risk
- Risk management processes & frameworks
- Risk identification
- Risk and (financial) project control
- Risk categorization in infrastructure projects

b) Case studies

This research is based around six projects that are used as case studies. They all concern recent infrastructure projects in which VolkerInfra was or is involved in and they all have risk management processes and a database in VISE. They are not all the same, as no infrastructure project is, but are similar enough in that they are large projects in which risk management has played a large role in the project management. They are further elaborated in appendix B.

1. A1/A6 Diemen – Muiderberg - Almere Havendreef: combination SAAone
2. A4 Delft – Schiedam: combination A4All
3. A9 Badhoevedorp: combination BadhoeverBogen
4. A27/A28 Everdingen – Hoevelaken: combination Utrechtse Tulp
5. Galecopper bridge: combination Galecom
6. Zuid-Willemsvaart: combination WillemsUnie

This research will apply two of those methods, namely qualitative surveys and document study, which will shortly be described below (Yin, 2003, p. 85-96).

i. Qualitative surveys

The qualitative surveys are set up according to Problem Centered Interviews (PCI) as described by Witzel (2000). PCIs have the goal of developing knowledge by having a dynamic process that creates an objective, analytic framework and thus trying to prevent incorporating bias from the interviewee. This is done by sharing the foreknowledge of the interviewer with the interviewee, leading to the discussion of relevant topics. The interviews are semi-structured, meaning that the interviewee receives general directions and questions in which the interview will take place, but preventing too specific formulations early. This will leave room for the interviewee to elaborate on his points of view without pushing him/her in a certain direction and allowing to dive deeper into the subjects (Grix, 2004).

ii. Document & database study

The document study consists of the reviewing of available documents on the different cases relating to the subject. This may vary from meeting minutes to progress reports, policies and management reports. The documents will be identified in the systems of the projects and in the overviews of the process structures which reveal what documents should exist. These are at least, but not limited to:

- Risk management process and relating flow chart
- Project Management Plan
- Risk Management Plan
- Overview of occurred risks
- Overview of actual costs of risk
- Overview of risk budget

Additionally, the databases of the selected projects will be monitored for new entries. This will be done in the online database in VISE, as was mentioned before. This database contains the risk database of the different projects and all new entries can be viewed here.

Part II - Theoretical background

This part contains the first aspect of the research; the theoretical foundation of the research. It consists of definitions of relevant concepts and an extensive review of the existing body of literature on risk management, corresponding frameworks, risk identification and risk classification.

4. RISK MANAGEMENT

This chapter describes the theoretical rationale of risk management, and reviews the current discussion in research on risk. It is important to understand relevant concepts before they can be managed (Chapman, The controlling influences on effective risk identification and assessment for construction design management, 2001), or knowledge about them can be developed. Therefore this chapter will start the theoretical analysis with sections on defining risk, risk analysis and risk management and its corresponding aspects. It contains descriptions from recent scientific literature and international standards, such as ISO and COSO. These definitions lead to a new perspective on risk, incorporating *strength of knowledge* and *unforeseen events* and may help to understand the dynamics in the industry, described in chapter 2.

Since the development of 'Risk Management' as a scientific discipline, many attempts have been made to define universally accepted terms for relevant concepts within the risk management discipline and these definitions are continuously developed. These definitions are continuously subject to change, since no international consensus has yet been reached, despite efforts of multiple researchers and organizations. The key discussion lies within the definition of 'risk' itself and how this should be measured. Therefore an extensive section is used to discuss that topic, after which multiple other definitions will be discussed in following sections. This chapter will be the basis for understanding the nature of this research project and is used to form an answer on the first theoretical research questions.

4.1. RISK

To define risk management implicitly requires a definition of the term 'risk' and the term 'management'. Even after decades of research in many different fields of study there is no consensus on a definition for risk itself, but there are two recurring concepts in almost every definition: risk is related to *uncertainty* and to *consequences*. This for example becomes clear in the definition of risk in ISO 31000: "*effect of uncertainty on objectives*" (Purdy, 2010, p. 2). Since *effect* is defined as "*a deviation from that expected*", *uncertainty* as "*the state of deficiency of information related to an event, consequence or likelihood (in that a single action may lead to different consequences, but is unknown which)*", *objective* as "*desired or expected result*". Furthermore it is defined that an *event* is "*the occurrence or change of a particular set of circumstances*", while the outcome of an event is defined as *consequence* (Luko, 2013). Thus can be concluded that *risk* relates to a deviation from the desired or expected outcome of a set of circumstances due to a state of deficiency of information. The definition of ISO still leaves a lot of room for interpretation, for example when objectives are not defined, is there no risk in that case? (Aven T. , Foundational Issues in Risk Assessment and Risk Management, 2012). In many situations, e.g. in social sciences, the direct link between risk and objectives is questionable and researchers, e.g. (Rosa, 2003), prefer to link risk to 'something that humans value'. Other studies, e.g. Aven & Aven (2011), prefer to use the broader term 'reference level' of which one reference level can be an objective. However, this research is about infrastructure projects. In that context, the link to objectives is actually quite accurate since these are clearly defined for projects and therefore in this research no point of discussion. Also the risk as epistemology vs. the risk as ontology viewpoints are not a point of discussion for this research, e.g. see Rosa (2003) and Aven et al. (2011) for more information. ISO has received further criticism for, among others, failing to correctly define included concepts and avoiding any use of mathematical concepts, e.g. by Aven (2011) and Leitch (2010) and therefore the discussion will continue below.

4.1.1. PROBABILITY

Following the criticism on ISO, an important concept relating to risk is introduced here. As said, ISO has been criticized for failing to produce a specific definition for risk. Therefore the concept of *likelihood* or *probability* (the mathematical quantification of likelihood) is used. Likelihood or probability both refer in a broad sense to *"the chance of something happening"*, according to the ISO standard, but are only briefly mentioned in side notes (Luko, 2013). A discussion is possible on the exact meaning of probability, but that is not part of the scope of this research. Since risk is related to uncertainty, as described above, the chance of events happening is uncertain as well. Therefore, to be able to quantify risk, probability is introduced, which expresses the chance of events happening in a number between 0 and 1. Together with a quantification of the consequences, which is expressed in terms of cost or revenue of the different outcome of an event, compared to the desired or expected outcome, probability and consequences are used to quantify risks. This is done by multiplying probability with the quantified consequences, giving an amount that needs to be reserved in the budget to hedge the risk. However, when the risk does occur, the amount reserved will be too little since it was multiplied by the probability and thus only a small portion of the actual cost for the risk was reserved. Therefore, this process is repeated for all risks that have been identified for the project or organization and are entered into a Monte Carlo simulation. This simulates many possible outcomes of all individual risks by generating values for the given risk parameters, based on assigned distributions, creating an overall distribution for the project that shows the probabilities of all combined risks and its consequences. When enough resources are reserved to hedge against risk in at least 50% of the simulation outcomes, in theory there should be enough reserved, assuming *all* risks have been identified *correctly*. Since this is never certain, in practice often extra is reserved in the budget, e.g. 70% or 80%, depending on the policy of the entity (70% is used in VolkerInfra projects). Explicit examples of this will be given in the empirical analysis, when further research is executed. This means that measurement of risk or the potential of this risk is based on a level of subjectivity, implicit in the estimation of the individual probabilities and consequences. This is in broad terms the process of quantifying risks, as it is done for infrastructure projects. In some more specific definitions of risk these two concepts, used to quantify risks, are included, e.g. by the U.S. Department of Homeland Security's Risk Lexicon, as cited in Luko (2013). Following these lines of arguments and reviews on existing definitions of risk, the definition for risk becomes the following: *"effect of uncertainty on objectives, as determined by its likelihood and consequence"*.

4.1.2. UPSIDE RISK

To fully capture the current state of risk management possibilities, this definition is still lacking. It fails to emphasize that there are also positive effects possible. Positive effects of risk are implicit in the definition explained above, since no explanation is given on the nature of the effects (negative nor positive), but they are still often forgotten in practice and therefore explicitly used in the following definition: *"an uncertainty that could have a positive or negative effect on one or more objectives."* (Hillson & Murray-Webster, Understanding and Managing Risk Attitude, 2004). While it is emphasized that risk may consist of positive effects, a commonly heard description of risk on the work floor, and even in an article by Cervone (2006), is: *"a problem that has not happened (yet)"*, giving a negative tone to risk due to the use of the term *problem*. The fact that risks are, in practice, almost always perceived to be negative consequences can be explained by a number of factors. The first is because exploiting *"upside risk"* has only more recently received attention in research, for example Hillson (2002) is one of the researchers into

exploiting upside risk. Furthermore, managers often focus on control and want to ensure that all risks with negative consequences are reduced as much as possible before even thinking about exploiting opportunities. Thirdly, at least for the Netherlands, is that important clients such as Rijkswaterstaat use the following definition for risk (translated from Dutch): *"Event that may or may not occur that may lead to schedule or budget overruns or failing to meet quality requirements"* (Rijkswaterstaat, 2007), which already indicates that risk only concerns events with negative consequences. Finally, there are several frameworks, i.e. COSO ERM, that twist the definitions of these concepts in comparison with others, namely because they speak of uncertainty that can present both risk and opportunity in which risk has the potential to erode or prevent value and opportunity the potential to enhance or preserve value, which also indicates the negative nature of risk (COSO, 2004), whilst maintaining that there are positive opportunities related to risk management as well, but failing to explicitly mention them. Thus arriving at the following updated definition:

"Risk is the positive or negative effect of uncertainty on one or more objectives, as determined by its likelihood and consequence."

4.1.3. STRENGTH OF KNOWLEDGE

Following even more recent developments on the concept of risk that has started to generate more interest in the last five years, more criticism can be delivered. This has to do with the deficiencies of solely determining risk by its likelihood and its consequences. There are two key weaknesses in that approach: The first weakness of this more-or-less traditional approach is that probabilities could be the same in two situations in which the knowledge on the subject is completely different. E.g. in one situation the probability is based on a lot of readily available relevant and reliable data or knowledge, while in the other situation there hardly is any data or knowledge, still resulting in identical probabilities (Aven & Krohn, 2014). Clearly there is a discrepancy between both situations, warranting a different approach in both situations. The second is that there is no distinction between risks involving potential large consequences and small probabilities and risks involving small consequences and high probabilities. Also these situations could warrant a different approach, because mathematically they result in identical numbers while the situation for both is clearly different. As stated in the previous sub-sections, *subjectivity* comes into play here, increasing difficulty in correctly measuring risks and implicit in both of the key weaknesses named here. The fact that subjectivity is implicit in measuring risk for infrastructure projects shows that the probability (P), is estimated based on subjectivity (Bayesian perspective) as opposed to the objectivist perspective (Frequentist perspective). A second argument for the subjectivist view on risk (at least in the industry that is subject of this research) is that the risks cannot reasonably be expected to be repeatable, since infrastructure projects of this size are relatively unique, while objective repeatability is required for experimentation in the objectivist (frequentist) perspective. This is for example distinguished by Aven (The risk concept - historical and recent development trends, 2012; On how to define, understand and describe risk, 2010) and these schools of thought are also identified by Winch (2010, p. 348). The probability (P) of event/risk (A) happening can thus be expressed by $P(A|K)$, showing that this probability is conditioned on certain background knowledge and/or assumptions expressed by (K). This subjectivity needs to be included in the estimation to meaningfully measure risk. In order to take this subjectivity into account, Aven & Krohn (2014) introduce the concept *strength of knowledge*. This concept reflects the strength of knowledge on which the assumptions that

probabilities are based, not the assumptions themselves (reflected in probability itself). Thus arriving at the final definition for risk:

"Risk is the positive or negative effect of uncertainty on one or more objectives, as determined by its likelihood, consequence and strength of knowledge."

This final definition is formulated after a thorough review of relevant literature. It still leaves room for interpretation, while also defining risk specifically as a broader concept rather than a concept solely dependable on probability. It can be expressed by an alternative definition (Aven T. , On how to define, understand and describe risk, 2010):

$R = (A, C, U, P, K)$, in which:

R = risk

A = event (including probability distribution and prediction)

C = consequences (including probability distribution and prediction)

U = uncertainty component

P = subjective probability expressing U

K = strength of background knowledge on which P is based

The definition here includes likelihood or probability as a measure for risk, but is intended as a broader view on risk in which uncertainty is central and not the narrow definition of $R = (A, C, P)$ as argued against by Aven in his publications. The uncertainty that is present in data and in factors that influence the event needs to be included. Problem is that the required knowledge for that is not completely available, as is inherently implicit in the definition for uncertainty. Assessing these uncertainties beyond the initial probabilistic analysis is necessary to give a better informed description of the related risks, since there remains a certain degree of uncertainty, especially when negative and positive results are a possibility. This uncertainty requires a deeper understanding than just probability in order to exploit positive consequences and prevent negative consequences, for which knowledge is required (Perminova et al., 2008). Probability in this sense may initially be viewed somewhat similar as in Kaplan & Garrick (1981) in which they refer to probability as a numerical measure of a state of knowledge, thus uncertainty, opposed to their reference to 'frequency' for the objectivist view of probability. They then follow to combine both concepts by using frequency to calibrate a scale in which probability is used as measurement and for communication, distancing themselves from the traditional school of frequency in which only mass repetition of an event can assign probabilities. This very same distinction, between probability based on background knowledge (subjectivist) and probability based on frequency of occurrence in infinitely repeated experiments (objectivist), is made by Singpurwalla (1988). The definition here goes even further, since uncertainty plays an even larger role; it is difficult to perform a complete quantitative analysis as Kaplan & Garrick (1981) still propose. The situations that the method proposed by Aven is useful for, are also present in the construction industry in the target scope. Repeated experiments for large infrastructure projects are impossible. How could a large set of identical experiments be simulated where a number of aspects are fixed and a number of aspects can vary?; there are simply too many variables that cannot be meaningfully simulated or expected to be all included. This difficulty, or near impossibility, in applying the frequentist views to practical problems is acknowledged by authors as early as Kolmogorov (1963). This prevents the estimation of a 90% confidence interval for example; only a number of marginal distributions on selected aspects can be specified, thus the more nuanced approach given above is required, in which probability is conditional

on specific knowledge. This approach includes factors that can cause surprises to the probabilities in which simplifications, as are necessary in traditional probability analysis, are to be prevented. To improve future risk estimates and enable more flexibility and rapidness in decision making, the knowledge of these risks has to be build up over time. Reflective learning from past and current projects is therefore valuable to enable this.

4.2. *BLACK SWANS AND THE NEW PERSPECTIVE ON RISK*

This section will discuss the new perspective on risk that is currently receiving increasing attention in research. The first aspect, as mentioned in the previous section, is the aspect of knowledge and strength of that knowledge. This aspect, combined with new approaches for black swans (i.e. unforeseen events) can be recognized as a 'new perspective' in that it improves the more traditional perspective on risk of solely looking at probability (Aven, 2013). This section therefore shortly discusses the second aspect, the concept of black swans.

The term 'black swan' was derived in the past when everyone in the old world was convinced that all swans were white since there was no empirical evidence to suggest otherwise. After the accidental discovery of Australia by the Dutch in the 17th century and black swans were discovered, it appeared that this assumption was incorrect. The term 'black swan' therefore refers to a perceived impossibility that might be proven to be possible due to new knowledge. The term has been popularized by Nassim Nicholas Taleb in his book 'The Black Swan' (Taleb, 2007), arguing that these 'outliers' are too often ignored while they can have major influences in all matters. He describes black swans to have three characteristics:

1. It is an outlier, meaning it (i.e. the event) lies outside the realm of normal expectations for the considered, i.e. outside the expected values in the bell curve of normal distributions that are often used by statisticians to describe the probability distribution of (risk-) events. Initially black swans concerned financial events but has gradually developed to other fields such as history, scientific discoveries and technology.
2. The event has a relatively extreme impact or effect
3. The event is rationalized by people afterwards, as if it could have been expected and anticipated.

A recent example of a black swan is the nuclear disaster in Japan with the Fukushima reactor. The sequence of a large earthquake and high tsunami created a scenario that was both rare, had extreme impact and was later explained by people as if it should have been predictable. The plant was designed to withstand earthquakes of up to 7.9 on the Richter magnitude scale and tsunamis of up to 10m in height (10m seawall and plant height), not earthquakes of 9 on the Richter scale and a 13m tsunami wave that hit the plant on March 11, 2011. Furthermore the combination of both extremes is what made the plant eventually fail. The failure of the nuclear plant is in hindsight thought to be predictable according to several studies, for an overview see Lipsky et al. (2013).

4.2.1. **CRITICISM**

Taleb (2007) has been criticized by statisticians (e.g. see Lindley, 2008) for making patronizing comments whilst still adhering to some of the claims of statisticians and ignoring those of similar thought, falling victim to his own interpretation of black swans. Furthermore, to be of any use in any actual risk assessment in practice, sensible and

judgmental predictions, aided by empirical data are essential. For black swans, no clear method is available to achieve this and thus a formal justification for a risk management strategy in corporations based on black swan thinking is not yet available and further research is required (Westfall & Hilbe, 2007).

4.2.2. FURTHER CATEGORIZATION

Due to criticism on the description made by Taleb in his book, a further distinction between two categories of black swans is made by Aven (2013). The first category (cat. 1) are the *unknown unknowns*, which are the true surprises or unforeseen events; events that were truly overlooked or missed and were not seen coming. The second category (cat. 2) are the *low risk events*, which are events that are perceived to have such a low probability of occurrence that they are omitted from the risk dossier or risk management plan. The Fukushima example described above can be categorized in cat. 2, since Japan lies in a seismological active part of the world and earthquakes and high waves happen on a regular basis. The combination of both in an extreme form however was perceived to have such a low risk that it was perceived impossible and therefore omitted, thus falling in cat. 2. Both categories can have separate strategies to deal with them, as is indicated below:

- For cat. 1 black swans, the principles from a High Reliability Organization (HRO) can be applied. Since these events are unknown unknowns, it is impossible to take control measures since they are by definition impossible to anticipate and thus specifically prepare for. It is however possible to manage an organization in such a way that it is prepared for any unforeseen event, meaning in the way that processes are designed and that an organization's structure is flexible and designed to quickly respond to unforeseen events.
- Regarding cat. 2 black swans, the low risk events, are often omitted from risk dossiers after analysis since their probability of occurrence is deemed to be very low. Recent examples of this are the accident in Japan with the nuclear power plant in Fukushima. The plant was designed to withstand either an earthquake or a tsunami. A combination of both was deemed to have such a low probability that it wasn't taken into account. These can be kept on a separate list, besides the standard risk reports.

4.2.3. RESEARCH CONTEXT

To place this in a more relevant context for this research, Figure 4.1, derived from Winch (2010) is introduced. It shows how risk in time can be understood.

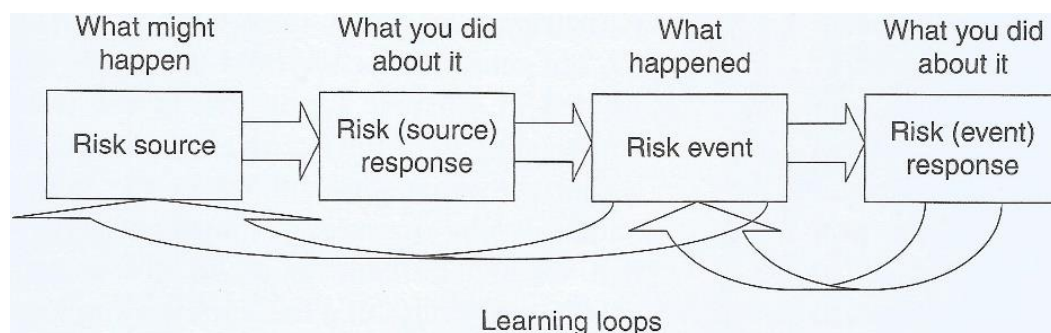


Figure 4.1 - Risk through time (Winch G. M., 2010)

This figure shows the risk process in a time-scale. It begins with risk sources, which are underlying conditions that can generate a certain risk event in the future, e.g. a risk source is unsafe working practices, while an actual accident that may occur in the future as a

result is a risk event (Winch G. M., 2010). A risk response is developed to prevent risk sources from generating risk events. If a risk does occur, it becomes a risk event, after which an additional response is introduced which will attempt to control the effect of the occurred risk events. The focus of this research will be at the front of this time-scale. It will look into the risk process that is carried out in the early stages, before risks sources develop into risk events. The HRO principles, however interesting, focus on *organizational mindfulness* and response of the organization after risk sources have become risk events and thus the capacity of management to handle the impact of risk events. So even though there are advocates for applying HRO within construction, e.g. (olde Scholtenhuis & Dorée, 2013), this falls outside the scope of this research. See Weick et al. (1999) for more information on HRO. The research will focus on two aspects, the risk identification process and the top occurred risk events in the case studies. The risk identification process will be further explained in chapter 6. The top occurred risk events will be analyzed to improve knowledge and improve the process in the early stages so that they may be prevented in future projects.

4.3. CONCLUDING REMARKS

This section will shortly answer the first theoretical research question, based on the literature review and discussion provided in the previous sections. The first research question was defined as follows:

1. *What is project risk management?*
 - a. *What recent developments can be identified in risk management literature?*
 - b. *How can project risk management be defined and measured?*

The recent developments in risk management research focus on improving existing methods. There is a trend in research to move away from the traditional approach of solely looking at quantified probabilities and impacts, since these are all subject to a high amount of uncertainty. This uncertainty is implicit in all activities linked to risk management; risk identification, risk analysis, risk control and monitoring. Thus propositions are made in research to look at the information and the strength of that information behind decisions regarding the quantification of probabilities and consequences. This should improve the strength of the risk analysis and also provide a sound basis for people that are actually working with these risks and decision makers that base decisions on that information. Strength of information can also provide an additional dimension to measure risk, on top of the traditional dimensions for measurement of risks, namely probability and consequences. Together with an increasing popularity of *black swans*, which are risks that are not identified or are deemed so improbable that they are omitted, this forms a new perspective on risk.

It is identified that the concept of black swans is generally responded to by referring to the HRO principles. As was seen in the review, these are also receiving more attention in construction management research. However, as the HRO principles are generally aimed at improved responsiveness of an organization and are not at the front of the cycle identified in figure 4.2, these principles lie beyond the focus of this research. Project risk management contains all activities aimed at controlling risks while moving through the project life-cycle.

5. FRAMEWORKS

Risk management is a very broad term. As shown in the chapters 2 and 3, risk management is very important in the current construction industry and has been for some time. A study by Al-Bahar and Crandall (1990) showed that 25 years ago, risk management already played an important role in construction, but that a systematical approach to risk management was lacking. In more recent years, the benefits of risk management have become clearer and widely accepted in construction. Hard benefits such as: "Risk management enables better informed and more believable plans, schedules and budget" and soft benefits such as: "Risk management helps develop the ability of staff to assess risks" are now commonly accepted (Association for Project Management, 2004). This has promoted risk management to become a standard procedure in construction companies and their projects.

In the construction industry, risk management traditionally came down to intuition, judgement and experience (Akintoye & McLeod, 1997; Al-Bahar & Crandall, 1990). Due to increased acceptance in scientific fields and subsequent research efforts over the past years, multiple models and frameworks have been developed in order to improve the available knowledge on the subject and guide construction companies in incorporating risk management in a systematic manner into their core business processes and projects. The exact terminology about risk management differ somewhat depending on the model or framework chosen, but all are more or less similar. As indicated in chapter 4, most of these models and frameworks distinguish at least two separate phases/processes:

1. Risk Analysis, consisting of steps such as identification, analyzing and estimating/ranking and thus concerning the preparation of (the tender of) projects.
2. Risk Management, consisting of steps such as treatment, implementation and monitoring and thus concerning the control of projects after the contract is awarded.

One of the more widely used and well-known generic frameworks is the COSO Enterprise Risk Management - Integrated Framework (COSO ERM-IF), which is, according to their annual report (VolkerWessels, 2015), also being used by the VolkerWessels concern. The COSO model has been adopted by many organizations worldwide and is meanwhile seen as an international standard, e.g. by Aven (Foundational Issues in Risk Assessment and Risk Management, 2012). The COSO ERM framework is even mentioned in the 'Code Tabaksblat', which is a Dutch issued corporate governance code of conduct for listed companies in the Netherlands (Commissie Corporate Governance, 2003). VolkerInfra themselves use a more project based risk management approach, because of their project-based way of working. They use the RISK MANAGEMENT (RISMAN) method, developed in the Netherlands through a joint effort of RWS Bouwdienst, RWS Zuid-Holland, Railinfrabeheer, Twynstra-Gudde, TU Delft and the Rotterdam Public Works Department (Van Well-Stam et al., 2004). Besides the COSO ERM model, the ISO 31000:2009 framework is one of the more prevalent frameworks currently available (Marks, 2012). ISO 31000:2009 is often compared to the COSO ERM framework, forming a rather comprehensive body of knowledge that is also used here. ISO 31000 is also available for viewing, though not directly applied, on SAAOne. Therefore these three frameworks: ISO 31000, COSO ERM-IF and RISMAN, will be discussed in this chapter. It is acknowledged that there are multiple others, e.g. PMBOK and AS/NZS 4360:2004, but these have no direct relation to this research and will not be further discussed.

5.1. ISO 31000

The International Organization for Standardization (ISO) has defined a standard for risk management, reflected in *ISO 31000:2009, Risk management - Principles and guidelines*, providing a framework and description of processes for managing risk (ISO, 2009). Together with *ISO Guide 73:2009, Risk management - Vocabulary*, regarding definitions, and *ISO/IEC 31010:2009, Risk management - Risk assessment techniques*, regarding risk assessment concepts, they form the body of knowledge from ISO regarding risk management (ISO, 2009). The ISO 31000:2009 originated from the AS/NZS 4360:2004 and has been developed into a standard that can be applied in a wide variety of organizations in any industry (Gjerdrum & Peter, 2011). Important to keep in mind is that these are voluntary guidelines, not compliance requirements nor is it intended as a certifiable standard like some other ISO norms. That said, ISO 31000 represents a body of knowledge that has been reviewed by thousands of risk management professionals, thus representing collective wisdom and can therefore be considered useful as a generic reference. ISO 31000:2009 is currently being revised, which will be ready somewhere between mid-2016 and 2017. This sub-section will shortly describe the current framework.

The ISO 31000:2009 framework consists of three parts; eleven principles (clause 3), a framework (clause 4) and a process (clause 5) and are shown in Figure 5.1 (Dali & Lajtha, 2012; Leitch, 2010; Purdy, 2010). The other two clauses (1 and 2) are not shown, since these concern a definition of the scope (clause 1) and terms and definitions (clause 2), which are not relevant in this context (Leitch, 2010).

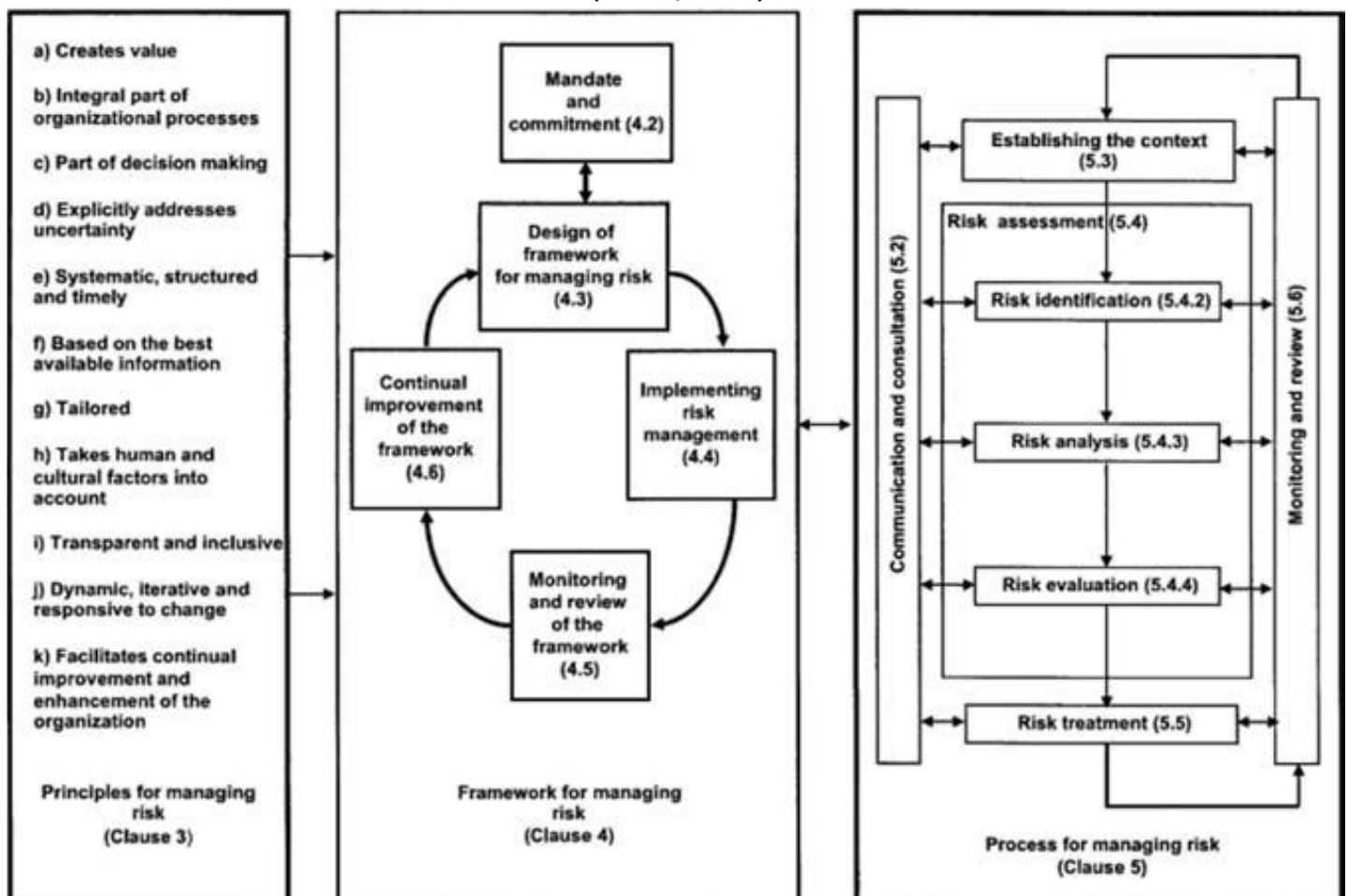


Figure 5.1 - Connection between principles, framework and process for risk management from ISO 31000, as stated in Dali & Lajtha (2012)

The principles describe the qualities that risk management in an organization requires to be effective. The framework for managing in ISO 31000 (clause 4 in figure 5.1) contains five steps that focus on the implementation and integration of risk management into an organization. It is the part of the framework that focuses on integrating the process in the organization not on the actual risks themselves. The basis for the cycle in the framework was the Plan-Do-Study (Check) -Act cycle, developed by Shewhart and popularized by Deming (Deming, 1994, p. 132). It is a dynamic, pragmatic framework, in which systematic learning about results achieved in the past is central (Washbush, 2002), with each cycle setting the new standard for the next cycle (if improved, if not then old standard remains). The cycle is therefore designed to help organizations improve and implement risk management incrementally.

The last part of ISO 31000 (clause 5 in figure 5.1) focuses on the actual process of risk management itself, meaning the process that is to be implemented and improved. This is the part of the framework that focuses on the risks themselves, identifying assessing and treating individual- or groups of risks. The main steps are risk assessment and risk treatment, while constantly communicating with internal en external stakeholders and monitoring and reviewing the process to quickly respond to changes. ISO 31000 emphasizes the importance of embedding risk management in the decision making process and link it to an organization's strategic objectives. It provides a framework in order to benchmark an organization's risk management practices. Furthermore, since the framework is set up to be flexible, it can adapt to different organizational structures.

Discussion

ISO 31000 is by no means intended as a strict standard, but as a generic tool for guidance in risk management. Therefore, practical guidance on implementation is sometimes missing, which can be considered a weak part of the guideline (Purdy, 2010). One should therefore be careful on a too strict focus on following the exact principles in the guideline and should instead focus more on the requirements and dynamics in the specific field and how risk management can be embedded in the decision making process. Furthermore, the framework in ISO 31000 is a framework meant for organizational risk management. The focus of this research is to improve risk management in projects, so the often differing timescale between organizations and projects may require further modification. Since the framework is quite generic and flexible and the case studies in this project concern large projects spanning multiple years (which are organizations in their own right, see section 3.1), the framework can still be applied.

5.2. COSO ERM

The Committee of Sponsoring Organizations of the Treadway Commission (COSO) has developed an integrated framework for Enterprise Risk Management (ERM). This framework was published in 2004 and is increasingly being used by organizations worldwide as a basis for their risk management, among which is the VolkerWessels concern. As well as ISO, COSO is currently working on an update for their framework, but until this is published the current framework will be used in this review.

The COSO ERM - Integrated Framework is visualized in a cube, shown in Figure 5.2 (COSO, 2004). The framework consists of eight components that need to be integrated with the management process (front of the cube):

1. Internal Environment: The tone of an organization, which forms the basis for its employees' view on risk
2. Objective Setting: Objectives need to be clear, before events that influence these objectives can be identified. These objectives need to be aligned with the mission of the entity and its risk appetite.
3. Event Identification: Internal and external events affecting objectives need to be identified and distinguished (risk vs. opportunity).
4. Risk Assessment: Risks are analyzed by likelihood and consequence to determine how they need to be managed.
5. Risk Response: Management selects risk response in order to align risks with the risk appetite and risk tolerance of the entity.
6. Control Activities: Implementation of policies and procedures to ensure effective execution of responses.
7. Information and Communication: Identification, capturing and communication of relevant information (up/down and across the entity).
8. Monitoring: Entirety of enterprise risk management is monitored and changed where needed, through management activities and separate evaluations.

These components are geared towards the achievement of an entity's objectives, which are in turn divided into four categories (top of the cube). These need to be integrated into four levels of management (side of the cube). The effectiveness of this framework is determined by assessing whether the eight components are present and functioning in the four categories of objectives and are therefore also criteria for effective ERM.

Discussion

Even though the COSO ERM framework is five years older than the ISO 31000, it is considered to have stood the test of time and it has been proven in multiple industries. It is written from a more corporate and financial standpoint, since COSO consists of mostly financial professions. In comparison with ISO, which focuses on the management processes, the COSO framework focuses more on audits, control mechanics and compliance than practical guidance (Uiterlinden, 2005). The ISO 31000 is therefore, outside of those fields, generally considered to be more flexible and easier to understand (Marks, 2012). When unfamiliar with the COSO cube, it is also found to be confusing due to its multilayered nature and complicated directive, especially when comparing it with the more pragmatic approach of ISO (Dali & Lajtha, 2012).

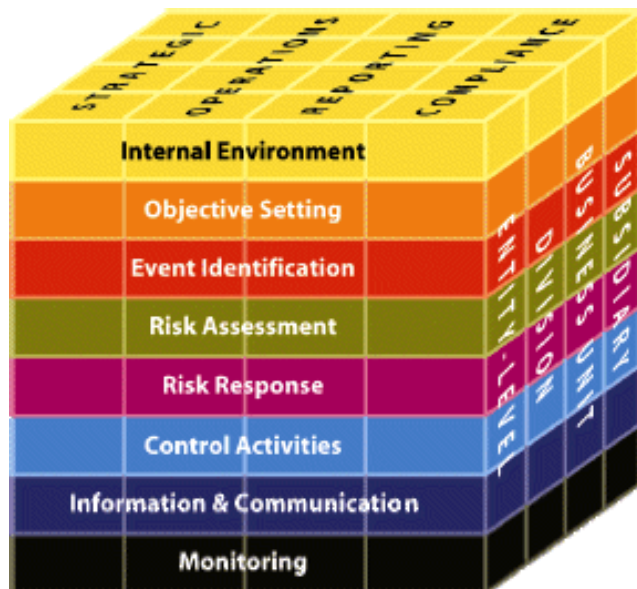


Figure 5.2 - COSO ERM Integrated Framework (COSO, 2004)

Besides the ERM framework, COSO has published another framework earlier, in 1992 and updated in 2013, the COSO Internal Control – Integrated Framework, used to improve internal control systems of an organization. The ERM framework complements that framework and builds on that knowledge and therefore organizations that are familiar with earlier work from COSO find it easier to adapt to the new ERM framework. The framework is specifically aimed at management and to help decision making in any business environment (Marks, 2012). Ultimately, both frameworks are found to have more in common than in opposition and when one is already fully implemented and working properly, there is no need to switch (Gjerdrum & Peter, 2011). Both agree on the importance of integrating risk management in management and decision making in order to achieve organizational success, or in this case, project success.

5.3. RISMAN

As stated in the beginning of this chapter, a commonly used project risk management framework in the Netherlands is the RISk MANagement (RISMAN) method. Initially this method was intended as a risk analysis tool, but has gradually developed into a more general framework for project risk management and even risk management for organizations and even further into a knowledge network of organizations in the construction industry about risk management (RISNET). The RISMAN method is commonly used in the Netherlands in the construction industry and is also being applied by VolkerInfra in their projects.

VolkerInfra applies the RISMAN method not only during the analysis but also during project execution to keep the risk register and dossier updated. The RISMAN method has thus developed into an iterative method in which in every project phase a number of subsequent steps are performed at least once (Van Staveren, 2014):

1. Setting project objectives
2. Identifying risks
3. Classifying risks
4. Remediation risks
5. Evaluating risks
6. Reporting risks

The process of risk management via the RISMAN method and the corresponding framework is schematically shown in Figure 5.3. The principal purpose of this method, as

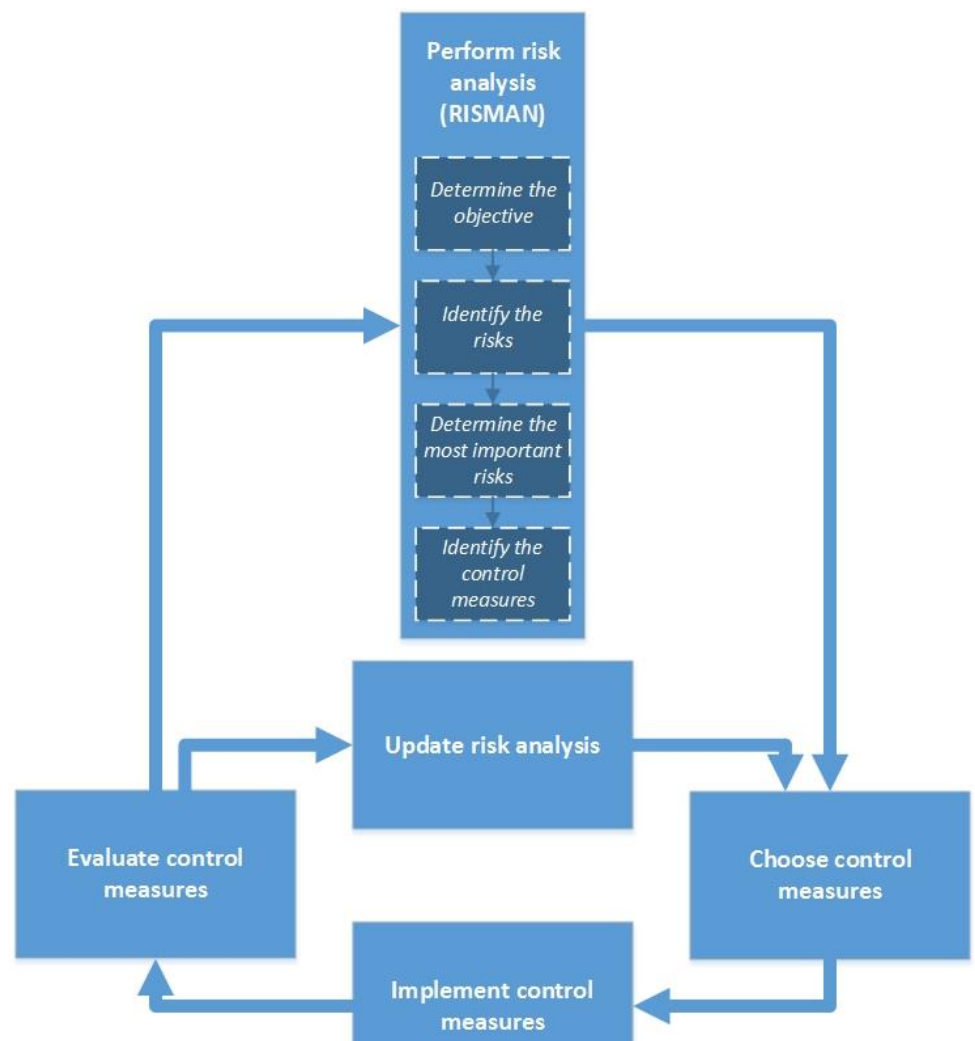


Figure 5.3 - Cyclical risk management framework (Van Well-Stam et al., 2004)

with the other methods described above, is to try and make risks explicit and pro-actively try to think about- and manage them and to consciously determine control measures that can be used to control these risks (Hartmann et al., 2012). For construction projects, risk is generally seen as events that influence project objectives of cost, time, quality, scope and sometimes information and organization, as was seen in the earlier discussion in chapter 4. The RISMAN method uses the same idea and therefore determines the objective of the project and identifies the risks that may influence those objectives. Corresponding control measures are identified and quantified and chosen whether they are implemented or not. The control measures are then monitored and evaluated and the residual risk is monitored as well. Because of the cyclical nature, this process can be repeated and adjusted to new situations as more information becomes available during the project life-cycle.

Discussion

The RISMAN method is predominantly used in the Netherlands and is therefore less discussed in international literature. However, a comparison here between the three methods shows that the RISMAN method is comparable to the ISO 31000:2009 and less so to the COSO ERM model. It is, as the ISO 31000:2009, more focused on the actual risk identification and analysis and the corresponding process than it is on more general monitoring and control of COSO. The framework is actually something that can be implemented, rather than corporate guidelines for monitoring and control. The main difference is that the RISMAN method originated as a project risk management tool, meant for application on projects, which is why it is more practically oriented than both other methods. It can actually be performed on a regular basis during projects, which reflects through the cyclical representation of the framework. This also illustrates the learning process that is seen when going through the project life-cycle, as highlighted in chapter 4.

5.4. CONCLUDING REMARKS

This section will answer the second theoretical research question, based on the literature review and discussion provided in the previous sections. The second research question was defined as follows:

2. *Which frameworks are available for risk management on infrastructure projects and what are their advantages and disadvantages?*

This chapter discussed three of the more widely used risk management frameworks. There are more available in the literature, but these are most relevant to this research. All three frameworks show elements similar to the generic aspects discussed in section 3.1. The RISMAN method and the ISO guidelines show the most similar aspects as compared to the COSO framework, which are more corporate guidelines. The RISMAN framework offers the most guidance on actual use and is therefore considered the most useful in a practical environment, such as on large infrastructure projects, the scope of this research. The advantage is that it focuses more on actual identification and analysis of risks, which is also the focus of this research. This comes from the specific purpose of the method to be applied on projects, while the other two are more generically oriented for wider application. Therefore, the RISMAN method is better suited for the purpose that VolkerInfra requires; practical application on projects.

6. RISK IDENTIFICATION

This chapter reviews relevant literature on risk identification. As was shown in sub-section 3.1.4, risk identification is the first step in the generic risk management process. As was seen in chapter 5, it is also part of the reviewed frameworks, including the RISMAN framework, applied by VolkerInfra. The specific focus on identification flows from the initial data analysis of identified risks in the six projects that are the basis of this research. These initial results are discussed in chapter 8. They show the majority of risks being identified after tender, at which point no additional budget can be reserved for the project, since it is already contracted.

This chapter first discusses the relevance of risk identification in the two paragraphs below. This is followed by listing a number of important aspects related to risk identification that were found while reviewing the relevant literature in section 9.1. This is followed by discussing the available methods and tools for risk identification in large infrastructure projects in section 9.2. These are consequently part of the empirical research, for which the results will be discussed in chapter 9.

Major decisions are often made in the early stages of a project, during the tender phase. It is therefore important to have realistically estimated the consequences of each project decision as early as possible in the project, in order to weigh these decisions. All potential risks that have an effect on-, or may follow from- these decisions, and thus have an effect on the project objectives, should therefore be identified as early as possible in the project's life cycle in order to manage the project (Perry J. , 1986). The identification process itself therefore plays a major role in managing risks and is arguably more important than the analysis itself. This is because risks can only be effectively managed if they have been identified in time (Winch G. M., 2010). Unidentified risks remain unmanaged and are therefore unchecked threats to a project's objectives (Chapman, The controlling influences on effective risk identification and assessment for construction design management, 2001). Early identification not only prevents surprises down the line, but also urges the project team to think critically about the project and the corresponding risks. This fact alone is considered to be worth the effort that has to be put into the risk identification process.

Authors agree on the fact that risk identification is very-, or even the most-, important step in the overall risk management process (Chapman, 2001; Maytorena et al., 2005; Elkington & Smallman, 2002 and Dalton, 2007). However, it is also mentioned by these same researchers that risk identification is neglected in research. Most emphasis is on the risk response and the overall process itself. A focus on the risk identification stage is lacking. The process of risk identification is therefore poorly understood and the tools and techniques are less developed than the overall field of risk management (Maytorena et al., 2005). It is for these reasons as well that risk identification is part of this research scope.

6.1. ASPECTS OF IDENTIFICATION

This section will list important aspects for the risk identification process that were derived from the literature review.

- As was made clear in chapter 4, there is a difference between risk sources and the actual risk events. Therefore, key features of the project that could be sources of risk need to be identified, in order to be able to identify risk events (Perry, 1986). Comprehension of the process and the sources are therefore key to a sufficient identification. This means that at first all available knowledge regarding the project needs to be acquired, e.g. client information in terms of objectives etc., expert opinions and other project parameters. Tools such as Work Breakdown Structures (WBS) can help to develop this knowledge further. These sources of risk can be classified in certain key components, which will be discussed in more detail in chapter 7.
- Pay attention to the selection of the team that will assist in the risk identification process. It is important to have all disciplines included and on larger infrastructure projects, even more specialized disciplines need to be included. On top of this, it is important that the team is on the same level as the risk manager regarding the meaning of the process and the meaning of risk itself (Chapman, 2001). When they are involved in the process, definitions need to be clear and unambiguous for the team to identify the right risks and for the process to have any meaning and usefulness. This also means the difference between cause, risk and effect.
- The team needs to comprehend the correlation and relation between different risks. Whether they positively or negatively influence each other and whether they are sequential or simultaneous (serial or parallel; Chapman, 2001). This also effects the modelling of the risks in the analysis stage later and therefore needs to be comprehended by the team.
- Prevent hindsight bias, meaning that it is important to prevent decisions being made that are too much based on hindsight knowledge (Bajaj et al., 1997). Doing so can have two implications. Firstly, when using hindsight knowledge to predict future events, for example in the form of historic data, it does not identify unique risks of new projects as they do not appear in the records. Secondly, because basing decisions on hindsight implies the assumption that the situation in which the risk occurred was inevitable, while in reality the event may happen different in different situations. To prevent this it is important to always look at additional risk identification methods than solely historic data in identifying unique project risks.
- In chapter 5 it was identified that risk management traditionally came down to intuition, judgement and experience. Experience is also identified by other authors as key to the risk identification process itself (Chapman, 2001). However, research by Maytorena et al. (2005) identifies education level and style of information search as key to successful risk identification, rather than experience. Their results show that higher education level and a feedback style of information searching, (i.e. an iterative investigative approach) contributes to a better risk identification performance. Both these aspects can be trained. This research is not conclusive, but it does show that other aspects, besides experience, are also important.

6.2. METHODS AND TECHNIQUES

There are a number of methods/techniques that can be applied to identify risks in infrastructure projects. They can be divided into three main categories: (1) identification by the risk manager, (2) identification by interviews and (3) group sessions (Chapman, 1998). The specific methods are outlined below and derived from a number of authors (Chapman, 1998; Chapman, 2001; Elkington & Smallman, 2002; Bajaj et al., 1997; Perry, 1986).

- **Brainstorming technique**
This is aimed at generating as many ideas and possible solutions as possible in a short time in a group format. Initial critique is avoided to improve the production of ideas and therefore it generally produces a larger quantity of possibilities than the other techniques here, but many then turn out to be infeasible or not applicable.
- **Semi-structured interviews**
Semi-structured interviews are interviews in which the interviewer predefines the general direction of the questions, but preventing too specific formulations too early. This will leave room for the interviewee to elaborate on his points of view without pushing him/her in a certain direction and allowing to dive deeper into the subjects. The results are generally of high quality, but it is a time-consuming method.
- **Nominal Group Technique**
This technique involves a group in which each individual writes ideas about the problem down and then shortly presents one of the ideas to the rest, one by one, preventing duplicates. This is then recorded on a flip chart until no more unique ideas are available, after which a discussion will take place. This discussion often leads to the combination and elimination of ideas, improving the results. Finally each individual writes down the most serious ideas by ranking them, which are then mathematically aggregated to obtain the highest ranked ideas, or in this case risks.
- **Delphi technique**
The Delphi technique concerns a panel of experts, who answer questionnaires consulting their estimates of the variables in question, in this case the identification of risks. Afterwards, the results of the questionnaire and the underlying reasons of each expert are summarized by the 'facilitator' and then anonymously provided to the other experts. They are then encouraged to revisit their earlier answers, in light of the answers of the other experts. These rounds can be repeated and the idea is that the answers will finally stabilize, resulting in the overall accepted solutions.

These methods can be aimed at purely identifying risks and/or in combination with an assessment to quantify them. Furthermore, there are a number of support options available for the risk identification process:

- **Identification tools and documents (e.g. Systems Dynamics Models, WBS and flowcharts)**
System dynamics models map out all aspects of a system and the interactions of the individual components in order to understand the overall system dynamics, e.g. flowcharts and influence diagrams. Also financial statements, WBS and other project documents can be used as tools to identify risks.
- **Identification aids (e.g. checklists)**
A lot of research has been done to develop standard checklists for risks within infrastructure projects. Even though every large infrastructure project is unique and

the risks greatly depend on specific aspects, e.g. the contract form and geographical cultural standards etc., some standard risks are often present and checklists will help to think about these and whether or not they apply to the project in question.

- Historic records

This concerns the use of a (project-transcending) database or other records of previous projects, in which the risks in those previous projects are maintained, which can then be used to identify possible risks in new projects. These should be carefully examined in new projects to prevent hindsight bias as was discussed in the previous section.

6.2.1. ADVANTAGES AND DISADVANTAGES

Whichever method is chosen, there are advantages and disadvantages for all of them. Both, the individual (i.e. one on one interviews) and the group methods, have advantages and disadvantages. Bajaj et al. (1997) argues that it is important to perform the risk identification process in a group, rather than as an individual. A group process will reduce personal bias of the individual, which is important for an objective identification of risks. It will reduce the influence of the personal experience of a single person, which is, as was argued in the previous sub-section, not the sole prerequisite for successful risk identification. The research that Chapman (1998) published, fits in with this argument. He evaluates the effectiveness of three group methods for risk identification based on the determinants of group effectiveness by Charles Handey. These were developed from research of behavioral scientists and contain the following determinates:

- The 'givens', meaning the group, the task and the environment.
- The 'intervening factors', meaning leadership style, process and procedure and motivation.
- The 'outcomes', meaning productivity and member satisfaction.

Each of these have some further underlying characteristics which will not be further discussed here. From his analysis, he concludes that all group methods show problems that need to be overcome, depending on the group. His results favor the nominal group technique over the brainstorming and Delphi techniques. This is mainly due to the facts that it can be better controlled than brainstorming, while maintaining better participation as compared to the Delphi method. There are a number of disadvantages of working with group methods that can result from the negative effects of group dynamics. The main concern is the effect of dominant personalities and the influence that these group members have on less dominant personalities. This can result in the ideas being generated by them, while the less dominant group members have limited influence on the process. This will bias the outcomes of these sessions towards these personalities and towards the composition of the group itself (Keizer & Halman, Diagnosing risk in radical innovation projects, 2007). This should be prevented by stimulating people to bring forward their ideas even if they go against the more dominant personalities or against opinion leaders. To prevent the negative effects of these group dynamics, Keizer et al. (2002) present a number of 'rules of conduct' or 'rules of engagement':

- Every one's viewpoint is valid!
- No holding back – Say what's worrying you!
- No management hierarchy
- The things we don't like to hear are probably key issues
- Explain from your area of expertise

The problems with group dynamics are also identified by Chapman (1998). It is therefore argued to use a mix of methods in varying combinations to obtain the best results.

6.3. CONCLUDING REMARKS

This section will shortly answer the third theoretical research question, based on the literature review and discussion provided in the previous sections. The third research question was defined as follows:

3. *What approaches to risk identification are available in current research and what are their advantages and disadvantages?*

The methods for risk identification can be divided in the following general groups:

1. Individual by the risk manager
2. One-on-one interviews
3. Group methods

All methods are proven to have some form of bias. Interviews are biased toward the personal viewpoints of the interviewee. Group methods can be subject to the negative effects of group dynamics. These are mostly influences from dominant personalities and thus underexposure of other viewpoints. A combination of methods works best to prevent bias from either methods. Furthermore, a number of tools can be used for proper risk identification. These can be project documents from the client, flowcharts and WBS and Resource Breakdown Structures. Further important tools can be checklists or historic records from past projects.

7. RISK CLASSIFICATION

This chapter discusses the literature review on the risk classification aspect of this research. The classification will be done according to a number of criteria, with each criteria containing a number of underlying categories. Four of these categories are derived from the literature review, namely nature, source of origin, timing of occurrence and control measures. These are discussed in the following sections respectively.

The most prevalent international research concerns BOT and PPP projects, but these are comparable, at least insofar as risk classification is concerned, to DBFM projects in the Netherlands, as was explained in sub-section 3.1.2. There are two criteria commonly used in the literature to classify risks in large infrastructure projects. This is either the 'nature' -criterion of a risk, or the 'timing of occurrence in the project's lifecycle' -criterion (Xenidis & Angelides, Identification and classification of risks in a new modelling process for Build-Operate-Transfer projects, 2005). This trend is also identified by Li & Zou (2008) in their publication on risk identification and assessment in PPP infrastructure projects. In addition to these two most common criteria, Xenidis & Angelides (2005) apply a third criterion for risks that is in close relation to the nature of risk criterion, namely the 'source of origin'. The following sub-sections describe the following criteria respectively: nature, source of origin and timing of occurrence. Furthermore, a fourth, less commonly used criterion will shortly be explained in the fourth and final sub-section, namely based on the control measures applied.

7.1. NATURE OF RISK

This subsection will discuss the risk classification according to their nature -criterion. The 'nature' and 'source of origin' criteria are derived from Xenidis & Angelides (2005). They introduce these criteria in order to classify risks in two ways and thus increase the accuracy of their assessment, before assigning them to the timing of occurrence criterion in their other publications. The nature of the risk reflects the type of the risk, i.e. financial, technical, etc. The following paragraphs will review research on the nature-criterion as it is most prevalent in research.

A multitude of different categories can be found in the literature in order to classify risks according to their nature. This criteria is generally divided in a number of different categories, ranging from three different categories to nine different categories. Xenidis & Angelides (2005) divide risks according to their nature criteria into three different categories: financial, technical and legal. Wiguna & Scott (2005) divide risks into four different categories, namely: external and site condition risks, economic and financial risks, technical and contractual risks, managerial risks. A division into six or more categories is often more specific in comparison to fewer categories, which are usually more collections or combinations of the multiple other categories presented by other studies. Six categories is seen in multiple studies:

- Mustafa & Al-Bahar (1991) apply a classification in order to introduce their Analytical Hierarchy Process (AHP) risk assessment method, which is a multi-criteria decision analysis method. Their categories are the following: acts of God (force majeure), physical, financial & economic, political and environmental, design and job site-related.
- De Lemos et al. (2004) use the following categories for their research into risks on a construction project of two bridges in Portugal: social, legal, economic,

environmental, political & regulatory and technological. These are identical to the PESTLE categories that are often used in business strategic management.

- Wang et al. (2000) use the following six categories for their research on China's BOT projects: political, construction, operating, market & revenue, financial and legal

Eight categories are presented by Pawar et al. (2015) in their study on risk management in infrastructure projects in India. They define the categories as follows: physical, financial, legal, construction, political, design, environmental and contractual.

Even though Grimsey & Lewis (2002) do not define their identified risks as categories or classes per se, the nine risks they state can be viewed as such as they are not very specific and comparable to most of the categories already seen above. They define the risks in relation to a case study on a PPP project of a waste water treatment facility in Scotland. They are defined as follows: technical, construction, operating, revenue, financial, force majeure, regulatory & political, environmental and project default. Miller & Lessard (2001) define three main risk categories, each containing 3 sub categories:

1. Market-related risks: demand, financial and supply
2. Completion risks: technical, construction and operational
3. Institutional risks: regulatory, social acceptability and sovereign

The categories from all aforementioned research are all somewhat similar and contain categories that overlap each other to a certain extent, depending on the exact definition given by the authors. Depending on the chosen categories, these will be described in more detail in section 2.2.

7.2. SOURCE OF ORIGIN

The source of origin is the second criterion applied by Xenidis & Angelides (2005) to classify risks. The source of origin reflects where the risk originated in the project, i.e. the contract, the state, etc. There are many published studies over the past few decades that go into classifying risks according to their source of origin. The starting point is that of Xenidis & Angelides (2005), who, as mentioned earlier, identify five categories within the source of origin criterion:

1. State-rooted: The state is a significant source of risks due to actions or omissions by governmental and public agencies.
2. Concessionaire-rooted: Issues in control of the concessionaire are an important source of risk.
3. Market-rooted: The environment of the project and the market wherein the project is developed are a source of risk.
4. Contract-package-rooted: The framework of agreements and legal documents that influence the project's development are complex and a source of risk.
5. Miscellaneous: Either more than one of the above or none of the above (e.g. force majeure).

This list is quite short and therefore quite clear and manageable. However, when reviewing Perry's (1986) list of categories for example, the overview is quickly lost. He defines the following sixteen categories: client/government, funding/fiscal, definition of project, project organization, design, local conditions, permanent plant supply, construction

contractors, construction materials, construction labor, construction plant, logistics, estimating data, inflation, exchange rates and force majeure.

As can be deduced from this list, sixteen categories is already difficult to understand. Many similar sources of origin have been identified by researches since then. Knowledge on this subject has thus increased further and the categories have become more extensive. To maintain a manageable overview, some researchers have proposed breakdown structures to structure the categories. These are structured by applying a number of hierarchy levels in order to make a distinction between the categories and underlying sub-categories. The Risk Breakdown Structure (RBS) can be defined as: "A source-oriented grouping of project risks that organizes and defines the total risk exposure of risk to the project. Each descending level represents an increasingly detailed definition of sources of risk to the project." (Hillson, The Risk Breakdown Structure (RBS) as an aid to effective risk management, 2003).

There are many published studies on risk breakdown structures and two general approaches to classify risks in these breakdown structures. Several researchers propose a generic RBS, into which any risk in any industry can be categorized. Others propose an RBS that is specifically oriented towards a certain industry, business area or type of project (Holzmann & Spiegler, 2011). The generic versions are unlikely to include the full scope of possible risks to every project in the industry under consideration and more specific versions may thus be required (Hillson et al., 2006). The more specific ones are considered more useful for this research, since the projects under consideration all concern one industry. Now the possibilities of making these RBS's more specific are near endless and therefore the review will include the ones related to civil engineering. Because of the large number of possibilities, final selection of the applied categories for this research will be done in chapter 10 after the empirical research is completed.

Chapman (2001) presents a risk identification breakdown structure in the form of a checklist. This breakdown structure classifies risks in four different main sources (first order hierarchy level) and some underlying categories in second- and third- order hierarchy levels. This is schematically represented in Table 7.1.

Table 7.1 - Risk breakdown structure by Chapman (2001)

Level 0	Level 1	Level 2	Level 3
Total Project Risk	Environment	Statutory	
	Industry	Market	
	Client	Client Team	
		Project Management Team	
		Targets (objectives)	
		Funding	
		Tactics (controls)	
	Project	Team	
		Tactics (controls)	Cost control
			Time control
			Quality control
			Change control
		Task	Site
			Design

Ebrahimnejad et al. (2010) developed a more extensive RBS for BOT projects in developing countries in Asia, mainly Iran. Their aim is to use the RBS to provide hierarchical, manageable and definable packages that can be used to facilitate understanding, communication and management of risks. Their proposed RBS is presented in Table 7.2.

Table 7.2 - Risk breakdown structure by Ebrahimnejad et al. (2010)

Level 0	Level 1	Level 2	Level 3
Total project risk	Organizational risks	Financing	
		Relationship between projects	
		Human resources	
		Benefit priority	
		Management	
	Technical risks	Initial process (technical and financial studies)	
		Executing	Planning and controlling
			Engineering
			Procurement
			Construction
			Delay or incompleteness
		Operating	Performance
			Maintenance
			Quality
	External risks	Legal	Changes in laws
			Fault in laws
			Conflict of laws
			Breach of agreements
		Subcontractors and suppliers	
		Political and social	Regulatory
			Expropriation
			Bureaucracy
			Social
		Force majeure	
		Economics	Economic macro factors
			Market and client

As can be seen in the table above, their initial level is to classify risks into organizational, technical and external risks, after which some lower level categories are introduced. Tah et al. (1993) provide an even more extensive RBS based on a selection of risk factors or sources that were assembled from Perry & Hayes (1985), who identified general risk factors that are retainable by contractors, consultants and clients. The selection by Tah et al. was based on the factors that affect contractors and therefore relevant in this research. The selection was then further structured into internal and external sources. The external sources of risk are relatively non-controllable and thus a strategy needs to be developed to manage the effect of external sources. The internal sources can be divided further into local sources that are related to specific work packages or disciplines and global sources that relate to the overall project. These can then be further divided into some more hierarchy levels. The overview is shown in Table 7.3.

Table 7.3 - Risk breakdown structure by Tah et al. (1993)

Level 0	Level 1	Level 2	Level 3	Level 4
Total project risk	Internal risk	Local (varying work packages)	Labor risk	Availability
				Quality
				Productivity
			Plant risk	Availability
				Suitability
				Productivity
			Material risk	Availability
				Suitability
				Supply
				Wastage
		Sub-contractor risk	Availability	
			Quality	
			Productivity	
			Failure	
		Site risk	Ground conditions	
			Accessibility	
			Type of work	
			Complexity of work	
		Global	Performance risk	Management experience
				Availability of partners
				Relationship with client
				Workload commitment
	Contractual risk		Contract type	
			Contractual liabilities	
			Amendments to standard form	
	Location risks		Head office	
			Project	
Financial risk	Funding			
	Cash flow			
	Economic conditions			
External risk	Inflation			
	Exchange rate fluctuation			
	Technology change			
	Major client induced changes			
	Politics			

El Sayegh (2008) provides a similar first level division between internal risks and external risks in his study on significant risks in the UAE construction industry. His developed RBS can be seen in Table 7.4.

Table 7.4 - Risk breakdown structure by El-Sayegh (2008)

Level 0	Level 1	Level 2	Level 3
Total project risk	Internal risks	Owners	Delayed payment to contractors
			Unreasonably imposed tight schedule
			Improper intervention
			Change of design
			Lack of scope definition
			Delays in obtaining site access
			Breach of contract
			Sudden bankruptcy
		Designers	Defective design
			Deficiency in drawings
			Changes in design
			Documents not issued on time
		Contractors	Construction accidents
			Poor quality
			Low productivity
			Technical problems
			Contractors' incompetence
			Lack or departure of qualified staff
		Sub-contractors	Poor performance
			Breach of contract
		Suppliers	Material quality problems
			Delay of material supply
	External risks	Political	War threats
			Labor strikes
			Changes in laws
			Corruption & bribes
			Delays in approval
		Social & Cultural	Criminal acts
			Substance abuse
			Conflicts due to differences in culture
		Economic	Inflation
			Currency fluctuation
			Shortage in material availability
			Shortage in manpower availability
			Shortage in equipment availability
		Natural	Unexpected inclement weather
			Unforeseen site conditions
		Others	Delays in resolving contractual issues
			Delays in resolving litigation
			Unfairness in tendering
			Local protectionism
			Difficulty in claiming insurance

As can be seen in the given RBS's above, most go beyond the intended meaning of the source of origin criteria. They also incorporate internal allocation aspects in the form of work packages or stakeholders (Tah et al., 1993; El-Sayegh, 2008), nature criteria (Ebrahimnejad et al., 2010; El-Sayegh, 2008) or project phases (Ebrahimnejad et al., 2010) in these RBS's. The fact that an RBS can be so extensive illustrates one the main advantages of applying an RBS to structure risks. Which is that an RBS can be reduced or broadened, in depth of in breadth, depending on the needs of the user (Holzmann & Spiegler, 2011). This offers a great flexibility to the user for applying the RBS to varying projects and industries. However, this flexibility also exposes the main drawback of an RBS, which is that there is no consensus on how to develop one (Mehdizadeh et al., 2012). Each user can develop one without any guidelines, which is why there are many variations

available in the literature. Chapter 10 will elaborate how the criteria are incorporated and adapted for this research.

7.3. *TIMING OF OCCURRENCE*

As said in the introduction of this section, the timing of occurrence is the third most prevalent criterion to classify risks on large infrastructure projects (Xenidis & Angelides, Identification and classification of risks in a new modelling process for Build-Operate-Transfer projects, 2005). After their review of existing literature, Li & Zou (2008) also argue in favor of a classification based on the timing of occurrence of a risk, instead of a classification based on the nature of a risk. A classification based on the nature of risk criterion cannot reflect the perspective of lifecycle management. Therefore, in order to conduct lifecycle risk management, risks need to be identified, classified and analyzed from the lifecycle perspective. This requires a classification which is based on the timing of occurrence in the lifecycle of a project. This is reflected in the proposed categories of Li & Zou (2008), which are derived from the different phases in the lifecycle of PPP construction projects. They are the following six categories: feasibility study, financing, design, construction, operation and transfer.

Xenidis & Angelides do not assign the risks to the lifecycle phases in their initial publication (Xenidis & Angelides, Identification and classification of risks in a new modelling process for Build-Operate-Transfer projects, 2005). However, in their succeeding two publications, i.e.: 'The financial risks in BOT projects' (2005) and 'The legal risks in BOT projects' (2005), they assign their identified financial and legal risks to the lifecycle phases on BOT projects. Their categories within the timing of occurrence criterion are based on that lifecycle and are the following: sponsor's preparation to bid, selection of a bidder, concessionaire formation-contracts, implementation, operation/maintenance and transfer. The risks that are classified in these categories may occur in more than one phase of the lifecycle of the project. They can therefore be classified into more than one of the categories mentioned above.

However, the project scope of the selected case studies in this research does not contain an operation phase and two out of the three do not contain a maintenance phase either. The maintenance risks only play a role on the SAAone project, but that project is still in the build phase. It is therefore expected that this criterion will offer limited classification options for the occurred risks on the selected case studies, since there currently are only two relevant phases: design and build.

7.4. *CONTROL MEASURES*

A fourth, less discussed classification method for risks is according to the control measures applied. These are measures aimed at mitigating the effects from risks or preventing the risk altogether. According to Winch (2010), there are five options in broad terms for a response to an identified risk source, which can be applied before the risk source becomes an actual risk event:

1. Accept the risk source and plan to respond to the risk event.
2. Externalize the risk down the supply chain by subcontracting it to another party.
This should only be done if the party to which the risk is outsourced has a better position to manage the risk. Otherwise a secondary risk is generated that that party fails to meet commitments and effectively hands the risk back to the original owner.

3. Mitigate the risk source by changing the project mission or scope.
Generally the most appropriate response to an identified risk source and a good example of why risk management needs to happen early in the project life cycle.
4. Insure or hedge against the risk source.
Insurance is usually only possible for low probability rare catastrophes beyond the control of any of the stakeholders, e.g. a fire, and is in those cases also the best course of action. Hedging is generally only appropriate or possible if the risks are purely financial and spread across a large number of decisions, in which case portfolio management becomes an option.
5. Delay the decision until more information is available.
Frequently used for risks that are generated by the regulatory system or high impact risks that require more information.

The general approach is to mitigate risks as much as possible and look at insurance options for the risk source, before deciding to accept the risk. If the risk is so large it could bring down the firm, abandoning the project entirely may be the best course of action. Some types of risk, e.g. management challenges, can be externalized more easily, if the other party has superior experience or capabilities for example. Some risks are also a case of bad luck if they occur. These risks are generally best accepted, since any other approach will involve excessive transaction costs (Winch G. M., 2010). After the risk response is determined a contingency budget or slack in schedule is incorporated. This is why risks are preferably identified in the tender phase, because then the budget and schedule can still be adapted. If the risk is identified after tender, the budget and schedule are more fixed and the occurrence will result in failure cost. After this, the risks are monitored throughout the project life cycle, so that as more information becomes available, the risks can be reassessed. See sub-sections 3.1.5 and 3.1.6 for an overview of this process.

Bing & Tiong (1999) performed a study on risk factors and their mitigating measures in International Construction Joint Ventures (ICJVs) based on Asian case studies. They categorize the most effective risk mitigating measures into eight groups, which are divided over two phases of the ICJVs:

- The start-up phase, containing the following four measures:
 - Partner selection for the JV
 - Clear JV Agreement
 - Committed and unbiased employment to the JV
 - Management control
- The operation phase, containing the following four measures:
 - Selecting suitable subcontractors
 - Fair engineering contract with client
 - Set up and maintain good relationships with stakeholders and government
 - Reviews and renegotiation of conflicts

7.5. CONCLUDING REMARKS

This section will shortly answer the final theoretical research question, based on the literature review and discussion provided in the previous sections. The final theoretical research question was defined as follows:

4. *What risk classification methods are available in current research and how can they be applied to risks?*

There are four main criteria for the classification of risks that can be derived from the literature review. These are:

- Nature
- Source of origin
- Timing of occurrence
- Control measures

Especially for the nature and source of origin criteria many researchers propose different approaches. They are often applied in a number of levels, in the form of risk breakdown structures, especially the source of origin criteria. The specific categories that will be applied within the criteria will be discussed in chapter 10. For these four criteria however, they are derived from the literature discussed in the previous sections. Since the possibilities for classification are seemingly endless, the number of categories that will be applied need to be limited. Especially since the dataset for which they are intended only consists of 45 risks. For the nature of risk criterion, these are limited to five categories and for the source of origin these are limited to eleven categories. For this limited dataset it is not yet necessary to develop multiple levels for the risk criteria. It was found that many criteria relate to BOT projects and are therefore also related to the operational phase of these projects. In this research this phase is not present however. As well as the maintenance phase, which is not included in the scope of this research, since there is no project included that has reached a maintenance phase yet.

Part III - Empirical results

This part contains the empirical results of the research, divided over three chapters. Chapter 8 contains the initial empirical results about available data, which also lead to the final definition of the research. Chapter 9 and 10 give the results of the empirical research into risk identification and classification respectively.

8. INITIAL RESULTS: AVAILABLE DATA

This chapter will discuss the initial results from empirical findings on the case studies. These initial findings relate to the initial research goal to provide insight in occurred risks and relating costs and failure costs. The data was collected from preliminary interviews, joint stakeholder consultations and the databases in which the risks were maintained on the project. Further documentation included the risk management- and project management- plans. After accessing the databases, it became apparent that there was limited available data on risks on the cases. Therefore the initial research goal slightly changed during the execution of the research. The data that is available is still useful to provide some insights and leads, which will be discussed in this chapter and will set up the rest of the research.

The chapter is split into four sections. The first section will discuss the tender data of the risks on the cases. The second section will discuss the results of the findings on identified risks. This mainly concerns the differences between the number of identified risks during tender and the number of identified risks at project completion, or in the cases of SAAone and CBB, the identified risks to date. The third section will discuss the results on the findings on occurred risks. These were available on three of the six cases, namely SAAone, A4All and Galecom. The final section of this chapter will discuss the results on the cost estimates versus the actual costs. These were only ascertained for the SAAone case.

8.1. TENDER VALUES

This section discusses the initial values of the projects, namely the tender values of the identified risks, meaning the number of identified risks and the available budget. The relevant values are shown in Table 8.1.

Table 8.1 - Initial values of identified risks in the tender phase of the cases

ID	Project	Contract	Approx. initial contract value (€)	Identified risks tender (number)	Eliminated or mitigated risks in tender (number)	Remaining risks after tender (number)	Tender Risk Budget (€)	Percentage from contract value (%)
1	SAAone	DBFM	Confidential	265	66	199	Confidential	Confidential
2	A4All	D&C	Confidential	102	n/a	102	Confidential	Confidential
3	CBB	D&C	Confidential	153	45	108	Confidential	Confidential
4	Utrechtse Tulp	D&C	Confidential	110	n/a	110	n/a	Confidential
5	Galecom	D&C	Confidential	351	50	301	Confidential	Confidential
6	Willems Unie	D&C	Confidential	23	n/a	23	n/a	Confidential
Total			Confidential	1004		843		
Average			Confidential	167		141	Confidential	Confidential

The cases show a combined contract value of approximately € 1.4 billion, with an average of € 231.7 million. Furthermore, it was found that a number of identified risks during tender is already eliminated from the risk register, e.g. when sufficient control measures have been developed so that the residual risk is considered 0. This results in a number of remaining risks after tender (7th column), for which the tender risk budget is reserved (8th column).

The average percentage of the contract value reserved for risks is confidential. A plot of these individual percentages in relation to the approximate initial contract value is shown in Figure 8.1, including a trend line.

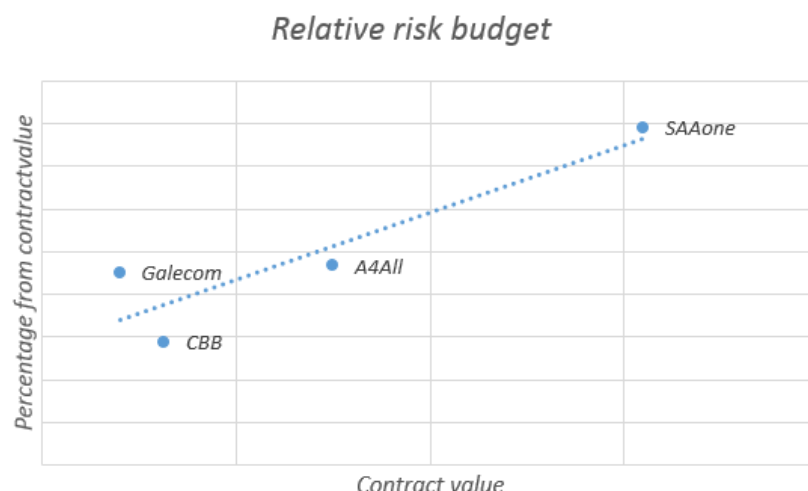


Figure 8.1 - Plot of reserved risk budget as a percentage of the contract value

As is shown, the relative budget reserved for risks, increases with the contract value. It is notable that CBB, A4All and SAAone show an almost perfect linear increase of relative risk budget, with only Galecom being relatively high. This could be explained because of the technical specific challenges in the Galecom project. The use of High Strength Concrete and lifting of the entire bridge are technical challenges where there is little experience with.

8.2. IDENTIFIED RISKS

The only additional useful data that is available for all six cases is the number of identified risks to date⁶. The other data that was found is not available on all cases, as will be described in the following sections. A comparison can be made between the number of identified risks during tender and the number of identified risks at project completion. This will provide a basis for assessing the strength and quality of the risk identification process. Table 8.2 shows an overview of the six case studies and the identified risks during the tender phase and the available risk budget that was reserved during tender.

Table 8.2 - Overview of identified risks in tender - execution phases and available risk budget

ID	Project	Identified risks tender (number)	Eliminated or mitigated risks in tender (number)	Remaining risks after tender (number)	Identified risks to date (number)
1	SAAone	265	66	199	687
2	A4All	102	n/a	102	531
3	CBB	153	45	108	213
4	Utrechtse Tulp	110	n/a	110	237
5	Galecom	351	50	301	467
6	Willems Unie	23	n/a	23	571
Total		1004		843	2706
Average		167	54	141	451

⁶ Since two of the cases, SAAone and CBB, are not yet completed, the number of identified risks is up to the latest update of the identified risks, on May 14, 2016.

As can be seen, the total number of risks identified increases a lot from the tender phase to the project to date phase. The number of identified risks to date also consists of the remaining risks after tender, so for SAAone, there are 687 risks identified to date, of which 199 were identified and remaining during tender. The number of identified risks to date doesn't include the eliminated risks and is therefore comparable. This effect is more clearly shown in Figure 8.2.

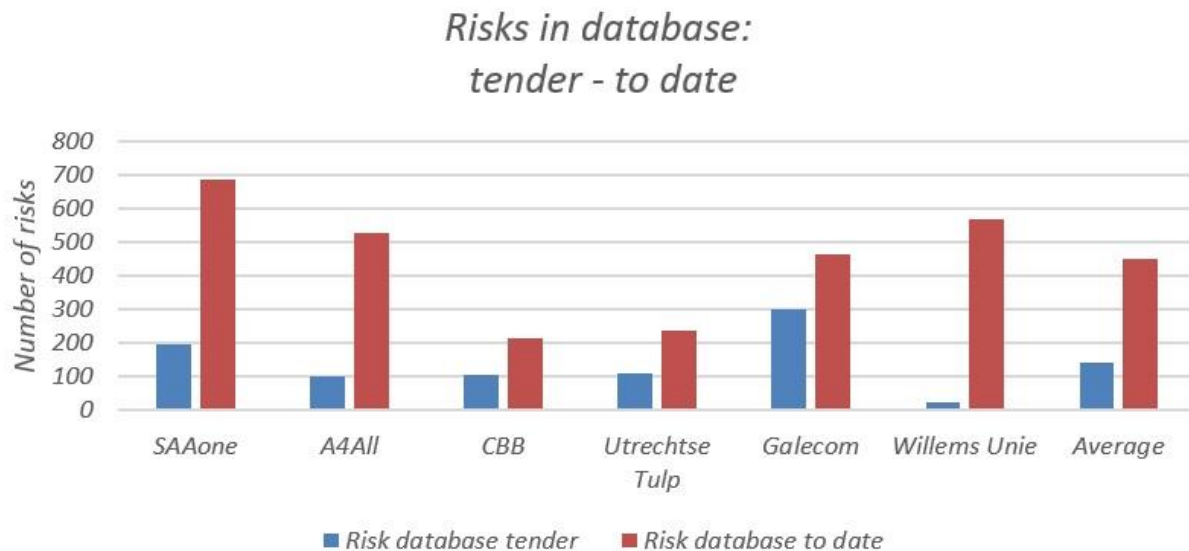


Figure 8.2 - Comparison identified risks: tender - to date

On average, over the six case studies, the number of identified risks increases with 653% from tender to project completion. It should be noted that the case study Willems Unie can be seen as an outlier, since the tender dossier only showed 23 identified risks, while the final dossier ended with 571 identified risks. It was not possible to ascertain whether this was the actual risk register by which the tender was won. The increase from 23 to 571 risks represents an increase of 2483%, which is very extreme. However, even when Willems Unie is omitted as outlier, the average increase of identified risks between tender and project completion is still 287%. This effect can increase even more, since 2 of the selected cases (SAAone and CBB) are not yet finished and more risks may be identified before the project is completed. This effect could partly be due to the limited availability of information during the tender phase, which can lead to unforeseen circumstances during the execution phase. However, this doesn't completely explain the lack of identified risks during tender. It calls into question the quality of the risk identification process during tender. It also raises the question whether additional budget should be reserved during tender as standard, because of the number of risks that aren't- or cannot- be foreseen during tender. Based on this high increase of identified risks, it was decided to include the risk identification process that the risk managers of VolkerInfra apply in the research scope. This analysis is based on a comparison of the literature review in chapter 6, with results from interviews that were held with the risk managers of VolkerInfra. The results of this analysis are discussed in chapter 9.

8.3. OCCURRED RISKS

Initially it was attempted to find out what risks occurred on the case studies and what the corresponding actual costs were of these occurred risks. If a risk occurred, it either meant that it was an unidentified risk and thus a surprise, or an identified risk, meaning that the

control measures were insufficient or it was badly managed. Therefore, these occurred risks would be an important source of information and could be used to improve management on similar risks in future projects. However, it turned out that the data on occurred risks was only available on some of the case studies. Only three out of the six projects register occurred risks. These are SAAone, A4All and Galecom. The other three did not have records on which risks occurred and which identified risks didn't occur. The analysis on occurred risks is therefore limited to the three mentioned cases. An overview of the data that were available on occurred risks is shown in Table 8.3.

Table 8.3 - Overview of the available data on occurred risks on the case studies

ID	Project	Identified risks to date (number)	Total occurred risks ⁷ to date (number)	Percentage occurred from identified (%)	Tender Risk Budget (€)	Total calculated value occurred risks to date (€)
1	SAAone	687	84	12.2	Confidential	Confidential
2	A4All	531	69	13.0	Confidential	Confidential
3	CBB	213	n/a	n/a	Confidential	n/a
4	Utrechtse Tulp	237	n/a	n/a	n/a	n/a
5	Galecom	467	49	10.5	Confidential	Confidential
6	Willems Unie	571	n/a	n/a	n/a	n/a
Total		2706				
Average		451	67	11.90	Confidential	Confidential

Table 8.3 shows that the average percentage of risks occurring on the three available cases is 11.9%. The total value of these occurred risks (last column) is multiple times higher than the budget that was reserved during tender. This means that, in theory (the total calculated value is an estimated value, see sub-section 3.1.6), the reserved risk budget is insufficient to cover the costs of the risks. This budget shortage partly results from the risks that were identified after tender and for which is therefore no budget available in the first place. It also results from some of the major risks occurring that were identified during the tender phase, which is not accounted for in the Monte-Carlo analysis. The separation between the values of the occurring risks that were identified during tender and that were identified later is shown in Table 8.4.

Table 8.4 - Separation values risks identified tender phase - identified later

Project	Total occurred risks to date	Occurred risks from tender phase	Occurred risks identified later	Total calculated value occurred risks from tender phase	Total calculated value occurred risks after tender phase
SAAone	84	32	52	Confidential	Confidential
A4All	69	Separation not possible			
CBB	n/a	n/a	n/a	n/a	n/a
Utrechtse Tulp	n/a	n/a	n/a	n/a	n/a
Galecom	49	27	22	Confidential	Confidential
Willems Unie	n/a	n/a	n/a	n/a	n/a

⁷ The total occurred risks are part of the identified risks to date in the previous column. Thus for SAAone: 84 out of 687 identified risks have occurred up to May 14, 2016.

As can be seen, the separation was only possible for two of the three cases that had occurred risks available. For the A4All case this separation is not possible as the risk register from the tender phase is completely different from the online risk database in VISE. As can be seen, for the SAAone case, most risks that occurred were identified after the tender phase, 32 during tender and 52 later. It is notable however that the total value of the occurred risks from the tender phase is higher than of the occurred risks that were identified later, even though that value consists of 20 less risks. This can indicate that the most valuable risks were identified during the tender phase. For Galecom, the most risks that occurred were identified during the tender phase, namely 27 out of 49. The value of these occurring risks however, is nearly the same, indicating that the risks identified later are more valuable. To understand the nature of the costs of these risks, it was decided to analyze the accuracy of the original calculated value (budget estimate). In order to do this, it was attempted to determine the actual costs for the occurred risks. These can then be compared to the calculated value in order to determine the accuracy of the calculated values and gain more insight in the real costs of occurred risks compared to the available budget. These results will be discussed in the next section.

8.4. COST DATA: ESTIMATES – ACTUAL COSTS

The actual costs for the occurred risks were only ascertained for the SAAone case. Obtaining these actual costs turned out to be an extremely time-consuming process. This was, among others, caused by the size and complexity of the construction organization. Furthermore, on the cases there is no connection between project cost controllers and the risk managers, meaning that there is no direct input from the cost controllers and thus the costs of risks are unknown to the risk managers. Therefore these costs are not readily available and require a lot of work to obtain. Because a lot of the risks are combinations of different disciplines and activities and are therefore not readily available in budget overviews, this was made even more difficult. Because there was only limited time available, it was decided not to attempt to ascertain the actual costs for the other cases. Based on the results of the SAAone case and the process however, some conclusions can still be made. The actual costs of the occurred risks on SAAone are shown in Table 8.5.

Table 8.5 - Overview of risk budget, calculated value occurred risks and actual costs occurred risks

ID	Project	Tender Risk Budget (€)	Total calculated value occurred risks to date (€)	Actual costs occurred risks (€)	Available budget per occurred risk (€)	Calculated value per occurred risk (€)	Actual cost per occurred risk (€)
1	SAAone	Confidential	Confidential	Confidential	Confidential	Confidential	Confidential
2	A4All	Confidential	Confidential	n/a	Confidential	Confidential	n/a
3	CBB	Confidential	n/a	n/a	n/a	n/a	n/a
4	Utrechtse Tulp	n/a	n/a	n/a	n/a	n/a	n/a
5	Galecom	Confidential	Confidential	n/a	Confidential	Confidential	n/a
6	Willems Unie	n/a	n/a	n/a	n/a	n/a	n/a

Furthermore, Table 8.5 shows a comparison between: the original calculated tender budget, the total calculated value of total occurred risks and the actual costs of occurred risks. It also shows these respective values when they are divided over the 84 occurred risks. From these values the difference between available budget and actual costs, or when not available calculated value (the estimate of the costs), can be deducted and thus shows

the budget shortage. Furthermore, the difference between the total calculated value and the actual costs is a measurement for the accuracy of the assessments made, as they are based on the same risks.

It indicates a difference of Confidential between the total calculated value and the actual costs of the 84 occurred risks on the SAAone case. This difference is only Confidential. This seems to be a small difference. However, when looking at individual risks, the differences are sometimes more extreme. These vary from a risk with a calculated value of Confidential, while having no actual costs to a risk with a calculated value of Confidential, while having Confidential actual costs. These examples are derived from table E.1 in appendix E, in which the individual occurred risks on the SAAone case are shown, including their corresponding financial values. This means that the mutual differences between the risks are very high. Consequently, the similarity between the total calculated value and total actual costs (less than 5% difference on the totals) can also be coincidental. Since the actual costs are not available on the other cases, there is no further comparison possible to determine the accuracy of the assessment. One last notable aspect is deducted from the A4All case. The total calculated value of occurred risks is Confidential. This seems like an extreme amount of money in relation to the reserved risk budget, which was only Confidential, as shown in Table 8.5. This could indicate that the concept of calculated value and the difference with expected value is not clear for everyone in the organization as these values do not represent actual costs.

The overview of occurred risks and their financial values for the SAAone case are shown in table E.1 in appendix E. There were some other notable findings while performing the research:

- A number of risks have not occurred due to additional control measures that were determined after initial identification of the risk itself. These additional control measures can be costly, but due to the fact that the risk does not occur, they are not traceable as the cost of control measures is not recorded. The costs of these additional control measures are not recorded, while they are a direct result of the threat of the risk. As such, the actual costs of occurred risks is not the same as the total costs resulting from risks on the cases.
- This is also true for all risks identified after tender and thus for which no budget was made available. These also have control measures that can be costly, but not recorded if the risk does not occur.
- Occurred risks are currently not part of any of the processes on the cases. Meaning that they are not part of internal reports, reviews or checks and balances. They are therefore currently not exploited as opportunities to establish a learning curve.
- There are a number of other aspects present on the cases that result in cost overruns that are not directly related to risks, or are currently not defined as having a relation to risks. Examples are: cost bandwidth, meaning the variability of required quantities of materials, inefficient work-processes leading to rework and the lack of cooperation or integration between disciplines leading to inefficiencies and failure costs. It is debatable whether these should be part of risks, but they do lead to cost overruns and specific cases are sometimes present in the risk database.
- Some occurring risks lead to rework that is paid for by the client, leading to some extra profits being made, which flows back into the construction organization.

For these reasons, it is impossible with the current manner of cost recording to determine the total costs resulting from risks on the cases. Analysis of the financial consequences of

occurring risks is therefore limited to the SAAone case and even these numbers are not absolutely certain. Since the occurred risks are still a valuable source of information, it was decided to perform additional analysis on the top fifteen occurred risks from the three available cases. The top fifteen is determined based on calculated value, leading to a list of 45 occurred risks total, since they were only available on three cases (SAAone, A4All and Galecom). These will be subjected to further classification, which is derived from the literature review in chapter 7 and applied in chapter 10.

8.5. CONCLUDING REMARKS

This section will shortly answer the first empirical research question, based on the available data and discussion provided in the previous sections. The first empirical research question was defined as follows:

5. What data is currently available on risks and risk management on VolkerInfra projects and what follow up research is recommended based on that?

The current available data on risks in VolkerInfra projects is very limited. Only the number of identified risks, during the tender phase and during the execution phase, are available for all six cases and some internal allocation aspects. Occurred risks themselves are only recorded on the SAAone case, the A4All case and the Galecom case. These are not available for the Combinatie Badhoever Bogen, Utrechtse Tulp and Willems Unie, while the occurred risks are considered to contain valuable information.

Actual costs of occurred risks are not recorded and therefore a further analysis to determine the effectiveness of risk management based on a comparison between actual cost and the calculated value is not possible. The costs of control measures, either developed during tender or during the execution phase is not available, while these may influence the actual cost of the risk management process. Furthermore, there are cost overruns on the project that are not linked to risk management but that do influence the risk management process. All these aspects provide an unclear picture of the cost of risk. The actual cost of risks that were discovered for the SAAone project may therefore be incomplete. There are no actual costs available on the other cases so further analysis on these aspects is not possible. Since the number of identified risks rapidly increases after tender, it was decided to further focus the research on risk identification. A risk classification can aid in the risk identification process as well and is therefore the second further focus of this research.

9. RESULTS RISK IDENTIFICATION

This chapter describes the empirical research that was held in relation to the risk identification part of the risk management process. Interviews were held with six risk managers within VolkerInfra. These were the six risk managers responsible for the six different case studies. They were asked to describe how they identified risks on new projects. The goal was to determine their risk identification process. The results can be divided into two parts, namely a qualitative part and a quantitative part:

The qualitative part concerned the following:

- The risk managers were asked how they performed risk identification on projects. Whether they followed specific steps and a fixed procedure or that it differed per project. They were also asked what important aspects they consider while executing risk identification on a project. They were also interviewed about their experience and whether anything in their process has changed over time and why. This also included a motivation for why they chose the process that they apply.

The quantitative part concerned the following:

- The risk managers were asked whether or not they used any of the methods that were described in chapter 6. These results are visible in Table 9.1. They were also asked whether they had used any method at any time that had not yet been mentioned.

For the description of their applied identification methods and the list of techniques, a distinction was made between the tender phase and the execution phase. The results will then show differences between both phases of the project and thus reveal preferred practices among the risk managers in two phases of projects. One of the risk managers did not have any prior experience on risk identification during the tender phase of projects and therefore there are only five results for that phase and six for the execution phase. The results will discuss the quantitative results first in section 9.1, since they will also clarify some of the qualitative results that are given in sub-section 9.2.

9.1. *QUANTITATIVE RESULTS*

The results for the applied risk identification methods that were identified in the literature are shown in Table 9.1 below. The numbers represent the number of risk managers that replied yes or no respectively in both of the phases. There were only five of the six interviewed risk managers that had experience with risk identification during the tender phase of large infrastructure projects. Therefore the table only shows a total of five during the tender phase and a total of six during the execution phase.

Table 9.1 - Applied risk identification methods by risk managers

	Tender Phase		Execution phase	
	Yes	No	Yes	No
Brainstorm sessions	4	1	0	6
Personal interviews	4	1	5	1
Aids (checklists)	1	4	1	5
Historic records	2	3	2	4
Nominal group technique	0	5	0	6
Delphi method	0	5	0	6
Tools (loop-diagrams/system flow charts etc.)	1	4	2	4
Risk manager leading work group	4	1	2	4
Failure mode, effects and criticality analysis (FMECA)	1	4	1	5

Other methods that were not yet mentioned in the literature, but that were applied at some point by one or more of the risk managers are:

- 'Toolbox'
These are short sessions shortly before the work is executed on an operational level and not lead by the risk manager. Comparable to a Last Minute Risk Analysis (LMRA).
- 'Versnellingskamer'
This is a manner of cooperation in a workgroup, in which all the members are assigned to a workstation, laptop or tablet and in which they can all share their thoughts and ideas anonymously. The advantage is that it generates a large amount of information in a short amount of time. Two of the six interviewed risk managers have used this method once before. The main disadvantage was that the amount of information is too large and all quite similar and therefore creates a lot of extra work without much benefits. This was therefore only applied once.
- 'Technical session'
This is a session with a small group, with two or three additional persons, that is set up kind of like a workshop. Usually for when a specific expert requires help from the risk manager to structure his risks when there are changes in the project scope or working method.
- Other group session
Other group sessions have been done that were quite similar to the nominal group technique. These sessions can include some flip overs and post-it-notes in a wide range of variations and uses.
- Reactionary session
This session is held right after some personal interviews are done. It offers the interviewees a chance to react on each other's ideas and is therefore not a brainstorm session.
- Join meetings
This simply means to invite yourself to join meetings between different departments that are not intended for the risk manager per se, but are joined to get a feeling for the current problems on the project. This is usually done in the early stages after joining a project team to get a feel for the current situation. After this, some of the other techniques are usually applied for more detailed information.

The results show that during the tender phase of the project, the brainstorm sessions, personal interviews and the risk manager leading a workgroup are the most used methods for risk identification. These are applied by four of the five interviewees. The personal interviews become even more important during the execution phase of the project, when five out of the six interviewees apply that method. The brainstorm sessions fall away completely when moving to the execution phase as none of the risk managers apply that method once the project is in the execution phase.

The results also show that the risk managers make limited use of the support options that are available. Identification aids such as checklists are only used by one out of the five or six interviewees in the phases respectively. Identification tools such as system flow charts are only used by one out of five and two out of six interviewees in the phases respectively. Historic records are only used by two out of the five or six interviewees in the phases respectively. None of the interviewees were familiar with the Delphi method or the nominal group technique and they were therefore not applied by any of the interviewees. The FMECA method is generally only applied for maintenance projects as it looks at the impact of failure on the system and therefore not part of the scope of this research. Overall, the number of applied methods reduce when comparing the tender phase to the execution phase. The results show that risk identification becomes a different sort of process as the project progresses. This indicates that the nature of the project changes as the project progresses through its life-cycle. More specific knowledge and expertise is required as the project progresses and therefore more targeted methods are used, such as personal interviews. These are considered to yield better results as people on the project become more informed and experienced. Brainstorm sessions become less useful as people are more informed.

9.2. *QUALITATIVE RESULTS*

The main results from the qualitative part of the interviews are listed below:

- There are no company guidelines on how to perform the specific risk identification part of the risk management process. The development of this specific process isn't directed by VolkerInfra.
- All the risk managers have their own approach to the risk identification process. This is usually based on personal experience and preference and not on guidelines.
- The approach that each of them follows, generally consists of a fixed pattern every time a new project is started. These patterns do not vary much over time as it has become a routine for most. They are however mutually different between the respective risk managers.
- It generally only depended on the timing they got involved in the project which approach was followed. When involved early, most preferred to start with a brainstorming session, while when involved late, personal interviews were preferred, but again this differed mutually between them.
- The brainstorming method was only preferred in the early stages of a project, because later on the people involved are biased based on their experience. The brainstorming session is then influenced too much by inside knowledge. Furthermore, brainstorm sessions are considered less useful as they are not applicable any more, since more specific knowledge is required as the project progresses. The nature of the project is different as the project progresses and requires more specific expertise on specific aspects of the project. That specific

knowledge usually doesn't surface when performing brainstorm sessions, but when more targeted methods are applied.

- Most interviewees would rather not use checklists as these are often too general and therefore create the chance that important risks are overlooked. The general fear is that checklists become too much of a standard or mandatory guideline which, especially when used too early in the process, prevents critical thinking about the project as the tendency is to just stick to the checklist and look no further. The only 'checklist', if you can call it that, which is commonly applied are the categories in VISE that need to be filled in for each risk. Since the introduction of VISE several years ago, it has become a prerequisite as well as a tool. Meaning that the method that is used for risk management needs to fit with VISE as well.
- As was seen in the previous sub-section, only two of the six interviewees used historic records. These historic records were personally kept by them and are not company standards. They are however considered useful by both interviewees.
- Five out of the six interviewees applied group sessions for risk identification in some form or shape during the project life cycle. Only one interviewee indicated that he preferred not to use group sessions. The interviewees indicated that they preferred group sessions with not too many people. Eight to ten people is the preferred maximum to be able to maintain oversight and keep the group manageable.

9.3. *DISCUSSION*

Given the recent focus on risk management in the construction industry in the Netherlands, it is unsurprising that many construction organizations are trying to improve their risk management practice. It was found that there was little attention for the risk identification part of the risk management process, in both research (chapter 6) and practice. This is quite surprising as it is an essential (arguably even the most important) step in the risk management process. During the interviews it was found that the risk managers each have a fixed process for risk identification that they follow on most projects. This process is based on personal preference and experience and few new methods are developed or experimented with. There are only two risk managers, although limited, trying to experiment with new methods for risk identification. There is no company guideline from VolkerInfra on this step either. Now it is acknowledged that there is no need for strict regulations on risk identification, but an outline of important aspects and considerations and best practices can lift risk identification within the company to a higher level. When looking at specific results in Table 9.1, the main room for short-term improvement lies with increasing the use of historic records and identification aids (which can be historic records). These are currently applied in a limited way. The same can be said for group sessions of any form in the early stages of the project. Also notable is the fact that brainstorming is used by nearly everyone during tender, but by no one during the execution phase. Main argument was that brainstorming is of no use when everyone is already very well informed when the project reaches its execution phase as they are then already too biased to generate useful ideas. Furthermore, as said in the previous section, the nature of the project changes as the project progresses. This requires more targeted methods to obtain specific knowledge and expertise than is usually acquired during brainstorm sessions. However, it was observed during the empirical research on site that there is a sufficient employee turnover to at least consider performing new brainstorm sessions. The use of external advisors or exchanging VolkerInfra personnel across different projects for a brainstorm session can also be used for that.

9.4. CONCLUDING REMARKS

This section will provide some concluding remarks regarding the results on empirical research on risk identification and provide an answer to the sixth research question, which was defined as follows:

6. *What risk identification methods are currently applied within VolkerInfra and how can they be further developed?*
 - a. *What risk identification methods are currently applied within VolkerInfra?*
 - b. *What are the main differences between the approaches applied and how do they compare to the literature?*
 - c. *How can the risk identification process of VolkerInfra be further developed?*

There are a variety of methods currently applied by the risk managers of VolkerInfra. Each of them has an own preferred approach to risk identification and there is not guideline on this aspect from VolkerInfra. The approaches to risk identification can be generally divided in three parts: individual methods by the risk manager, one-on-one sessions and group sessions. The results were split between the tender phase and the execution phase of projects. During the tender phase, the brainstorming (group method), personal interviews (one-on-one session) and work groups (group method) led by the risk manager were the preferred methods for risk identification. During the execution phase the personal interviews (one-on-one session) were most prevalent and little other methods were used. Little use is made from historic records or checklists. As the results indicate that there is no systematic approach to risk identification present, the development of guidelines for such an approach are the best way to further develop the risk identification process. This systematic approach has to consist of a mix of methods (individual, group and tools) to prevent bias. A deliberate use of certain experts in these methods should be applied. Furthermore, if more data on risks is collected on future projects, this data could also be used as a tool for risk identification.

10. RESULTS RISK CLASSIFICATION

This chapter discusses the applied criteria and categories for risk classification. Part of these criteria and categories result from the literature review in chapter 7. The others have been developed based on the empirical research of the documents of the cases and the interviews with the risk managers of VolkerInfra. The chosen and discussed criteria and categories are used to classify the top fifteen occurred risks on the available cases. The total classification in all criteria is designed to contain as much information as possible in order to characterize the risks in a comprehensive manner. This is done to gain insight into specific aspects of occurring risks on infrastructure projects of VolkerInfra. This results in an overview of most occurring categories for these risks. These can be used to identify targets of improvement within the risk management process for future projects.

10.1. *APPLIED CRITERIA AND CATEGORIES*

This section describes the criteria and categories in these respective criteria that are applied to the top fifteen occurred risks to provide the first step in developing a risk database covering multiple projects. The categories within the criteria are chosen in such a way that they are able to cover the identified top fifteen occurred risks from the three available case studies. They are sufficient for this stage of development of the research. The categories within them can be expanded in the course of time if they are found incomplete to cover the new risks. As was indicated in chapter 8, the financial values currently do not offer additional insight as the actual cost of risks is not clear. This section contains the substantial criteria that are applied, the criteria that are more generic, such as number and project that it relates to are given in appendix H. The criteria relating to these financial values are included in the appendix as well. The appendix offers a description on them, but they are not part of the further analysis as this is not possible for all risks included, as was discussed in chapter 8.

10.1.1. **PHASE IDENTIFIED**

This criterion is split into three different aspects:

- Phase defined
- Traceable to tender 'container' risk
- Resulting from an unforeseeable scope change (e.g. due to a stakeholder/client changes)

The phase defined represents the phase in which the risk was defined, not the phase in which the risk occurred. It corresponds with the phases that are present in DBFM projects, plus the tender phase, as is shown in figure 3.1. As stated in section 3.2, some of the risks are a further specification of container risks and therefore could have been identified sooner, only defined later. Therefore the second aspect, traceable to tender 'container' risk is added to ascertain whether the risk was actually part of a container risk identified during tender. Finally, the risk could have resulted from an unforeseeable scope change of the project and therefore not have been identified during the tender phase. For example: a change in the scope due to changing client demands or stakeholder requirements that could not have been foreseen. This is also ascertained for the risk. The resulting risks are from risks that were unidentified due to insufficient risk identification.

10.1.2. MAIN- AND SUB-OBJECT

These criteria represent the main- and sub- objects respectively that the risk relates to. These have been derived from the objects trees that were created on the cases. These contain extensive information on all objects present on the different cases. There are ten main objects on the cases:

- Civil structure
- DTM facility
- E&M installation
- Fitting facility
- Irrelevant
- Multiple
- Rail
- Road
- Service area
- Temporary object

There are many more underlying objects, for example the main object 'road' has the following sub-objects: understructure, superstructure, road marking, signs/beacons, signposts, drainage. Due to the high number of sub-objects that can be formulated in this category, only the ones currently present to the dataset have been included in the database. The complete list is shown in appendix F. The currently included sub objects are the following:

- Civil structure:
 - Aqueduct
 - Bridge
 - Cable culvert
 - Ecoduct
- DTM facility:
 - Software
 - Tunnel installation
- Fitting facility:
 - Earth retaining structure
 - Noise reduction structure
- Irrelevant
- Road:
 - Superstructure

The multiple category is only used within the main object criteria, to indicate if a risk relates to more than one object. If the risk relates the entire main object and not to a specific sub object, the category irrelevant is assigned in the sub object criteria. Some risks are not related to an object at all, in which case the category 'irrelevant' is used for both criteria. Some process risks are not assigned to a specific object for example.

10.1.3. DISCIPLINE

In large infrastructure projects, there are a number of disciplines involved, responsible for different aspects of the project. This criterion can therefore also be described as the 'internal allocation' of the risk. The following disciplines generally exist on these projects:

- Civil, for most civil structures excluding GWR
- Coordinating Organization ('De koepel'), representing the overarching organization, containing management, staff services and the design department for the project
- Dynamic Traffic Management (DTM), for the installations, e.g. for matrix signs and traffic routing
- Electrical and Mechanical engineering (E&M), often used for moving parts within projects, e.g. pumps etc.
- Ground Water and Road construction (GWR)
- Sound barriers

These disciplines represent different fields of work that have to work together in these large infrastructure projects. Their work has to be integrated to be actually able to design and build the project. The project phases represent parts of the process that are completed consecutively and are also integrated in the entire project. The interaction between these phases and the disciplines is schematically represented in figure 2.1, in which the disciplines are vertically separated and the phases are horizontally separated. This illustrates a part of the complex set of interactions that take place in these large infrastructure projects.

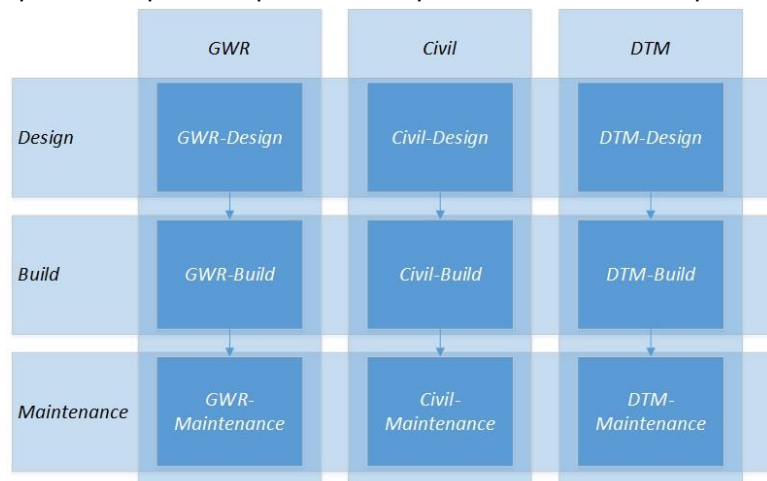


Figure 10.1 - Integration between disciplines and project phases

10.1.4. NATURE OF RISK

The nature of risk criterion is derived from the literature review in chapter 7. As was reviewed, there are many categories that can be applied within the nature of risk criterion, varying from three to nine categories. The categories that are applied within this research are listed below:

- Financial
- Legal
- Managerial
- Process
- Technical

These categories can cover the risks that are currently included in the database. There are some underlying assumptions to these categories that were necessary upon analysis of the currently included risks:

- Risks are classified as financial when they are solely related to finances of the project, so for example risks regarding interest rates or price volatility. Nearly all risks bear financial consequences upon occurrence, but this doesn't mean that the risk is classified as financial.
- Legal risks are the risks that are related to rules and regulations.
- Risks relating to conscious management decision are classified as managerial risks. For example, consciously deviating from the process by management is classified as a managerial risk, since it is a choice by the manager to do so and therefore not a process risk.
- Consciously deviating from the technical requirements by management is also classified as a managerial risk, since it is a choice by the manager to do so and therefore it is not a technical risk.
- Process risks are risks resulting from flaws in any of the work processes and are not related to decision making. These processes are maintained on the projects in VISE as well and in the project management systems, so this risk means a deviation from that process.
- Technical risks are risks relating to technical shortcomings or technical issues on the project.

10.1.5. SOURCE OF ORIGIN

The source of origin criteria follows from the literature review in chapter 7. As was reviewed, there are many different risk breakdown structures that classify risks according to their source of origin. Most of them however also incorporated aspects from the other criteria that are applied separately in this research. Therefore the categories in this criterion will not entail a complete breakdown structure. There are a number of categories named below that are currently sufficient to cover the included risks in the database. These have not been organized into an RBS, since that is not yet necessary with the current risks on which they are applied. However, together with the other applied criteria and categories this could be a next step in future research or applications when more risks are added to the database.

- Client
Risks that originate from the client during project execution.
- Contract requirements
Risks that originate from the requirements that are part of the contract for the project.
- Contractor
Risks that originate from the contracting party itself, mostly relates to general risks relating to the realization of the project.
- Design
Risks that originate from flaws in the design.
- Force majeure
These are the true surprises or unforeseen events, the so called unknown-unknowns as described by Aven (2013) and discussed in chapter 4.

- **Geotechnical**
Risks that result from (unforeseen) ground conditions or errors in the geotechnical analysis of the area of the project. For example residual settlement requirements that are not reached in time or weak subsurfaces.
- **Government**
Risks that originate from the government, e.g. changing laws and regulations.
- **Insufficient technical quality**
This category is applied for risks that are based around technical solutions that did not meet the requirements or worked different in practice than in theory and as a result have an impact on the project.
- **Occurrence of another risk**
Some occurring risks lead the occurrence of other, additional risks. This link currently is not available in the risk database or initial register, but this category allows for an initial identification and classification of that link.
- **Opportunism**
Opportunism can be a major source of risk, and this category generally relates to decisions that are consciously made during tender that conflict with requirements from the contract or the client. This is often done for commercial reasons, when it is believed that cooperation from the client can eventually be achieved.
- **Stakeholder**
Risks that originate from other stakeholders than the client or the contractor. For example when a job is outsourced to a third party, but the risk remains the responsibility of the contractor.
- **Uncertain site conditions**
Uncertain site conditions are an important source of risk, especially during the tender phase. There are limited options during tender for exploration and research of the construction site, for example the geotechnical ground conditions, and can therefore result in surprises during project execution.

10.1.6. PHASE OF OCCURRENCE

The phases of occurrence are chosen as similar to the phases as they were known from section 3.1. The literature review in chapter 7 did not reveal any additional useful phases that could play a role for the top fifteen occurred risks on the selected case studies. In the literature review there were examples of phases from the viewpoint of the client of the project, e.g. sponsor's preparation to bid and selection of a bidder (Xenidis & Angelides, The financial risks in build-operate-transfer projects, 2005). These are not relevant for the risks in this research or future projects however, as those are all risks relating to the contractor and are therefore not included. The phases are therefore the following:

- Design
- Build
- Finance
- Maintain
- Multiple
- Operate

The 'multiple' category is included to classify risks that either occur more than once in different phases or risks that span multiple phases in the project. The operation phase is included as a category, but not relevant in the selected case studies as they do not have an operation phase. For possible future projects this category could however play a role and is therefore included.

10.1.7. CONTROL MEASURE

The tender dossiers of the two cases: SAAone and Galecom, introduced a predetermined classification on control measures. These consist of categories similar to those introduced by Winch (2010), see section 7.4, and are shown in Table 10.1 below.

Table 10.1 - Classification control measures in tender

SAAone	Galecom
Accept	Accept
Preventive	Preventive
Corrective	Adjust/monitor
Insure	Corrective
Transfer	Insure
	Transfer

The accept measure is intended as a neglect, meaning that no further action is taken, the risk is 'accepted', as well as any possible consequences. Preventive measures are intended to prevent a future risk. Corrective measures are intended to yet comply with a requirement by removing the deviation. Adjust measures are intended to remove the cause of the risk. The interviews that were held revealed that the 'adjust' category originated from the deviation management department and has since been merged with the 'corrective' category. The adjust measures are therefore in the database classified as corrective measures, since in the risk management practice they are considered the same. The categories that Bing & Tiong (1999) propose are not specific enough to cover the measures that are used for the mitigation of risks on the case studies. Therefore the categories that were introduced in the tender dossier of SAAone are applied within this criterion. Additionally, there is an 'Unknown' category for measures that have not been assigned one of the categories in the risk dossiers of the cases. Most risks in the database have multiple control measures assigned to them and therefore there are many more control measures than there are risks. Therefore, the risks can be assigned more than one category of control measures and every category can be assigned more than once. A further distinction could be made between the measures assigned during the tender phase and the total number of measures assigned at the point of occurrence of the risk. This distinction is not possible on the A4All project however, since its tender dossier differs from the final risk dossier. This is also not possible for risks identified after tender. Therefore this distinction is currently not implemented for that case.

10.1.8. ALLOCATION

For allocation there are only three options: contractor (ON), client (OG) or both (OG/ON). This category is derived from its addition in VISE and used to identify whether the client or the contractor is formally responsible for the risk.

10.2. RESULTS

The results of the risk classification in the aforementioned criteria can be displayed by a number of graphs and tables that will be given and discussed in this section. The total number of risks classified is 45 (three times the top fifteen). The 45 risks and their descriptions themselves are given in appendix G. The results of the following criteria will be examined successively:

- Phase identified
- Main- and sub-object
- Discipline (internal allocation)
- Nature
- Source of origin
- Phase of occurrence
- Control measure
- Allocation

10.2.1. PHASE IDENTIFIED

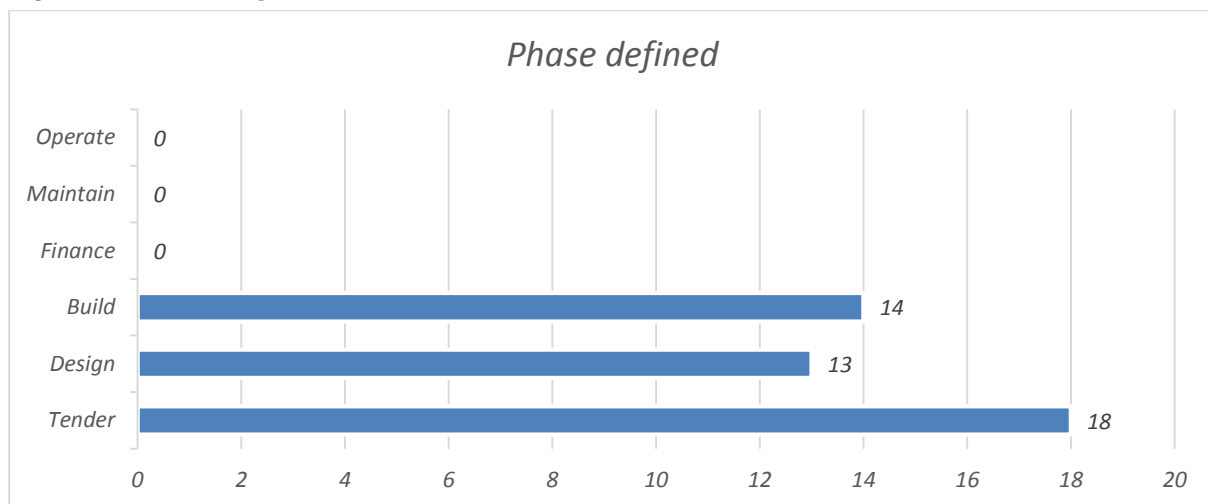


Figure 10.2 - Results of phase defined aspect of phase identified criterion for top fifteen occurred risks

Figure 10.2 indicates that most of the top occurring risks are defined after the tender phase, namely 27 out of 45. To further analyze the effectiveness of the risk identification during the tender phase regarding top occurring risks, three additional aspects were assigned to the risks. Whether they were traceable to a tender 'container' risk, whether they resulted from a scope change and whether they were the result of a force majeure (included in the source of origin criterion) and could therefore not have been identified sooner. This resulted in only 4 of the 27 risks being traceable to other risks identified during the tender phase and thus 23 remaining risks not traceable to the tender phase. Of these 23 remaining occurred risks, 4 are a result from an unforeseeable scope change, for which either the client or a stakeholder was responsible. Another 4 are the result of a force majeure and therefore true surprises that are unforeseeable. Therefore 15 remaining risks are true unidentified risks during the tender phase. True unidentified risks are risks that could have been identified during the tender phase of the projects and were therefore due to insufficient identification.

10.2.2. MAIN- AND SUB-OBJECT

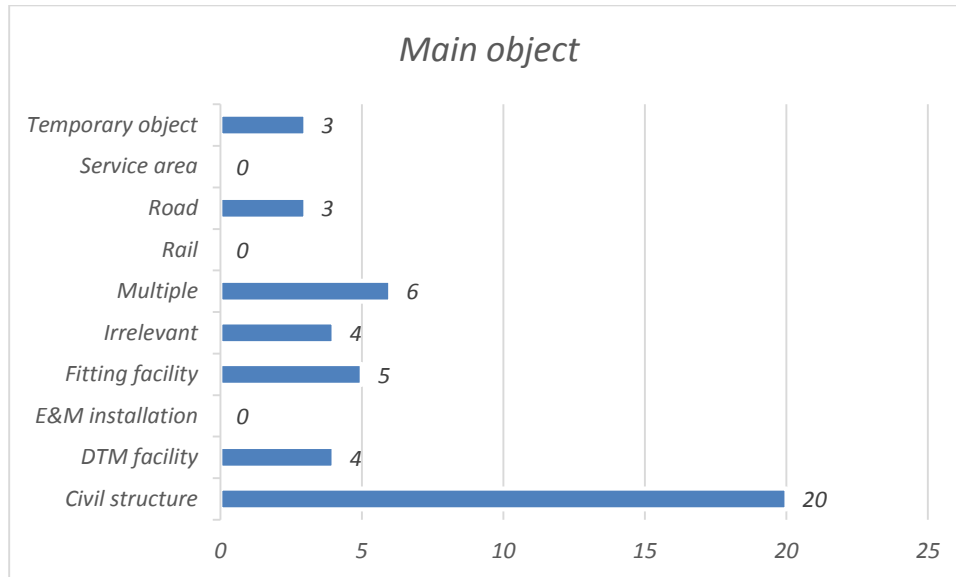


Figure 10.3 - Results of main object criterion for top fifteen occurred risks

Figure 10.3 shows that most risks are related to civil structures, namely 20 out of 45. Following that, risks relate to multiple objects and fitting facilities the most; 6 and 5 out of 45 respectively. Figure 10.4 shows that most occurred top risks are not assigned to a specific sub object, namely 14 out of 45 have not been assigned a sub object. Of the risks that are assigned a sub object, most are related to a bridge, namely 11 out of 45. Since there are many more sub objects identified (see appendix F) than currently necessary, it can be seen that the sample size of the 45 included risks is relatively small for the sub object criterion. The influence of a single case is therefore relatively high. This effect is for example reflected through the Galecom case. This case concerns a bridge renovation project and therefore most risks of the top fifteen occurred risks from Galecom are related to the 'bridge' sub object. Once more projects, or risks, are included in the database, the overview will show a more diverse classification, giving more reliable information.

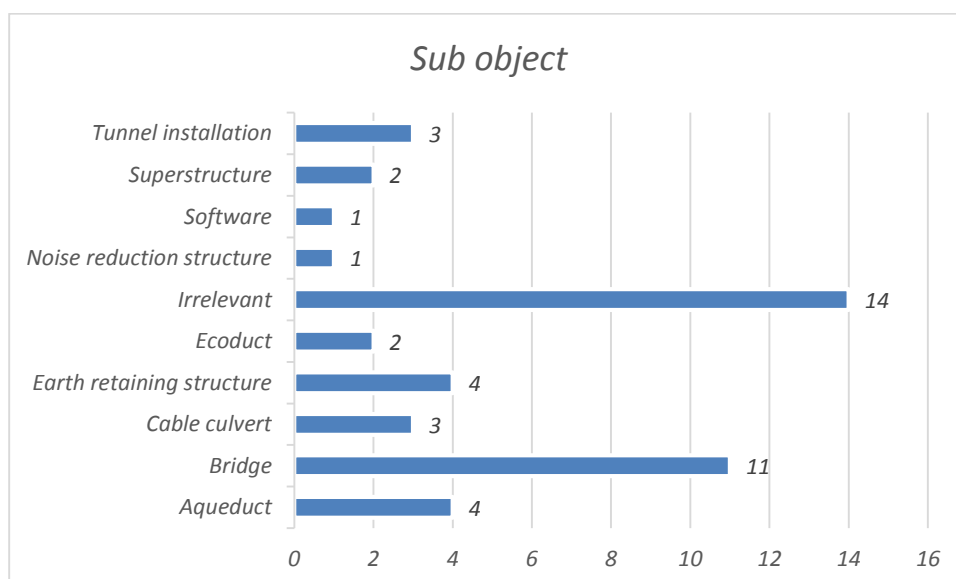


Figure 10.4 - Results of sub object criterion for top fifteen occurred risks

10.2.3. DISCIPLINE

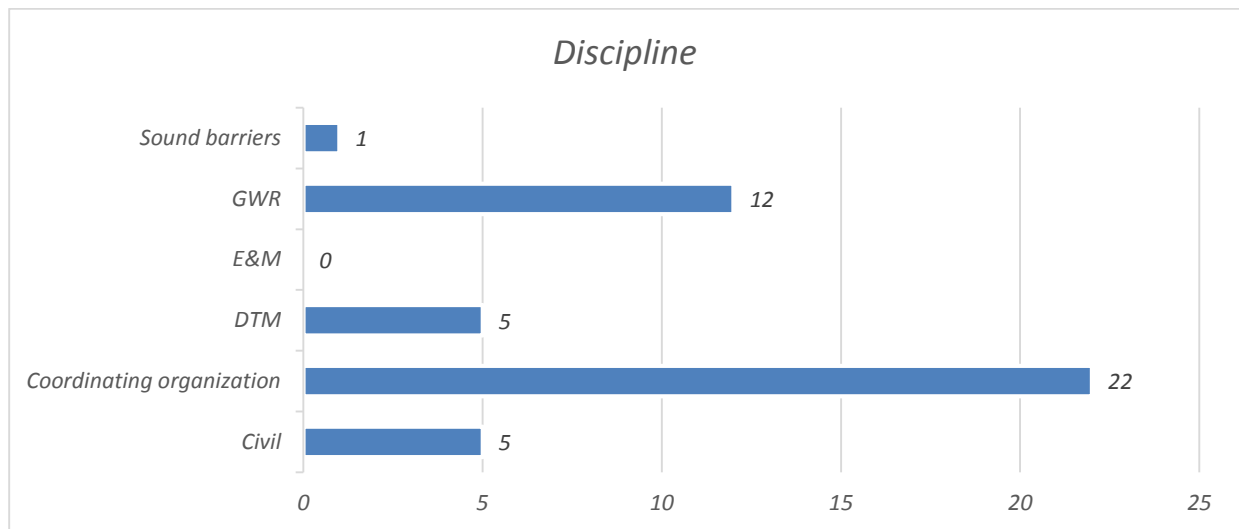


Figure 10.5 - Results of discipline criterion for top fifteen occurred risks

Figure 10.5 shows that nearly half of the top occurring risks are the responsibility of the coordinating organization (the overarching organization containing management, staff and design, see section 10.1), with 22 out of 45. The discipline GWR has the second most occurring top risks under its responsibility, with 12 out of 45. Both DTM and civil have 5 out of 45 occurring top risks under their responsibility and there is 1 risk allocated to sound barriers. The relative low number of risks allocated to civil is notable since there are many risks allocated to civil structures, as was seen in figure 10.3. It appears as though most of those are allocated to the coordinating organization. None of the top occurring risks are allocated to E&M.

10.2.4. NATURE OF RISK

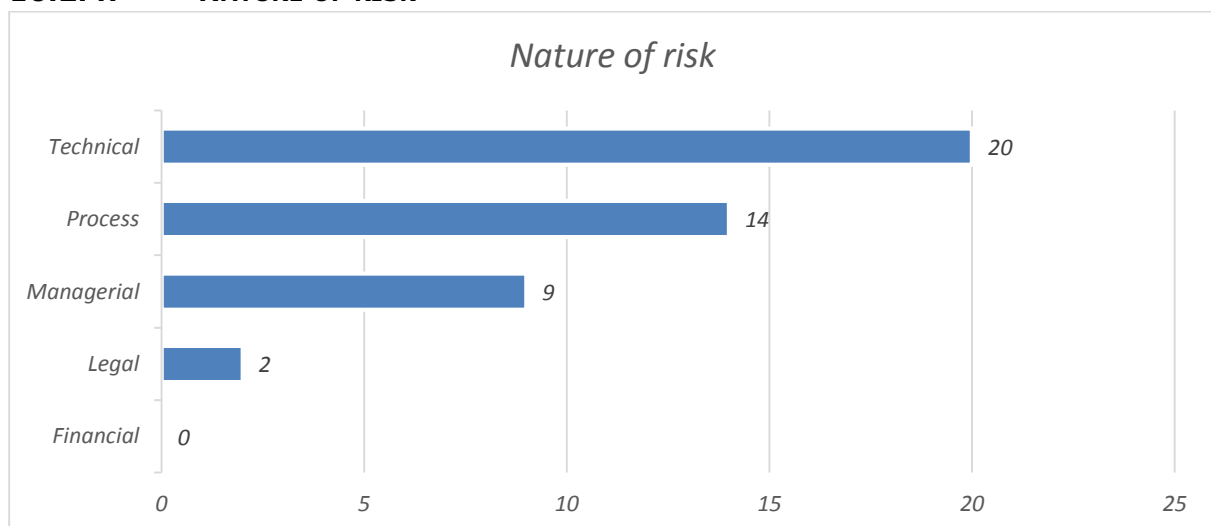


Figure 10.6 - Results of nature of risk criterion for top fifteen occurred risks

Figure 10.6 shows the results for the classification in the nature of risk criterion. As is shown, contrary to popular belief, most of the top fifteen occurring risks are technical risks, namely 20 out of 45. Furthermore, 14 are process related risks and 9 are managerial risks. There are 2 legal risks and no financial risks in the top fifteen of occurring risks on the

three selected cases. The relative large number of technical risks can have two explanations:

- Most of the risks included in the risk database are technical by nature. Therefore, it would be logical that more technical risks occur than others, since they also occur more in the database.
- The technical risks are less controlled or controllable than managerial or process risks since they are also dependent on other variables outside the control of the organization. Managerial and process risks are better controllable by management decisions. To analyze this further, the number of control measures assigned to each of the technical, managerial and process risks is discussed in sub-section 10.2.7.

10.2.5. SOURCE OF ORIGIN

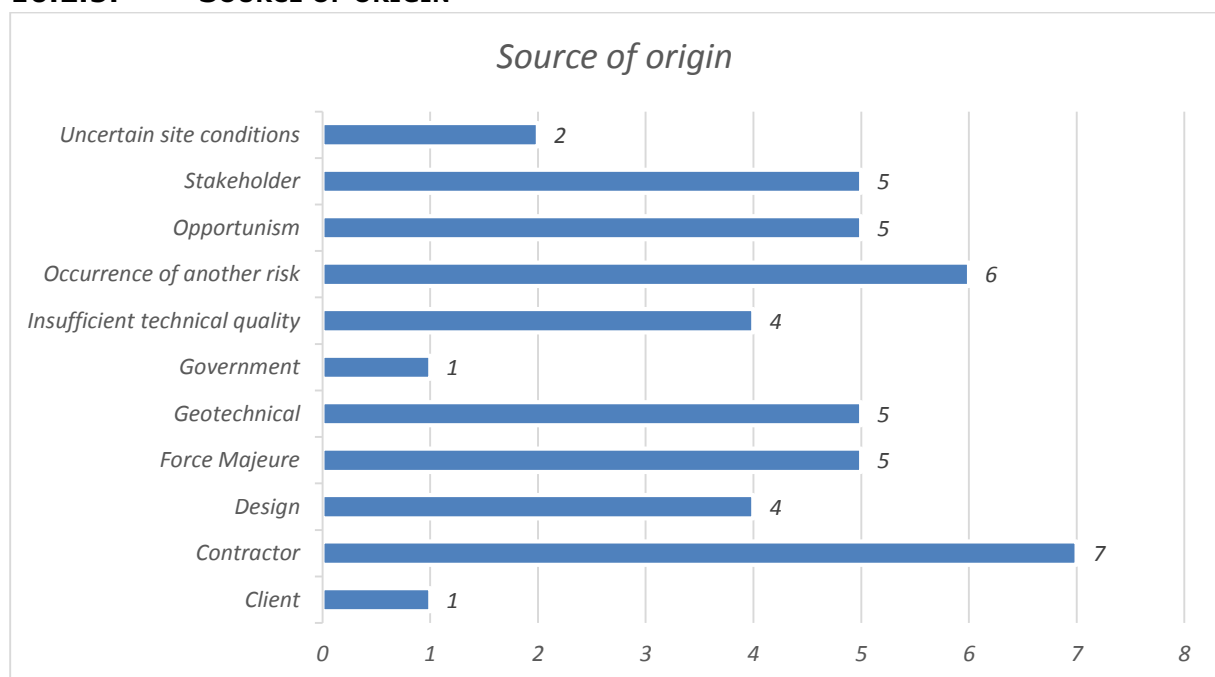


Figure 10.7 - Results of source of origin criterion for top fifteen occurred risks

Figure 10.7 shows the results of the classification in the source of origin criterion for the top fifteen occurred risks on the cases. The results show a wide range of sources of origin. Most risks are classified in the contractor category, 7 out of 45, indicating internal sources for the occurrence of the risk. 6 out of 45 risks occur as a result from another risk occurring. Force majeure, geotechnical, opportunism and stakeholders each have 5 out of 45 risks classified into that category. Design and insufficient technical quality each have 4 out of 45 risks assigned. Finally uncertain site conditions, government and client have 2, 1 and 1 out of 45 risks assigned respectively.

10.2.6. PHASE OF OCCURRENCE

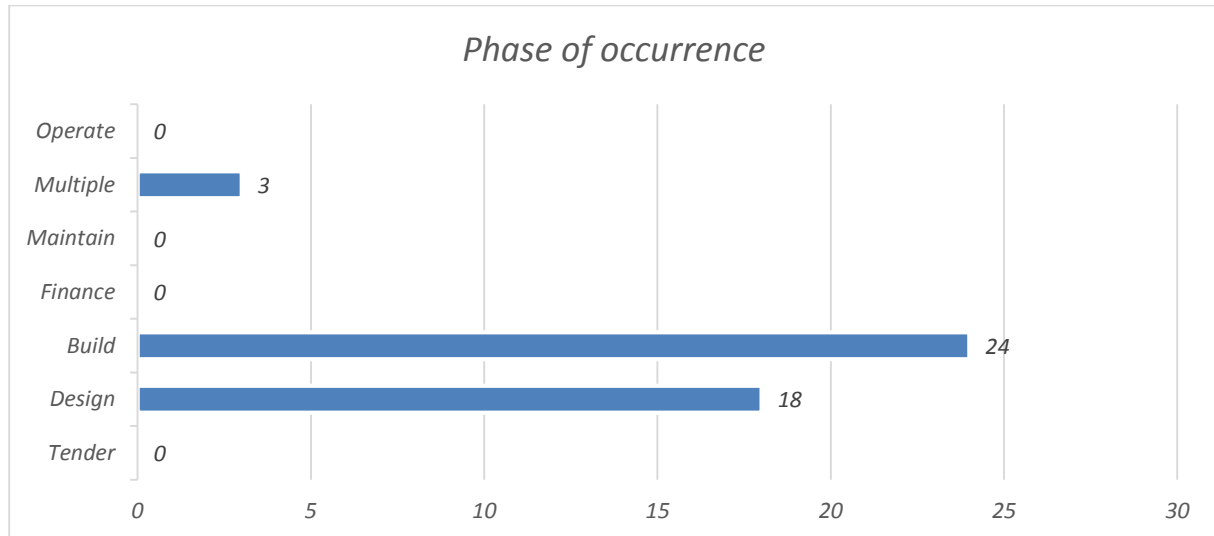


Figure 10.8 - Results of phase of occurrence criterion for top fifteen occurred risks

Figure 10.8 shows that all risks occur during the execution phase of the projects. None occur during tender, because when risks occur during tender they are not included in the database that is transferred to the execution phase. 18 out of 45 occur during the design phase and 24 out of 45 occur during the design phase. None occur during the maintenance phase, as there are no cases included that already reached that phase of the project. Neither are there risks occurring during the finance phase, since that phase is parallel to the others and therefore not specific. None of the cases include an operation phase. 3 out of 45 occur during multiple phase, meaning they span from the design to the build phase. This is mainly assigned to container process risks that are unclear on exactly when it is they occur. This criterion could be further expanded for future cases by splitting the design and build phases further into underlying stages, e.g. site preparation etc. This is not included in this research.

10.2.7. CONTROL MEASURES

A total of 209 control measures has been defined for the 45 occurred risks, meaning an average of 4.6 control measures per risk.

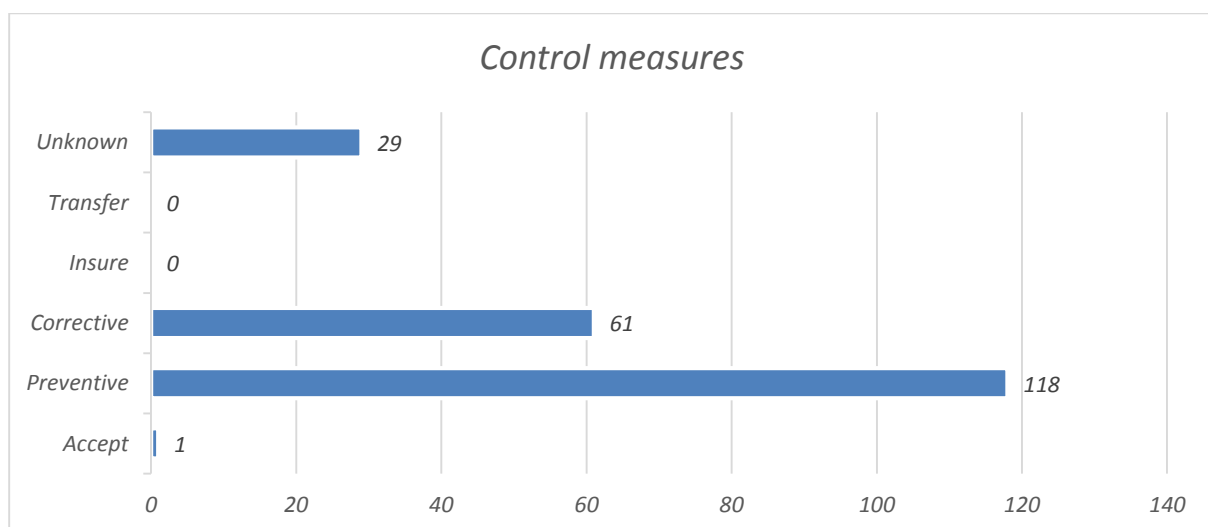


Figure 10.9 - Results of control measure criterion for top fifteen occurred risks

Figure 10.9 shows the results of the control measure criterion. More than half of the assigned control measures are preventive measures, namely 118 out of 209, intended to prevent the risk from occurring. 61 out of 209 are corrective measures and 29 out of 209 are not classified.

Table 10.2 - Control measures per risk in nature categories

Nature	Number	Number of control measures	Average number of control measures per risk
Financial	0	0	n/a
Legal	2	4	2
Managerial	9	36	4
Process	14	58	4.1
Technical	20	111	5.6
Total	45	209	4.6

As indicated in sub-section 10.2.4, to analyze the controllability of the categories in the nature of risk criterion, the number of control measures per nature category is given in Table 10.2. This also gives the average number of control measures per risk per nature category. As is shown, the technical category has the highest number of control measures defined per risk. The average is 5.6 control measures per risk in the technical category, while only 2, 4 and 4.1 in the legal, managerial and process categories respectively. This is shown as a basis to determine the effectiveness of control measures. It can also indicate the controllability of the nature of risk criteria, as it indicates how many control measures have been taken, while the risk still occurs. It indicates that there are more control measures developed for technical risks, while they still occur (these are control measures for the occurred risks). However, these need to be combined with financial values for a full analysis. For example, some of these measures may not have been costly and therefore have had less impact. This is currently not available however, and for a better analysis this could be a target for future research.

10.2.8. ALLOCATION

The risk allocation is shown in Table 10.3. As can be seen, over two thirds of the risks are assigned to the contractor. Only 6 are shared between the contractor and the client and 8 out of 45 are the responsibility of the client. Due to the contractual arrangements and the developments described in chapter 2 and section 3.1, most of the risks are transferred to the contractor.

Table 10.3 - Results of allocation criterion for top fifteen occurred risks

Allocation	Number of risks assigned
Client	8
Client/contractor	6
Contractor	31

10.3. CONCLUDING REMARKS

This section will provide some concluding remarks regarding the results on the risk classification and provide an answer to the seventh research question, which was stated as follows:

7. *In what way can risks be classified in order to reveal key aspects and enable generic oversight on VolkerInfra projects and how can this oversight assist in risk identification?*

The top fifteen occurred risks from the three cases, SAAone, A4All and Galecom, have been classified and the results were shown in the previous section. The dataset comprises 45 risks in total. Four of the criteria on which the risks have been classified were based on the literature review in chapter 7. The others were derived from the risk database of the projects and were results of important aspects that were suggested during the interviews.

As was indicated in chapter 8, the recorded financial values are currently too limited and there are too many missing links to enable further analysis. The phase identified criterion, consisting of three different aspects, namely traceable to container risk, relating to unforeseen scope change and force majeure. It indicates that 15 out of 45 risks are 'true' unidentified risks. As was discussed in sub-section 10.2.1, these are risks that could have been identified during the tender phase. This supports the statement from chapter 8, that there is need for improvement regarding the risk identification process.

The sub object criterion requires a larger dataset, since the single projects, e.g. the bridge of Galecom, has too much influence on the outcomes for further analysis. The nature of risk criterion shows interesting results, with most risks being classified in the technical category. This can indicate two things, as mentioned in sub-section 10.2.4. Most of the risks in the database are technical, since there are more technical risks in the database. This is because the technical risks are often the most obvious, tangible and explicitly looked for during risk identification. Managerial risks and process risks are often less explicitly present in the databases and when they are, they are often in the form of container risks. This can also indicate that on future projects, more attention needs to go to explicitly extracting managerial and process risks from the project team during the risk identification process. It shows that the risk database and the risk management process as it is currently applied by VolkerInfra is mainly aimed at technical risks. It could also indicate that technical risks are less controllable, as they are directly present in the risk database, while process and managerial risks are less present. Managerial risks and process risks are under direct control from management and could therefore be considered by them as more controllable. While they promote others to provide insight in the technical risks, which are then put into the risk database. This is also endorsed by table 10.2, which indicates a higher number of control measures being developed for technical risks, while yet they still occur. The source of origin classification shows a wide range of sources. Most notable are the risks resulting from opportunism. This indicates that there is still opportunistic behavior during the risk identification and assessment of VolkerInfra. This opportunistic behavior is mostly caused by commercial decisions to lower the risk assessment of consequences to lower the bid and win the work. This can also be caused when it is considered possible to get approval from the client for cheaper design solutions that do not comply with the initial contract, which are then put in the risk database as a risk. If the client doesn't comply however, the risks occurs, which has a lot of unnecessary cost as the design could have been made to comply with the contract, while including an opportunity that the design could be made cheaper. There should be a place for commercial decisions during the tender phase, but the risks themselves should be assessed properly and opportunistic design choices should be included as an opportunity, not as starting point with a risk that it doesn't get approved. The occurrence of another risk category is also often present, but the link between these consecutive risks is missing and has to be manually derived from the risk database.

Part IV – Synthesis

This part contains the conclusions and recommendations of the research. The research ends with a chapter on limitations and advice on follow-up research.

11. CONCLUSIONS

This chapter will provide an overview of the conclusions of this research. The recommendations based on these conclusions will be given in chapter 12, which will also answer the main research question. The first section provides general conclusions. Section two will give conclusions regarding the risk identification process and section three will provide conclusions regarding the risk classification.

11.1. *GENERAL CONCLUSIONS*

This section will provide the general conclusions that are drawn based upon the performed research. These are further divided in two sub-sections.

11.1.1. **DATA**

Currently, there is limited data available on the cases on risks. The available data also differs per project of VolkerInfra, indicating that there is no company-wide systematic approach to risk data management. Each case has a structured approach for risk management in itself, but mutually comparing the results is difficult as each approach yields different data. The risk management process itself has a general outline, as was shown in appendix C, but the interpretation of that differs per project.

The only consistent available data on each case was the number of identified risks. It was decided to focus on occurred risks as these were considered to contain the most valuable information. However, occurred risks were only recorded on three of the six available cases, namely SAAone, A4All and Galecom. Actual costs of the occurring risks were not recorded at all and were only obtained for SAAone due to the time-consuming process of obtaining actual costs. The process of obtaining actual costs was further complicated for a number of reasons:

- Cost of control measures are unavailable, while they influence the cost of the risk (occurring and not occurring risks)
- Not all cost overruns are linked to risks, while they can have an influence on risks, e.g. when they lead to the formulation of a risk but that initial cost overrun is not linked to the risk

All this means that the actual cost of risk and occurring risks themselves, which can be valuable sources of information, can currently not be exploited as opportunities for reflective learning. There was some useful data however:

- The number of identified risks greatly increases after tender. On average this increase was 287% (with Willems Unie as outlier, see chapter 8). This can partly be explained by 'container risks', partly by scope changes of the contractor and partly by an insufficient risk identification process.
- For four of the six cases the reserved risk budget during tender was available. Compared to the total contract value, the average budget reserved for risks is Confidential. Plotting the individual values revealed that the reserved budget increases almost linearly with the contract value. Only Galecom has a relatively high risk budget, probably due to the technical challenges in that project.
- For three of the six cases the occurred risks were available. This showed that on average 11.9% of the identified risks occur.
- The actual costs were only obtained for the SAAone case. These showed to differ only Confidential but mutual differences are much higher (see appendix E) and

therefore this could be coincidental. Therefore more cases need to record actual costs to make an assessment of the accuracy of the risk estimates.

11.1.2. DEFINITIONS

For this research, risk was defined as follows: *"Risk is the positive or negative effect of uncertainty on one or more objectives, as determined by its likelihood, consequence and strength of knowledge."* The definition of risk of VolkerInfra is not always clear in comparison and is interpreted differently by the risk managers, leading to discussion. Some risks are included in the risk database by some risk managers and not by others. These points of discussion are:

- Price/quantity bandwidth
- Inclusion of other purely financial risks
- Inefficiency in work and work processes
- Lack of cooperation or integration between disciplines leading to inefficiencies

Furthermore, the application of the RISMAN method requires that the categories (the one to five categories, see section 3.1) within that method are representative of the actual possible cost. Otherwise the Monte-Carlo assessment is based on false data. This became apparent in table 8.3, in which the calculated value of occurred risks is Confidential, while the risk budget is only Confidential. Even after the risks allocated to the client are subtracted from that amount, Confidential of value of occurred risks remain for the contractor. During the interviews it was indicated that the risk budget for A4All was not even depleted. This means that either the RISMAN categories are poorly defined or the concept of calculated value is not clear to everyone working with them.

11.2. RISK IDENTIFICATION

The methods for risk identification can be divided in three main groups: individual methods by the risk manager, one-on-one interviews and group methods. Furthermore there are a number of tools available for risk identification, such as historic records and checklists. All of the methods are proven to have some form of bias implicit, be it personal bias or negative effects from group dynamics.

Interviews were held with the six risk managers on the six cases. The interviews showed that there is no collectively accepted and applied risk identification method among the risk managers of VolkerInfra. A systematic approach to risk identification is therefore lacking. The current risk identification process largely relies on the risk manager involved. Based on his/her experiences and preferences, the process is shaped. A separation between the tender phase and execution phase indicated that brainstorm sessions and personal interviews and the risk manager leading a work group were the preferred methods during the tender phase. During the execution phase group methods were little applied and almost only personal interviews were used. The risk managers overall make little use of historic records and checklists. Most interviewees indicated that they preferred not to use checklists fear of missing the important risks and only identifying the generic risks on the checklists.

11.3. *RISK CLASSIFICATION*

The risk classification was made to apply to the top fifteen occurring risks of three of the six cases, namely SAAone, A4All, Galecom (the ones that had occurred risks available). This top fifteen is selected based on the latest calculated value of these risks (the latest estimation, before the actual costs could be known). The occurred risks are considered to contain valuable information. The classification allows for the identification of trends among occurring risks and to identify points of improvement, in which it could be used as a tool for future risk identification. The criteria and underlying categories of each criterion were partly developed from the literature and partly from the interviews and discussions with the risk managers. They are developed to contain as much relevant data on risks as possible.

Out of 45 risks, 27 are identified after the tender phase. However, some of these risks were part of larger, overarching risks, termed 'container' risks. These container risks contain multiple underlying risks and are usually identified during the tender phase when limited information is available and are specified later. Of the 27 risks identified after tender, 4 can be traced to container risks and are therefore part of risks identified during tender. Furthermore, 4 of the 23 remaining risks were the result of unforeseen scope changes and were therefore not possible to be identified sooner. Another 4 were caused by a force majeure (or true surprise, see chapter 4 and 7) and were therefore also unable to be identified sooner. This leaves a total of 15 risks that could have been identified sooner, illustrating the importance of developing the risk identification process.

The classification further revealed that the risk database is mainly aimed at technical risks, as these make up 20 of the 45 in the nature of risk criterion. Managerial and process risks are less explicitly present in the risk database. This could be for two reasons: there are less managerial and process risks present in the entire database, or the technical risks are more difficult to control and therefore are more present among the top occurring risks. If they are less present in the entire database, this could be because the database is more aimed at technical risks. Which in turn could be because they are found to be more tangible and less controllable and therefore need to be put in the database to enable some form of oversight. Managerial and process risks are mostly under the control of higher management, which are less likely to report their problems as 'risks' and may therefore be less present among the top occurring risks in the databases. Financial risks are not present among the top occurring risks. These are within the sphere of influence of the involved banks on SAAone, since this is a DBFM project. They are however not present in the risk database and are maintained somewhere else. Financial risks are not present on the A4All and Galecom cases since these are D&C projects. The difference between these construction organizations was not found in this research. This is mainly because the financial risks are not present in either risk database. Furthermore, the maintenance phase of SAAone has not yet started (which is the other main difference with D&C contracts) and therefore these risks have not yet occurred and are therefore not among the top 15 occurred risks and not present in the current dataset.

Furthermore, a total of 209 control measures has been developed for the 45 risks, meaning an average of 4.6 control measures per risk. When comparing this with the nature of risk criterion, it showed that the technical risks received the most control measures, namely 5.6 on average. This indicates that there are relatively many control measures required to control the technical risks, while they end up occurring anyway. This could be a starting point for further analyzing the effectiveness of control measures. The results of most of

the other criteria that were applied indicated that the data set was too small for representative results. For example the sub-object criterion revealed that there are 14 bridge related risks among the top 45 of occurred risks on the three cases. This is however biased because of the Galecom case, which is a bridge renovation project. Therefore a larger data set is required for the other categories to be used for identifying points of improvement.

The source of origin criterion revealed a wide range of common sources of risk. Most notable was the presence of risks resulting from opportunism. This opportunism resulted from commercial decisions to deviate from the contract requirements in order to offer a cheaper solution (e.g. a design solution). It was thought that they could get the client to accept the deviation, but were put in the risk database in case the deviation wouldn't be accepted. There were also many risks that occurred as a result of another risk occurring. This link between successive risks is not yet present, but could be a useful feature to identify the chain of events when risks occur because of other risks occurring.

12. RECOMMENDATIONS

Based on this research and the conclusions based on it, a number of recommendations can be made to VolkerInfra that are listed in this final chapter. These recommendations also answer the main research question, which was formulated as follows:

How can the current risk identification process be further developed and how can data be used to enable generic oversight on projects and to assist in risk identification on future VolkerInfra projects?

12.1.1. RECORD DATA

Aside from the available generic risk management process, as was shown in appendix C, there should be guidelines towards the interpretation of it. Especially for which data should at least be recorded per project. This data is necessary to be able to analyze the effectiveness of the risk management process and measure the success of risk management. This data can also provide information on how to improve further. The following data should at least be maintained:

- If a risk has occurred or not and the phase of occurrence, this should be a status of a risk as it is currently applied at SAAone.
- Cost data relating to risks:
 - The actual cost of the risk once it occurs. This could be an extra field that has to be filled in, before the status 'occurred' can be assigned to a risk. That way the risk manager is obliged to fill this when changing the status and it will trigger the risk manager to at least think about it.
 - The cost of relating control measures. This could be an estimate that has to be made for the cost and the benefit of the control measure. This can be done by the responsible person actually developing the control measure.
- The classification of risks, which should at least contain the following criteria:
 - Main- and sub-object of the risk
 - The nature
 - The source of origin
 - These could be other categories of which there are a number already present in VISE. Via a dropdown menu a selection could be made on what category is applicable for that risk in both criteria.

These values should be recorded to be able to analyze the data in the future in order to:

- Be able to set a benchmark for occurred risks based on the average percentage of occurrence on past projects. The long term average can be used as an indication for the performance of the risk management process on future projects. This can also be used to set targets for improvements, e.g.: "By 2025 we want the average percentage of occurring risks to be below Confidential on new projects". In that way it can be used as a performance indicator.
- Analyze the effectiveness of control measures. For this is additional research required however, see the final chapter.
- The cost data can be used to evaluate the accuracy of estimates. Combined with the different criteria for classification these can indicate where the estimates are below the target. This can also be used to formulate a concrete future goal, e.g.: "By 2025 we want to have the average deviation between calculated values and

actual cost below Confidential". Different goals can be determined for different criteria.

12.1.2. DEFINE RISK MANAGEMENT CONCEPTS

Also part of this interpretation of the risk management process should be the definitions of important concepts relating to that process. Some concepts are not yet clear for everyone in the organization. This is for example shown in table 8.3, in which the calculated value of occurred risks is Confidential, while the risk budget is only Confidential. Even after the risks allocated to the client are subtracted from that amount, Confidential of value of occurred risks remain for the contractor. During the interviews it was indicated that the risk budget for A4All was not even depleted. Therefore there is some ambiguity in these concepts. Either the RISMAN categories are poorly defined or the concepts are not clear to everyone working with them. Properly defining these and explaining these to the organization will help prevent confusion on them, which is essential for a properly understood and functioning risk management process.

12.1.3. DEFINING THE PURPOSE

Defining of the purpose of the risk management process is another important aspect. Only once that purpose is clear to everyone involved, can the process be properly applied and the right risks be identified. As was seen in the risk classification, most highly valued occurring risks are currently of a technical nature. Defining the purpose in that sense means determining whether or not the risk database is meant for technical risks or also for process and managerial risks. Process and managerial risks are also considered important as they are all categories that are present in the literature (chapter 7). Therefore it is recommended to actively pursue these as well. This means involving higher management in the risk management process. These should be asked to specifically name their managerial and process risks. This will ensure that these are also safeguarded through the risk management process.

12.1.4. PREVENT OPPORTUNISM

Opportunism is an important source of origin for risks. Opportunism can have catastrophic results, e.g. when tendering below cost price in order to win the tender, refer to the examples in chapter 2. It was found that opportunism was also present in the top occurring risks on the three selected cases. As was discussed in sections 10.3 and 10.4 the risks that are caused by opportunism are related to commercial decisions. This should be prevented to influence the risk management process. Risks should be properly identified and assessed so that everyone in the organization understands what risks are involved. After they have been properly assessed, commercial decisions can be made, but only after it is completely clear what the implications are of these commercial decisions. These decisions are often necessary to win the tender, but a full understanding of the consequences is necessary to prevent surprises down the line. One way to do this is to not define opportunistic decisions as risks, but rather as opportunities. The examples of opportunism in the current dataset are defined as risks, because the design change that they relate to is included in the tender bid. This means that the contractual deviation is part of the bid for the tender. This contractual deviation should not be in the tender bid as they will sometimes not be accepted by the client, resulting in these risks occurring and leading to higher costs. However, if the proposed contractual deviation (design change) is formulated as an opportunity and the design for the bid doesn't include this deviation, then the design complies with the contractual requirements, while still having the design change included in the plans. If this opportunity then gets accepted, it is a lucky break, but if it doesn't get accepted, it doesn't directly lead to higher costs. Because it is formulated as an

opportunity, it has an influence on the budget as well, which is why it is a commercially viable option as well.

12.1.5. LINKING CONDITIONAL RISKS

Not only opportunism was a notable source of origin among the top occurring risks, also risks resulting from other risks occurring is a notable source of origin as this indicates a certain chain of events or risks causing each other. Currently no link is available between these risks and these are therefore not traceable. In order to notice these chains sooner a conditional probability can be added to risks of which it is known that they are related. This should also be done for the 'container' risks. This conditional probability is measure of the probability of occurrence of a risk, given that another risk has occurred. Establishing this link and the conditional probability can be done in VISE. The only thing that is required is to establish a link between the respective risks that are dependent. This link should then detect whether one of the risk occurs and then automatically raise the probability of occurrence of the other risk with the conditional probability. This conditional probability can be a set value, or another category within the RISMAN categories. E.g. also 5 classes:

- Class 1 – Given that risk X occurs, this risk has an increased probability of <1%
- Class 2 – Given that risk X occurs, this risk has an increased probability of <10%
- Class 3 – Given that risk X occurs, this risk has an increased probability of <25%
- Class 4 – Given that risk X occurs, this risk has an increased probability of <50%
- Class 5 – Given that risk X occurs, this risk occurs as well

These probabilities can be linked to the existing probability of the risk and be added to it if risk X occurs. The total RISMAN value then changes directly, placing the dependent risk high in the risk overviews.

12.1.6. RISK IDENTIFICATION PROCESS

Guidelines should be developed for the risk identification process itself. Currently there is no companywide overview of best practices or procedures regarding risk identification, while this is arguably the most important step in the risk management process. Research has shown that most available methods for risk identification are biased. Therefore a combination of methods is recommended. The following guidelines are at least recommended:

One-on-one interviews are recommended as starting point to prevent early negative influences from group dynamics and prevent early influence from dominant personalities. This ensures that everyone's opinion is heard and should be done as soon as possible during the tender phase. After that, group methods should be applied to reduce personal bias from the interviewees and enable reciprocity between project team members. These methods also require certain skills from the risk manager:

- The risk manager needs to be aware of the possibilities of group dynamics and needs to be able to prevent the negative influences. This means also keeping an eye on dominant and less dominant personalities to ensure that everyone can have their say.
- The risk manager needs to be able to use a feedback-style approach of information gathering during interviews, meaning asking a series of related questions in an investigative manner to get to the core of the problem.

Furthermore, a number of rules of conduct should apply when using group sessions during the risk identification sessions to reduce the negative effects of group dynamics:

- Every one's viewpoint is valid!
- No holding back – Say what's worrying you!
- No management hierarchy
- The things we don't like to hear are probably key issues
- Explain from your area of expertise

For longer or critical sessions the risk manager could also consider to require every participant to fill out a personality test beforehand, so he knows what personalities will be present and can account for that. A number of documents are important to consider during the risk identification process as they can help visualize the project. It is important to know what activities are when to be executed and what is needed for them. The following documents can enable that:

- Flowcharts
- Project planning, insofar this is yet available
- Organizational-, Work- and Resource- Breakdown Structures, insofar these are yet available
- Available tender documents from the client

12.1.7. HISTORIC RECORDS AS RISK IDENTIFICATION TOOL

One of the specific purposes of the recording of data is mentioned separately in this recommendation. Historic records should be used as an identification tool on future projects. Currently a few of the interviewed risk managers apply historic records, but these are not collectively applied, while they contain valuable information. Occurred risks should form the initial basis for historic records as they are considered to contain the most valuable information to learn from. To keep these useful and traceable they have to be classified, otherwise oversight is quickly lost. This requires a proper risk classification. The recommended data to be recorded in the first recommendation of this research is the starting point for that. These criteria can be further developed based on the requirements of specific clients or projects or based on new insights from following research. These historic records can be used to identify trends and common aspects of risk. These commonalities can then be used in new projects to identify new risks. This could be an application in VISE, in which risks from past projects can be entered, provided that they contain the required data. To prevent the checklist forming a new kind of baseline, this checklist should not replace the extensive sessions held. A proper relating classification will reveal the most prevalent sources of risk and thus the sources that should at least be considered during the risk identification. The specific interpretation of these prevalent sources on each specific project is still open to the experts and risk managers on the project, thus preventing them from becoming a standard list and more of a list of important general sources to at least consider. This prevents the fear of the risk managers of a too generic checklist, while still being able to form a starting point for risk identification that is based on actual data, rather than personal preferences and thus preventing personal bias from the risk manager.

12.1.8. APPLY HISTORIC RATE OF RISK OCCURRENCE TO BUDGET CALCULATION

Not only can the historic records be used as risk identification aid, they can also be applied for the assessment of the required risk budget. Once the average percentage of occurring risks (see table 8.2) is recorded on more cases, this percentage can be used for generating an indication of the required risk budget. This could be used in the following way:

1. Identify the risks in the manner described

2. Assess the risks as is normal procedure; assign a value to indicate the financial consequences of the risk, the calculated value
3. Add the calculated values of all identified risk up together
4. Multiply this with the percentage of average occurring risks on the project

This results in an indication of the required risk budget, based on historic data. It is important to note that more cases are required before this percentage gains enough statistical value and this recommendation is therefore for the longer term. The resulting value can be used similarly as currently the Monte-Carlo analysis is used. These together could give a more realistic estimate of the required risk budget and thus reduce unforeseen cost on future projects.

12.1.9. TRIGGER QUESTIONS

In order to further aid the entire process, a set of trigger questions should be developed per subject. These trigger questions should be used for risk identification and promote objectivity in the process and prevent bias from entering the risk identification process even further. They can be used for preventing preferences from specific risk managers to leave too much of a mark on the entire process. Examples of trigger questions that should at least be used:

- What risk identification method have I not used before?
This will make the risk manager think about the specific risk identification methods that are available and whether his/her standard method is applicable on the current project. Ideally the risk manager then uses this other method. The fact that he will think about his applied method is already gain.
- What aspect of the project could I put into the tender bid in an opportunistic way?
This will trigger the risk manager to think about any opportunistic possibilities on the project. Of course he then needs to take the decision not to do it, but the idea is to trigger him on the existing identified risks and whether they are actual risks or opportunistic assumptions.
- Name another technical/financial/managerial/process risk.
This will trigger the risk manager to think of all aspects of the project, including the managerial and process risks, which as were seen are not always prevalent.
- Ask higher management to name a managerial/process risk (recommendation 3)
The same as above, but with the help of higher management. This will trigger higher management to actively think about their own managerial risks, which may be something they are not used to as the usual risks in the dossier are technical.
- Identify a risk that can be linked to another risk
This will trigger to think about conditional risks as well. If the system from recommendation 5 is implemented, this can be directly put into the categories. It will promote the actual use of the new possibility of creating these links, as the risk managers are currently not used to doing that.

These questions all relate to the actual recommendations and will trigger the risk manager to actively think about them. Further triggering could be in the form of mandatory fields that have to be filled in before the risk can enter the database. E.g. nature of the risk and actual costs when the risk receives the occurred status. These are not questions, but will also trigger the risk manager into action.

12.1.10. RISK IDENTIFICATION FLOW CHART

All the aforementioned recommendations can lead to the development of a risk identification flowchart, in which all these aspects are summarized. This is shown in Figure 12.1 and recommended to be used as guideline for the risk identification process. This

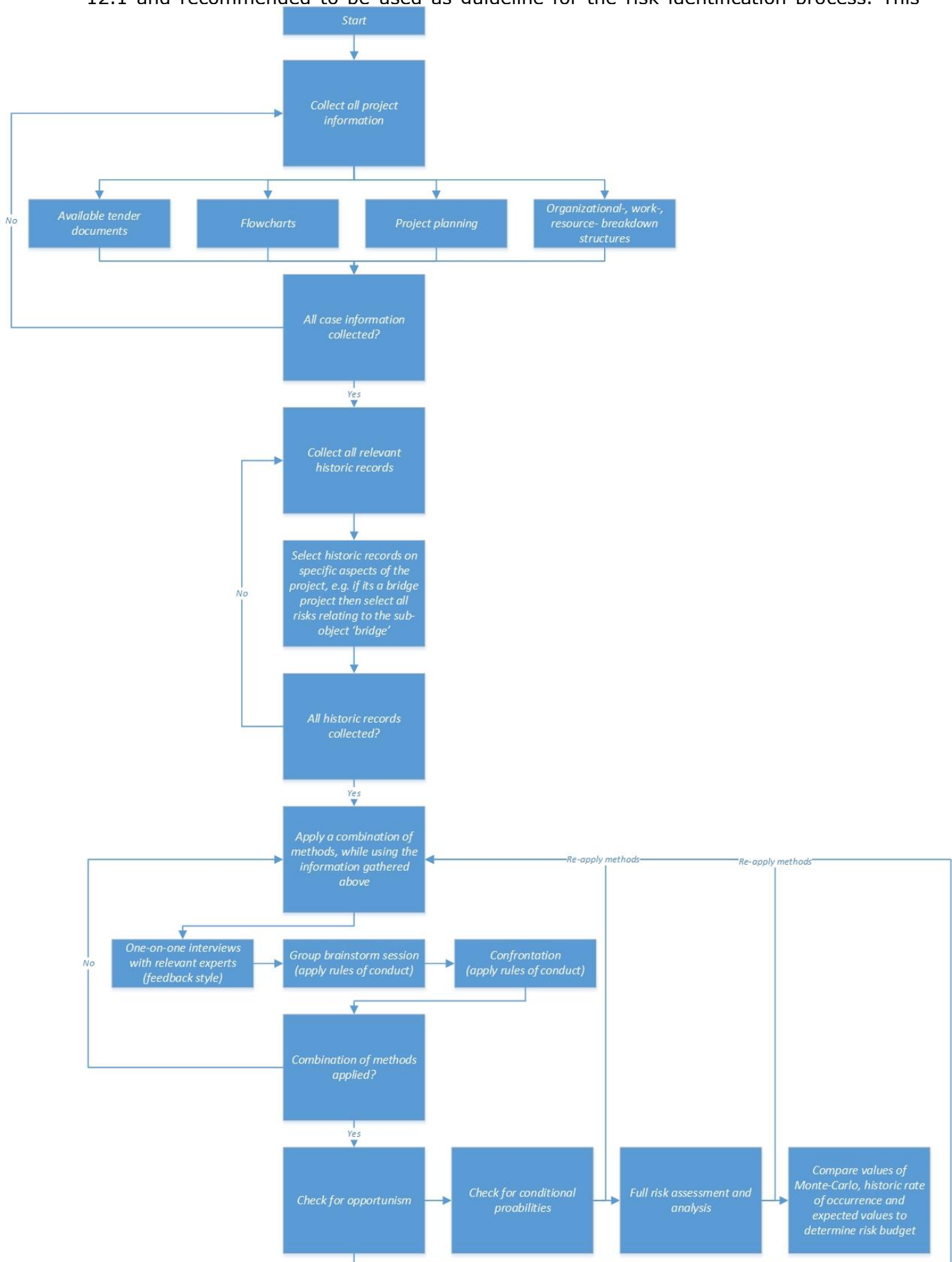


Figure 12.1 - Risk identification flowchart

The flowchart consists of the steps previously explained, but these are shortly summarized below:

- All available data has to be collected for a complete identification
- Once all data is collected, the historic records can be checked for all relating risks. This can be done via the classification that is applied to risks if the first recommendation is followed.
- Once all historic data is collected, the risk manager has to apply a combination of methods to prevent bias. During the interviews a feedback style of information gathering is required. During the group sessions the rules of conduct and the negative effect of group dynamics need to be kept in mind.
- Then the identified risks have to be checked for opportunism, where necessary with the aid of the previously applied methods.
- Conditional probabilities have to be checked if this feature has been added into VISE and the RISMAN categories.
- Once all risks are identified, they can be assessed and the Monte-Carlo simulation can be run. That outcome can be compared with the estimated costs based on the historic rate of occurrence and the expected value to determine the final risk budget.

13. LIMITATIONS AND FOLLOW-UP RESEARCH

This chapter will highlight the limitations of this research and give recommendations for follow-up research where necessary.

First of all, this research is based on a limited amount of data. As has become apparent by now, there is only one case where all data is available, namely SAAone. The other cases have all one or more of the parameters unavailable. Especially the actual costs of the risks was only available for the SAAone case. Therefore, when this data is recorded on future projects, then the data can be fully analyzed. Secondly, the number of cases themselves is quite limited, with only six cases in total. These six are representative of the work VolkerInfra has done so far, since it is a relatively young company. However, for improved supporting of all the findings and statistics, more cases is of course better. For these reasons it is recommended to update this research once more data from more cases becomes available and to develop a larger dataset. This research should also focus on a further development of the selected criteria and underlying categories, as well as a further development of the risk identification flowchart.

Follow-up research can focus on a number of things to further develop the risk management process of VolkerInfra:

- Follow-up research could focus on the specific manner of applying different levels in the risks. This is necessary to obtain an overview of 'container' risks and their underlying risks.
- The research could be expanded to also include maintenance risk. This was currently outside the scope of this research. VolkerInfra also executes maintenance projects and DBFM projects, which also include a maintenance phase, follow-up research could focus on that. The SAAone DBFM has not yet reached the maintenance phase however, so currently only the maintenance-only projects can be further researched. This could focus on the effect of the long-term scope of these projects on risks and risk management.
- Further research should focus on the control measures themselves and assessing their effectiveness. This will allow VolkerInfra to improve these on future projects and reduce unnecessary costs due to failing control measures. The starting point could be the in this research given average number of control measures in combination with different other criteria. Furthermore, financial data of control measures is required for that purpose as well, which is currently not readily available.

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Part V - Appendices

This part contains the appendices, A through H, of this research report.

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Appendix B. CASE STUDIES

This appendix contains descriptions of the projects that will be included in this research as case studies. For these projects data regarding risks and corresponding costs will be collected and several interviews will be conducted as described in section 3.5.

B.1. CASE STUDY 1: A1/A6 DIEMEN - ALMERE HAVENDREEF

SAAone is the name of the consortium that is currently executing the A1/A6 Diemen - Almere Havendreef project, commissioned by Rijkswaterstaat. The project consists of road expansion of over 20 km of the A1/A6, construction of a change lane, repositioning of large parts of the A1 between Diemen and junction Muiderberg and multiple infrastructure objects and engineering works, among others, multiple bridges, overpasses, a large railway bridge and an aqueduct. SAAone is the SPC for the project. This company is responsible for the project and consists of four companies as its shareholders:

- Hochtief, a German construction-related service provider, one of the largest in the world.
- VolkerWessels, one of the largest construction companies in the Netherlands
- Boskalis, one of the world's largest companies in dredging and maritime infrastructure
- DIF, a leading investment company in infrastructure

The design and construction parts of the project has in turn been transferred to the SAAone Engineering, Procurement, Construction and Maintenance (EPCM) consortium, consisting of Hochtief, VolkerWessels and Boskalis. Together these companies are responsible for the design and construction (execution) phases of the project. Furthermore they are responsible for the maintenance of the road during the execution phase. Once the construction has been completed, the maintenance will be transferred to a special maintenance company, which is also in service of the SPC. This means that the SPC itself is only responsible for the financing of the project, as is common in DBFM constructions.

The A1/A6 project is one the five project that are part of the SAA corridor projects, which are developed by the Ministry of Infrastructure and the Environment, intended to improve the flow of traffic between Schiphol, Amsterdam and Almere. The project is currently in the execution phase and construction will finish around 2020, after which the maintenance phase will start, lasting another 25 years.

B.1.1. RISK MANAGEMENT SAAONE

In the SAAone project, risk management is part of project management, within the EPCM contracting arrangement. The goal of the risk management process in the SAAone project is described as: "the process of continuously identifying, analyzing, settling and monitoring of risks, during all phases of the life cycle of the project". The specific arrangement of the risk management processes is visible in appendix C.

B.2. CASE STUDY 2: A4 DELFT – SCHIEDAM

A4All is a combination of Heijmans, Boskalis and multiple VolkerWessels operating companies. The combination was contracted in a D&C. The combination was responsible for the construction of the missing link in the A4 between Delft and Rotterdam. The link connects the old end of the A4 at Delft to the A20 and other part of the A4 at junction Kethelplein. The project connects the A4 and improves traffic flows between Den Haag - Delft and Rotterdam. The new stretch of highway is 7 kilometers long and consists of several parts: 2.6 km of semi-sunken road, 1.4 km of sunken road, a 2 km long land tunnel below the urban area of Vlaardingen/Schiedam and finally a connection to the existing A4 and A20 junction; Kethelplein.

B.3. CASE STUDY 3: BADHOEVERBOGEN

Badhoeverbogen is a combination of Mourik Groot-Ammers, Boskalis and multiple VolkerWessels operating companies. The combination was contracted in a D&C for works on the A9 between junctions Raasdorp and Badhoevedrop. The A9 between junctions Raasdorp and Badhoevedorp will be moved to a new location further south, closer to Schiphol and away from the center of Badhoevedorp. The new road will be reconstructed approximately 600 meters south of the village Badhoevedorp, right after junction Raasdorp. The project entails the construction of a 2x3-lane highway plus an emergency lane in both directions, 10 overpasses (hence the name of the combination), a new exit at Badhoevedrop and a new junction with the A4 at Badhoevedorp. Case Study 4: Utrechtse Tulp

Utrechtse Tulp was a combination of multiple VolkerWessels operating companies and Mourik Groot-Ammers. The combination has expanded the A27 between junctions Everdingen and Rijnsweerd and expanded the A28 between junctions Rijnsweerd and Hoevelaken. The combination was contracted in a D&C contract and the project has been delivered in 2013. The existing highway is expanded to 2x3 lanes and also entails 22 civil structures.

B.4. CASE STUDY 5: GALECOM

Galecom is a combination of multiple VolkerWessels operating companies, CT de Boer, Hollandia, Mercon, Sarens and Feijenoord. The combination was contracted for the renovation of the Galecopperbrug, in the A12 south of Utrecht. The construction organization was contracted in a D&C and has been delivered in 2015. The renovation mainly consisted of replacing worn-out parts of the steel deck and the steel girders and replacing the outside pre-stressed girders. Furthermore, the bridge has been strengthened and raised by about 70 centimeters. The asphalt on the bridge deck has been replaced by High Strength Concrete (Hoge Sterkte Beton) and a wear layer.

B.5. CASE STUDY 6: *WILLEMSUNIE*

WillemsUnie was a combination of GMB, Van den Herik and multiple VolkerWessels operating companies. The combination was contracted in a D&C-contract for the diverting of the Zuid-Willemsvaart (a channel) to the newly constructed Maximachannel between the Maas and Den Dungen (Northeast of 's-Hertogenbosch). The channel was constructed so that larger ships wouldn't have to navigate through the center of 's-Hertogenbosch. The newly constructed channel is approximately 9 kilometers long and also entails 6 new bridges and 2 new locks at Berlicum and Empel. The channel was commissioned in December 2014 and has been completed in 2015.

Appendix C. RISK MANAGEMENT PROCESS VOLKERINFRA

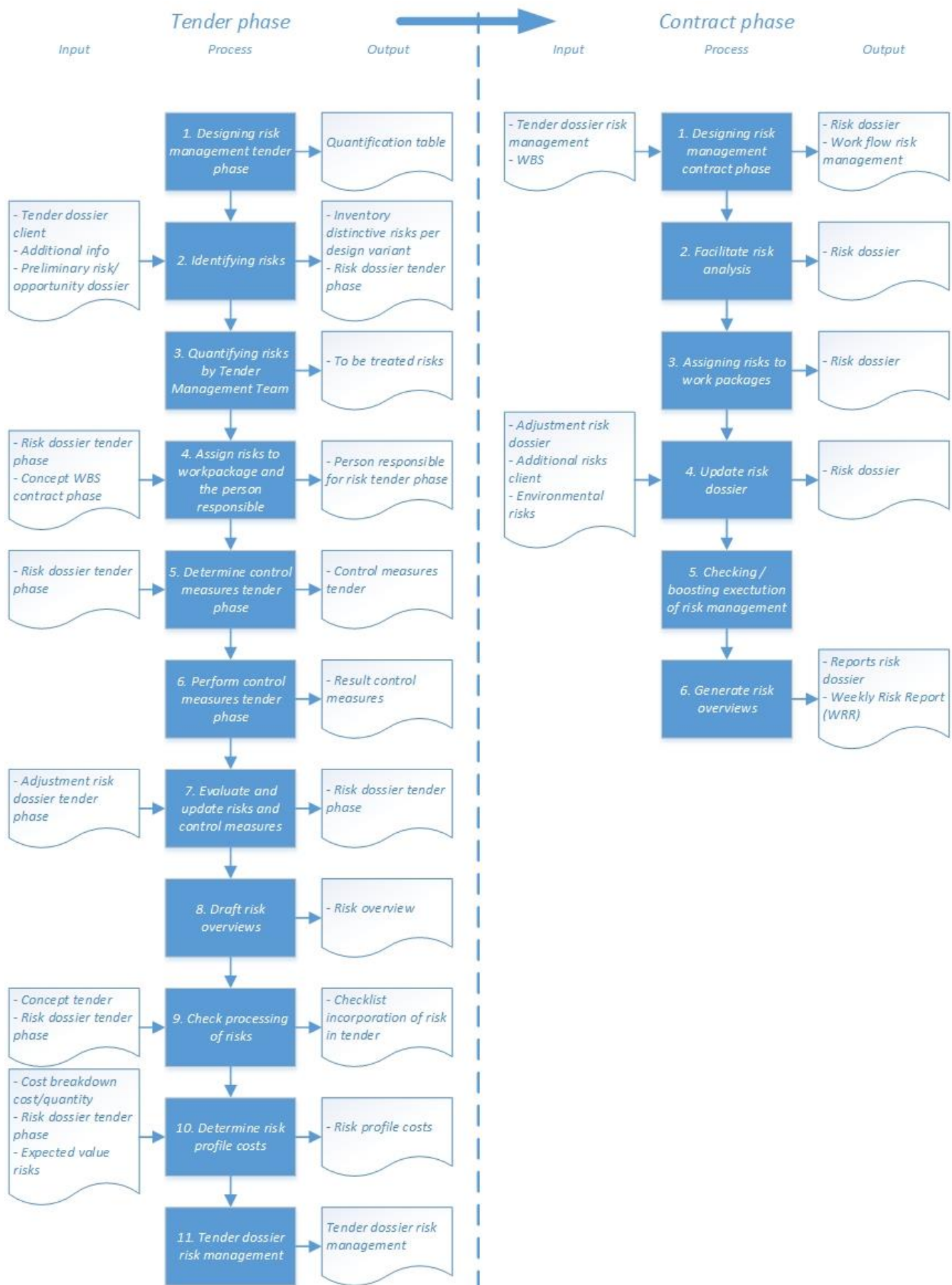


Figure C.1 - Overview of the theoretical Risk Management Process of VolkerInfra

Appendix D. CLASSES RISMAN METHOD AND THRESHOLD VALUES

Table D.1 - Overview of RISMAN classes and probability and consequence labels (Example)

Risk table							
	Probability of occurrence	Consequences - cost	Consequences - time	Consequences - quality	Consequences - safety	Consequences - surroundings	Consequences - image
0	Kan niet optreden: 0%	€ 0	0 days	No consequences for quality	Safe	No nuisance	None
1	< 5 %	< € 100,000	< 1 week	Non-conformance to norm/directive/plan	Near accident	Noticable for surroundings	Very small
2	5 - 10 %	€100,000 - €250,000	1 week – 1 month	Non-conformance to requirement while maintaining functionality	Accident without default	Complaint of surroundings	Small
3	10 - 25 %	€250,000 - €500,000	1 - 3 months	Functional loss of lesser component	Accident with default	Repetitive complaint of surroundings	Average
4	25 - 50 %	€500,000 - €1,000,000	3 - 6 months	Essential functional loss, repairable	Accident with long term default, permanent injury	Exceeding boundaries (environmental requirements)	Serious
5	> 50 %	> € 1,000,000	> 6 months	Essential functional loss, non-repairable	Fatal accident	Enforcement authorities	Major

Table D.2 - Threshold values RISMAN method, values above threshold in red (VolkerInfra)

Probability-class	Probability-class x consequence-classes				
5	5	10	15	20	25
4	4	8	12	16	20
3	3	6	9	12	15
2	2	4	6	8	10
1	1	2	3	4	5
Consequence-classes	1	2	3	4	5

Appendix E. OCCURRED RISKS ON SAAONE

Table E.1 - Overview occurred risks SAAone and financial values

Nr.	Risico-ID	Omschrijving	Calculated value at moment of tender (€)	Most recent calculated value (€)	Actual costs (€)
1	R-00021	Afwijkend grondgedrag/-opbouw - ten westen en oosten ARK (hoge terpen)	Confidential	Confidential	Confidential
2	R-00058	Vergunningen Rhenus in IJmeer zijn vertraagd (was: Markermeer in originele lijst v47)	Confidential	Confidential	Confidential
3	R-00077	Onzekerheid over de scope van het werk. De interpretatie van de architectonische ambitie komt niet overeen met de contracteisen	Confidential	Confidential	Confidential
4	R-00078	Onvoorziene uitbreiding scope.	Confidential	Confidential	Confidential
5	R-00086	Prorail accepteert het ontwerp met een zettingsvrije plaat zonder palen van SAAone niet (KW 37)	Confidential	Confidential	Confidential
6	R-00087	Plaatsen van tijdelijke voertuigkerende constructies (barriers) op repak (puinverharding) wordt niet toegestaan door RWS	Confidential	Confidential	Confidential
7	R-00123	Afwijking van TB (TracéBesluit) wordt niet (op tijd) goedgekeurd, KW42 rotatie	Confidential	Confidential	Confidential
8	R-00141	Gasleiding niet tijdig verlegd. Betreft GasUnie, HD-leiding, st-450mm, A6 km 46-47.6	Confidential	Confidential	Confidential
9	R-00143	BP, Middenspanningsvoorziening, A1 brandstofverkooppunt (X)	Confidential	Confidential	Confidential
10	R-00150	Vertraging ontheffing APV (Algemene Politie Verordening) mbt bouwlawaai, deel 2 KW43	Confidential	Confidential	Confidential
11	R-00151a	Vertraging grondverwerving RWS tov planning SAAone: aanvraag sloopvergunningen e.d. kan pas als grond verworven is	Confidential	Confidential	Confidential
12	R-00175	Geen toestemming of toestemming te laat voor gedeeltelijk open laten van dak van aquaduct (KW43)	Confidential	Confidential	Confidential
13	R-00177	Toepassen S-460 staal is niet toegestaan door ProRail/RWS, KW50	Confidential	Confidential	Confidential
14	R-00186	Versmallen van de ecopassage 8 van 50m naar 10m wordt niet door RWS goedgekeurd	Confidential	Confidential	Confidential

15	R-00189	Niet toepassen van power-backup voor de wisselbaan wordt niet goedgekeurd door RWS-SAA	Confidential	Confidential	Confidential
16	R-00193	SAAone moet onverwacht alsnog rekening houden met vrachtverkeer op de hoofdrijbaan tussen knp Diemen en KW43	Confidential	Confidential	Confidential
17	R-00197	SAAone ontwerp om bestaande duiker 25H-313 te verlengen en hiermee niet aanbrengen van duiker D11 wordt niet goedgekeurd door RWS-SAA	Confidential	Confidential	Confidential
18	R-00199	Verkeerde aanname mbt scope onderliggend wegennet (aardebaan en asfalt)	Confidential	Confidential	Confidential
19	R-00205	Kritische vertraging KW43; onvoorzien moeten nemen van versnellingsmaatregelen	Confidential	Confidential	Confidential
20	R-00209	Zettingsmeetslangen moeten alsnog toegepast worden	Confidential	Confidential	Confidential
21	R-00216	Maken van bypass A1 is onvoorzien noodzakelijk	Confidential	Confidential	Confidential
22	R-00219	Onvoorzien moeten plaatsen van tijdelijke hoogtebeperkingen op bouwwegen tpv hoogspanningskabels A9-A1-A6	Confidential	Confidential	Confidential
23	R-00223	Risico budget voor additionele gebruikerswensen max 10K€ per keer, gerelateerd tot Gebruik gronden derden	Confidential	Confidential	Confidential
24	R-00231	Onvoorzien redesign, niet kritisch in tijd	Confidential	Confidential	Confidential
25	R-00235	Meer legekosten mbt vergunning Muiden	Confidential	Confidential	Confidential
26	R-00236	Meer te verwijderen asbest dan ingecalculleerd in te slopen 50 gebouwen	Confidential	Confidential	Confidential
27	R-00238	Onvoorzien moeten uitrijden van KW tbv sloop (niet mogelijk om in-situ te slopen) Speelt bij: Googbrug, Viaduct A1, Gooimeer, v Hogering, Havendreef	Confidential	Confidential	Confidential
28	R-00249	Meer gebruik moeten maken van verkeersregelaars	Confidential	Confidential	Confidential
29	R-00252	Onvoorzien alsnog moeten hydrofoberen van dekken van alle viaducten daar waar alleen een membraan is voorzien	Confidential	Confidential	Confidential
30	R-00255	Onverwachte overschrijding budget staff koepel	Confidential	Confidential	Confidential

31	R-00256	Onverwachte overschrijding engineering budget	Confidential	Confidential	Confidential
32	R-00263	Afwijkend grondgedrag/-opbouw ter plekke van aanaardingen aan bestaande weg- of spoorlichaam Als volgens eis ON_M2b5.2a omvangrijke zettingen worden verwacht als gevolg van aanaardingen aan bestaande weg- of spoorlichaam dienen tijdelijke grondkerende constructies toegepast en gemonitord te worden om de stabiliteit te waarborgen	Confidential	Confidential	Confidential
33	R-00325	Ontwerpwaterstand in het pleistocene zand is hoger dan aangenomen (KW43)	Confidential	Confidential	Confidential
34	R-00350	Eco passage 10 moet toch separaat van KW60 worden gebouwd	Confidential	Confidential	Confidential
35	R-00371	Optimalisatie, laten vervallen van KW49A gaat niet door	Confidential	Confidential	Confidential
36	R-00372	Optimalisatie parallelbanen KW42 gaat niet door	Confidential	Confidential	Confidential
37	R-00374	Gaten asfaltboorkernen worden niet goed afgevuld, betonprop komt los	Confidential	Confidential	Confidential
38	R-00378	Wijzigingen in het MX-model en/of X-ref. worden niet verwerkt in het ontwerp van discipline Systemen	Confidential	Confidential	Confidential
39	R-00386	Benodigd verlichtingsniveau in KW43 is substantieel hoger dan aangenomen in tender	Confidential	Confidential	Confidential
40	R-00417	Gemeente Almere vertraagd goedkeuring bouwvergunningen	Confidential	Confidential	Confidential
41	R-00421	Afwijkende paalfunctie tov tenderuitgangspunten, geluidsschermen	Confidential	Confidential	Confidential
42	R-00424	Ontwerp geluidsschermen onvoldoende/te laat	Confidential	Confidential	Confidential
43	R-00431	Vertraging start werkzaamheden sanering/grondwerk kopterp west ARK, vak 1.1.5, de Stoeterij	Confidential	Confidential	Confidential
44	R-00439	DO wordt afgerond zonder volledig grondonderzoek	Confidential	Confidential	Confidential
45	R-00466	Aanwezigheid van zeer slappe toplaag (5m veen/dik water) KW43	Confidential	Confidential	Confidential
46	R-00467	Conflict tussen tijdelijke masten Tennet (mast 14N) en werkterrein KW43	Confidential	Confidential	Confidential

47	R-00477	De aangetroffen ontgronding nabij de bestaande Hollandse Brug (KW59) geeft de noodzaak tot aanpassing (verzwaring) van het funderingsontwerp van de nieuwe Hollandse Brug - KW59A	Confidential	Confidential	Confidential
48	R-00478	Er dienen rondom de pijlers van KW59A, bodembeschermende maatregelen te worden aangebracht om nieuwe ontgrondingen te voorkomen	Confidential	Confidential	Confidential
49	R-00480	UO van GWW te laat gereed voor start uitvoering	Confidential	Confidential	Confidential
50	R-00481	Gasleiding bij KW64 vereist een beschermingsvoorziening of licht ophoogmateriaal	Confidential	Confidential	Confidential
51	R-00486	Ontwerp aanpassingen na start uitvoering	Confidential	Confidential	Confidential
52	R-00490	Omleggen gasleiding door derden tpv Kromslootpark is niet op tijd gereed	Confidential	Confidential	Confidential
53	R-00499	Optreden van niet geplande restzettingen bij nieuw aan te brengen funderingen voor landhoofden	Confidential	Confidential	Confidential
54	R-00512	Aanpassing funderingsconstructie van de westelijke pijler KW39 door slappe laag onder deel van fundering	Confidential	Confidential	Confidential
55	R-00515	Problemen bij aanbrengen funderingspalen KW39	Confidential	Confidential	Confidential
56	R-00545	Grondkerende constructie 7 nabij KW51 kan niet gerealiseerd worden conform tender	Confidential	Confidential	Confidential
57	R-00546	Moeten toepassen onvoorzien hulpwerk (damwand), KW51, KW55, KW56	Confidential	Confidential	Confidential
58	R-00548	Aanbrengen hulpbruggen landhoofd KW50 lukt niet binnen TVP (TreinVrijePeriode)	Confidential	Confidential	Confidential
59	R-00552	Bouwvergunning KW51 te laat beschikbaar tov level 3 planning	Confidential	Confidential	Confidential
60	R-00557	Start werkzaamheden zonder door TIS (Technische Inspectie Service) goedgekeurde tekeningen/berekeningen	Confidential	Confidential	Confidential
61	R-00560	De kwaliteit van de afdichtingsplaat van de Lepelaar voldoet niet aan het saneringsplan fase 1	Confidential	Confidential	Confidential
60	R-00576	Moeizaam op diepte komen en niet en/of moeizaam kunnen trekken van VC-paal casing, KW43	Confidential	Confidential	Confidential

63	R-00587	Schade aan risicovolle objecten inclusief kabels en leidingen buiten TB	Confidential	Confidential	Confidential
64	R-00614	Ongelijkmatige restzettingen door veeninsluitingen bij aanbrengen werkvloer grondvlak 1.1.5	Confidential	Confidential	Confidential
65	R-00619	De breedte van KW66 moet mogelijk van 2x2 naar 2x3 aangepast worden	Confidential	Confidential	Confidential
66	R-00621	Vondst NGE (NietGesprongenExplosieven) nabij bypass A9 (vak 1.1.5)	Confidential	Confidential	Confidential
67	R-00644	GasUnie gaat toch niet akkoord met verleggen leiding bij KW37	Confidential	Confidential	Confidential
68	R-00647	Voegen in kunstwerk over Naardertrekvaart in de A1 kunnen niet volgens planning van SAAone vervangen worden	Confidential	Confidential	Confidential
69	R-00664	Zwaar heiwerk bij aanbrengen heipalen KW40	Confidential	Confidential	Confidential
70	R-00668	De bouwtijd voor GKC (GrondKerendeConstructie) 8 is mogelijk onvoldoende	Confidential	Confidential	Confidential
71	R-00669	Het onderwater moeten verwijderen van een grote hoeveelheid grout van een groot aantal ribbelpalen in de waterkelder KW43.	Confidential	Confidential	Confidential
72	R-00686	Retourwater van het hydraulisch aanbrengen van het zand in cluster 2 komt op rijbanen van de snelweg A1	Confidential	Confidential	Confidential
73	R-00689	Geplande TVP KW37 gaat niet door	Confidential	Confidential	Confidential
74	R-00702	Het niet (tijdig) bereiken van de restzettingseis ter plaatse van de overgangsconstructies van het zuidelijke landhoofd van KW38	Confidential	Confidential	Confidential
75	R-00703	Onvolledige stort door stagnatie in aanvoer KW39	Confidential	Confidential	Confidential
76	R-00717	Ontwerpaanpassingen systems noodzakelijk na afronden UO systemen	Confidential	Confidential	Confidential
77	R-00729	Hoeveelheid benodigde wapening in dekken KW43 is veel groter dan begroot.	Confidential	Confidential	Confidential
78	R-00736	Optreden trillingen in diagonale hangers K050 na in gebruik name	Confidential	Confidential	Confidential
79	R-00758	Te weinig werkruimte voor realisatie KW66	Confidential	Confidential	Confidential

80	R-00767	Lekkage bij aansluiting onderwaterbeton op bestaande vloer moot 11 KW43	Confidential	Confidential	Confidential
81	R-00770	Lekkage bij aansluiting onderwaterbeton op stalen schotten ter plaatse van de HWA-goten KW43	Confidential	Confidential	Confidential
82	R-00795	Schade aan rijbaan door trillen damwanden K036 fase 2 beperkt beschikbaarheid (HRR A9).	Confidential	Confidential	Confidential
83	R-00806	Ontwerpaanpassingen fundering ecopassage 10 noodzakelijk op basis van aanvullend grondonderzoek.	Confidential	Confidential	Confidential
84	R-00809	Geproduceerde randelementen voldoen niet	Confidential	Confidential	Confidential

Appendix F. OBJECT CLASSIFICATION

Table F.1 - Main object and sub object classification

Main object	Sub object
Road	Understructure
	Superstructure
	Road marking
	Signs/beacons
	Signposts
	Drainage
Civil structures	Bridge
	Overpass
	Aqueduct
	Underpass
	Culvert
	Cable culvert
	Ecoduct
DTM facilities	Shipping signals
	Roadside system for detecting and monitoring
	Video gathering system
	Transmission
	Alternating lane traffic system
	Emergency landing presence detection
	Public lighting
	Traffic regulation installation
	Traffic management support structure
	Traffic center
	Frost detection system
	Emergency phones
	Utilities
Service area	
Fitting facilities	Earth retaining structure
	Noise reduction structure
	Bank
	Ditch
	Water features
	Greening
	Landscaping
	Water retaining structure
	Other
Rail	Crossing
	Structural support system
	Intersection system
	Guidance system
	Command and control system
	Train safety system
	Power supply system
Temporary objects	
E&M installations	Pumps
	Movable parts

Appendix G. TOP FIFTEEN OCCURRED RISKS

Table G.1 - Top fifteen occurred risks on SAAone, A4All and Galecom cases

Numbe r	Personal- ID	Project	Risk Description
1	R-00078	Confidential	Onvoorziene uitbreiding scope.
2	R-00175	Confidential	Geen toestemming of toestemming te laat voor gedeeltelijk open laten van dak van aquaduct (KW43).
3	R-00729	Confidential	Hoeveelheid benodigde wapening in dekken KW43 is veel groter dan begroot.
4	R-00205	Confidential	Kritische vertraging KW43; onvoorzien moeten nemen van versnellingsmaatregelen.
5	R-00021	Confidential	Afwijkend grondgedrag/-opbouw - ten westen en oosten ARK (hoge terpen). (KW39)
6	R-00077	Confidential	Onzekerheid over de scope van het werk. De interpretatie van de architectonische ambitie komt niet overeen met de contracteisen.
7	R-00087	Confidential	Plaatsen van tijdelijke voertuigkerende constructies (barriers) op repak (puinverharding) wordt niet toegestaan door RWS.
8	R-00186	Confidential	Versmallen van de ecopassage 8 van 50m naar 10m wordt niet door RWS goedgekeurd.
9	R-00325	Confidential	Ontwerpwaterstand in het pleistocene zand is hoger dan aangenomen (KW43).
10	R-00350	Confidential	Eco passage 10 moet toch separaat van KW60 worden gebouwd.
11	R-00512	Confidential	Aanpassing funderingsconstructie van de westelijke pijler KW39 door slappe laag onder deel van fundering
12	R-00587	Confidential	Schade aan risicovolle objecten inclusief kabels en leidingen buiten TB
13	R-00644	Confidential	GasUnie gaat toch niet akkoord met verleggen leiding bij KW37
14	R-00686	Confidential	Retourwater van het hydraulisch aanbrengen van het zand in cluster 2 komt op rijbanen van de snelweg A1
15	R-00703	Confidential	Onvolledige stort door stagnatie in aanvoer KW39
16	R-00571	Confidential	Door de aanwezigheid van zandpalen in de ondergrond voldoet de ontwerpoplossing van de verdiepte en halfverdiepte ligging niet aan de functionele eisen.
17	R-00681	Confidential	Overschrijding maximaal toegestaan lekdebiet.
18	R-00001	Confidential	Werkzaamheden E&M (TI) niet tijdig gereed.
19	R-00748	Confidential	Uitloop in de planning als gevolg van dat Evides de ontwerpoplossing jetgrouten rondom de leiding niet accepteert.
20	R-00245	Confidential	Aanvullend geohydrologisch en geotechnisch onderzoek leidt tot wijzigingen.

21	R-00628	Confidential	TI testgereed wordt niet gehaald t.g.v. uitloop ontwerp DO/UO
22	R-00714	Confidential	Uitloop in de planning van GLS (Geluidschermen), TD3 als gevolg van deflectie van de damwanden.
23	R-00480	Confidential	Niet geaccepteerd krijgen van ontwerp oplossing A4All inzake het jetgrouten rondom de leiding voor het sluiten van het compartiment t.p.v. de Evidesleiding.
24	R-00721	Confidential	GWW kan niet starten ten gevolge van het niet waterdicht zijn van de CB-wanden.
25	R-00633	Confidential	ABB heeft een langere doorlooptijd voor de ontwikkeling van het UO software nodig dan gepland.
26	R-00311	Confidential	Na het afronden van de werkzaamheden worden er nog additionele eisen ingebracht.
27	R-00545	Confidential	Risico op vertraging in vergunningverlening m.b.t. de watergangen in tracédeel 2 en 3
28	R-00679	Confidential	De ontwikkeling van de software is niet op tijd gereed als gevolg van het uitloop van het DO TI.
29	R-00764	Confidential	Continue test C06/C07/C3B en C11 t/m 14 kan niet afgerond worden.
30	R-00315	Confidential	Vertraging in ontwerp/realisatieproces
31	R-00064	Confidential	De hoeveelheid uit te voeren dekplaatreparaties (per fase) wijkt sterk af van de verwachte hoeveelheid (meer dan 20%).
32	R-00198	Confidential	Hechtproef HSB geeft onvoldoende aantoonbaar resultaat voor fase 1
33	R-00411	Confidential	(Te) late levering dikke plaat door Dillinger, niet conform overeengekomen levertijd, op de criteria vanuit de voorgeschreven mechanische eigenschappen.
34	R-00500	Confidential	Brugdek vertoont 'kwispeleffect' en vervormt verder dan tolerantie.
35	R-00473	Confidential	Er worden nieuwe scheuren zichtbaar en bestaande (niet gerepareerde) scheuren groeien nadat inspecties zijn uitgevoerd.
36	R-00409	Confidential	Uitloop HSB-fasering.
37	R-00059	Confidential	De hoeveelheid laswerkzaamheden tbv troggen / trogaansluitingen is hoger dan verwacht.
38	R-00063	Confidential	De beoordeling en goedkeuring van reparatievoorstellen nav TOFD onderzoek (en andere inspecties) of controles duurt te lang.
39	R-00118	Confidential	Het engineeringsproces verloopt trager dan verwacht / engineering niet tijdig gereed.
40	R-00209	Confidential	Onvoorziene tegenslagen bij het plaatsen of gebruik van de doorwerkvoorziening.
41	R-00242	Confidential	Uitloop van de werkzaamheden met stremming of beperking ARK tbv invaren en verbinden VSL-secties.
42	R-00243	Confidential	De voor het werk benodigde hulpvoorzieningen aan de brug mogen niet worden aangebracht.
43	R-00246	Confidential	Instabiliteit van de middensectie binnen-VSL tijdens inbrengen.

44	R-00360	Confidential	Verslechtering relatie met gem. Utrecht ivm aanleg en moment van ingebruikname definitieve Griffioenlaan
45	R-00465	Confidential	Realisatie voegovergang HSB-fasering niet tijdig afgerond.

Appendix H. ADDITIONAL CRITERIA

Number

Number in the occurred risk database.

Personal-ID

The identification number of the risk in its own project database in VISE.

Risk Description

The short description of the risk or title of the risk as it is in its own project database in VISE.

Project

This is self-explanatory to indicate the project name, or in these cases the names of the respective combinations that are responsible for executing the project.

Initial Value

The financial value of the risk, i.e. the theoretical value of the financial consequences if the risk were to occur, as it was initially calculated or determined to be upon the analysis of the risk after it had initially been identified.

Tender Value

The financial value of the risk, i.e. the theoretical value of the financial consequences if the risk were to occur, as it was calculated or determined in the final decision on the tender bid. This value is important, as it represents the value for which the risk was included in the Monte-Carlo simulation and on which the tender budget for risks was based and calculated. If the risk has no tender value, it means that the risk was not yet identified during tender, so in theory there is no reserved budget for the risk. This means that if the risk were to occur, all corresponding financial consequences would be additional unforeseen costs, unless the risk is a further specification of one of the container risks. In that case the costs of the specific risks should be traceable to that container risk. This data is currently not available however, so further analysis on that is not possible.

Most Recent Value

The financial value of the risk, i.e. the theoretical value of the financial consequences if the risk were to occur, as it was calculated or determined to be upon the most recent update of the risk in the risk database. This mostly relates to the RISMAN categories, as was indicated in section 3.1.

Actual Cost

This value represents the actual costs made by the contractor as a consequence of the occurring of the respective risk. This value has only been obtained for the SAAone project and is given here as an indication, not as definitive value. The project is still being build and these values may therefore eventually change, they are represented as an indication. A separation between actual cost contractor and cost for the client may be required in the future. However, the cost that were obtained for SAAone were the costs for the contractor and not those for the client.