Dealing with human biases in the risk management process for infrastructure projects in the Netherlands

MSc. Thesis

Robbert Vonk

May 2024

TU Delft

DURA VERMEER

MSc. Thesis

Dealing with human biases in the risk management process for infrastructure projects in the Netherlands

By

Robbert Vonk

in partial fulfilment of the requirements for the degree of

Master of Science

in Construction Management and Engineering,

Faculty of Civil Engineering and Geosciences

at the Delft University of Technology

Author

Name:	Robbert Vonk
Student number:	4598547

Graduation Committee

Chair:	Prof. dr. Paul Chan	TU Delft
First Supervisor:	Dr. ir. Marian Bosch-Rekveldt	TU Delft
Second Supervisor:	Dr. Tong Wang	TU Delft

Preface

Conducting this research on human biases in risk management, from identification to response strategies, not only provided me with new insights into the topic but also deepened my interest in risk management at my employer, Dura Vermeer.

I would like to express my gratitude to Dura Vermeer Infra for allowing me to undertake this research within their organization, especially to those who participated in interviews, the questionnaire, and evaluation. I also thank my graduation committee, Prof. Dr. Paul Chan and Dr. Tong Wang, for their support throughout this long journey that my thesis writing has become. Their positivity and enthusiasm were crucial in motivating me. I want to thank my initial first supervisor Dr. ir. Martine van den Boomen, who helped me develop the idea I had for the master thesis to a full research plan and later first supervisor Dr. ir. Marian Bosch-Rekveldt, who joined the committee in October and has since helped me navigate my research smoothly after an earlier setback.

Finally, I want to thank my family, who provided me with motivation and energy throughout the thesis research and my entire master's program.

Summary

Infrastructural construction projects of, for example, roads, bridges and tunnels in the Netherlands have become larger and more complex today, compared to years or even decades ago. The construction industry knows many standard construction risks that occur on a frequent basis, but the projects are never the same and always have their own characteristics, depending on, for example, the location of the client. In construction projects, objectives tend to change during the project life cycle. All this makes it difficult to identify all possible risks, but also to assign reliable probabilities to the project-specific risks in particular.

This thesis examines the influence of human biases in the risk management process of infrastructure projects in the Netherlands, with a focus on the practices at Dura Vermeer, a major Dutch construction firm. The study is premised on the understanding that biases can significantly affect risk assessments and thereby impact the overall success of infrastructure projects.

Given the complex and high-stakes nature of such projects, the research aimed to uncover the extent to which biases influence decision-making processes and to explore potential strategies for dealing with biases. The following research question was formulated:

> *How do heuristics and biases influence project risk assessment, and what role can serious gaming play in enhancing awareness and management of these cognitive factors?*

The research adopted a mixed-methods approach, incorporating both qualitative and quantitative data collection techniques. The methodology was structured around four subquestions that guided the study to (1) gain theoretical insights about biases in project risk assessment from current literature, (2) investigate how project risk assessment is performed in practice and which heuristics and biases can be identified, (3) measure the actual use of heuristics and biases and practice and the extent to which people are aware of that and (4) to explore what contribution serious gaming can make in raising awareness regarding the use of biases and heuristics in risk assessment/management. Data were collected through a combination of literature review, semi-structured interviews with risk managers and project managers at Dura Vermeer, and a serious game designed to simulate decision-making processes in risk management.

The literature study offered insights from various perspectives on aspects of project risk analysis. Heuristics are mental shortcuts that typically allow for faster decision-making but can result in systematic deviations from rational judgments, known as biases. These biases arise from the complexity of making decisions under uncertainty and can lead to either an underestimation or overestimation of risk impacts, significantly affecting project execution and outcomes. The research focused on strategies to mitigate biases in risk management, including practical measures like training programs aimed at enhancing awareness and reducing the impact of cognitive and motivational biases.

Interviews with project managers and risk managers at Dura Vermeer revealed that the risk analysis process almost always involves creating an initial risk file and organizing collaborative brainstorming sessions to identify and assess risks. Several biases are recognized in the risk assessment process. Interviewees expressed unfamiliarity with structured interventions to

mitigate biases. It was acknowledged that some biases may serve a functional purpose. Concerns were also raised that introducing too rigorous or unfamiliar debiasing methods could demotivate team members or complicate the assessment process. This all resulted in the focus shifting from debiasing to dealing with biases, where debiasing is one of the strategies, but not the main goal. The importance of being aware of the presence and influence of biases was noted, along with the acknowledgment that the level of knowledge about biases in risk management is lacking.

A serious game was designed to increase awareness of the presence and impact of biases, aiming to improve risk decision-making. Based on the findings from serious game research focused on risk assessment and management, it appears that while identified biases and heuristics like the representativeness heuristic, affective heuristic, and optimism bias are acknowledged, they are not predominantly employed by professionals in the infrastructure sector. Instead, there is a strong preference for adopting objective methodologies for assessing risks and risk aversion. This preference for objectivity is consistent across various job functions. The research highlights a notable discrepancy between the self-perceived and actual usage of biases and heuristics by the respondents. While participants believe they employ a more biased approach, their responses to the game's dilemmas suggest a higher preference for objectivity than they recognize. Despite a general awareness of biases and heuristics among professionals in the infrastructure sector and a clear preference for objective risk management practices, there is a significant gap between self-perception and actual behavior.

In an evaluation session, the added value of serious gaming in Dura Vermeer's risk analysis process was considered. The use of serious gaming emerged as a promising tool to increase awareness among project managers and risk assessors. Games designed to mimic real-life risk scenarios enabled participants to actively engage with risk elements, fostering a deeper understanding of biases. The testing and evaluation of serious gaming into the training protocols at Dura Vermeer provided the following insights:

- Engagement and interaction in diverse teams: Games designed to simulate real project risks engage participants more actively than traditional risk management. By bringing together individuals with different backgrounds and viewpoints, serious games foster a collaborative environment where biases can be challenged and counterbalanced, leading to more effective risk management.
- Increased awareness: Participants exhibited a heightened awareness of their own decision-making processes and the potential biases influencing them. Through gameplay, participants are prompted to reflect on and recognize their personal and collective biases. This recognition helps in mitigating the adverse impacts these biases may have on risk management.
- Educational value: Serious gaming served as an effective educational tool, providing hands-on learning experiences that are difficult to replicate through traditional training methods. Players not only see the consequences of their choices but also learn to identify their instinctual leanings towards certain biases.

This thesis contributes to the theoretical and practical understanding of risk management in infrastructure projects by highlighting the impact of human biases on risk assessments. The findings suggest that while biases are pervasive, they are also manageable through targeted interventions such as serious gaming. For Dura Vermeer, the research provides insights into current practices and offers recommendations for enhancing the effectiveness of risk management processes through increased awareness and better handling of biases.

Samenvatting

Infrastructuurprojecten voor bijvoorbeeld wegen, bruggen en tunnels in Nederland zijn tegenwoordig groter en complexer geworden vergeleken met vroeger. De bouwindustrie kent veel standaard bouwrisico's die vaak voorkomen, maar de projecten zijn nooit hetzelfde en hebben altijd hun eigen kenmerken, afhankelijk van bijvoorbeeld de locatie van de opdrachtgever. Bij bouwprojecten veranderen de doelstellingen vaak gedurende de levenscyclus van het project. Dit maakt het moeilijk om alle mogelijke risico's te identificeren, maar ook om betrouwbare kansen toe te kennen aan de projectspecifieke risico's.

Deze scriptie onderzoekt de invloed van menselijke vooringenomenheid in het risicobeheerproces van infrastructuurprojecten in Nederland, met een focus op de praktijken bij Dura Vermeer, een groot Nederlands bouwbedrijf. De studie gaat uit van het begrip dat vooringenomenheden de risicobeoordelingen aanzienlijk kunnen beïnvloeden en daarmee het algehele succes van infrastructuurprojecten. Gezien de complexe en risicovolle aard van dergelijke projecten, was het doel van het onderzoek om de mate waarin vooringenomenheden besluitvormingsprocessen beïnvloeden te ontdekken en om potentiële strategieën voor het omgaan met vooringenomenheid te verkennen. De volgende onderzoeksvraag werd geformuleerd:

> *Hoe beïnvloeden heuristieken en vooringenomenheid de projectrisicobeoordeling, en welke rol kan serious gaming spelen bij het vergroten van het bewustzijn en beheersing van deze cognitieve factoren?*

Het onderzoek hanteerde een gemengde methodenbenadering, waarbij zowel kwalitatieve als kwantitatieve gegevensverzameltechnieken werden gebruikt. De methodologie was gestructureerd rond vier subvragen die de studie leidden om (1) theoretische inzichten te verkrijgen over vooringenomenheid in projectrisicobeoordeling uit de huidige literatuur, (2) te onderzoeken hoe projectrisicobeoordeling in de praktijk wordt uitgevoerd en welke heuristieken en vooringenomenheden kunnen worden geïdentificeerd, (3) het daadwerkelijke gebruik van heuristieken en vooringenomenheden in de praktijk en de mate waarin mensen zich daarvan bewust zijn te meten en (4) te verkennen welke bijdrage serious gaming kan leveren aan het verhogen van het bewustzijn over het gebruik van vooringenomenheden en heuristieken in risicobeoordeling/beheersing. Gegevens werden verzameld door middel van een combinatie van literatuuronderzoek, semigestructureerde interviews met risicomanagers en projectmanagers bij Dura Vermeer, en een serious game, ontworpen om besluitvormingsprocessen in risicobeheer te simuleren.

De literatuurstudie bood inzichten vanuit verschillende perspectieven op aspecten van risicoanalyse bij projecten. Heuristieken zijn mentale snelkoppelingen die meestal zorgen voor snellere besluitvorming, maar kunnen leiden tot systematische afwijkingen van rationele oordelen, bekend als vooringenomenheden. Deze vooringenomenheden ontstaan door de complexiteit van het nemen van beslissingen in onzekerheid en kunnen leiden tot het onder- of overschatten van risico's, wat aanzienlijk effect heeft op de uitvoering en resultaten van projecten. Het onderzoek richtte zich op strategieën om vooringenomenheid in risicobeheersing te verminderen, inclusief praktische maatregelen zoals trainingsprogramma's gericht op het verhogen van bewustzijn en het verminderen van de impact van vooringenomenheid.

Interviews met projectmanagers en risicomanagers bij Dura Vermeer onthulden dat het risicoanalyseproces bijna altijd bestaat uit het creëren van een initieel risicodossier en het organiseren van gezamenlijke brainstormsessies om risico's te identificeren en te beoordelen. Verschillende vooringenomenheden worden herkend in het risicobeoordelingsproces. Geïnterviewden gaven aan onbekend te zijn met gestructureerde interventies om vooringenomenheid te verminderen. Het werd erkend dat sommige vooringenomenheden functioneel kunnen zijn. Ook werden zorgen geuit dat het introduceren van te rigoureuze of onbekende *debiasing*-methoden teamleden zou kunnen demotiveren of het beoordelingsproces zou kunnen compliceren. Dit leidde ertoe dat de focus verschoof van *debiasing* naar het omgaan met vooringenomenheid, waarbij *debiasing* een van de strategieën is, maar niet het hoofddoel. Het belang van het zich bewust zijn van de aanwezigheid en invloed van vooringenomenheid werd opgemerkt, samen met de erkenning dat het kennisniveau over vooringenomenheid in risicobeheersing beperkt is.

Een *serious game* werd ontworpen om het bewustzijn te vergroten over de aanwezigheid en impact van vooringenomenheden, met als doel de besluitvorming over risico's te verbeteren. Gebaseerd op de bevindingen uit onderzoek naar *serious games*, gericht op risicobeoordeling en -beheersing, blijkt dat hoewel geïdentificeerde vooringenomenheden en heuristieken zoals de representativiteitsheuristiek, affectieve heuristiek en optimismebias worden erkend, deze niet overwegend worden gebruikt door professionals in de infrastructuursector. In plaats daarvan is er een sterke voorkeur voor objectieve beoordeling van risico's en risicoaversie. Deze voorkeur voor objectiviteit is consistent over verschillende beroepsfuncties heen. Het onderzoek benadrukt een opmerkelijk verschil tussen het zelf waargenomen en het daadwerkelijke gebruik van vooringenomenheden en heuristieken door de respondenten. Hoewel deelnemers denken dat ze een meer vooringenomen aanpak gebruiken, suggereren hun reacties op de dilemma's van het spel een hogere voorkeur voor objectiviteit. Ondanks een algemeen bewustzijn van vooringenomenheden en heuristieken onder professionals in de infrastructuursector en een duidelijke voorkeur voor objectieve risicobeheerspraktijken, bestaat er een significant verschil tussen zelfperceptie en daadwerkelijk gedrag.

In een evaluatiesessie werd de toegevoegde waarde van *serious gaming* in het risicoanalyseproces van Dura Vermeer beschouwd. Het gebruik van *serious gaming* kwam naar voren als een veelbelovend hulpmiddel om het bewustzijn onder projectmanagers en risicomanagers te vergroten. Spellen ontworpen om echte risicoscenario's na te bootsen stelden deelnemers in staat om actief om te gaan met risico-elementen, waardoor een dieper begrip van vooringenomenheden werd bevorderd. Het testen en evalueren van *serious gaming* bij Dura Vermeer leverde de volgende inzichten op:

- Betrokkenheid en interactie in diverse teams: Spellen ontworpen om echte projectrisico's na te bootsen betrekken deelnemers actiever dan traditionele risicobeheersing. Door individuen met verschillende achtergronden en perspectieven samen te brengen, bevorderen *serious games* een omgeving waar vooringenomenheden kunnen worden uitgedaagd en geneutraliseerd, wat leidt tot effectiever risicobeheersing.
- Verhoogd bewustzijn: Deelnemers vertoonden een verhoogd bewustzijn van hun eigen besluitvormingsprocessen en de mogelijke vooringenomenheden die hen beïnvloeden. Door middel van *serious gaming* worden deelnemers aangespoord om na te denken over hun persoonlijke en collectieve vooringenomenheden. Het herkennen daarvan helpt bij het

verminderen van de negatieve effecten die deze vooringenomenheden kunnen hebben op risicobeheersing.

- Onderwijskundige waarde: *Serious gaming* diende als een effectief educatief hulpmiddel, dat hands-on leerervaringen biedt die moeilijk na te bootsen zijn via traditionele trainingsmethoden. Spelers zien niet alleen de gevolgen van hun keuzes, maar leren ook hun instinctieve neigingen naar bepaalde vooringenomenheden te identificeren.

Deze scriptie draagt bij aan het theoretische en praktische kennis van risicobeheersing in infrastructuurprojecten door de impact van menselijke vooringenomenheid op risicobeoordelingen te beschouwen. De bevindingen suggereren dat, hoewel vooringenomenheden wijdverbreid zijn, ze ook beheersbaar zijn door gerichte interventies zoals *serious gaming*. Voor Dura Vermeer biedt het onderzoek inzichten in huidige praktijken en aanbevelingen voor het verbeteren van de effectiviteit van risicobeheerprocessen door verhoogd bewustzijn en verbeterde omgang met vooringenomenheid.

Table of Contents

List of figures and tables

1. Introduction

In section 1.1, the research context is outlined, clarifying the focus of this study. Section 1.2 describes the research setup, including its motivation and relevance. In section 1.3, the structure of the remainder of this research report is presented.

1.1 Research context

Infrastructure projects in the Netherlands

Infrastructural construction projects of, for example, roads, bridges and tunnels in the Netherlands have become larger and more complex today, compared to years or even decades ago (Bosch-Rekveldt, 2011). This is because factors such as environment are becoming increasingly important (Ruijter, 2019). Moreover, due to more and denser building activity in the Netherlands, the environment now is more often affected by these infrastructural projects.

A project can be defined as an organization of people that commit themselves and resources to a specific goal (Steiner, 1969). Important pillars for the execution of a project are the completion of the project within the established schedule, the budget, the established quality requirements and with the least possible disruption for the environment. Determining planning and directing resources to achieve project goals are components of project management (Fan, Lin & Sheu, 2008). These infrastructure projects are often commissioned by public parties, usually government institutions, and are built by private parties, the contractors.

Dura Vermeer and projects

This research is being conducted within Dura Vermeer, utilizing documentation from the company and input from its personnel. Dura Vermeer is one of the contractors operating in the Netherlands and has the focus on both housing and infrastructure. Dura Vermeer employs approximately 3000 people, a third of whom work in infrastructure. Dura Vermeer's focus is on projects with different contract types, from D&C to DBFM- and, for example, long-term maintenance contracts. That is why Dura Vermeer is not only a building party, but rather a construction developer, acting within the entire life of a project.

Risks – in general in projects and specifically in infrastructure

Determining planning and directing resources to achieve project goals are components of project management (Fan, Lin & Sheu, 2008). In many projects, also risk management, which then is a part of project management, plays a role to get insight in which possible risks may arise during the project and how they can or should be handled to meet the project objectives and avoid project failures. In order to meet the project objectives, it is important to identify and manage risks in all phases of the project. A risk is a potentially unwanted and unexpected event that can result in one or more of the project goals not being achieved (Teneyuca, 2001). Projects have a less “predictable” nature than day to day business activities which makes them riskier (Elkington & Smallman, 2002). The risks are often unique and arise from different sources (Norzima, Sorooshian & Chow, 2011; Sorooshian, 2014). After all, in addition to technical risks, projects often involve several stakeholders with different goals, desires and visions (Bing, Akintoye, Edwards & Hardcastle, 2005; Ankit, Jayesh, Pitroda & Bhavsar, 2013). Measures can be taken to minimize the likelihood of risks occurring or the consequences if they do occur. A

budget is often allocated for the identified residual risks prior to the project. If it later turns out that some risks have not been considered or considered risks have not been correctly estimated, this budget may not be sufficient, which can lead to quick overruns of the risk budget. This stresses the importance of proper risk management in practice.

Risk analysis methods

There is a widespread range of methodologies for analyzing risk within projects. Risk assessment methods have ranged from quantitative methods such as Monte Carlo Simulation, Sensitivity Analysis and Fault Tree Analysis to qualitative methods such as Delphi method and interviews and combinations of both quantitative and qualitative methods. The mentioned quantitative methods require high quality data that is often not available in projects. After all, even if quantitative data is available, it is recognized that much knowledge in the real world is imprecise, rather than precise (Olcer & Odabasi, 2005). The construction industry knows many standard construction risks that occur on a frequent basis, but the projects are never the same and always have their own characteristics, depending on, for example, the location of the client. In construction projects, objectives tend to change during the project life cycle (KarimiAzarii Mousavi, Mousavi & Hosseini, 2011) and also the scenarios are numerous. This is due to changes that can take place in the macro-environment to which projects are sensitive, the high number of parties involved in the project value chain and the non-repetitiveness of projects (Dikmen, Birgonul, Anac, Tah & Aouad 2008). All this makes it difficult to identify all possible risks, but also to assign reliable probabilities to the project specific risks in particular. Therefore, failure risk assessment is often very subjective in projects (Mills, 2001).

Risk management at Dura Vermeer

Dura Vermeer uses the RISMAN (RISk MANagement)-method in their projects to quantify the consequences of risks in terms of cost, time, quality, safety and environment. By quantifying different risks on the same impact categories, the risks become more tangible and easier to compare in importance. The RISMAN-method was developed in the Netherlands through a collaboration between RWS Bouwdienst, RWS Zuid-Holland, Railinfrabeheer, Twynstra-Gudde, TU Delft and the Rotterdam Public Works Department (Van Well-Stam, Lindenaar, Van Kinderen & Van den Bunt, 2004). Originally, the methodology was developed as a risk analysis tool, but over time it has developed into a complete framework that is used by many companies, for example in the construction industry. This makes that RISMAN is often not only applied incidentally when a quick analysis of risks is required, but that a carefully constructed register is developed during the whole duration of a project, based on this RISMAN framework. The consequences of the occurrence of a risk are quantified on a scale between 0 and 5 for each of the impact categories, after which the assigned values for all impact categories are added together. By multiplying this value by the probability of the risk occurring, which is also assessed on a scale between 0 and 5, the eventual RISMAN score is obtained. The risks then will be displayed in a risk matrix.

1.2 Research setup

In this section, the problem that this study aims to address is presented. Subsequently, the research gap is identified, which is intended to be filled through this report. Finally, both the theoretical and practical relevance of this research are explained.

1.2.1 Problem statement

The idea of estimating risk consequence and probability on a 5-point scale, leading to one score to visualize in a risk matrix is widely applied, although not always using the full RISMAN framework. Many studies have focused on the limitations of using a risk matrix in practice. However, they cannot resolve the limitation that lies in the subjective classification of consequence and probability (Duijm, 2015).

Objective data is extremely difficult if not impossible to obtain for the use in construction project risk assessment. Using objective data in risk assessment in construction projects is unrealistic, because of the uncertainties and uniqueness of individual construction projects. Therefore, risk assessment will often rely on subjective judgments. The task of estimating probabilities, especially those of rare events, is difficult. In that process, people naturally rely on a set of heuristic procedures that can often be helpful, but may also result in biased outcomes (Morgan and Henrion, 1990). Subjective assessments can vary among decision makers with different culture, education and experiences. This can lead to inconsistent and unprecise risk assessments in projects that can have huge consequences.

1.2.2 Research gap

Hubbard and Evans (2010) argue what is problematic about scoring methods as a tool for risk assessment. It is said that the methods often do not take into account cognitive biases that impair most people's ability to assess risk. For example, a common bias in risk assessments is overconfidence (Kahneman & Tversky, 1972; Kahnemen & Tversky, 1973). Many people are prone to overconfidence about the certainty of their predictions regarding risks, often giving estimates that are too close to zero or one (Morgan & Henrion, 1990). Assessing risk includes assessing the likelihood of a risk occurring. Due to overconfidence about the non-occurrence of a certain risk (e.g. 90% certainty that it will not occur), there is a possibility that the risk is insufficiently analyzed and that no or few measures are taken, while the chance that the risk will actually occur can be much higher. In addition, one would be inconsistent in assessing risks. If the same person were asked to rate a risk at different times, he or she would tend to give different estimates, even though there is no change in the information that is available to that person that might justify the change in judgment. They argue that good risk assessment should allow for research in human judgment and decision making to be applied in a corrective fashion.

Hunt and Naweed (2023) recognize that human factors in risk assessment work sessions can lead to skewed estimated of either likelihood or impact. Tabachnick, Fidell and Ullman (2018) distinguish two types of errors as a result of high and low skew estimates. Type 1 errors occur when the team overestimates the likelihood or impact. This can lead to an overconservative risk approach in which unnecessary (large) risk reduction measures are implemented. Type 2 errors occur when the team estimates the likelihood of impact too low, resulting in insufficient action on the relevant risk, which makes this type of error the most dangerous.

Researchers have a great awareness of how heuristics lead to human biases with possible false estimates as a result. In addition, it is also known that risk management plays an essential role in the construction industry. However, despite recognizing the importance of risk assessment and acknowledging that this process is influenced by human biases, there is a gap between what literature underlines as important in risk management and how risk management is applied in practice. Researchers have been focusing on biases and heuristics within risk

management processes within different types of industries, but there is too little verification of the theory on heuristics and biases in practice within companies (Sprinkle, 2018). This is necessary to gain a better understanding of the impact of heuristics per type of organization, based on its risk culture and the maturity of a company's risk management procedure (Hopkinson, 2010).

1.2.3 Research relevance

For the master thesis, the aim is to have both academic and practical added value.

Theoretical relevance

Hunt and Naweed (2023) focused their research on the risk management procedure in different industries and found that biases originated from cultural or societal forces, industry norms, company pressures and pressures associated with occupational roles, and in some cases very dominant individual views. The process of using heuristics that create human biases in risk evaluation leading to possible false estimates has been studied several times. A verification of the theory about heuristics and human biases in practice could provide more insight into how certain heuristics and biases are used and arise, depending on how risk averse or how risk seeking one organization is and how mature it's organization is when it comes to risk management. After all, Thompson (1990) argues in his culture theory that groupings are formed based on common objectives, values and perceptions, which is consistent with differentiated risk perceptions about groups. How risk is considered would therefore be very organization-specific.

Practical relevance

Within this graduation project, the risk management procedure as prescribed by the management system of Dura Vermeer and the risk management process currently applied in tenders and projects are considered to map the use of heuristics in this process. In addition, it is investigated how the use of heuristics can lead to biases in the risk assessment, resulting in possible false estimates. Based on identified gaps in the awareness of the use of heuristics and findings from the literature, adjustments will be proposed to improve the risk management process with better project performance as the end goal.

1.3 Structure of the report

This thesis is structured as follows. Chapter 2 describes the research design, introducing the main research question and subquestions. It explains which research methodologies are used to address each subquestion. Chapter 3 provides a theoretical background on risk management in projects, including its pitfalls where heuristics and biases will be explained. Chapter 4 explores how risk analysis is performed in practice through the execution and analysis of interviews with personnel from Dura Vermeer. Chapter 5 presents and discusses the results from a serious game conducted as a survey among professionals in the field. Chapter 6 discusses the added value and possible improvements of the serious game based on an evaluation with some of the participants. Chapter 7 contains a discussion on the results and the research. Chapter 8 answers the research questions and presents the conclusion and recommendations for further research.

2. Research design

In section 2.1, the research plan is outlined. Section 2.2 elaborates on the research methodology for addressing each research (sub)question.

2.1 Research plan

This section introduces the research questions to be answered, the scope, and the expected results.

2.1.1 Research questions

Recent studies have raised concerns regarding how human biases, resulting from the use of heuristics in risk management are incorporated in the risk management process in practice. Studying the wide variety of known heuristics and testing its presence in the risk assessment process from the contractors perspective can give a better understanding of the impact of human biases on risk estimates. Effectively recognizing the influence of human biases could lead to improvement of a company's risk assessment performance. The main research question is therefore formulated as follows:

> *How do heuristics and biases influence project risk assessment, and what role can serious gaming play in enhancing awareness and management of these cognitive factors?*

To guide and structure this study in order to be able to answer this question, case study research is performed at Dura Vermeer and generalized for the construction sector afterwards. To answer the main research questing, the following sub questions have been determined and will be answered:

SQ1: What theoretical lens can be obtained from state of the art literature on biases in relation to using heuristics in project risk assessment?

SQ2: How is project risk assessment performed in practice? What heuristics are used and what biases are identified?

SQ3: To what extent are identified biases/heuristics actually used in risk assessment/management, and to what extent are people aware of that?

SQ4: What contribution can serious gaming make in raising awareness regarding the use of biases/heuristics in risk assessment/management?

2.1.2 Research scope

In this research the focus is on the risk assessment process, followed by Dura Vermeer in infrastructural construction projects through the tendering and execution phase. In the

literature, it can be found that in most projects, the identification of risk is mainly done in the budget preparation phase, which is already in the tendering phase or early in the project preparation phase after a tender (Nielsen, 2004). Also, it is mentioned that often risks are not monitored sufficiently during the execution phase.

At Dura Vermeer, the identification of risks also takes place in the tender phase or early in the preparation phase. After all, the sooner it is identified which risks can occur and which are estimated to potentially have the greatest consequences, the better measures can be taken to prevent this occurrence as much as possible or to reduce the severity. Risk management is important in the early project phases, because choices made then can have a major impact on the final project result (Kähkönen, 2001). For that reason, it makes sense to focus on the entire risk management process from risk identification and risk assessment in the early (tender) phase to handling risks in the execution phase.

2.1.3 Expected results

The expected results of this research are multifaceted and are expected to benefit both Dura Vermeer and the wider construction industry. By thoroughly answering the subquestions, the study aims to clarify the specific heuristics and biases present in the risk assessment processes used in practice at a construction company, and more generally in infrastructure construction projects. This understanding is projected to enhance the theoretical framework on biases and heuristics within risk management, providing a robust foundation for further academic research.

For Dura Vermeer, the study is expected to provide an analysis of their current risk assessment practices, highlighting specific biases and the prevalence of heuristic use within their processes. This will enable Dura Vermeer to pinpoint inefficiencies and areas prone to error, thereby enhancing the accuracy and reliability of risk assessments. Furthermore, an exploration into the role of serious gaming in raising awareness and managing biases is expected to yield innovative strategies for training and development within the company. Such tools can lead to a more bias-aware culture, potentially reducing costly oversights and improving project outcomes.

This research is poised to offer both theoretical contributions to academic literature and actionable recommendations that can lead to tangible improvements in project performance and risk mitigation.

2.2 Research methods

This section explains how the sub-questions will be answered. The input for this research relies on qualitative data such as interviews and reports and also quantitative data will be used.

2.2.1 Research method for subquestion 1

The first subquestion to be answered is: *"What theoretical lens can be obtained from state of the art literature on biases in relation to using heuristics in project risk assessment?"*. The relationship between the use of heuristics and risk assessment is observable on a daily basis in everyone. Throughout the day, in any environment, people are busy making decisions. Many factors can influence the decisions people make. In the late 1950s, Herbert Simon introduced the principle of bounded rationality (Simon, 1957). This was an alternative to the prevailing view of classical rationality in decision-making in economics, among others. It was assumed that people are rational on average and that their actions are largely determined by their preferences

to maximize utility by means of using, for example, probability theory and statistics. Simon emphasized the specific limitations people face, such as limitations in time, information and the cognitive capacity to arrive at the optimal decision, forcing them to use heuristics to make their decisions (Simon, 1957). In the early 1970s, Tversky and Kahneman (1974) expanded on this by introducing the term cognitive bias to describe people's systematic, but flawed, decision-making patterns.

In risk assessment too, people have to make choices that can be assumed to be bounded rational due to a lack of precise data. Many different biases due to bounded rationality in risk analysis have been introduced in the literature.

The starting point of this research is a literature review to obtain a theoretical lens on biases in relation to using heuristics in project risk assessment. Research into cognitive biases goes back several decades. In this period, many publications have appeared that have a link with heuristics and/or cognitive biases in decision making. In order to find suitable sources from the large collection of literature as input for this research, it is important to be critical on the publications to be selected. Finding the right keywords is therefore an important step in the literature research. After generating a collection of potentially useful publications in Scopus and Google Scholar, it is important to select which sources are suitable as input for the literature review. Relevant publications include understanding behavioral aspects in decision making and risk analysis in general, but more specifically in project management and ideally construction project management.

The goal of the literature review is multifold. First of all, in literature review it is important to provide a summary of the theory or topic under consideration. In this case, this concerns the prevention of biases and the use of heuristics in project risk management and more specifically in construction project risk analysis. Different prevailing perceptions regarding biases and the use of heuristics in project risk analysis will be considered. The goal is to gain insight into both the known occurring biases in risk analysis and the way in which biases creep into risk analysis through the use of heuristics. The latter part should give better understanding in the area of research on behavioral aspects in risk analysis. An explanation of the known occurring biases serves as input for the second research question.

2.2.2 Research method for subquestion 2

In answering the first sub-question, insight is gained into how biases in decision-making arise within the risk analysis process. In addition, it will be explained which different biases exist and into which categories they can be divided. This serves as input for answering sub-question 2: *"How is project risk assessment performed in practice? What heuristics are used and what biases are identified?"*.

The first study on judgment and decision-making under uncertainty with a psychological perspective was conducted by Amos Tversky and Daniel Kahneman (1974). In this study, they conducted several gambling experiments, the aim of which was to understand how the participating people evaluated odds. In addition, they found that people use different heuristics to evaluate and process information. Demonstrating the use of heuristics in risk analysis at Dura Vermeer by conducting experiments would only demonstrate again what is already known; people use heuristics in decision-making under uncertainty. That is why this is considered as a

given. The goal of sub-question 2 is to critically examine the risk analysis procedure at Dura Vermeer and to conduct interviews with risk managers at Dura Vermeer.

The input for sub-question 2 is therefore twofold. First of all, the answer to sub-question 1 serves as a theoretical framework for the analysis of risk assessment at Dura Vermeer. Second, semi-structured interviews will be conducted with project managers and risk managers at Dura Vermeer to discuss the internal risk analysis process, possible biases and bias interventions. This also ensures that an even deeper insight into the risk analysis procedure at Dura Vermeer can be obtained.

Semi-structured interviews are held in situations where information is not available in documentation, but can be explained through the experience of people who are frequently involved with a subject. In this case, that applies to risk managers. Semi-structured interviews also allow new ideas to emerge as the interview progresses. In the first part, the focus will be on the prescribed procedure of risk analysis in Dura Vermeer from the management system and the way risk analysis is carried out in practice at Dura Vermeer. The ultimate goal is to determine which biases, resulting from the use of heuristics, could potentially occur in risk analysis at Dura Vermeer.

In the second part of the semi-structured interviews, gained information about heuristics and biases in risk analysis from answering the first subquestion, will be addressed. The goal in this part of the interview is to check whether the interviewees are aware of biases in others and themselves. Often, people tend to see biases in others quite well, but have a blind spot for themselves. Together with the interviewees, risk management in past projects will be evaluated to see if we can recognize biases and possibly also the effect of biases on decision making. Judging whether biases are present, can include subjectivity, which makes it important to check for specific mechanisms that are known in biases.

The third part includes the discussion of knowledge about bias interventions, the need for bias interventions and the possible ways for that. The interviews will be conducted face-to-face or via Microsoft Teams. The interviews will be recorded and transcribed for later analysis. The answers to the questions by the various interviewees will be compared with each other in order to arrive at the clearest possible pattern that emerges from the answers.

2.2.3 Research method for subquestion 3

Concluding on subquestion 2, a selection of three biases/heuristics is made for the continuation of the research. This selection is based on their prevalence and potential issues arising from their presence, as derived from semi-structured interviews. This means that the answer to subquestion 2 serves as input for addressing subquestion 3: *"To what extent are identified biases/heuristics actually used in risk assessment/management, and to what extent are people aware of that?"*.

A serious game is being developed in which participants are presented with recognizable project risks and must make decisions for their risk assessment and -management. Internal documentation of risks serves as input for the risks presented in the game, ensuring they are familiar to the participants. The decision-making options are formulated as dilemmas, resembling the trade-offs typically made in real risk sessions and projects. The three selected

biases/heuristics are integrated into the response options, though they are not explicitly referred to.

Based on the chosen answers, it becomes clear whether participants prefer the biased response options or the objective ones. Additionally, the game explores whether participants favor a risk-averse or risk-tolerant approach to risk management.

The game concludes with several reflective questions asking participants to consider their responses; they assess their own use of biases and risk aversion. With the data collected from the game, the actual use of biases and risk aversion in responding to the dilemmas can be analyzed and compared with participants' self-assessments of their preferred choices. Moreover, the role and years of work experience are also queried to explore any correlations between these factors and preferences for risk assessment and management.

2.2.4 Research method for subquestion 4

The final goal of this research is to gain insight in how heuristics and biases can be dealt with in Dura Vermeer's risk analysis procedure by making people aware of the effect biases have on people's estimation. After having found the most prevalent existing biases in the risk analysis procedure at Dura Vermeer through earlier subquestions, a serious game was developed with the goal of making people more aware of their own behavioral preferences, biases, and their potential impact on risk assessment. Based on the results from the game, an evaluation session is organized with some of the game participants to discuss the results, the added value of the game, and potential improvements to address subquestion 4: *"What contribution can serious gaming make in raising awareness regarding the use of biases/heuristics in risk assessment/management?"*

For this, the results are presented in figures (as shown in this thesis) to the evaluators, along with explanations of how to 'read' the results. The evaluation is divided into three parts. In the first part, the preferences of all participants across all dilemmas and specifically for the three selected biases are presented (anonymized). Each of the three biases/heuristics will be discussed to determine how their use by project managers, risk managers and tender managers might be problematic or functional and what this implies for the risk management process.

In the second part, the self-assessment of bias usage and risk aversion from the final part of the game is presented, compared to the actual use of biases and the level of risk aversion. This can determine whether the participants' self-assessment of their dilemma choices aligns with their actual choices and what this means.

In the third and final part of the evaluation, the discussion focuses on whether and how a serious game can add value by raising awareness about the use of biases/heuristics and thereby improving the overall process of risk management. Additionally, shortcomings and potential improvements to the serious game are discussed and included in the recommendations for further research.

2.2.5 Approach to answering the main research question

The output of answering sub-questions continually serves as input for answering the next subquestion. The answers to all subquestions ultimately result in: a theoretical framework of the functioning of biases arising from the use of heuristics and a categorization and explanation

of known biases (subquestion 1), an overview of possible biases based on the implementation of risk analysis within Dura Vermeer (subquestion 2), an inventory of the actual use of biases in risk management at Dura Vermeer through dilemma choices in a serious gaming format, an self-assessment of one's own behavior in risk management and a potential addition to the existing risk analysis procedure at Dura Vermeer (subquestion 3), and finally a joint evaluation to interpret the results and their significance, discuss the added value of serious gaming for risk management, and make recommendations for its further development (subquestion 4).

This all contributes to the main goal that follows from the main question of this research. That goal is to find a way to deal with human biases in project risk assessment in the infrastructure industry in order to enhance project performance.

3. Theoretical background

In this chapter, the findings of a literature review are presented to address subquestion 1: *"What theoretical lens can be obtained from state of the art literature on biases in relation to using heuristics in project risk assessment?"*. The results are derived from articles, books, and conference reports identified through Scopus and Google Scholar. Various search terms were employed, including 'heuristics AND "risk management" AND construction'. In section 3.1, the focus is on the application of risk management, including its history, framework, and added value. Section 3.2 discusses the pitfalls in risk decision-making, followed by section 3.3 which describes mitigating biases; one of the possible strategies to deal with biases, which has been researched extensively in recent years. In section 3.4, an analysis of the findings from previous paragraphs is provided, followed by the formulation of an answer to subquestion 1 in section 3.5.

3.1 Application of risk management in focus: Understanding the impact and results

As stated in the introduction, risk management in construction is a tedious task. This is among other reasons due to the fact that objectives tend to change during the project life cycle, changes that can take place in the macro-environment to which projects are sensitive, the high number of parties involved and the non-repetitiveness of projects. The success of a project is closely tied to the effectiveness of the project risk management, as risks are evaluated based on their potential impact on the project's goals. Nevertheless, the construction sector lags behind in risk analysis reputation when compared to industries like finance and insurance (Laryea, 2008). In the academic world, risk management in the construction industry has received huge attention.

Risk management involves more than risk analysis alone. Risk management is the systematic process of identifying, analyzing and responding to project risk. Edwards and Bowen (1998) point to the text of Hayes, Perry, Thompson and Willmer (1986) as one of the first systematic treatments of construction risks, in which risk identification, risk analysis and risk response are distinguished from each other and follow each other. Before that, the focus of many researchers was on mathematical approaches to risk analysis. The CRM Manual from 1987 offered a procedural, task-oriented manual for construction risk management, a theme also explored by certain later researchers such as Flanagan and Norman (1993), as well as Rafferty (1994a). By 1989, attempts had been made to use expert systems techniques in the analytical process of risk management (Kangari & Boyer, 1989). Williams (1994) advocated a 'risk register' in the management system of a project to generate an accessible database of risk experience. According to him, three different items come from the risk register; 1) various risk analyzes (cost, time and risk), 2) contractual decisions on transferability of risks, and 3) planning on risk reduction and contingency actions.

Although risk management in the construction industry already gained a lot of attention from researchers in the 80s and 90s, this does not provide certainty that this attention is also there in practice. In 1997, Akintoye and MacLeod interviewed managers of a hundred top construction firms in the UK and found that the usage of risk analysis techniques by the responding firms

was generally low in construction projects, except for judgment based on experience. This supported the view of Birch and McEvoy (1992) that risk analysis was largely based on using checklists to think of all possible risks, but this approach gives little confidence that all risks have been identified. In 1998, Baker, Ponniah and Smith examined the most effective tools for both qualitative and quantitative risk analysis within the construction and oil & gas industries. Their findings indicated that qualitative methods, that were frequently used, predominantly relied on personal and corporate experience, as well as engineering judgment. Besides that, the quantitative methods that were used, were not highly complex, implying that industry professionals often opt for straightforward quantitative approaches to complement their experiential and judgment-based risk assessments. Also Wood and Ellis (2003) and Dikmen, Birgonul and Arikan (2004) concluded that reliance on personal judgment and experience was prevailing. Most researchers that studied risk management in practice in the construction industry, concluded that the practical execution of risk assessment relies heavily on accumulated experience and individual judgment. This can be explained by the fact that high quality data is often not available and carrying out complex risk analysis methods requires a lot of skill and can take up much time.

However, this method can benefit from an analytical framework intended to assist construction industry experts in assessing risk by structuring their experiential insights and personal judgments. In the construction industry in the Netherlands, several risk management frameworks are known, such as ISO-31000, COSO ERMF and RISMAN. ISO-31000 is a structured policy document that can serve as a basis for risk management, developed in 2009. The document focuses on the steps of a risk analysis and the implementation of risk management, where core values of risk management, such as corporate culture, are also considered. The ISO-31000 framework can be applied in a wide variety of organizations and industries (Gjerdrum & Peter, 2011). ISO-31000 is not a fixed standard but rather serves as a guiding document based on the principles of risk management, with practical guidance on implementation being less detailed. The ISO-31000 framework is primarily designed for the management of risks at organizational level and less within the framework of projects. The COSO ERMF (Enterprise Risk Management Framework), developed in 2004 by COSO, is a detailed risk management model with twenty principles that can be used for the implementation of risk management within organizations. In the Netherlands, but probably also worldwide, COSO's ERMF is the most widely used risk management standard for companies (Paape, 2006; Simkins & Ramirez, 2007). Where the ISO-31000 framework places its emphasis on management processes, the COSO framework leans more towards aspects like audits, control mechanisms and compliance, rather than offering practical guidelines (Uiterlinden, 2005). After all, the COSO framework is primarily designed from a corporate and financial viewpoint. The RISk MANagement (RISMAN) framework is a method that is mostly known within infrastructure projects, as it is in fact specifically designed for projects, initiated by Rijkswaterstaat and Twynstra & Gudde in the 90s. More than COSO, RISMAN is focused on risk identification, analysis and response, rather than it serves as a monitoring framework as COSO. The main difference between ISO-31000 and RISMAN is that RISMAN was initially developed as a project risk management tool, designed for practical uses in projects, making it more application-proof.

RISMAN is often applied at earlier project phases (sometimes already in the tender). The method consists of identifying risks, classifying risks and identifying control measures. RISMAN is often applied iteratively in later project phases, because identified risks can disappear or new risks

can be identified. In addition, it is also the case that the effectiveness of control measures after implementation turns out to be different than expected and the control measures need to be updated.

3.2 Risk management pitfalls: Understanding decision-making heuristics and biases

No risk management method is fully capable of quantifying risks impacts on project success. All methods have their own flaws. Those can be in either the risk identification, analysis or response part of risk management. In this research, the focus is on the risk analysis, both before and after addressing risk responses. After all, the difference between risk scores before and after control measures, describe their effectiveness.

Risk is often expressed as a combination of the consequences of an event and the likelihood that that event will occur. Consequences are typically characterized using a categorial scale with ratings such as “insignificant, minor, moderate, major and catastrophic” and likelihood can for example be described as “rare, unlikely, possible, likely or almost certain”. Verbal methods like these are employed due to the belief that users can achieve a higher level of understanding and, consequently, utilize the method more reliably when straightforward labels are used. Hubbard and Evans (2010) however discussed some of the existing evidence that undermines this assumption. When various people interpret identical labels to convey vastly distinct meanings, problems in communication arise. In such cases, individuals might employ the same verbal description to discuss the likelihood of an event, assuming that they are in agreement, while in fact they might attribute different probability ranges to the same verbal label. Furthermore, a single person might assign varying probability ranges to the same label in different circumstances. This can be remedied by agreeing in advance on the ranges associated with the different verbal terms. For likelihood, this could be a percentage between 0 and 100% to describe the probability of the event occurring. For consequences in terms of time and money, the categories can be divided into percentages compared to the contract price or percentage compared to the planned lead time. This allows one to express how much more or less costs a risk will entail and how much longer or shorter a project will take if the risk occurs. For other scoring risks such as '(nuisance to) the environment', this is more difficult to express in a percentage and one will have to fall back on verbal descriptions, which again potentially cannot be interpreted unambiguously by different people.

Even if the probability- and risk categories can be made clearly understandable for different people, another limitation of the scoring method that lies in the subjective classification of consequence and probability cannot often be resolved (Duijm, 2015). The literature on risk management typically categorizes decision-making scenarios into three distinct types: certainty, risk, and uncertainty. In situations of certainty, every action leads to a predetermined outcome. In cases of risk, all potential outcomes and their associated probabilities are known. In uncertainty, outcomes might be known, but not all their probabilities are necessarily certain (Mousavi & Gigerenzer, 2014).

Decades of empirical research in psychology have shown that people struggle to accurately assess risk. Making decisions when faced with uncertainty can be exceptionally intricate, as individuals often need to consider a multitude of relevant pieces of information. This complexity

is compounded by the human brain's limitation in consciously processing only a limited amount of information at any given time, a phenomenon known as bounded rationality. The combination of bounded rationality, task complexity and the pressure of time imposes significant implications on the process of forming judgments. Constrained by these cognitive boundaries, people are forced to simplify their decision-making processes while simultaneously striving to maintain an acceptable level of accuracy. To navigate these challenges and arrive at decisions under uncertainty, individuals often turn to heuristics. Heuristics are simple decision rules that have been shaped through experience or over the course of evolution that enable quick judgments without the exhaustive integration of all available information. The advantage of heuristics lies in their ability to save time and effect while still yielding sound judgments and decisions in most cases (Kahneman & Tversky, 1972). Contrary to what is sometimes assumed, the trade-off between accuracy and effort is not the fundamental nature of a heuristic. Research on fast-and-frugal heuristics has shown that reduced effort can result in more accurate judgments. These heuristic strategies rely on deeply ingrained and developed cognitive skills, including memory and recall. This means that more calculation, time, and information are not always better. Shah and Oppenheimer (2008) propose that all heuristics rely on one or more of the following methods for effort-reduction: 1) Examining fewer cues; 2) Reducing the difficulty associated with retrieving and storing cue values; 3) Simplifying the weighting principles for cues; 4) Integrating less information and 5) Examining fewer alternatives. They emphasize that people do not explicitly choose these effort-reduction strategies, but that heuristics they use consist of these effort-reduction principles, even if they are not aware of them

Individuals instinctively depend on a series of heuristic methods that frequently prove beneficial, yet can occasionally lead to biased outcomes (Morgan & Henrion, 1990). A decision becomes biased when certain information is assigned incorrect importance, such as the overestimation of a risk. Biases exert a more significant influence on decisions in cases where there is insufficient information or when the available information is too complex to be easily processed. However, critics argue that labeling these situations as bias may not always be accurate. Instead, individuals often adapt to the specific context by using the best judgment tools available to them in that particular situation (Neth & Gigerenzer, 2015). Numerous heuristics can be applied across various circumstances, but they tend to be most effective within specific sets of situations. Errors may occur when a heuristic, proven effective in one problem, environment, or context, is applied in a decision scenario where it is not well-suited (Reimer & Rieskamp, 2007).

So far, studies on the human elements of construction and project risk management have focused on three distinct areas: determining subjective probabilities, investigating heuristics and biases, and conducting surveys of risk management practices within the construction industry. Mak (1992, 1995), Mak & Raftery (1992) and McKim (1991, 1992) have examined behavioral approaches to decision-making for construction and project risk management. The general conclusion they draw is that professionals in the construction industry exhibit just as many heuristics and biases in their judgments as the population as a whole. In other words; their decision-making abilities are not significantly better, which suggests that most construction professionals would benefit from a more explicit and thorough understanding of the intellectual processes of decision-making (Raftery 1994b). It is important to state that heuristics have their benefits, but they should be prevented from leading to biased outcomes.

Tversky and Kahneman (1974) distinguished three types of heuristics: the *representativeness* heuristic, the *availability* heuristic and the *adjustment* and *anchoring* heuristic. Research into heuristics and biases mainly focused on the nature of cognitive biases and how they influence decision-making. In recent years, research has focused more on understanding why some individuals exhibit heuristics and biases on certain tasks and other individuals do not (West, Meserve & Stanovich, 2012). Subsequently, numerous heuristics have been identified in recent decades that no longer fit within Tversky and Kahneman's (1974) classification (Blumenthal-Barby, 2016). Blumenthal-Barby and Krieger (2015) identified nineteen different types of heuristics and biases through an analysis of 214 empirical studies focused on biases and heuristics in judgment and decision-making. In several studies, the identified biases overlap and sometimes different names are used for what appears to be the same heuristic. The table below briefly describes the 19 biases as identified by Blumenthal-Barby and Krieger.

Table 1. Identified biases and heuristics from Blumenthal-Barby and Krieger (2015)

Biases/Heuristics	Definition
Affect heuristic	Relying on emotions, rather than on concrete information when making decisions
Ambiguity aversion	The display of preferences for known or certain probabilities over uncertain probabilities regardless of actual benefits
Anchoring bias	Rely too heavily on the first piece of information they receive on a topic, regardless of the accuracy of that information
Availability bias	Rely on immediate examples that come to a given person's mind when evaluating a specific topic, concept, method, or decision
Brandwagon effect	Tendency to adopt certain behaviors, styles, or attitudes simply because others are doing so
Commission bias	Tendency towards action, even in a situation where not performing an action results in the same, or even better outcome
Confirmation bias	Tendency to search for, interpret, favor, and recall information in a way that confirms or supports one's prior beliefs or values
Decoy effect	Tendency to have a specific change in preference between two options when also presented with a third option that is asymmetrically dominated
Default bias or status quo bias	Tendency to generally accept the default option in a strategic interaction, because the disadvantages of leaving it loom larger than advantages
Frequency/percentage framing effect	Frequency scales generally lead to higher perceived risk
Impact bias	Failure to anticipate our remarkable ability to adapt to new states. People tend to overestimate the long-term impact of both positive events and negative events
Loss/gain framing bias or loss aversion bias	Tendency to make risk-avoidant choices when options are positively framed, while selecting more loss-avoidant options when presented with a negative frame
Omission bias	People prefer omission (inaction) over commission (action) and people tend to judge harm as a result of commission more negatively than harm as a result of omission
Optimism bias or optimistic overconfidence	Tendency to overestimate the likelihood of positive events and underestimate the likelihood of negative events
Order effects: primacy/recency	Differences in research participants' responses that result from the order (e.g., first, second, third) in which the experimental materials are presented to them

Outcome bias	Allowing a prior event or decision outcome to influence subsequent independent decisions
Relative risk bias	A stronger inclination to [choose treatment] when presented with the relative risk than when presented with the same [information] described in terms of the absolute risk
Representativeness heuristic	We estimate the probability of an event based on how similar it is to a known situation, prototype or stereotype we already have in mind
Sunk-cost effect	We continue to support our past decisions despite new evidence suggesting that it isn't the best course of action

Given that this is a fairly long list which currently lacks a coherent structure, it would be beneficial to organize the heuristics and biases into distinct categories. One potential division involves categorizing cognitive biases, stemming from how the information is processed, and motivational biases, which emerge due to preferences for specific outcomes (Montibeller & Von Winterfeldt, 2015). Those effects can be present at the same time (MacCoun, 1998). Arkes (1991) also categorizes biases according to their psychological origins. These include 1) strategy-based errors, which occur when decisionmakers use a suboptimal cognitive strategy, 2) association-based errors, which are a consequence of automatic mental associations and 3) psychophysically-based errors, which result from incorrect mappings between physical stimuli and psychological responses.

Moreover, a clear distinction exists between conscious biases and unconscious biases. Conscious biases, also referred to as explicit biases, are characterized by an individual's awareness of their biases and intentional actions based on those biases. These biases often involve prejudiced attitudes with a malicious intent. On the other hand, unconscious biases, or implicit biases, are beliefs and attitudes that operate beneath the surface of one's awareness. These biases can be in conflict with an individual's consciously held beliefs and values. Identifying unconscious biases, particularly within oneself, is challenging. These biases may exert a more subtle influence on actions and behaviors compared to conscious biases, often without the individual realizing it. Neth and Gigerenzer (2015) mention the absence of a comprehensive taxonomy and emphasizes that heuristics aren't independent but rather interconnected, sharing knowledge structures. Nonetheless, they also propose the utilization of categories like recognition-based rules, heuristics relying on one good reason, and trade-off heuristics.

Heuristics can also be divided into different factors of risk perceptions which they have influence on. Godovykh, Pizam and Bahja (2021) describe that factors affection risk perceptions can be broadly classified into cognitive, affective, individual and contextual types.

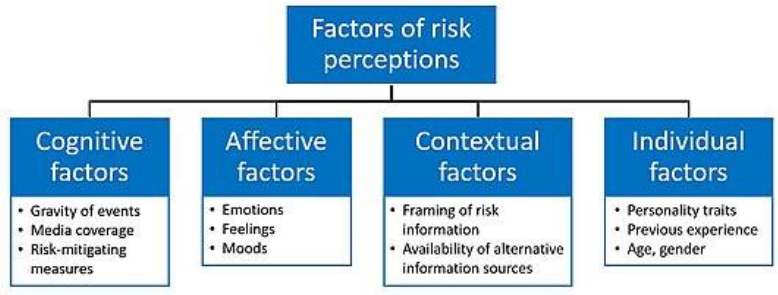

Figure 1. Factors of risk perception (Godovykj, Pizam and Bahja, 2021)

The table presented below reorganizes the 19 biases identified by Blumenthal-Barby and Krieger (2015) based on the origin of their occurrence or the utilization of heuristics. Additionally, it specifies whether each bias is classified as cognitive or motivational. Biases highlighted in green are the ones that will be addressed in the exploratory interviews with project managers and risk managers in the practical field (Chapter 4). These biases appear to be closely associated with risk assessment using RISMAN, the focal point of this study. The biases have sufficient spread over the different categories of its origin.

Table 2. Categorization of heuristics and biases

Origin of heuristic / bias	Heuristic / bias	Definition	Cognitive / Motivational
Misinterpretation / wrong use of data	Affect heuristic	Relying on emotions, rather than on concrete information when making decisions	Motivational
	Confirmation bias	Tendency to search for, interpret, favor, and recall information in a way that confirms or supports one's prior beliefs or values	Motivational
	Decoy effect	Tendency to have a specific change in preference between two options when also presented with a third option that is asymmetrically dominated	Cognitive
	Frequency/percentage framing effect	Frequency scales generally lead to higher perceived risk	Cognitive
	Impact bias	Failure to anticipate our remarkable ability to adapt to new states. People tend to overestimate the long-term impact of both positive events and negative events.	Cognitive
	Outcome bias	Allowing a prior event or decision outcome to influence subsequent independent decisions	Cognitive
	Relative risk bias	A stronger inclination to [choose treatment] when presented with the relative risk than when presented with the same [information] described in terms of the absolute risk.	Cognitive

Missing data	Ambiguity aversion	The display of preferences for known or certain probabilities over uncertain probabilities regardless of actual benefits	Cognitive
	Representativeness heuristic	We estimate the probability of an event based on how similar it is to a known situation, prototype or stereotype we already have in mind	Cognitive
Failure to consider alternatives	Anchoring bias	Rely too heavily on the first piece of information they receive on a topic, regardless of the accuracy of that information	Cognitive
	Default bias or status quo bias	Tendency to generally accept the default option in a strategic interaction, because the disadvantages of leaving it loom larger than advantages	Cognitive
	Order effects: primacy/recency	Differences in research participants' responses that result from the order (e.g., first, second, third) in which the experimental materials are presented to them	Cognitive
	Sunk-cost effect	We continue to support our past decisions despite new evidence suggesting that it isn't the best course of action	Cognitive
Reliance on earlier events / ignoring data	Availability bias	People rely on immediate examples that come to a given person's mind when evaluating a specific topic, concept, method, or decision	Cognitive
	Brandwagon effect	Tendency to adopt certain behaviors, styles, or attitudes simply because others are doing so	Cognitive
Use of intuition	Commission bias	Tendency towards action, even in a situation where not performing an action results in the same, or even better outcome	Cognitive
	Loss/gain framing bias or loss aversion bias	Tendency to make risk-avoidant choices when options are positively framed, while selecting more loss-avoidant options when presented with a negative frame	Cognitive
	Omission bias	People prefer omission (inaction) over commission (action) and people tend to judge harm as a result of commission more negatively than harm as a result of omission	Cognitive
	Optimism bias or optimistic overconfidence	Tendency to overestimate the likelihood of positive events and underestimate the likelihood of negative events	Motivational

3.3 Mitigating biases in risk management

Due to the inherent connection between heuristics and bias, there is a widely embraced notion that employing heuristics invariably leads to errors in decision-making. This perspective assumes that individuals are consistently irrational and prone to poor decision-making (Ika, Love & Pinto, 2023). However, other researchers view heuristics as an advantage rather than a drawback (Katsikopoulos and Gigerenzer, 2013). They argue that heuristics prove adaptive in addressing real-world decision problems, particularly in situations of uncertainty. This argumentation assumes that heuristics are not rigid and can be adjusted to, for example, mitigate the occurrence of biased choices.

One strategy in dealing with biases is 'debiasing', which refers to attempts to eliminate or at least reduce cognitive or motivational biases. Debiasing strategies are designed to increase objectivity in critical decisions. They could assist individuals in overcoming the limitations of their decision-making skills when biased perspectives lead to incorrect risk assessments. Based on Arkes' taxonomy (1991), as previously outlined, Montibeller and Von Winterfeldt (2015) categorize biases into three groups: cognitive biases that are challenging to correct, motivational biases that are challenging to correct, and cognitive biases that are easily correctable. They also identify the specific areas in decision and risk analysis where these biases occur and provide a list of major biasing techniques. According to their framework, biases that are difficult to correct tend to resist logical reasoning, decomposition, and the application of training and analytical tools. Motivational biases are universally classified as hard to correct. Despite the authors' observation that motivational biases are infrequently addressed in the literature, they emphasize that, in contrast to the discussed cognitive biases, all discussed motivational biases are relevant to decision and risk analysis.

Larrick (2004) categorized debiasing strategies into motivational, cognitive, and technological approaches. Motivational strategies operate under the premise that individuals can employ normative reasoning when sufficiently motivated. Increasing motivation may involve holding individuals accountable for their decisions or providing additional incentives. On the other hand, cognitive and technological strategies are grounded in the belief that intuitive approaches are inherently flawed and should be replaced with methods aligning more closely with normative standards. Cognitive strategies aim to mitigate biases by introducing context-specific rules, such as encouraging individuals to "consider the opposite" or through educational training. In contrast, technological strategies leverage tools beyond the decision maker's direct control. This category includes computer-based applications like decision support systems and alterations in information presentation, such as decision aids that present risks in a balanced fashion.

Bhandari and Molenaar (2020) compiled a comprehensive overview of popular debiasing strategies, especially in risk management applications. The strategies covered include nudges, cognitive diversity, cognitive mapping, scenario planning, consider the unknown, delayed decision-making, consider the opposite, third-party intervention, and training. Among these, training stands out as a widely used method for reducing biases, adaptable to target specific biases (Morewedge, Yoon, Scopelliti, Korris & Kassam, 2015). It's been proven to heighten awareness of personal biases, particularly in intuitive decision-making situations, leading to better long-term choices (Aczél, Bagó, Foles & Lukács, 2015). Such trainings help risk assessors in rationally evaluating probabilities. Pairing training with third-party intervention extends its

effectiveness by fostering discussions and avoid biased decision-making during risk management processes. While other techniques mentioned are less versatile than training, they can still prove effective in specific scenarios. For instance, considering the unknown prompts risk assessors to play the devil's advocate, scrutinizing uncertainty across potential choices and outcomes. This control mitigates biases like confirmation bias, optimism, and anchoring. The technique of considering the opposite encourages assessing arguments for alternative choices, pushing assessors to seek more cues to evaluate probabilities beyond relying solely on memory, countering availability bias (Anderson & Godfrey, 1987). This approach also prompts assessors to become mindful of missing information and adjust their evaluations accordingly. Cognitive mapping involves experts evaluating the entire risk assessment and decision-making process, including how information and choices are presented (framing).

The research findings unequivocally reveal that the degree of bias and its impact on risk ratings tends to fluctuate across various scenarios and in relation to diverse risk attitudes. Aggregating these responses poses a significant challenge, as identifying a singular debiasing formula applicable to every scenario proves to be elusive (Dikmen, Budayan, Birgönül and Hayat, 2018). Instead of relying on the aggregation of individual responses, they mention a more dependable approach, anticipated through group decision-making. In that method, risk ratings are established through a group consensus that stems from a shared comprehension of project conditions and scenarios.

3.4 Analysis of the literature findings

The review of literature indicates that heuristics are commonly employed in risk assessment, whether consciously or unconsciously. Utilizing heuristics can be beneficial in situations where time and/or information constraints hinder a thorough analysis of risks. Nevertheless, it is acknowledged that relying on heuristics may also lead to biased decision-making in relation to risks. The absence of a clear taxonomy for heuristics and biases poses a challenge in identifying, distinguishing, and preventing their occurrence through a standardized process. This study, like others, has attempted categorization based on the origins of biases, but these categories are not always mutually exclusive. Occasionally, a bias may arise from various causes.

A comprehensive inventory of heuristics in decision making has been made. The extent to which these heuristics are recognized in practice in the construction industry and how their presence is perceived can be assesses by professionals from the field. To delineate the scope for this assessment, an initial funneling of heuristics and biases known in the literature was conducted, based on the researcher’s evaluation of the likelihood of biases occurring in the RISMAN process. Also, training is mentioned as a versatile debiasing method as it can be specifically designed to reduce certain biases on which is focused.

3.5 Conclusion of the literature study

A literature study was conducted to obtain a theoretical lens from the state of the art literature on biases in relation to using heuristics in project risk assessment. In conclusion, this literature review has provided a comprehensive exploration of the theoretical perspectives derived from recent literature on biases in the context of the use of heuristics in project risk assessment. The focus was on understanding the application of risk management in the construction industry,

the pitfalls associated with decision-making heuristics and biases in risk management, and strategies for mitigating biases.

The research into risk management in construction highlighted the challenges posed by the dynamic nature of construction projects and highlighted the importance of effective risk management for project success. The literature review mapped the historical development of risk management in construction, noting a shift from mathematical approaches to more systematic processes that include risk identification, analysis and response. Furthermore, the study delved into the influence of biases and heuristics in risk assessment, especially in the construction industry. The literature has emphasized the reliance on personal judgment and experience in risk analysis, as well as the challenges arising from the subjective nature of risk categories and the limitations of human cognitive processes. The identification and categorization of different heuristics and biases, as well as their potential impact on risk assessment, were discussed in detail. The literature review presented a rich landscape of cognitive biases, ranging from representativeness and availability heuristics to adaptation and anchoring heuristics. The study recognized the complexity of decision making under uncertainty, influenced by factors such as bounded rationality and the need for simplification through heuristics.

Moreover, the literature study explored strategies for mitigating biases in risk management, with a focus on debiasing techniques. The division of biases into cognitive and motivational provided a framework for understanding the challenges associated with each type. Strategies for eliminating bias were discussed, focusing on the potential benefits of training as a versatile method for reducing biases.

The findings also underlined the importance of considering risk perceptions and individual factors that influence decision-making in the construction industry. The literature review forms the basis for the next phase of the research, which involves semi-structured interviews with project managers and risk managers from Dura Vermeer. Through these interviews, the aim is to identify specific heuristics leading to biased choices and understand whether they stem from individual factors or the framing of risk information within the standard business process for risk management.

This literature review provides a solid foundation for further research, shedding light on the theoretical perspectives, challenges and possible solutions related to biases in the context of using heuristics in project risk assessment, especially within the construction industry.

4. Biases in risk analysis from experience

The purpose of this chapter is to answer the second subquestion: *"How is project risk assessment performed in practice? What heuristics are used and what biases are identified?"*. Risk management at Dura Vermeer will be considered through semi-structured interviews with project managers and risk managers from Dura Vermeer. The aim is to identify the main heuristics that potentially lead to biased choices and to focus on them in the remainder of the research. Exploratory semi-structured interviews were conducted with three risk managers and three project managers from the field, all working at Dura Vermeer. The risk analysis process, possible biases and bias interventions are considered. This chapter is structured in the same way as the interview protocol (Appendix A), which is divided into three parts. In section 4.1, risk decision-making in practice at Dura Vermeer is considered (part 1 of the interview). In section 4.2, the perceived presence and possible problems resulting from heuristics and biases are discussed (part 2 of the interview), followed by section 4.3, which outlines the knowledge of debiasing intervention strategies and suggestions for them (part 3 of the interview). Subsequently, in section 4.4, an answer to sub-question 2 is formulated.

4.1 Risk decision-making in practice

In this and the following sections, the answers of the various interviewees to the same questions are considered. The aim is to consider both the similarities and differences between the answers in order to arrive at a complete picture of risk analysis in practice at Dura Vermeer. Below a summary of the results from this interview section is given. The full answers can be found in table 3 in appendix B. The interviews were analyzed by transcribing the responses and searching for patterns/similarities or notable differences in the answers from the risk managers and project managers.

Summary of the results:
The interviewees unanimously express their adherence to the RISMAN methodology, as mandated for the entire infrastructure division at Dura Vermeer. While most state that they usually compile a risk file during the tender phase, some acknowledge that this may not always occur due to time constraints or insufficient personnel. Moreover, the allocation of risks between the contractor and the client, dictated by the contract form, as well as a risk assessment requested by the client in the tender phase influences whether risk analysis already takes place in the tender phase.

Two out of the six interviewees underscore that the tender phase tends to adopt an overly optimistic perspective on potential risks. They note that both the probability and consequence scores are adjusted upwards during the execution phase of the project when reconsideration of risks takes place.

A participant in the interviews reveals that, in tenders, the consequences of risks on financial aspects are regularly quantified in such a way that the potential financial consequential damage is equal to a standard percentage that is sometimes included for risks in the tender price. This participant highlights the challenge when actual risks are significantly higher, suggesting the

need for a larger risk provision or even reconsideration of participation in the tender to avert potential financial losses.

Five of the six interviewees mention a collective brainstorming session as the starting point for risk analysis to identify potential risks. They stress the importance of involving a diverse range of specialists, including for example those in design management and environmental management, to create a comprehensive file across various disciplines. The sixth interviewee indicates being accustomed to having the project manager or risk manager carry out the process of developing the risk dossier. In this process, which includes identifying risks, quantifying the likelihood and consequences, and identifying control measures, input is obtained through individual interviews conducted with specialists possessing risk knowledge. Two out of the five interviewees that are familiar with plenary risk sessions, express a preference for subsequent individual sessions with those specialists for quantification, focusing solely on risks within their respective disciplines. One of these individuals specifies that control measures are only inventoried during these individual sessions. The remaining three interviewees opt for quantification during the plenary session, with agreement reached through mutual discussion.

The risk managers indicate their role in facilitating the risk sessions and subsequently building the risk dossier. Project managers also express a preference for assigning this task to the risk managers. One of the interviewed risk managers mentions that this role is sometimes assigned to a risk manager from the client when risk management occurs collaboratively during the execution phase. Nearly all interviewees highlight a crucial responsibility for the facilitator of risk sessions in ensuring that everyone has a voice and in identifying and preventing incorrect and biased assessments.

Four out of six interviewees indicate that a common understanding of risk is crucial for a proper assessment of the risk. Sometimes, risks are stated in a vague or incorrect manner (for example, the consequence of the risk is identified as the actual risk), leading participants in the risk session to have different perceptions of which risk is actually being assessed. A shared understanding of scores for consequential categories such as time and money is also considered crucial. For instance, increasing percentages of the contract sum may correspond to different scores for financial consequential damages when a risk occurs. In this way, the consequential score is measurable. The collective quantification of risks in a plenary setting is mentioned in the interviews both as a potential success factor and a potential failure factor in risk analysis. Discussions about the likelihood and consequences of risks can be constructive as they help to establish a clear understanding of a risk and eliminate individually incorrect assessments by allowing others to correct them. However, a plenary session also poses a pitfall, as in group dynamics, a few individuals may dominate others, giving the impression that a consensus has been reached on the assessment when it may not be the case.

All interviewees indicate that they eventually work towards a top 3, 5, or 10 list of risks. This is done for practical reasons to be able to focus on predominantly managing the most significant risks. However, this results in the possibility of evaluating risks relative to each other, rather than treating them as separate risks each time. One of the interviewees mentions that at the end of the plenary session, the top 10 is considered, and if it does not align with the gut feeling about the most significant risks, the quantification may be adjusted to either include or exclude risks from the top 10.

The interviewees all indicate that they have been applying the RISMAN methodology for decades, with no changes in its application. However, they note that risk management has gained more attention in the last 15-20 years, both from clients and internally within the company. The role of a risk manager as a distinct position has also emerged in the last 15-20 years. Previously, the project manager was responsible for assessing and managing risks, and it received less attention. It is mentioned that documentation of risks is now more structured, which is mainly practical for building a comprehensive file but does not impact the analysis of risks itself. Lastly, one interviewee pointed out that RISMAN is increasingly being combined with software programs. Following the analysis, for example, a Monte Carlo analysis is conducted to determine an appropriate risk provision.

4.2 Heuristics and biases in the risk analysis

At the start of the next part of the interview, table 2 (section 3.3) with the ten heuristics/biases marked in green was presented. Subsequently, both the recognition of the heuristics/biases from practice and the problems for the analysis if a bias occurs were questioned. Below a summary of the results from this interview section is given. The full answers can be found in table 4 in appendix B.

Summary of the results:
From the six interviews, it is evident that many of the heuristics and biases are recognized in practice. Some interviewees even claimed to recognize all discussed heuristics and biases. The interviews also revealed a poor understanding of the names and definitions of heuristics and biases; these terms were new to all interviewees. This confusion led to instances where when citing an example for bias x, the interviewees were actually providing an example for bias y. This discrepancy was corrected during discussions with the interviewees and in processing their responses.

The affect heuristic, in which judgment is influenced by emotion, is universally acknowledged. Two of the interviewees draw a connection between the affect heuristic and the representativeness heuristic: when someone identifies something from another project (representativeness), they may evaluate it emotionally (affectively). Half of the interviewees indicate that they view the representativeness heuristic as more advantageous than obstructive. They contend that the most reliable assessment is grounded in experience from other projects. Concerning confirmation bias, it is observed to be a "human" tendency and quite prevalent. The anchoring bias is considered a potential issue when previous risks influence subsequent risk assessments. In other words, anchoring bias occurs when risks are evaluated in relation to each other rather than through an individual, objective assessment. This often occurs in risk sessions where a top 3, 5, or 10 ranking is sought. Nevertheless, when aiming to identify the top 3 risks and the fourth is slightly smaller in comparison to the first three but still significant, it would be advisable not to overlook it. The status quo bias is more recognized in the establishment of control measures than in risk assessment. In control measures, this can lead to consistently implementing the same measures to control a specific risk, even when a different project might require a completely different control methodology under different circumstances. One interviewee mentioned the sunk cost effect as more relevant to control measures too. In such cases, one might adhere to a particular control measure simply because costs have already been incurred, even if it may not be the most effective measure. The availability bias was often

considered similar to the representativeness heuristic. All participants believed that another representative project comes available to mind first when analyzing risks, and they base their judgment on that. One of the interviewees also cited examples of the availability bias within the infrastructure sector, such as issues like PFAS contamination or the introduction of the new environmental law. When these factors are frequently highlighted in internal and external information sharing, they tend to appear more frequently in risk files. The bandwagon effect was universally recognized when one or a few individuals dominate the discussion. The interviewees state that the facilitator of risk sessions plays a crucial role in ensuring that these individuals do not dominate, and the opinions of all participants are heard. The gain-loss framing bias was predominantly not often recognized because risks generally need to be framed negatively. A positive framing of a risk would be considered incorrect and should be corrected before proceeding to risk assessment. The optimism bias was recognizable to everyone, and all mentioned that optimism is much greater in the tender phase than in the execution phase, where a more realistic outlook is adopted according to the interviewees.

The occurrence of the commission bias was identified from question 9. In the subsequent interview where this bias was presented, it was also mentioned that it is recognized in practice. Additionally, aspects of group dynamics, namely power games and personal authority, were mentioned twice as influential on the analysis during plenary risk sessions.

Interviewees identified a varying number of biases and heuristics as most common and problematic. Since all biases were recognized multiple times in the six interviews, the occurrence of these biases and heuristics seems certain. However, there is disagreement among interviewees regarding the problematic nature of these heuristics and biases when they occur. Availability bias, confirmation bias, loss/gain framing bias, and sunk-cost effect were mentioned once as the most problematic, while the bandwagon effect was mentioned twice and the affect heuristic, representativeness heuristic and optimism bias were mentioned three times.

There is no clear distinction between what risk managers and project managers consider as the most problematic heuristics and biases. Risk managers sequentially identify affect heuristic (RM-1), representativeness heuristic (RM-2), and availability bias, confirmation bias, and bandwagon effect (RM-3) as the most problematic. On the other hand, project managers identify representativeness heuristic, gain-loss framing bias (PM-1), affect heuristic, sunk cost effect, and optimism bias (PM-2), and affect heuristic, representativeness heuristic and optimism bias (PM-3) as the most problematic. The assessments differ between risk managers as is also the case for project managers. At the same time, assessments from individuals from different groups (risk managers vs. project managers) show overlapping perspectives. It is noteworthy that biases related to costs (gain-loss framing bias and sunk cost effect) were deemed most problematic by project managers on both occasions. This could potentially be explained by their role, which involves a greater focus on cost management compared to risk managers.

4.3 Debiasing intervention strategies

In this section, the knowledge of debiasing strategies in practice at Dura Vermeer is outlined, based on the interviews. Below, a summary of the results from this interview section is provided. The complete responses can be found in Table 5 in Appendix B.

Summary of the results:
The interviewees indicate that they are not familiar with specific debiasing interventions. When asked if they are familiar with such interventions, reference is repeatedly made to the current applied methodology (e.g., joint assessment, facilitator acting as devil's advocate, letting specialists speak first) as a means to prevent biases. However, it becomes apparent that there are no specific interventions targeting biases. While the value of implementing interventions is acknowledged, there is a cautionary note about the potential 'burden' it may pose for participants in risk sessions. Interviewees mention that dealing with risks is generally challenging, and an additional element can be demotivating. Demotivation is cited as a pitfall because maintaining a positive flow is deemed essential for collaboratively exploring solutions to risks. Demotivation is also mentioned as a potential outcome of excessive discussion. At the same time, it is noted that discussion can have a positive impact on risk sessions, encouraging participants to challenge each other in the quest for a risk solution and to be critical of each other's potentially flawed assessments.

It is noted that debiasing interventions could potentially make assessments more objective. As a suggestion for debiasing interventions, there is a predominant reference to group dynamics where individuals assess independently, and participants subsequently 'check' each other. One alternative approach mentioned by one of the interviewees is to have specialists from different disciplines assess each other's risks. This allows the risk to be considered from a perspective other than the usual one within a specific field of expertise. This approach can lead to new insights, rather than having a designer consistently assess a specific design risk in the same way. The 'crystal ball method' is also highlighted, where participants in a risk session are asked to visualize for themselves how the situation would be if a risk occurs and then to reflect on the possible causes. This is believed to contribute to a better understanding of the considered risks. Additionally, raising awareness of the presence of possible biases is considered effective, although it is emphasized that this is likely to quickly fade from people's thoughts and should be reiterated before each session.

In response to the concluding question (*what question did you expect, but wasn't asked?*), almost all interviewees express that they anticipated a focus on examples of specific risks prevalent in the sector. The current topic was a surprise for all, something new to draw special attention to within risk analysis.

4.4 Conclusion of the interviews

The interviews conducted with project and risk managers at Dura Vermeer shed light on the methodologies and practices employed in project risk assessment within the infrastructure division. The results of the interviews can be used to describe how project risk assessment is conducted at Dura Vermeer and to identify the heuristics and biases present within it.

The RISMAN methodology serves as the cornerstone for risk management activities, although its application may vary due to factors such as project timelines and personnel availability. The process typically involves compiling a risk file during the tender phase, with adjustments made during execution based on actual project experiences. During the tender phase, there's a noted tendency towards optimism in risk assessment, with adjustments made during the execution phase based on actual project realities. Risk assessment sessions typically involve collective brainstorming, with input from a diverse range of specialists. While plenary sessions are common, there's a preference among some for subsequent individual sessions to focus on discipline-specific risks. The role of facilitators, often risk managers, is crucial in ensuring all voices are heard and biases are mitigated. However, there's a recognized need for better understanding and addressing biases within the risk assessment process.

Various heuristics and biases were identified among the interviewees, although terminology confusion was evident. Despite this, biases like the affect heuristic, representativeness heuristic, confirmation bias, and optimism bias were recognized as common pitfalls. There's a discrepancy in perceptions regarding the most problematic biases, with project managers often emphasizing biases related to costs. While specific debiasing interventions are not familiar to interviewees, there's acknowledgment of the need for such strategies. Suggestions include independent assessments followed by group discussion, involving specialists from different disciplines, and raising awareness of biases before each session. However, there's caution regarding the potential demotivating effect of excessive intervention.

Furthermore, the way the risk management process is structured contains internal aspects that influence the assessment: the tender phase tends to adopt an overly optimistic perspective on potential risks, risks are stated in a vague or incorrect manner (for example, the consequence of the risk is identified as the actual risk) and all interviewees eventually work towards a top 3, 5, or 10 list of risks.

Moreover, while recognizing the existence of presented biases, there remains a lack of consensus regarding which biases pose the most significant challenges. Furthermore, it is acknowledged that some biases may serve a functional purpose (1). Interviewees mention that they are not familiar with specific debiasing techniques, and it is highlighted that introducing a new component to the assessment method may potentially lead to demotivation (2). Additionally, creating awareness about the existence of potential biases is considered effective (3). Because of the above-mentioned three reasons, indicated as (1), (2), (3), the focus for the remainder of this study shifts from *de*biasing to *dealing* with biases. The emphasis should be on increasing awareness of biases to help individuals deal with biases more effectively.

5. Use and awareness of biases in practice

The purpose of this chapter is to answer the third subquestion: "*To what extent are identified biases/heuristics actually used in risk assessment/management, and to what extent are people aware of that?*". To answer this question, a serious game in the form of a questionnaire has been distributed among risk managers, project managers, and tender managers (responsible for the project team in the tender phase). In section 5.1, the design of the serious game (dilemma game) is described, as well as the conditions that a serious game must meet. It is detailed how the dilemma answers were processed for analysis purposes. The results of these analyses are described in various subsections in section 5.2, after which in section 5.3 an answer is formulated to subquestion 3.

5.1 Serious game as questionnaire

Serious games motivate participants to learn and change the way they learn. In the literature, general conditions of a serious game can be found (Heijer, Podt, Bosch-Rekveldt, De Leeuw & Rijke, 2023): 1) The game should have the ability to simulate complexity in risk management. The game should serve as a representation of reality, maintaining playability while providing a clear resemblance to real-world situations (Simulation); 2) The game should offer a distraction-free environment to participants, minimizing distractions through stylistic (writing) choices (Unambiguous, Understandable); 3) The game should be playable by project teams and reach a relatively large target audience (Scalable); 4) The game should enhance participants' understanding of various roles through the simulation process and reflection on outcomes (Valuable); 5) The game should respond to participants' actions through in-game feedback or discussions among participants (Interactive).

The serious game in this research is designed as followed:

- Participants face a dilemma on how to act in order to arrive at a risk assessment where they must choose between two options. The focus is not on scoring the risk, but rather on the assessment- and management process. Biased responses in risk assessment are 'hidden' in the answer options. The dilemmas simulate the complexity often recognizable in risk analysis; making a plan for the assessment and management of risks with limited time, resources, and knowledge of the risks (Simulation).
- The presented risks have been obtained from a scan of risk files on completed or current projects of Dura Vermeer, ensuring they should be recognizable in content and wording (Unambiguous, Understandable, Simulation).
- The answer options are structurally composed of two elements: 1) a methodology for assessing risk (systematic (=objective) vs. based on biases/heuristics) and the tendency one has in risk management (risk-averse vs. risk-tolerant) (Unambiguous).
- The dilemmas and answer options are incorporated into an online questionnaire (in survey software Qualtrics), making it easy to distribute the dilemma game to a large audience (Scalable).
- After capturing and processing the results, it becomes clear how colleagues from different roles respond to presented risks, allowing for joint evaluation of what this means for the risk analysis process (Valuable).

- To fully execute the game within limited time and due to the constraints of this research, it was decided not to add an interactive element during the game (~~Interactive~~). In a joint evaluation session, however, interaction can be encouraged. It may add value to explore the influence of interactivity on answering the dilemmas in future research.

From the interviews (Chapter 4), it has been found that three heuristics/biases are frequently mentioned as most common and potentially problematic, namely the representativeness heuristic, affect heuristic, and optimism bias. Therefore, these three heuristics/biases are included in the dilemma game.

As mentioned, the answer options consist of two elements: 1) a methodology for assessing risk (systematic (=objective) vs. based on biases/heuristics) and the tendency one has in risk management (risk-averse: making safe, cautious decisions to minimize risks vs. risk-tolerant: willingness to accept a certain degree of uncertainty in decisions). For example, response option 1 could describe a systematic (objective) assessment + risk-averse management (bottom left quadrant in figure 2), and response option 2 a biased assessment and risk-tolerant management (top right quadrant in figure 2).

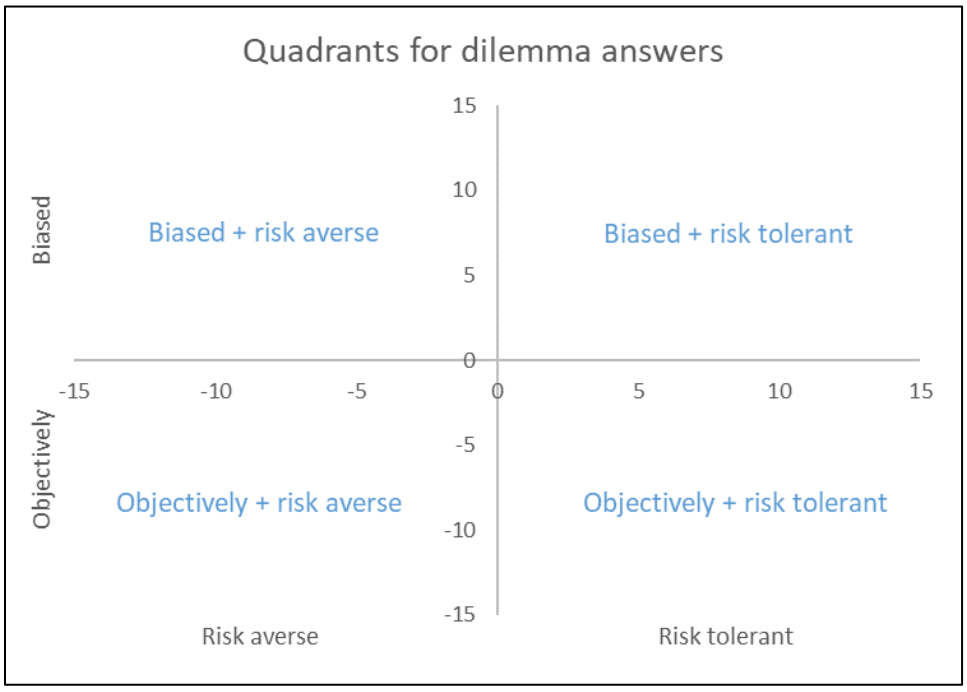

Figure 2. Quadrants for dilemma answers

An example of the presented risks and answer options is provided in figure 3.

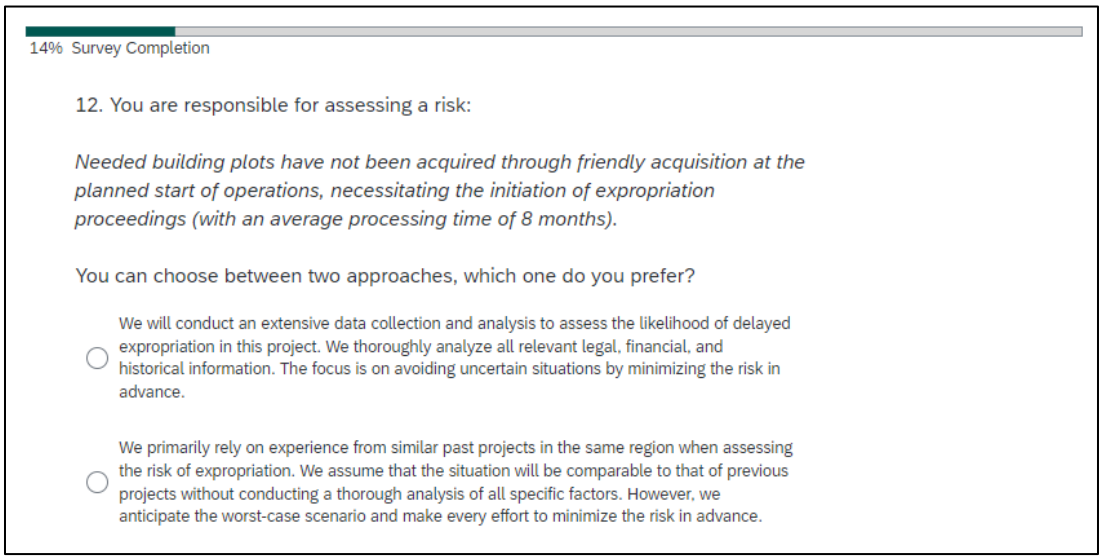

Figure 3. Risk dilemmas in Qualtrics

In the first answer option, an objective assessment and risk-averse management approach are 'hidden' (bottom left corner), while in the second answer option, a biased assessment and risk-averse approach to control are present (top left corner), with the biased assessment occurring according to the representativeness heuristic.

For each dilemma, answer options from two different quadrants are offered. With two answer options out of four variants, six different combinations can be made that need to be presented: 1) top left vs. top right; 2) top left vs. bottom left; 3) top left vs. bottom right; 4) top right vs. bottom left; 5) top right vs. bottom right; and 6) bottom left vs. bottom right. To incorporate the three different biases (representativeness heuristic, affect heuristic, and optimism bias) in the biased answer options, a total of 18 different dilemmas need to be presented (6 times 3), with 6 dilemmas devised for each of the three biases. The complete overview of the presented risks and answer options can be found in Appendix C.

In addition to asking the preferred assessment and management approach in the various dilemmas, the respondent's role, years of work experience in the infrastructure sector, and years of experience with risk management were also requested. Furthermore, after responding to the dilemmas, respondents were asked to what extent they found the presented risks representative of real-world situations, whether they considered themselves more risk-averse or risk-tolerant, how much they thought they would rely on the three mentioned biases/heuristics, and whether the assessment method (systematic / objective vs. based on biases) or the level of risk aversion/tolerance was most decisive in answering the dilemmas.

5.2 Results of the dilemma game

The dilemma game was conducted by 25 respondents, including 6 risk managers, 9 tender managers, and 10 project managers. Project managers and risk managers are jointly responsible for managing risk registers, which include assessments and control measures, and for allocating these control measures. During the tender phase, this responsibility lies with the

tender manager or risk manager if they are already involved at this stage. The link to the questionnaire in Qualtrics has been distributed among the members of these three job function groups. The respondents' experience in the infrastructure sector ranges from six months to 30 years, and their experience with risk management ranges from six months to 25 years. Firstly, it is relevant to consider whether the risks presented by the respondents are considered representative. This is presented in figure 4.

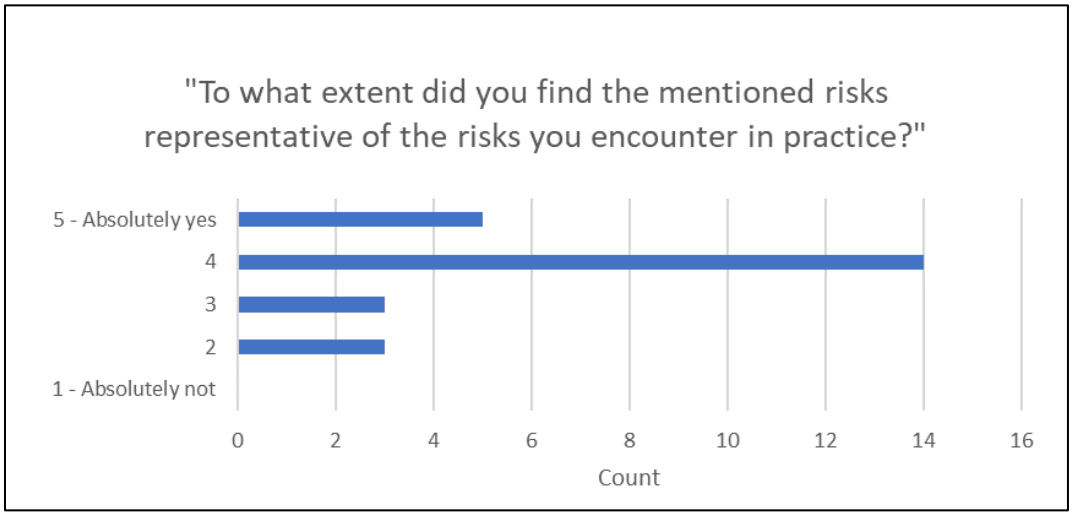

Figure 4. Representativeness of the presented risks

From this bar chart, it can be concluded that the vast majority found the presented risks to be entirely or almost entirely representative of the risks they encounter in practice. Three respondents mentioned via separate email that the responsibility for the consequences (and thus the allocation of risk management) from the presented risks was not clear, but is highly influential in the choice of risk management. The contract type is decisive in this regard, as the management of many of the presented risks in a UAV-GC contract falls under the responsibility of the contractor, while in a RAW contract, they fall under the responsibility of the client.

5.2.1 Risk assessment and -management for all dilemmas

As described in section 5.1, each of the answer options represents one of the 4 quadrants from the overall plot (figure 2). To determine the degree of objectivity/biasedness and risk aversion/risk tolerance across all 18 dilemmas, the coordinates on the plot are calculated:

Participants start in the middle of the plot: x = 0; y = 0. Each dilemma choice moves the respondents to one of the four quadrants, considering all dilemmas as equally important. Since movement can occur along two axes, this means that a dilemma choice labeled *'objectively + risk averse'* (answer option 1 in figure 3) moves the respondent x − 1; y − 1, and a dilemma choice labeled *'biased + risk averse'* (answer option 2 in figure 3) moves the respondent x − 1; y + 1. The plotted position of the respondent is the sum of the movements. In figure 5, the final positions of all 25 respondents are displayed in a single plot.

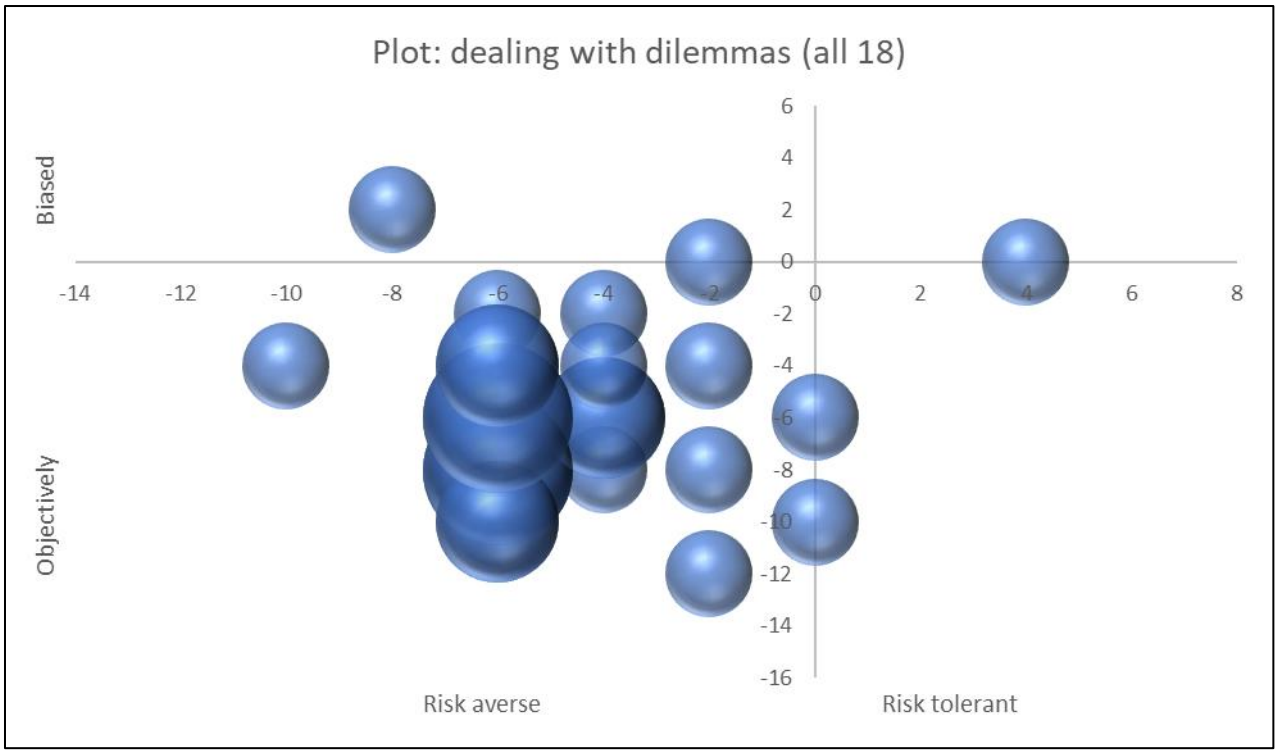

Figure 5. Plot: dealing with dilemmas (all 18)

The size of the bubbles depends on the number of respondents that end up at the same coordinates. For example, if 3 out of 25 respondents end up at coordinate -6,-8, and only one respondent ends up at -8,2, the bubble at the first mentioned coordinate will be presented larger. This helps to better visualize where the majority of respondents are located on the plot.

Across all 18 dilemmas, the vast majority have opted for an objective methodology for assessing risks and risk-averse management. Only 1 out of 25 respondents predominantly chose a biased assessment, just as only 1 out of 25 respondents predominantly opted for risk-tolerant management.

In figure 6, the roles corresponding to the coordinates are indicated by colors. To prevent the plots of different respondents with the same coordinates from overlapping, the calculated coordinates are sometimes slightly adjusted to show where each respondent ends up. For example, the two project managers and one risk manager at coordinate -6,-8 all have exactly -6,-8 as their calculated, final coordinate, but this has been slightly adjusted in the plot to make them visible side by side.

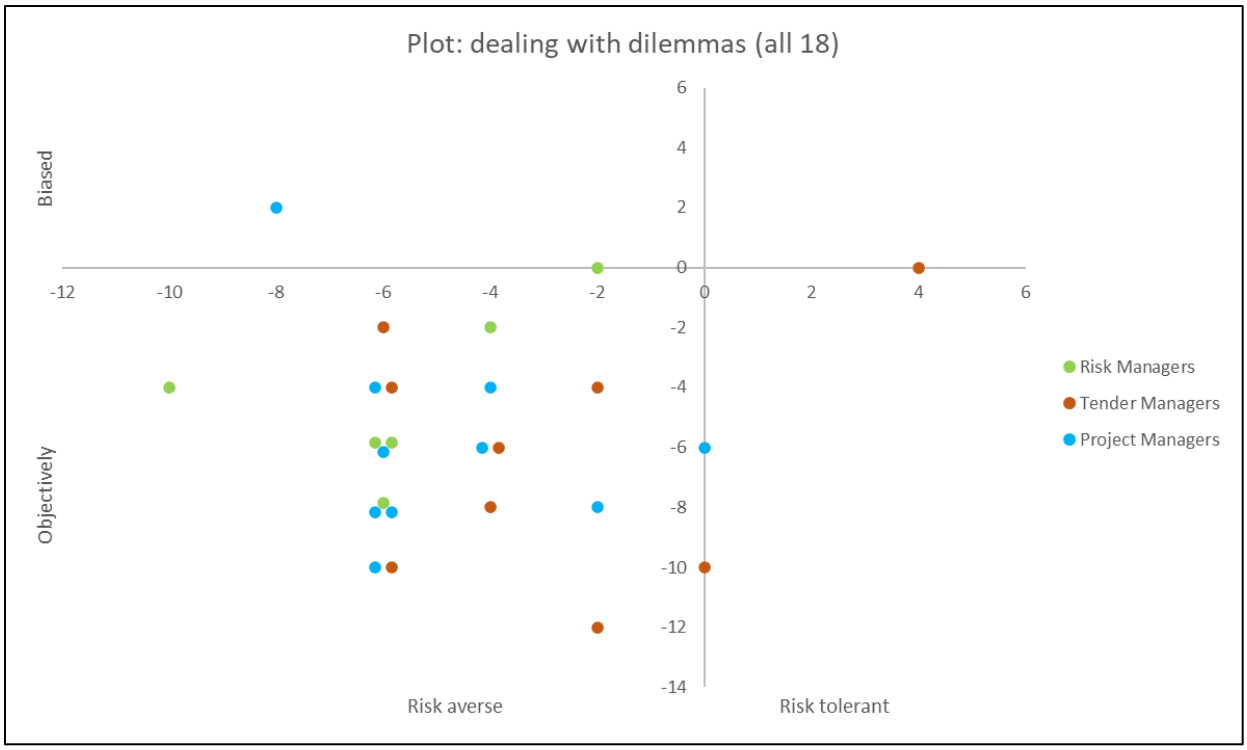

Figure 6. Plot: dealing with dilemmas (all 18) – broken down into job function groups

Based on a visual examination of this figure, it appears that respondents from the same job function group do not cluster together and significantly differ from other job function groups. Normally, the One-way ANOVA (ANalysis Of VAriance) can be applied as a parametric test to determine whether the means of the three independent job function groups are indeed equal or differ from each other. However, One-way ANOVA assumes that the underlying data follows a normal distribution. Due to the limited amount of data points in this study, this assumption cannot be met. The Kruskal-Wallis test (a non-parametric test procedure) serves as an alternative to ANOVA when its assumptions are not met. With the Kruskal-Wallis test, it is possible to test whether the medians of two or more independent groups are equal. For the plotted data above, the Kruskal-Wallis test was conducted for both biasness and risk aversion. A p-value <0.05 would suggest that the null hypothesis (*there is no difference between the medians of the three groups*) should be rejected. The p-values of this test for biasness and risk aversion are 0.589 and 0.216 respectively, meaning that the null hypothesis cannot be rejected. This indicates that there is no difference in both biasness and risk aversion among the three different job function groups.

5.2.2 Risk assessment for dilemmas with representativeness heuristic

In figure 7, the plot of all respondents is shown for the six risks where as the biased answer option, the representativeness heuristic is incorporated (risks 1-6, Appendix C). The size of the bubbles depends on the number of respondents ending up at the same final coordinate. In these 6 dilemmas, it appears that individuals have not predominantly chosen either an objective method for assessment or a biased method (according to the representativeness heuristic). The bubbles in the plots are predominantly located at y = 0 / y = -2, but also frequently at y = 2 and y = 4.

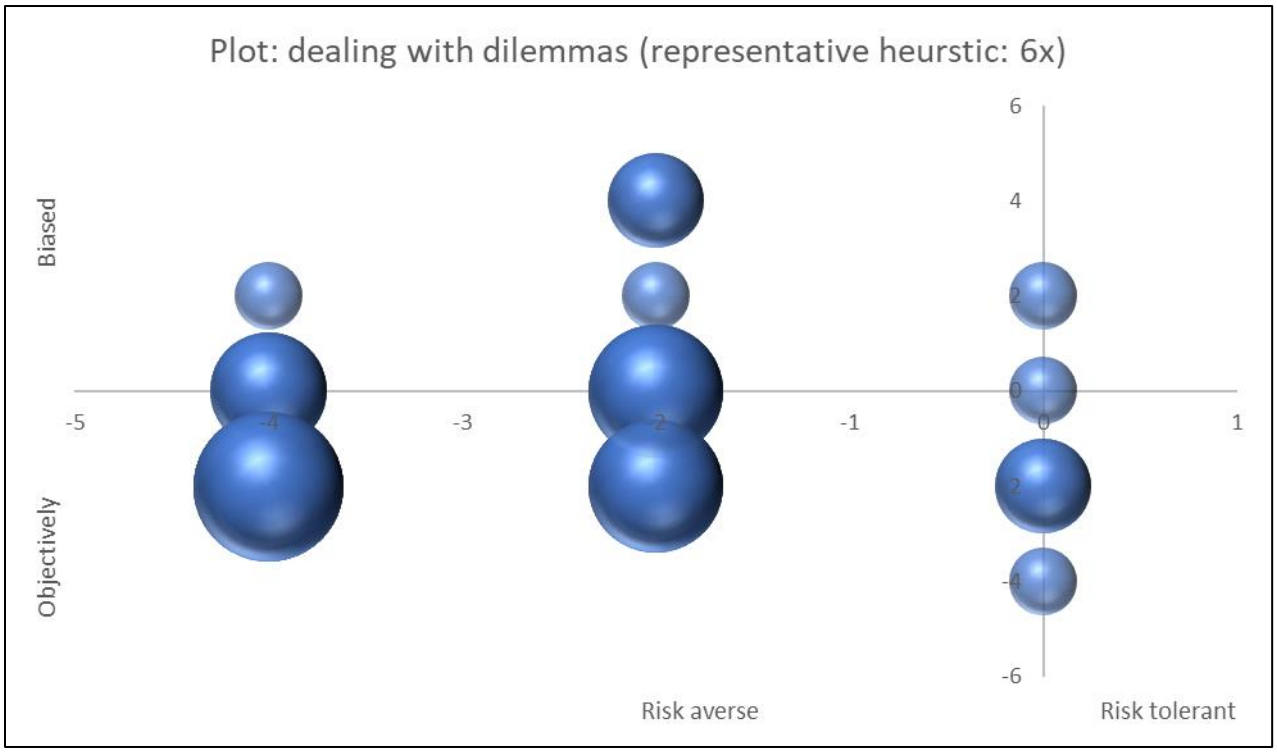

Figure 7. Plot: dealing with dilemmas (representativeness heuristic: 6x)

In figure 8, the roles corresponding to the coordinates are indicated by colors.

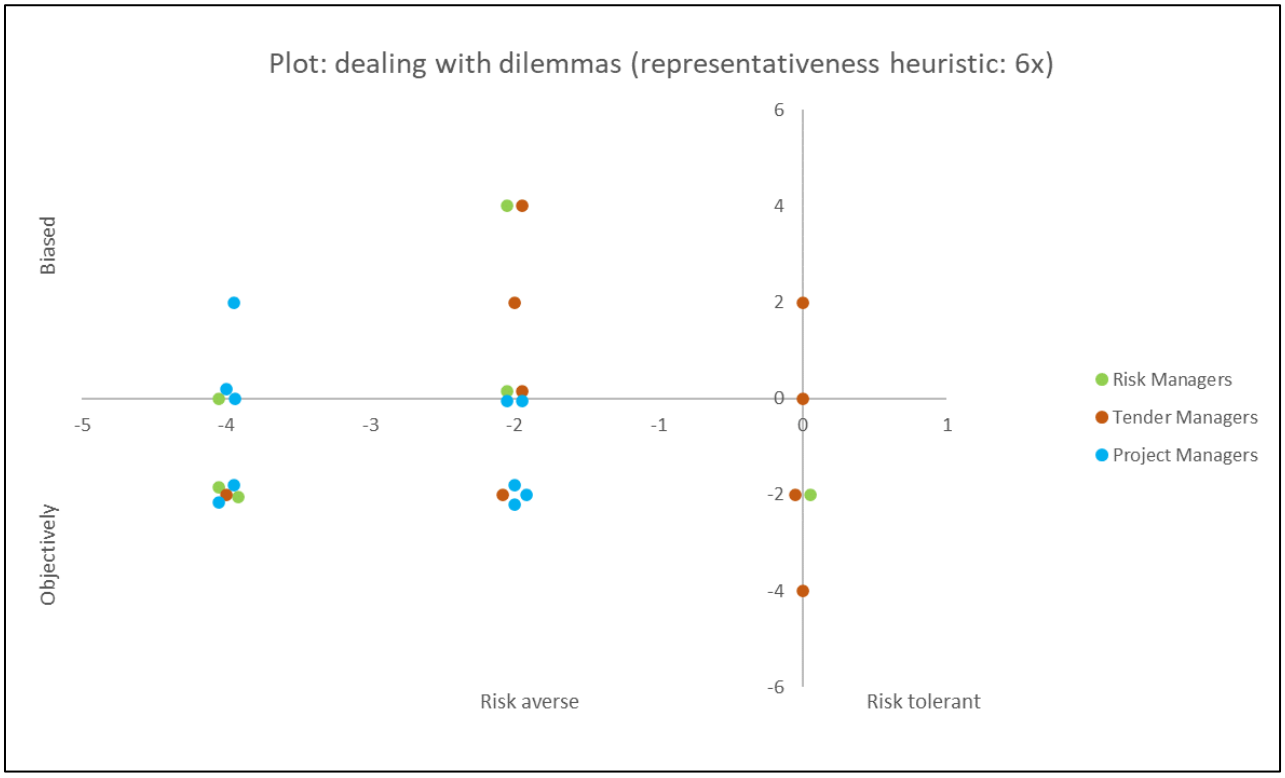

Figure 8. Plot: dealing with dilemmas (representativeness heuristic: 6x) - broken down into job function groups

Based on a visual examination of this figure, respondents from the same job function group do not cluster together and significantly differ from other job function groups. For the above plotted

data, the Kruskal-Wallis test was conducted to assess whether the medians of the different job function groups significantly differ in their use of the representativeness heuristic. The p-value of this test is 0.904, which means that the null hypothesis (*there is no difference between the medians of the three groups*) cannot be rejected. This means that there is no difference in the degree of use of the representativeness heuristic among the three different job function groups.

5.2.3 Risk assessment for dilemmas with affect heuristic

The plot below (figure 9) displays the responses of all participants for the six risks where as the biased answer option, the affect heuristic is incorporated (risks 7-12, Appendix C). The size of the bubbles depends on the number of respondents ending up at the same final coordinate. In these 6 dilemmas, the vast majority appears to have opted for an objective method of risk assessment (predominantly y = -2 / y = -4) and thus not frequently for assessment through the use of the affect heuristic.

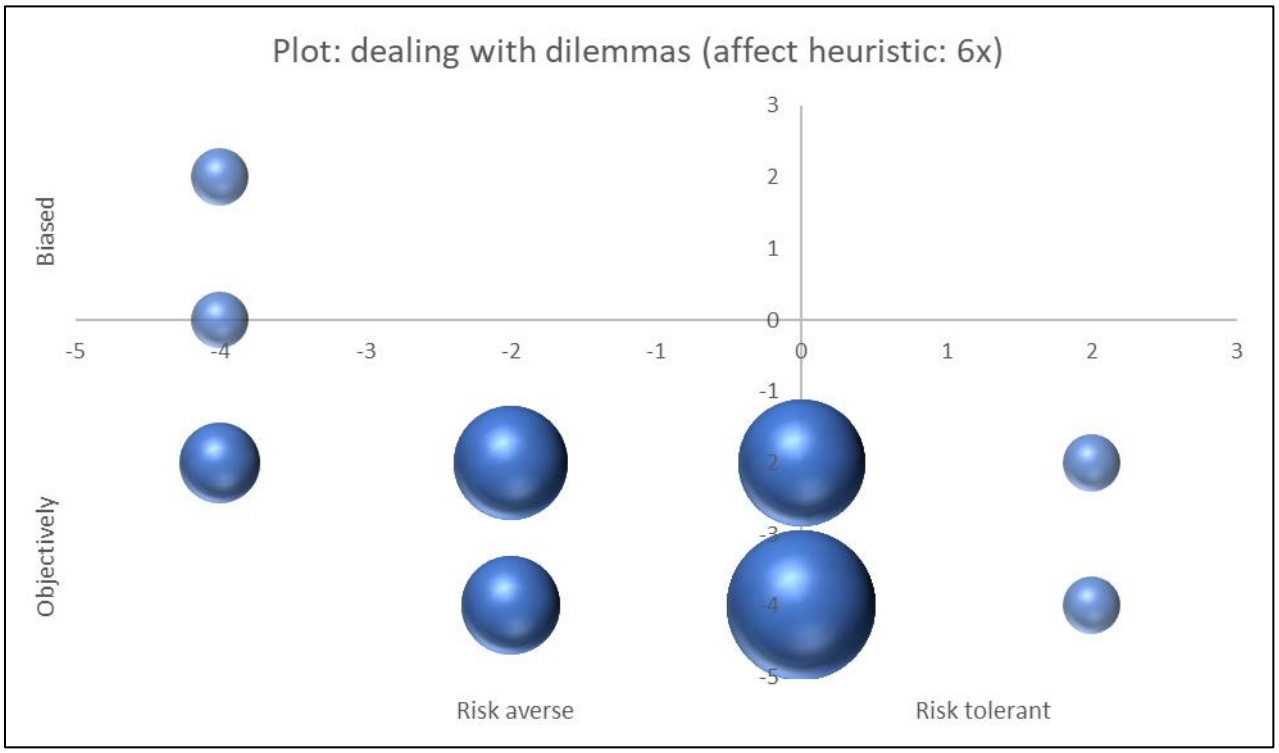

Figure 9. Plot: dealing with dilemmas (affect heuristic: 6x)

In figure 10, the roles corresponding to the coordinates are indicated by colors.

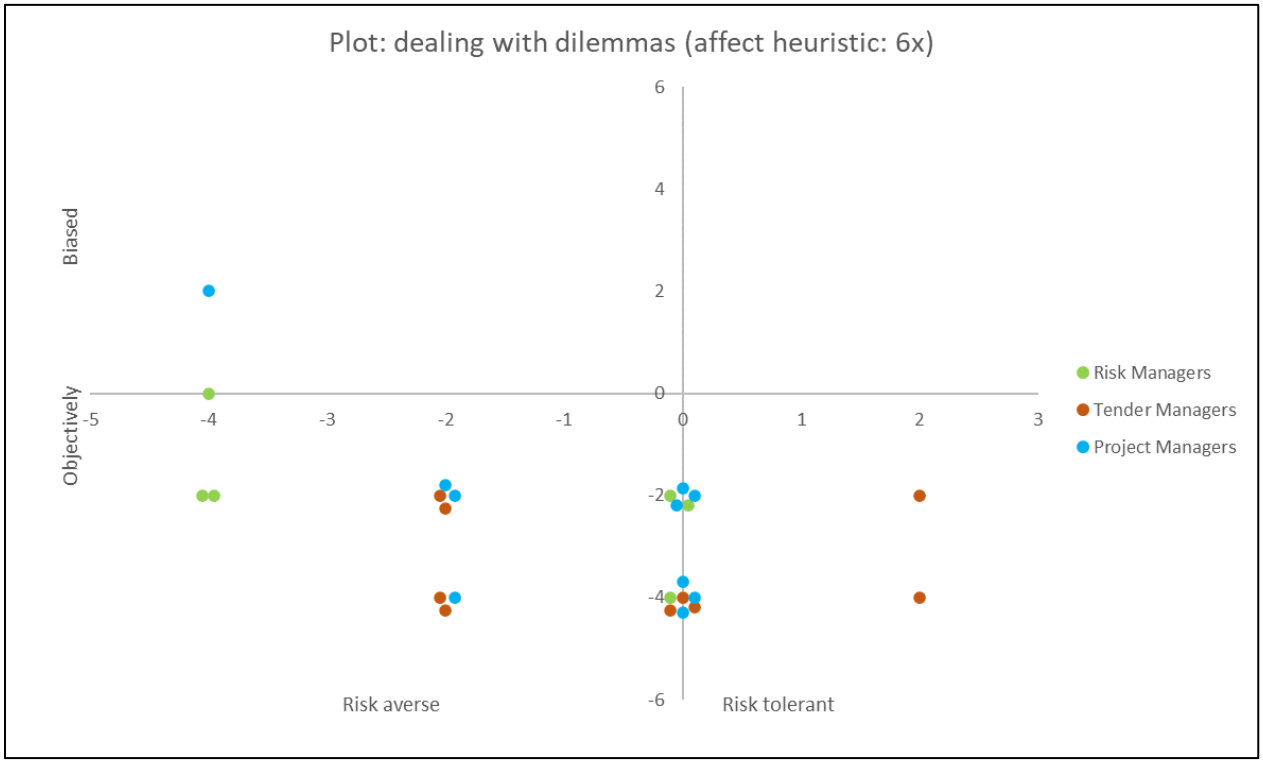

Figure 10. Plot: dealing with dilemmas (affect heuristic: 6x) - broken down into job function groups

Based on a visual examination of this figure, respondents from the same job function group do not appear to cluster together and significantly differ from other job function groups. For the data plotted above, the Kruskal-Wallis test was conducted to assess whether the medians of the different job function groups significantly differ in their use of the affect heuristic. The p-value of this test is 0.198, indicating that the null hypothesis (*there is no difference between the medians of the three groups*) cannot be rejected. This means that there is no difference in the degree of use of the affect heuristic among the three different job function groups.

5.2.4 Risk assessment for dilemmas with optimism bias

In figure 11, the plot of all respondents is shown for the six risks where as the biased answer option, the optimism bias is incorporated (risks 13-18, Appendix C). The size of the bubbles depends on the number of respondents ending up at the same final coordinate. In these 6 dilemmas, the vast majority has opted for an objective methodology of risk assessment (mostly y = -4), thus not frequently opting for assessment through the use of the optimism bias. Two of the respondents do end up in the quadrants labeled 'biased', indicating that they do use the optimism bias.

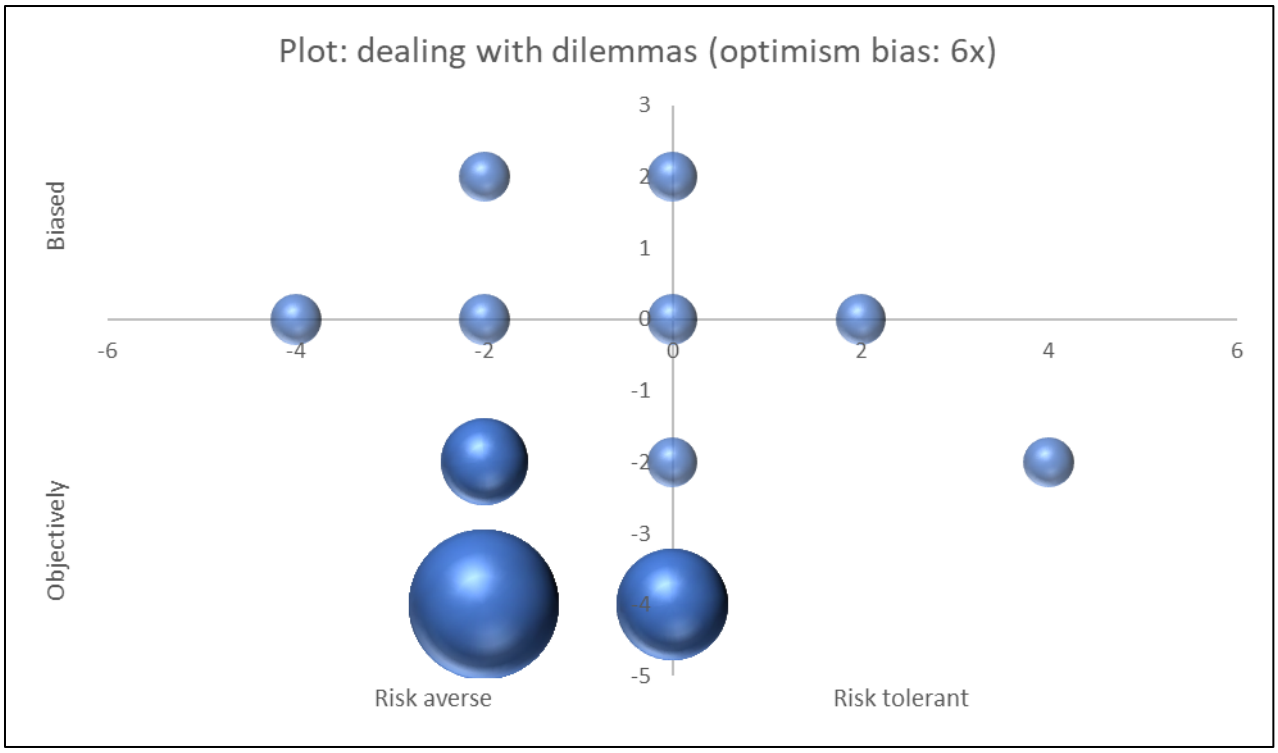

Figure 11. Plot: dealing with dilemmas (optimism bias: 6x)

In figure 12, the roles corresponding to the coordinates are indicated by colors.

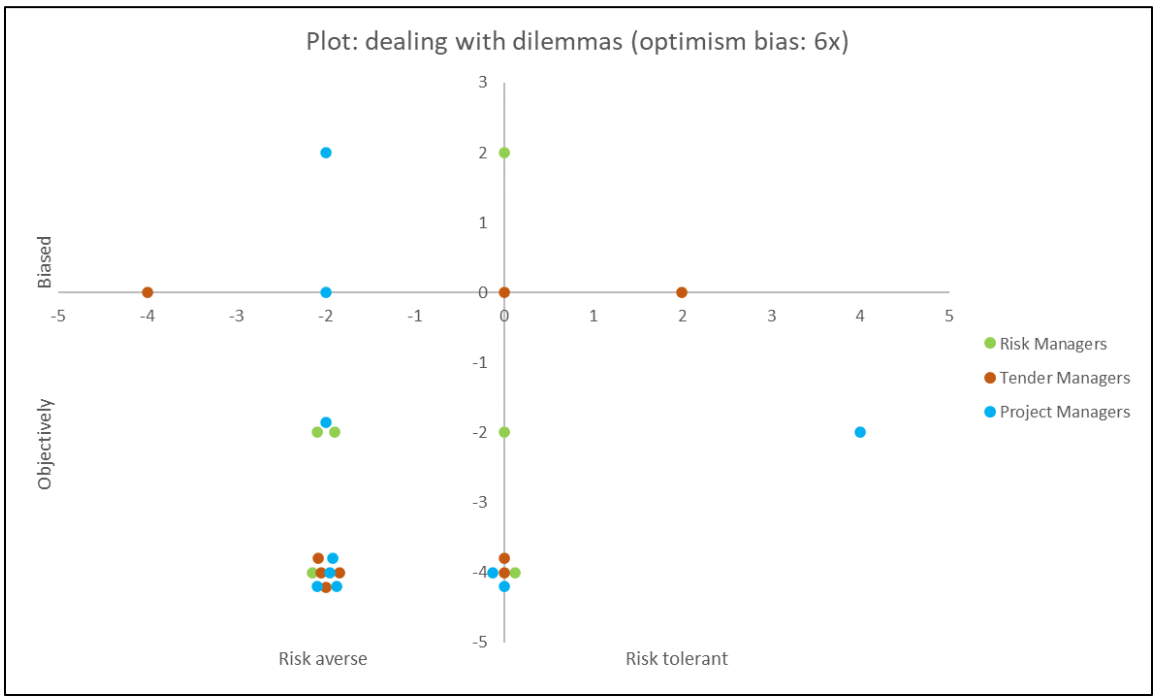

Figure 12. Plot: dealing with dilemmas (optimism bias: 6x) - broken down into job function groups

Based on a visual examination of this figure, respondents from the same job function group do not appear to cluster together and significantly differ from other job function groups. For the plotted data above, the Kruskal-Wallis test was conducted to examine whether the medians of the different job function groups significantly differ in their use of the optimism bias. The p-value

of this test is 0.674, which means that the null hypothesis (*there is no difference between the means of the three groups*) cannot be rejected. This implies that there is no difference in the degree of use of the optimism bias among the three different job function groups.

5.2.5 Respondents' perception of own risk assessment and -management vs. calculated risk assessment and -management scores

After answering the dilemmas, respondents were asked to what extent they perceive themselves as risk-averse/tolerant and to what extent they think they utilize the three examined biases/heuristics.

In figure 13, the x-axis represents the perceived extent of using the representativeness heuristic, and the y-axis represents the calculated usage of this heuristic derived from the responses to the dilemmas associated with this heuristic (risks 1-6, Appendix C). This figure indicates that all respondents believe they frequently or entirely utilize the representativeness heuristic ($x \geq 3$). However, the actual calculated usage of the representativeness heuristic presents a rather diffuse picture; some respondents prefer a systematic, objective assessment of risks over a biased evaluation, while another group of respondents has the opposite preference. This implies that a significant portion of respondents believe they predominantly use the representativeness heuristic, while this is not evident from the calculated scores.

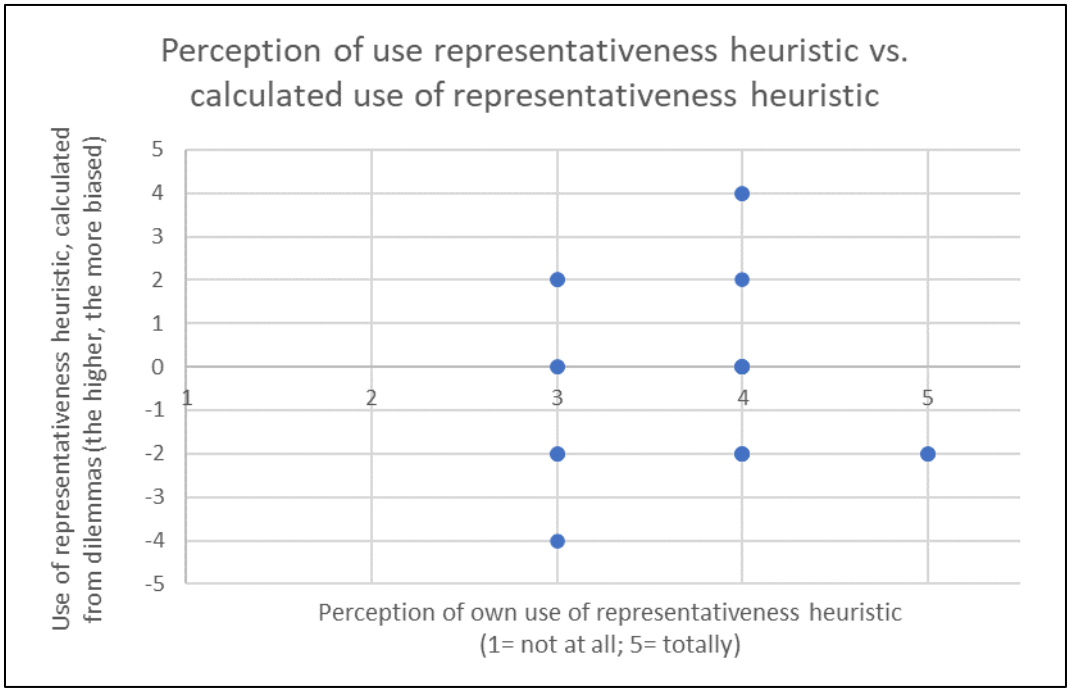

Figure 13. Perception of use representativeness heuristic vs. calculated use of representativeness heuristic

In figure 14, the x-axis represents the degree to which individuals perceive themselves to use affect heuristic, while the y-axis represents the calculated usage of this heuristic derived from responses to dilemmas associated with it (risks 7-12, Appendix C). This figure indicates that respondents have a highly varied perception of their own use of the affect heuristic (x ranges between 2 and 5). However, the actual calculated usage of the affect heuristic reveals that the vast majority predominantly prefer a systematic, objective assessment methodology over the use of this heuristic ($y < 0$).

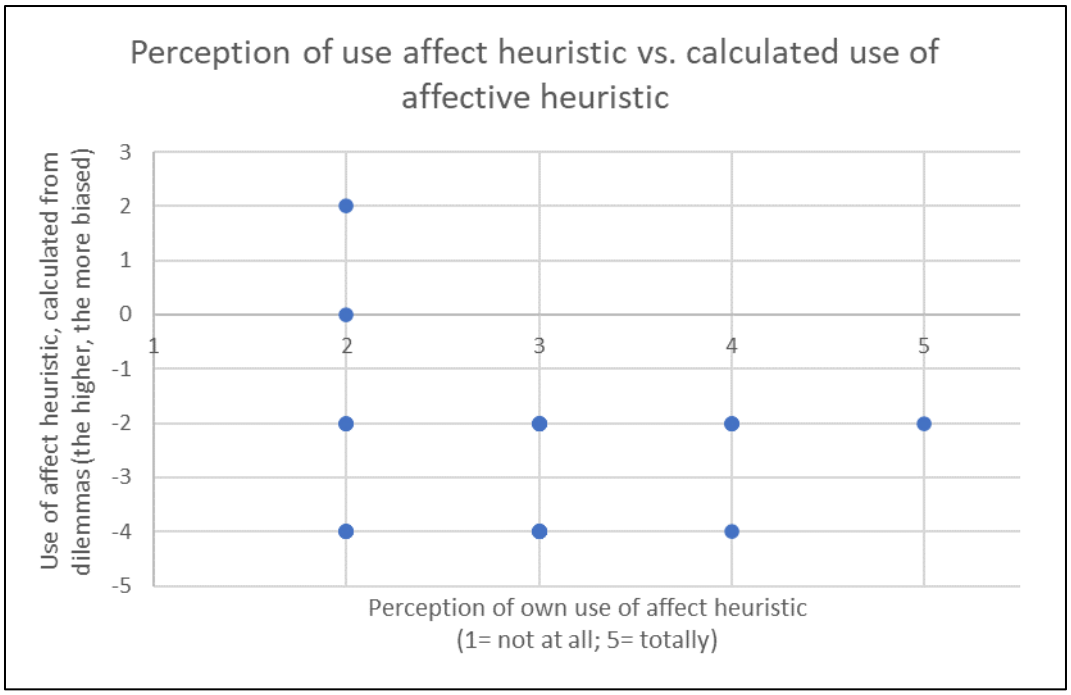

Figure 14. Perception of use affect heuristic vs. calculated use of affect heuristic

In figure 15, the x-axis represents the perceived extent of using the optimism bias, while the y-axis indicates the calculated utilization of this bias derived from respondents' answers to dilemmas associated with this bias (risks 13-18, Appendix C). This figure reveals that respondents hold a fairly uniform perception regarding their own use of the optimism bias; none of the respondents reported never using this bias, but similarly, none reported always using it (no respondents with x = 1 or x = 5). The actual, calculated usage of the optimism bias demonstrates that the vast majority predominantly prefers a systematic, objective assessment methodology over the use of this bias (y < 0).

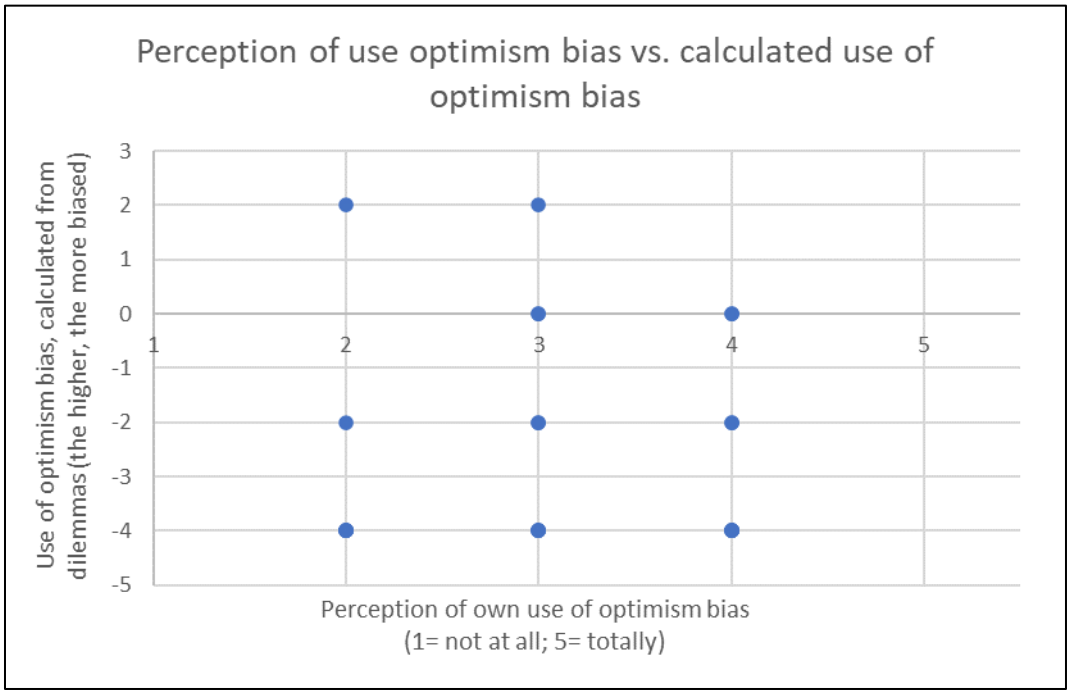

Figure 15. Perception of use optimism bias vs. calculated use of optimism bias

In figure 16, the x-axis represents the extent to which individuals perceive themselves as having risk-averse or risk-tolerant tendencies in risk management, and the y-axis represents the calculated risk aversion derived from the responses to all 18 dilemmas (Appendix C). This figure indicates that the majority of respondents believe they are not predominantly risk-averse or risk-tolerant, but rather somewhere in between (x = 3). However, the overall response tends more towards risk aversion than risk tolerance. This corresponds to the actual calculated risk aversion; almost all respondents predominantly opt for risk-averse management over risk-tolerant management (y < 0).

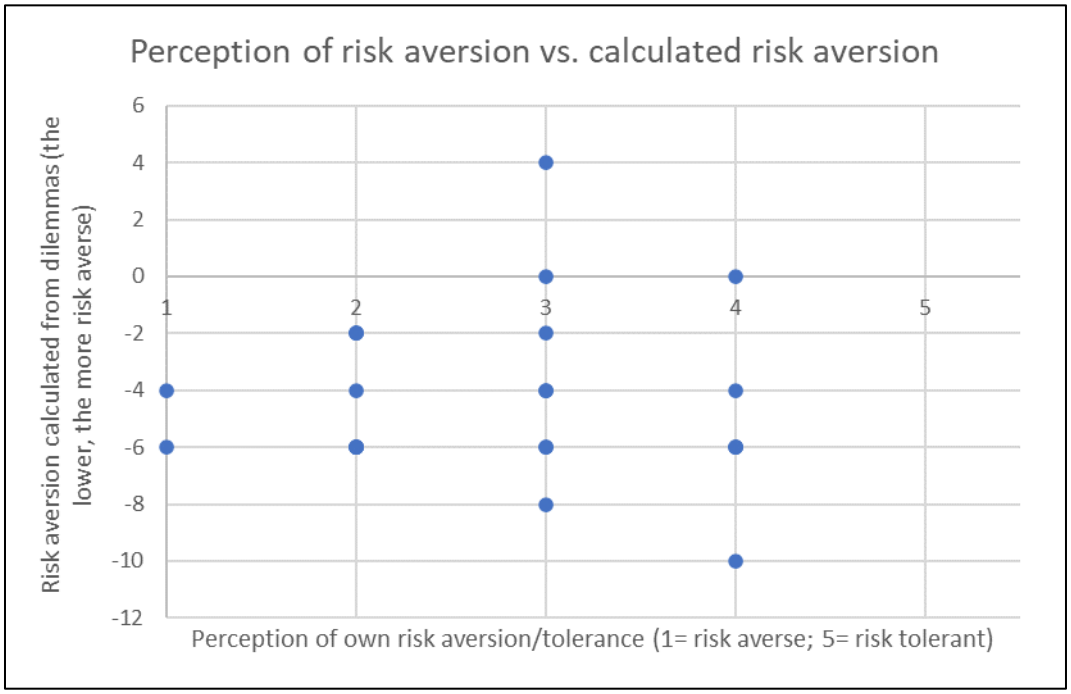

Figure 16. Perception of risk aversion vs. calculated risk aversion

5.2.6 Experience in risk management in relation to objectivity/biasedness in assessment and risk aversion/tolerance

The respondents were also asked about their years of work experience in risk management. In figure 17, 18, and 19, it can be seen that there is no clear relationship between the number of years of work experience and the extent to which individuals use any of the three examined biases/heuristics in risk assessment, as measured by their responses to the dilemmas. The representativeness heuristic is used the most out of the three examined heuristics/biases, but this does not clearly happen to a greater or lesser extent by respondents with more or less work experience. The affect heuristic and optimism bias are used by all respondents to a limited extent when they can also prefer an objective, systematic approach, regardless of the number of years of work experience.

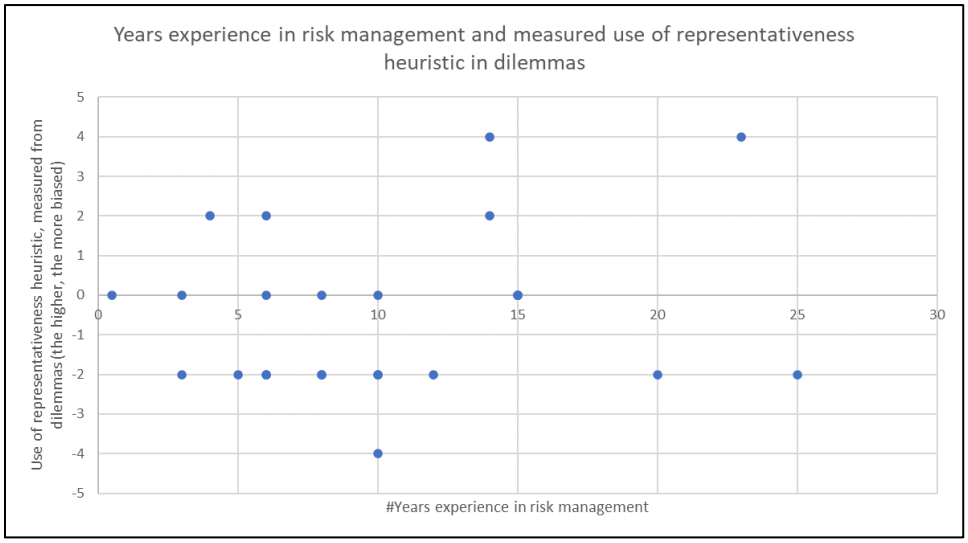

Figure 17. Years experience in risk management and measured use of representativeness heuristic in dilemmas

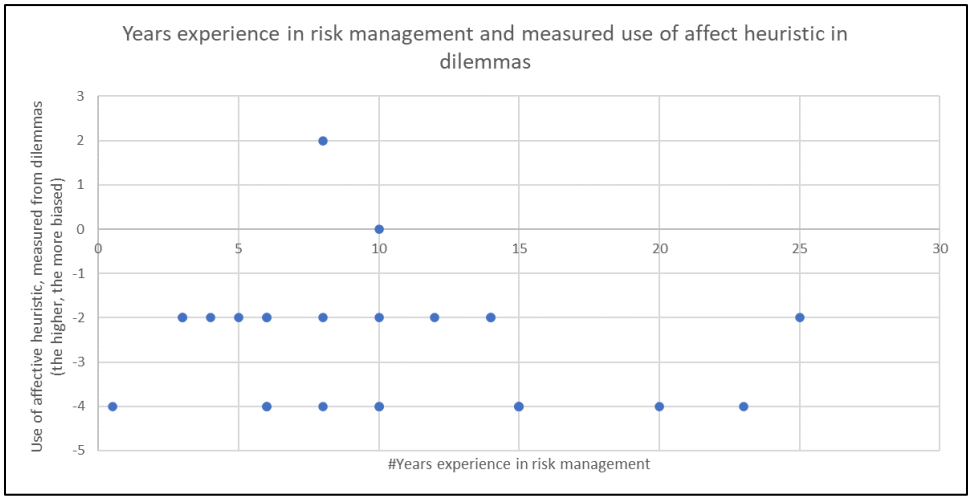

Figure 18. Years experience in risk management and measured use of affect heuristic in dilemmas

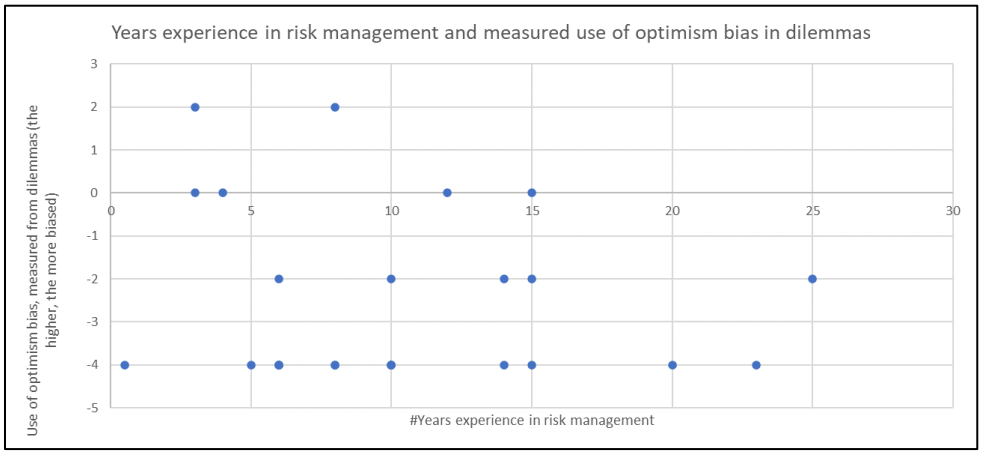

Figure 19. Years experience in risk management and measured use of optimism bias in dilemmas

Figure 20 shows that there is also no clear relationship between the number of years of work experience with risk management and the extent to which one is risk-averse or risk-tolerant. Respondents generally act more risk-averse in risk management, regardless of the number of years of work experience.

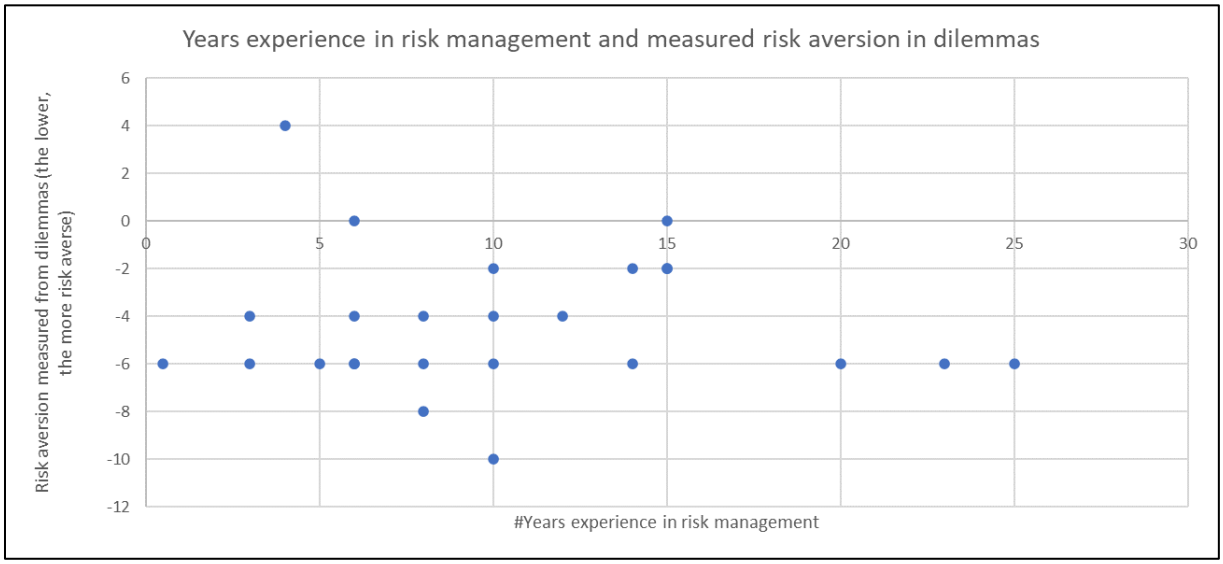

Figure 20. Years experience in risk management and measured risk aversion

5.2.7 Decisiveness of risk assessment and risk management in dilemma answers

In each of the answer options, as mentioned earlier, there were two elements: the method for risk assessment and the method for risk management. It is possible that a respondent preferred the description of the method for risk assessment from answer option 1 and the description of the risk management method from answer option 2. This does not become clear from the choice made. At the end of the questionnaire, respondents were asked which of the two elements, on average across all 18 dilemmas, was most influential in their decision-making. The result of the responses to this question is depicted in figure 21.

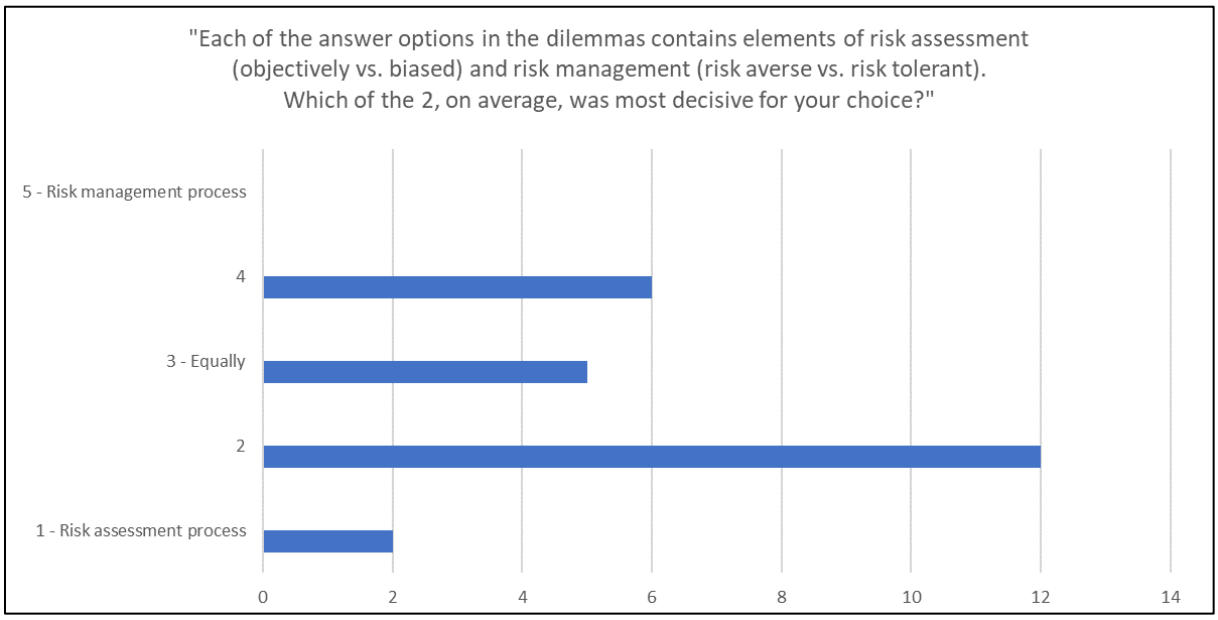

Figure 21. Decisive factors in dilemma response

From this figure, it is evident that only 2 out of 25 respondents state that their choice was entirely based on just one of the two elements: the risk assessment process. The other 23 respondents indicate that they took both elements into account in their decision-making, with the emphasis on the risk assessment process.

5.3 Conclusion of the serious game results

This part of the research aimed to explore the extent to which identified biases/heuristics are employed in the process of risk assessment and management, as well as the level of awareness individuals possess about their use of these shortcuts. The research employed an approach in which a questionnaire, framed as a serious game, was distributed among various professionals in the infrastructure sector, including risk managers, tender managers, and project managers.

The data, collected from 25 respondents with varying degrees of experience in both the infrastructure sector and in risk management, offered a variety of perspectives on the employment of the representativeness heuristic, affective heuristic and optimism bias. The respondents however, revealed a predominant preference for an objective methodology in both risk assessment and risk management, with only one respondent primarily choosing a biased assessment and another opting for risk-tolerant management. This preference for objectivity remains consistent across the different biases/heuristics, with no significant differences among various job function groups as demonstrated by the Kruskal-Wallis test.

Moreover, the study delved into the self-perception of respondents regarding the use of these bias and heuristics. The findings revealed a noticeable gap between the participants' self-assessed use of these shortcuts and their actual application as inferred from their responses to the dilemmas presented in the serious game. This discrepancy points to a broader theme in cognitive psychology and risk management: the challenge individuals face in accurately introspecting their decision-making processes and the heuristics they employ.

Furthermore, the research explored the relationship between the respondents' years of experience in risk management and their tendency to rely on biases and heuristics. Surprisingly, no clear correlation emerged, suggesting that the influence of experience on the use of biases and heuristics in risk assessment and management is not straightforward. This suggests that experience in risk management does not necessarily lead to a change in the approach to the use of biases or risk management styles.

The study's exploration of the dual components of risk assessment and management methods within each decision-making dilemma also sheds light on the nuanced preferences of professionals. Although a few respondents indicated a dominant influence of one component over their decisions, the majority acknowledged the integrated consideration of both risk assessment and management strategies in their decision-making process. This underscores the complexity of risk-related decisions and the multifaceted criteria professionals employ in navigating these choices.

In summary, this research confirms that, while there is general awareness of biases and heuristics, there is a tendency towards an objective approach in risk assessment and management among professionals in the infrastructure sector. This underscores the importance of ongoing education and awareness around cognitive biases and heuristics to

enhance the quality of risk management. However, the discrepancy between self-perception and actual behavior also suggests that there is room for improvement in self-awareness and reflection on one's own decision-making process.

6. Evaluating the serious game

This chapter describes the design of the evaluation with respondents and the findings that emerged from it. The purpose of this chapter is to formulate an answer to the question: *"What contribution can serious gaming make in raising awareness regarding the use of biases/heuristics in risk assessment/management?"*. In section 6.1, the setup for the evaluation setup is described. In section 6.2, the results of this evaluation session are considered in three parts, corresponding to the three parts that the evaluation session consisted of. Finally, in section 6.3, an answer to subquestion 4 is formulated.

6.1 Evaluation setup

After visualizing the results of the serious game in Qualtrics, an evaluation session was conducted with respondents from the different job function groups. All three job function groups participating in the serious game (project managers, risk managers, and tender managers) were represented by someone participating in the evaluation. In this session, the four plots were presented, showing everyone's response to the dilemmas (figures 5 – 12) in the first part. Also, figures 13 through 16 were shown, where the self-perceived response (risk assessment and management) was compared against the actual, calculated response, in the second part of the evaluation. Finally, the added value and potential improvement of the serious game were discussed. Specifically, the following questions were discussed:

Part 1 – Presence of biases and their consequences:

- Are you aware that project teams use this heuristic in risk assessment?
- To what extent is the use of the bias/heuristic a problem?

Part 2 – Respondents' perceptions:

- What do the differences between what I measure and what people experience mean?

Part 3 – Serious Game and its value:

- How can this 'dilemma game' assist project teams in risk management?
- What improvement in this game could make it more valuable?

6.2 Evaluation results

This section presents the findings from the evaluation, according to the aforementioned tripartite structure.

6.2.1 Presence of biases and their consequences

The use of the representativeness heuristic is strongly recognized during the tender phase. People often fall back on what has happened in the past, especially focusing on the most recent experiences. This may be partly because there is less time available during the tender phase than in the project phase, leading to less time for a fully objective approach. The use of the representativeness heuristic can be both positive and negative. While this heuristic introduces bias and makes the assessment less objective, drawing on recent past experiences also helps

in visualizing and making a risk more concrete, which in turn stimulates enthusiasm and involvement among colleagues in a joint session. It is also mentioned that in such sessions, experienced individuals are invited; they are asked precisely because they are presumed to have the necessary knowledge, encouraging them to share their experiences. However, it is important to clearly understand the similarities and differences between (recent) project experiences and the current project to avoid incorrectly overestimating or underestimating risks based on past projects.

The affect heuristic is also recognized by participants. It is noted that assessments influenced by emotions can stem from a negative experience in a previous project, showing some overlap with the representativeness heuristic. Besides influencing the assessment of an individual, the affect heuristic can also disrupt an entire risk session when someone feels a strong emotion or intuition about a risk and conveys this to others. For this reason, this heuristic is considered potentially more problematic than the representativeness heuristic. However, it is observed that an emotional response can indeed be relevant in risk sessions if it aligns with the emotions that a client may have towards certain risks, especially in niche markets like the construction/reconstruction of airports or major interventions in cables and pipelines, where typical risks cause "stomach aches" that, as contractors, we must always strive to manage, regardless of whether they are a top risk for the project. Additionally, emotional responses can also occur when a colleague with authority (due to a particular role or extensive experience) expresses their perception of a risk, making the authority of that person a credible consideration, leading others to follow along. This could also lead to blindly following the views of one or a few authoritative individuals.

The optimism bias is mentioned as being more challenging to recognize/identify in practice when considering an individual risk. However, it is thought that individuals and project teams do generally overestimate themselves, thus employing the optimism bias, which can be very problematic. It is noted that, while viewing the bias as problematic, believing oneself is not (overly) optimistic, can in itself be an optimism bias, essentially creating a blind spot for an individual or even the entire project team. Under the time pressure of a tender, one might be overly optimistic, deeming a risk acceptable to avoid delays in analysis. The danger is that we might be contracted, unaware that it carries a significantly higher risk profile than assumed during the tender, which then needs to be addressed in the project phase. Unlike the representativeness and affect heuristics, the optimism bias is not seen as functional, but solely as potentially problematic.

6.2.2 Respondents' perceptions

In the second part of the evaluation, we consider the respondents' perceptions regarding their own bias and risk aversion, in relation to the calculated bias and risk aversion.

It is mentioned that the 'type' of person working in the construction industry may be related to the response. Many respondents have a technical education background, where reliance on numerical facts and calculation rules is common. Therefore, they might prefer an objective, calculated approach to risk in their actions. However, all respondents indicate they think they (quite) frequently use the representativeness heuristic. This possibly means they assume drawing knowledge from previous projects is useful, but 'naturally' opt for an objective approach more frequently, perhaps due to their education background. A combination of both could be possible; an objective approach followed by comparison with previous projects for verification,

or vice versa. It is mentioned that it could be interesting to explore differences between various 'types' of people (according to motivation tests or, for example, Insights; distinguishing between more creative individuals and more process-oriented individuals) or those with different educational backgrounds in terms of the extent to which they opt for an objective approach and believe they do so.

Regarding the affect heuristic, the evaluators note that they too recognize emotions and intuitions in risk sessions, aligning with the perception of some respondents who say they often use this heuristic. They mention, however, that emotions do not usually dominate decisions, explaining why most respondents in the dilemmas opted for an objective approach. The evaluators suggest that emotions should be acknowledged and can sometimes be relevant, but relying solely on emotions is not advisable as they can be unreal in nature.

For the optimism bias, the respondents had a fairly average perception of their own use of the bias, with no extremes ("I never use this" or "I always use this"). This could arise from a real distribution in practice; "sometimes I do it, and sometimes I don't," leading to a middle ground due to a less pronounced view of the bias use. Additionally, it's noted that a significant number of respondents (9 out of 25) believe they use the optimism bias quite frequently. The context in which these individuals operate is deemed relevant. Under time pressure in tenders or projects, they might more readily overlook risks and somewhat disregard their potential severity. Also, one of the evaluators recognizes a tendency among colleagues in project teams to view every risk as a potential opportunity, believing that things will likely turn out well, thus not viewing optimism bias as problematic.

As for the respondents' perception of their own risk aversion, it presents a fairly average picture with no significant extremes. Similar to the optimism bias, this could also stem from viewing it as an average across all considered risks. However, it might be that for certain risks, a significant portion of the respondents prefer a predominant risk aversion, while for other risks, they show risk tolerance. This aspect was not examined in this study. Another suggestion emerging from the evaluation is to explore the relationship between the respondents' level of knowledge and their responses. The knowledge one has acquired, for example, about obtaining construction plots (as in the example in figure 3), can influence risk aversion or tolerance. Someone with less knowledge on a topic might opt for a risk-averse, safe management due to lack of knowledge, or conversely, a risk-tolerant management, not seeing the potential danger.

6.2.3 Serious game and its value

In the final part of the evaluation, we discussed the added value and potential improvements of the serious game. The overall conclusion is that a serious game/workshop can certainly help to create awareness on an individual level. However, it is deemed even more relevant that the results from responses provide insight into the distribution/balance of different perspectives within the tender/project team. For objective, interactive risk sessions, it is desirable for risks to be highlighted from various perspectives to make a proper assessment. If everyone in a team is (overly) optimistic, there's a danger of underestimating risks. Insight into the team composition leads to awareness of the tender/project team's course of action.

Questions are raised about the use of 'fictional' risks, or risks that may not be relevant for the tender/project the team is working on. In the dilemma game, a wide variety of risks were presented without coherence and the possibility that all could occur in a single project. This can

also be disruptive and reduce the supposed added value by losing connection with reality. It is mentioned that it might be wise to consider only project-relevant risks in the game when it is conducted with a tender/project team, and the game is specifically executed for the underlying project. Additionally, it is noted that an element like Edward de Bono's *'Six Thinking Hats'* could help a team through the game to highlight risks from different perspectives. In that publication, the premise is that the human brain can think in various ways (read: wear different hats) that are deliberately challenged and thus can be planned for use in a structured manner. The different 'hats' in this theory symbolize the perspectives: *The Big Picture*, *Facts & Information*, *Feelings & Emotions*, *Negative*, *Positive*, and *New Ideas*. This forces teams to illuminate a case from various perspectives.

6.3 Conclusion of the evaluation

Serious gaming has significant potential in creating awareness about the impact of biases and heuristics on risk assessment and management. By exposing participants to dilemmas and choice situations in a controlled environment, the study demonstrates that this method can help individuals and teams recognize and understand their tendencies towards certain biases (representativeness heuristic, affect heuristic, and optimism bias) and how these influence their decision-making. Recognizing the representativeness heuristic and the affect heuristic in particular shows that past experiences and emotional responses play a role, which can be both positive and negative depending on the context. The optimism bias, however, is recognized as a challenge to identify in practice, indicating its subtle and potentially problematic nature.

Not only does the serious game provide insights into individual biases, but it also highlights the value of team dynamics and the diversity of perspectives within a team. The study suggests that a balanced team composition, can lead to a more nuanced risk evaluation. This is crucial for effective risk management.

However, potential improvements for the serious game have also been identified. The relevance of the chosen risks and how they are presented can affect the effectiveness of the game in simulating realistic scenarios. Integrating methodologies such as Edward de Bono's *"Six Thinking Hats"* could encourage teams to view risks from a variety of perspectives, contributing to a deeper understanding and evaluation of risks.

In conclusion, serious gaming can make a significant contribution to raising awareness about the use of biases and heuristics in risk assessment and management. By actively engaging participants in the process and confronting them with their own ways of thinking and decision-making processes, it offers a powerful tool for both individual and team development. To further enhance the effectiveness of serious gaming, it is essential to closely align the game scenarios with the reality of the projects and to employ methods that promote a wide range of perspectives.

7. Discussion

In this chapter, there will be a reflection on this research report. This will be done in two sections, dividing the reflection between the research methodology (7.1) and the results (7.2).

7.1 Research methodology discussion

This section will cover the methodology discussion. In section 7.1.1, the research method used to answer the four sub-questions will be reflected on, emphasizing the value and choices made. Section 7.1.2 will address the overall limitations of the study.

7.1.1 Research methodology reflection

The structure provided in the research plan set a solid foundation for understanding the methodological flow. The formulation of the main and subquestions aligned with the intended goals, offering a logical progression that ensures each subquestion builds upon the previous one. This tiered approach enhanced the clarity of the research and helped maintain focus.

Defining the research scope around Dura Vermeer and its risk assessment processes ensured that the study remained relevant and practical. By honing in on specific phases within the construction projects (tendering and execution), the study gained specificity that is crucial for developing actionable insights.

The research methods were a balanced mix of qualitative and quantitative approaches.

Research method for subquestion 1. The literature review aimed to establish a theoretical lens on biases and heuristics. By emphasizing foundational concepts like bounded rationality and cognitive biases from Simon, Tversky and Kahnemen, the review provided a historical and theoretical context for biases in decision-making. The focus was particularly on decision-making in project management and construction. The literature review served as a crucial framework, enabling the identification of biases and heuristics that was later tested empirically.

In the literature study, no clear distinction was made between the terms ‘biases’ and ‘heuristics’. The concepts of heuristics and biases are closely related, yet distinct. Heuristics are cognitive shortcuts or rules of thumb that help simplify decision-making. They allow us to process information quickly and make choices without extensive analysis. For instance, the availability heuristic helps us judge the likelihood of events based on how easily examples come to mind.

Biases, on the other hand, are systematic errors or tendencies that influence our decisions and judgments, often leading to deviations from rational thinking. For example, confirmation bias is our inclination to favor information that aligns with preexisting beliefs while ignoring contradictory evidence.

Kahneman and Tversky (1974) noted that while these heuristics are generally useful, they often lead to systematic errors or biases in judgment. In the paper, they identify three fundamental heuristics: representativeness, availability, and anchoring. Their conclusion is that the concepts ‘heuristics’ and ‘biases’ interact: biases often emerge from reliance on heuristics. For instance, the anchoring bias arises when initial information disproportionately influences our decisions. On the other hand, the dual nature of biases can be found in multiple scientific studies and

theoretical works that outline their functional and potentially adaptive nature, in addition to their pitfalls. Cosmides and Tooby (1994) state that certain biases may actually function as decision-making shortcuts that are adaptive because they align with evolved cognitive mechanisms, even if they deviate from strict rationality. Also Todd and Gigerenzer (2012) argue that biases and heuristics are not just errors but adaptive responses to the structure of environments, providing effective strategies in many situations. A paper from Haselton, Nettle and Andrews (2005) explores how certain biases may have evolved as adaptations to recurrent problems in human ancestral environments. For example, the authors discuss how the negativity bias may have helped our ancestors stay alert to potential dangers, thus increasing their chances of survival. At the same time, one must be careful not to 'recognize' patterns in 'recurrent problems' that are actually different issues, as this could lead to an inappropriate risk response. Initially, this study adopted the view that biases are errors resulting from the use of heuristics, as stated by Kahneman and Tversky. For this reason, the focus in the literature review and interviews was on 'debiasing.' After the interviews, a perspective was adopted that aligns with the view of the authors of the three most recent articles: biases can be both harmful AND beneficial, similar to heuristics.

From identifying biases, a selection was made for the subsequent interviews to narrow the scope. The selection of heuristics and biases for the continuation of the research (highlighted in green in table 2) was not random but rather arbitrary. The literature review showed no consensus in categorizing known heuristics and biases. To make a selection, a categorization was created to distinguish heuristics and biases by their origin and whether they are cognitive or motivational. The distribution across various categories was considered when selecting heuristics and biases for further research. However, a different categorization could have led to a different selection. Therefore, the interviews and the serious game might not include heuristics and biases that would have been strongly recognized by professionals in the field.

Research method for subquestion 2. The use of semi-structured interviews allowed for a nuanced exploration of the risk assessment process at Dura Vermeer. It offered a grounded understanding of biases at play in their risk assessment process. The interviews focus on understanding the procedural and informal elements of risk assessment and identifying biases that may arise from heuristics.

For the interviews, six people were questioned (three risk managers and three project managers), and this small sample revealed various perspectives on the presented heuristics and biases. Eight of the ten presented heuristics and biases were mentioned in a list of the most problematic ones. This indicates a lack of consensus and possibly limited knowledge of heuristics and biases. This is further evidenced by the fact that almost all interviewees do not explicitly focus on heuristics and biases during risk sessions. Additionally, there is no clear distinction between what risk managers and project managers consider to be the most problematic heuristics and biases. This does not necessarily imply that this applies to all risk managers and project managers at Dura Vermeer. A larger number of interviews would provide a better basis for concluding whether patterns exist in the views of professionals in the field regarding heuristics and biases in risk management.

Research method for subquestion 3. The development of a serious game is a particularly innovative element of this methodology. The proposed integration of serious gaming to improve bias awareness is a novel approach that could provide actionable strategies to enhance risk

management. By embedding dilemmas involving recognizable project risks, the game simulates real-world decision-making scenarios. This design reveals participants' inherent biases and preferences for risk management strategies. By comparing self-assessments with actual game responses, the study highlighted discrepancies between perceived and actual behavior, revealing the impact of cognitive biases. This method also provides quantitative data, enabling cross-comparison of participants' roles and experience levels.

Requirements were established for the development of a serious game. It was mentioned that a serious game should be a *simulation* of real-world situations, should offer a distraction-free environment and therefore be *unambiguous* and *understandable*, should be *scalable* to target a relatively large audience, should be *valuable* for enhancing participants' understanding and should contain *interactive* elements. As argued in section 5.1, the developed game was a simulation, unambiguous, understandable, scalable and valuable, but not interactive.

The dilemmas simulated the complexity often seen in risk analysis: creating a plan for assessing and managing risks with limited time, resources, and knowledge of the risks. One difference between the serious game and reality, however, is that the game only allowed choosing between two risk responses. In reality, there's more nuance in risk response, and risks are assessed based on various categories like time, cost, quality, and safety. In practice, heuristics may be used for these assessments, but the evaluation may differ for each category.

The presented risks were sourced from risk files on completed or ongoing Dura Vermeer projects, making them recognizable in content and wording and with that unambiguous and understandable. Figure 4 shows that most participants found the risks presented to be fully or mostly representative of the risks they encounter in practice. However, the risks were not uniformly described. In the RISMAN methodology, a risk is usually formulated as an event resulting from one or more other events (causes) and leading to one or more subsequent events (consequences). However, risk formulation is not always clear in the risk files. For instance, risk 4 (Appendix C) is phrased as *"The impact on the schedule due to cable and pipeline work is greater than expected."* Here, the consequence (*impact on the schedule*) is already included in the risk description, which is only one of the possible outcomes of the actual risk (*the cable and pipeline work is greater than expected*). Such variations in risk formulation create ambiguity, possibly affecting the participants' responses.

The serious game was developed in digital form to facilitate easy distribution to a large audience, making it scalable. An online version of the game also makes it easier to collect results for analysis.

The added value of the serious game was aimed at increasing awareness of the use and consequences of heuristics and biases, as interviews indicated that this was not explicitly addressed. According to the evaluation session (Chapter 6), a serious game definitely raises awareness among risk assessors about heuristics and biases. It also increases engagement in risk sessions and helps in testing whether there's enough balance in the team to approach risks from multiple perspectives.

Lastly, no interactive elements were included during the game because group sessions of about four people each would have been required (to ensure everyone had a chance to speak). At least six of these sessions would have been necessary to obtain a comparable response to that achieved with online distribution. This would have been challenging given the available time and

participants' schedules. In other software tools, respondents can receive in-game feedback on their answers, providing a middle ground where the game can still be played individually while the program provides feedback, adding some interactivity. Another form of interactivity was added after the game in a joint evaluation session, where a group of risk assessors could collectively analyze the results and evaluate their significance.

Research method for subquestion 4. The post-game evaluation session provides valuable qualitative insights into the effectiveness of serious gaming. By presenting the game results and self-assessments, the evaluators can critically analyze the biases and reflect on their impact. The session also enabled discussions on improving the game for better bias identification, ensuring that the recommendations are grounded in practical needs.

The evaluation session was conducted in a semi-structured manner. This means that a set of questions was prepared beforehand, which needed to be answered through group discussion. At the same time, the structure was kept fairly open to avoid restricting or limiting people in sharing their insights. This means that an evaluation session can always yield different results and is highly dependent on the participants and their level of engagement. The value of an evaluation session can be found in various elements, which will be discussed in section 7.2.3.

7.1.2 Limitations of the research

In this section, the limitations of the results will be discussed.

Selection of biases/heuristics

In this study, the initial focus was broad, covering a wide variety of biases and heuristics, before narrowing down to just three. The selection of these three was based on interviews with three project managers and three risk managers. Therefore, this selection is solely based on the perceptions of six individuals, who did not unanimously agree on the problematic nature and prevalence of the various biases and heuristics. It is possible that a broader survey might reveal that different biases or heuristics are considered problematic, which were not included in the second part of the research. Future research could expand on this by exploring additional biases and employing a wider range of strategies.

Generalizability of company results

One limitation of this study is its focus on Dura Vermeer, which may limit the generalizability of the findings to other companies or industries without further validation. The specific cultural and operational context of Dura Vermeer might influence the prevalence and impact of certain biases differently than in other organizations.

Formulation of risks and dilemmas

The risks in the serious game were formulated based on previously established risk dossiers and exhibit a wide diversity. There is a possibility that a portion of the respondents in a specific field (e.g., primarily asphalt or primarily concrete) may not recognize the presented risks and might never encounter them. The way a risk and dilemma are phrased can significantly influence the sentiment a respondent has towards the risk. The dilemmas, in which biases/heuristics are 'hidden', are crafted by incorporating certain elements of a bias/heuristic, such as those based on previous experiences (representativeness heuristic) or on feelings/intuition (affect heuristic). It is then concluded whether or not a biased choice is made, but a slightly different phrasing could potentially have led to a different choice.

Forced choices and decision nuances

The design of the serious game forced respondents to choose between two predefined options, which did not permit the expression of more nuanced decision preferences that could combine elements of both choices. This limitation in the study design suggests that while the results are indicative, they might not fully capture the complexity of real-world decision-making, where combinations of choices are more common. Only 2 out of 25 respondents let their choice be fully guided by the formulation of the risk assessment process in the answer options. The other 23 respondents indicated that a combination of both the risk assessment process and the risk management process influenced their choice. However, a middle ground between the formulated answer options could not be selected. Future implementations of the serious game could consider formats that allow for a spectrum of responses to better capture this complexity.

Reliance on subjective data / interpretation

The reliance on self-reported data from the serious game poses limitations related to subjective interpretation and potential bias in responses. Although the game design aimed to minimize misunderstandings, the accuracy of self-perception versus actual behavior remains a challenging area to measure precisely.

7.2 Results discussion

In this section, the findings of the research are interpreted in relation to earlier scientific findings and the implications of the research (for Dura Vermeer specifically) are presented.

7.2.1 Interpretation of findings

The results from this study reveal a significant recognition and impact of biases in risk assessment, particularly the representativeness, affect, and optimism biases. The representativeness heuristic was frequently identified, indicating a strong reliance on similar past experiences to make risk assessments, particularly during the tender phase of projects. This heuristic helps visualize risks and generate enthusiasm but also introduces a potential for bias that can skew risk assessment away from objectivity. The comparison between the occurrence of the representativeness heuristic in the tender phase and the project phase has not been previously made in the literature. The affect heuristic shows that emotional responses to risks, while sometimes aligning with client concerns, can disrupt objective risk assessment. This heuristic underlines the influence of past negative experiences on current risk evaluations. Meanwhile, the optimism bias was noted as a subtle but significant challenge, suggesting a tendency among project teams to underestimate risks based on overly positive past outcomes.

This thesis presents several important findings that can be interpreted in relation to existing scientific literature. The mix of various methodological approaches has produced both confirmed and surprising results. This research aligns with previous findings in the literature while also providing new insights.

Confirmed results

Existence and impact of biases: Heuristics and biases like representativeness and optimism bias have been well-documented in risk assessment processes. Kahneman and Tversky's noted in 1974 already how representativeness serves as a cognitive shortcut that can both aid and impede accurate judgment. The finding that the occurrence of the affect heuristic is associated

with experience (and thus also the representativeness heuristic) aligns with the literature. Galavotti, Lippi and Cerrato (2021) note that the role of intuition (affect heuristic) in decision-making depends on the experience of the decision-maker: if they have no or only limited references from which they can project inferences onto the current decision situation, intuition can offer a solution as an alternative to relying on experiences. Conversely, for more experienced decision-makers, the increased number of references among which similarities can be identified with the current decision situation, creates difficulties because it hampers the ability to select clear similarities. This research corroborates these established biases by highlighting their presence in Dura Vermeer's risk management practices.

Serious gaming's educational potential: Prior studies advocate serious games as a learning tool. Games simulate real-world scenarios, allowing users to experiment with decisions without real-world consequences. Annetta (2010) advocates serious games as educational tools that create immersive learning experiences. This thesis' findings align with this, as Dura Vermeer employees showed enhanced awareness of biases and improved understanding of their decision-making processes in the evaluation session. The success of serious games in this study highlights the potential for experiential learning, where participants engage deeply with the material and internalize the lessons better than through traditional training. This form of training provides a "safe space" to learn from errors, making it a promising approach in dealing with biases.

Surprising results

Gap between self-perception and reality: In the serious game, respondents were asked to evaluate their own answers after making dilemma choices. Although participants believed they used biased decision-making, their actual decisions were more objective than they perceived. This discrepancy is surprising given existing literature suggesting people often underplay their biases. Pronin, Lin and Ross (2002) discussed the bias blind spot, where individuals acknowledge biases in others but not in themselves. This study identifies a contrasting dynamic where participants believe themselves to be more biased than they actually are, while literature often suggests that individuals have a tendency to underplay their susceptibility to biases. It may indicate that Dura Vermeer employees have a higher preference for objective methodologies than expected. Also, the gaming setup might have primed participants to be more introspective and objective, leading to decisions that were less biased than their self-perceptions suggested.

Functional purpose of biases: Some interviewees suggested that certain biases, such as optimism bias, serve functional purposes like maintaining morale and a forward-looking attitude. While the literature on biases usually emphasizes their negative effects on decision-making, this finding indicates a nuanced perspective where biases could have adaptive benefits, a concept not widely discussed. Since much of the literature indicates that biases hinder decision-making, the initial focus of this research was on reducing biases in participant assessments during risk sessions. Only after the interviews revealed that heuristics are frequently used, often leading to biases considered functional, did the focus shift to dealing with biases where reducing them is one possible strategy but not always the main goal. As noted in section 7.1.1, some researchers argue that biases can offer effective strategies due to their adaptability. However, most studies that adopt this perspective are not related to risk decision-making. The potential positive role of biases is not often highlighted in risk decision-making

literature. Recognizing this positive role shows a nuanced understanding of biases. While biases can lead to errors in judgment, some contexts can use their motivational benefits, suggesting that risk managers should strive for a balanced approach between optimism and realistic planning.

Preference for objective methodologies: When reflecting on their own risk judgment, respondents indicated that they believe they use all three heuristics and biases at least sometimes to (fairly) often. Although this doesn't directly mean that people are aware of the potential dangers of misjudging risks, it does suggest a certain awareness of their own use of heuristics and biases when asked to evaluate their response. However, the measures responses to the risk dilemmas showed a strong preference for objective risk assessment methodologies. This inclination toward objective measures might reflect industry standards or the specific organizational culture at Dura Vermeer. It also aligns with a broader trend in risk management that favors quantitative over qualitative methods, supporting the idea that objectivity is often seen as a safeguard against the subjectivity introduced by human biases (Tedlock & Gardner, 2015).

7.2.2 Implications of findings

The findings underscore the need for structured strategies to deal with biases within risk management processes. Implementing structured reflection sessions and training can mitigate potential negative influence of identified biases. Furthermore, the use of serious games as awareness-raising tool promotes a better understanding of biases among employees and fosters an environment conducive to open discussion and perspective sharing. This study has shown that there is a difference between perceived bias and self-perceived bias. This aligns with previous findings. Pronin, Gilovich, and Ross (2004) suggest that when considering whether one is biased, individuals consider the conscious thoughts that arise during the risk-decision process (which rarely show evidence of biases), rather than the corresponding behavior (which often does show evidence of biases). As a result, an individual tends to be unaware of their own cognitive biases (as they consider their own thoughts), while they are able to recognize cognitive biases in others (whose behavior they consider).

7.2.3 Practical implications for Dura Vermeer

For Dura Vermeer, the practical implications of these findings are multi-fold. Firstly, the serious game has proven to be an effective tool for not only assessing but also enhancing awareness of cognitive biases in risk assessment. It is recommended that Dura Vermeer incorporates such serious games into regular training modules to continually engage and train staff in recognizing and mitigating biases in their decision-making processes. Additionally, by allowing for more nuanced responses in future iterations of the game, Dura Vermeer can gain deeper insights into the decision-making preferences of their employees, which can inform more tailored and effective risk management strategies.

Integrating Edward de Bono's "Six Thinking Hats" method provides a structured way to think differently and explore various perspectives towards a complex subject like risk assessment in project management. Applying these hats during the analysis phase allows for a more nuanced understanding of how various thinking styles can influence the outcomes of risk assessment processes.

Serious gaming in risk management can be used for various purposes. For example, Dura Vermeer could use it with new employees to not only get to know the company but also to organize an interactive session where perspectives from new employees with backgrounds from other companies can be shared. Additionally, the serious game can be played prior to a risk session (e.g., several days beforehand) to increase awareness of biases and to check if there is a balance/spread of different perspectives in the project team. The serious game can also be used outside of projects and purely for team building and learning purposes. If it recurs annually, it can be used to assess how perspectives on specific risks evolve over the years.

It's important to recognize that serious games can provide value throughout different phases of a project. Risk management often relies on the information currently available, with decisions based on present circumstances. However, these decisions are made for future scenarios that could look quite different from the current situation. Given that future conditions often diverge from present expectations, effective risk management requires a flexible approach. Adaptive risk management and agile decision-making empower organizations to respond effectively to unforeseen changes. Strategies like diversification, contingency planning, and incremental decision-making help organizations prepare for various potential future scenarios. Serious gaming can support this process because it can be played in a similarly incremental manner. By adjusting the game to reflect evolving priorities and circumstances, the responses to potential risks will remain relevant and practical. There is added value in playing these games with a project team, holding an evaluation session afterward, and then replaying the game at a later project stage. During replay, the game can be adapted with an updated list of risks and reformulated strategies to manage them. After these evaluation sessions, participants should be more aware of their own susceptibility to biases and heuristics when devising risk strategies. Simultaneously, the team will have acquired more project knowledge, enabling them to base their judgments on better-substantiated data. This combination of heightened self-awareness and improved knowledge should lead to more reliable risk assessments.

Testing this in practice will reveal if this approach indeed improves risk assessments. Retrospective validation of a risk dossier against the actual outcome of a completed project enables teams to evaluate whether risk assessments have become more accurate over the course of the project.

8. Conclusion and recommendations

In section 8.1, the research question and subquestions are answered. Section 8.2 presents recommendations for further research on heuristics and biases in project risk analysis, including serious gaming as a part of the process.

8.1 Conclusion

Through a detailed examination of both theoretical perspectives and empirical data from Dura Vermeer, this research has illuminated the significant impact of cognitive biases on risk assessments in infrastructure projects and validated the efficacy of serious gaming as a tool for cognitive enhancement in risk management practices.

The following research question was formulated to cover the research goal:

How do heuristics and biases influence project risk assessment, and what role can serious gaming play in enhancing awareness and management of these cognitive factors?

The subquestions are now answered:

1. What theoretical lens can be obtained from state of the art literature on biases in relation to using heuristics in project risk assessment?

From the comprehensive literature study on biases and heuristics in project risk assessment, particularly within the construction industry, several theoretical lenses can be identified:

1) Bias framework: This theoretical lens explores how cognitive biases and heuristics such as representativeness, availability, adaptation, and anchoring heuristics influence decision-making in risk management. Heuristics are mental shortcuts that generally facilitate quicker decision-making but can lead to systematic deviations from rational judgments, known as biases. Biases stem from the inherent complexity of decision-making under uncertainty. These biases can potentially lead to underestimation or overestimation of risk impacts, which can have significant implications for project execution and outcome. Biases are exacerbated by the high-stakes, high-pressure environment of infrastructure projects, where decision-makers often have to make quick judgments with incomplete information. By understanding these biases, risk managers can more effectively anticipate and mitigate errors in judgment and decision-making processes.

2) Systematic risk management processes: Highlighting a shift from purely mathematical models to more systematic approaches, this lens emphasizes the integration of risk identification, analysis, and response processes. It addresses how biases influence each stage of this systematic process and underscores the need for structured risk management frameworks that can accommodate and correct for human biases.

3) Debiasing techniques and training: This perspective focuses on strategies for mitigating biases in risk management. It includes practical approaches such as training programs designed to enhance awareness and reduce the influence of cognitive and motivational biases. This lens is particularly actionable as it provides direct methods for improving decision-making

in risk assessments by targeting the reduction of bias through informed and structured training initiatives.

4) Perceptual and individual factors: This lens considers the role of individual factors and risk perceptions in shaping decision-making. It explores how personal experiences, judgment, and the subjective nature of risk categorization influence risk assessment outcomes. This theoretical perspective is crucial for understanding the variances in risk assessment approaches among different project managers and risk managers, offering insights into how biases are framed and perpetuated within organizational contexts.

These lenses collectively provide a robust theoretical foundation for understanding and addressing the challenges posed by biases in the use of heuristics in project risk assessment. They also suggest areas for further research and practical application, particularly in training and systematic risk management improvements, to enhance the efficacy of risk assessment practices in the construction industry.

2. How is project risk assessment performed in practice? What heuristics are used and what biases are identified?

Project risk assessment at Dura Vermeer is conducted through a structured process influenced by both the RISMAN methodology and practical adjustments based on project demands and realities. This multifaceted approach includes the following key components:

1. Initial risk file and adjustments: A risk file is compiled during the tender phase, which serves as a baseline for understanding potential project risks. As the project progresses, this file is dynamically adjusted to reflect actual experiences and unforeseen challenges encountered during execution.

2. Collaborative brainstorming sessions: Risk assessment is typically a collaborative effort involving specialists from various disciplines. Initially, collective brainstorming sessions are held to gather diverse perspectives. There is also a preference for subsequent discipline-specific sessions to delve deeper into specialized risks. The role of facilitators, often risk managers, is pivotal in these sessions to ensure that all participant views are considered and to help steer discussions.

Several cognitive biases are recognized in the risk assessment process. During the tender phase, there tends to be an optimistic underestimation of risks (optimism bias), which requires adjustments as more project-specific data becomes available. The affect heuristic and representativeness heuristic influence decision-making based on emotional responses or by relating situations to similar past experiences, possibly skewing risk assessment. Also, there is a tendency to favor information that confirms pre-existing beliefs, potentially overlooking contradictory data (confirmation bias).

Despite awareness of these biases, there is a noted difficulty in consistently addressing them due to a lack of familiarity with debiasing techniques. Interviewees expressed unfamiliarity with structured interventions to mitigate biases. Also, concerns were raised that introducing too rigorous or unfamiliar debiasing methods could demotivate team members or complicate the assessment process.

Instead of focusing solely on debiasing, Dura Vermeer emphasizes increasing awareness of biases among team members. This approach aims to enable individuals to recognize and manage their own biases more effectively. Suggestions for improving bias management include independent assessments to precede group discussions and the inclusion of specialists from different fields to provide broader insights.

In summary, the project risk assessment at Dura Vermeer incorporates both structured methodologies and adaptive practices, aiming to balance thorough risk identification with practical execution challenges. While cognitive biases are recognized as a significant issue, the current emphasis is on awareness and management rather than elimination, reflecting a pragmatic approach to dealing with the complexities of real-world project management.

3. To what extent are identified biases/heuristics actually used in risk assessment/management, and to what extent are people aware of that?

Based on the findings from the serious game research, focused on risk assessment and management, it appears that although identified biases and heuristics such as the representativeness heuristic, affective heuristic, and optimism bias are acknowledged, they are not predominantly employed by professionals in the infrastructure sector. Instead, there is a strong inclination towards adopting objective methodologies for assessing and risk aversion in managing risks. This preference for objectivity is consistent across various job functions as indicated by the lack of significant differences found using the Kruskal-Wallis test.

The research highlights a notable discrepancy between the self-perceived and actual usage of biases and heuristics by the respondents. While participants believe they employ a more biased approach, their responses to the game's dilemmas suggest a higher preference for objectivity than they recognize. This gap underscores a lack of self-awareness or difficulty in accurately introspecting their decision-making processes.

Moreover, the study found no clear correlation between the respondents' years of experience in risk management and their reliance on biases and heuristics. This indicates that experience in the field does not necessarily equate to a reduced influence of such cognitive biases, nor does it uniformly alter risk management styles.

The research also reveals that decision-making in risk management often involves a nuanced integration of both assessment and management strategies, rather than a dominance of one over the other. This suggests that professionals consider a variety of factors and criteria in their decision-making process, reflecting the complexity of risk-related decisions.

In conclusion, while there is a general awareness of biases and heuristics among professionals in the infrastructure sector, and a clear preference for objective risk management practices, there remains a significant gap between self-perception and actual behavior. This highlights the importance of ongoing education and initiatives to enhance self-awareness and the quality of decision-making in risk management.

4. What contribution can serious gaming make in raising awareness regarding the use of biases/heuristics in risk assessment/management?

The use of serious gaming emerged as a promising tool to increase cognitive awareness among project managers and risk assessors. Games designed to mimic real-life risk scenarios enabled participants to engage actively with risk elements, fostering a deeper understanding of biases. This experiential learning process was instrumental in highlighting the discrepancies between perceived and actual risks, thereby enhancing cognitive vigilance against biases. The testing and evaluation of serious gaming into the training protocols at Dura Vermeer provided the following insights:

- Engagement and interaction in diverse teams: Games designed to simulate real project risks engage participants more actively than traditional risk management, enhancing their understanding of risk complexities and interdependencies. Serious games highlight the importance of team dynamics and the value of diverse perspectives in achieving more nuanced risk evaluations. By bringing together individuals with different backgrounds and viewpoints, serious games foster a collaborative environment where biases can be challenged and counterbalanced, leading to more effective risk management.
- Increased awareness: Participants exhibited a heightened awareness of their own decision-making processes and the potential biases influencing them. Through gameplay, participants are prompted to reflect on and recognize their personal and collective cognitive biases. The identification of these biases, such as the often subtle and problematic optimism bias, is crucial for understanding their effects on decision-making. This recognition helps in mitigating the adverse impacts these biases may have on risk management.
- Educational value: Serious gaming served as effective educational tool, providing hands-on learning experiences that are difficult to replicate through traditional training methods. This experiential learning approach is particularly effective in demonstrating how biases like the representativeness heuristic, affect heuristic, and optimism bias influence risk assessments. Players not only see the consequences of their choices but also learn to identify their instinctual leanings towards certain biases.

The integration of structured thinking methodologies, such as Edward de Bono's "Six Thinking Hats", within serious games can enhance the ability to view risks from multiple perspectives. This not only deepens understanding but also promotes a comprehensive approach to evaluating risks, making the learning process more robust and applicable to real-world scenarios.

In conclusion, serious gaming serves as a powerful educational tool that actively involves individuals and teams in the process of identifying and mitigating cognitive biases. By simulating realistic risk scenarios and encouraging reflective thinking, serious games enhance the ability to manage risks more effectively, making them a valuable addition to traditional training methods in risk management.

The main research question can now be answered:

> How do heuristics and biases influence project risk assessment, and what role can serious gaming play in enhancing awareness and management of these cognitive factors?

In response to the main research question, it is evident that heuristics and biases significantly influence project risk assessment by potentially leading to inaccurate evaluations or actually being useful. These cognitive factors can disrupt effective risk management and impact project outcomes adversely. The literature reveals that while biases can negatively affect risk assessments, understanding and addressing them through systematic risk management processes and targeted training programs can mitigate these effects.

Project risk assessment incorporates structured methodologies like the RISMAN method. There is a recognized challenge in effectively managing the inherent cognitive biases, with a significant emphasis on increasing awareness rather than eliminating biases. Despite professionals' preference for objective risk management practices, a gap remains between their self-perception and actual behavior concerning the use of biases and heuristics. This discrepancy highlights a lack of self-awareness or difficulty in introspection.

The application of serious gaming in this context provides an environment where individuals and teams can experience and reflect on their decision-making processes in a controlled setting. By simulating real-life risk scenarios and engaging participants in reflective learning processes, serious games facilitate a deeper understanding of personal and collective biases. Serious games designed around risk management scenarios can simulate the complexities of real-world projects, allowing participants to engage with risk assessments in a reflective manner. The game's structure encourages exploring different perspectives, especially when methodologies like Edward de Bono's "Six Thinking Hats" are integrated, thereby broadening the understanding of risks from multiple viewpoints.

In conclusion, while heuristics and biases pose challenges to objective risk assessment, structured methodologies, increased awareness, and innovative tools like serious gaming can enhance the ability to manage these cognitive factors effectively. Serious gaming, in particular, plays a critical role in raising awareness and improving risk management practices by simulating complex risk scenarios and fostering active engagement with the elements of risk.

8.2 Recommendations for further research

While this thesis provides foundational insights into the intersection of cognitive psychology and risk management, several areas warrant further exploration to broaden the understanding and application of debiasing strategies in project risk assessment.

8.2.1 Deepening theoretical insights

Further research should delve deeper into the psychological underpinnings of heuristics and biases, particularly in high-stakes environments like construction projects. Cross-disciplinary studies incorporating insights from behavioral economics, psychology, and project management could yield more robust frameworks for understanding and dealing with cognitive biases.

8.2.2 Enhancing serious gaming applications

Future studies could explore the development of more sophisticated serious games that incorporate a wider range of project scenarios and risks. There is scope for developing serious games tailored to specific types of biases or particular stages of project management. These games should aim to simulate the complexities of entire project lifecycles and include features that allow for interaction and the manipulation of variables to see how different biases impact decision-making over longer periods and under varying conditions.

8.2.3 Longitudinal studies on the impact of serious games

Future research could involve longitudinal studies to assess the long-term effects of serious gaming on risk management practices. This would help determine how durable the effects of such interventions are and whether they translate into improved project outcomes over time.

8.2.4 Sector-wide implementation and evaluation

Expanding the implementation of serious gaming and debiasing strategies across different sectors and different types of projects within the construction industry could provide valuable insights into sector-specific challenges and benefits. Comparative studies could identify best practices and tailor debiasing approaches to the unique needs of different types of construction projects.

8.2.5 Measurement of economic impact

Further studies could aim to quantify the economic impact of improved risk assessment resulting from serious gaming interventions. This would provide compelling evidence for organizations to invest time and money in the development of advances serious games.

8.3 Recommendations for Dura Vermeer

As infrastructure projects continue to grow in complexity and scale, the need for sophisticated risk management strategies becomes increasingly critical. This research underscores the profound impact of heuristics and biases on risk assessment and highlights the potential of innovative approaches like serious gaming to foster risk awareness and thereby decision-making processes.

The implementation of a serious game within Dura Vermeer offers a multifaceted tool that could enhance organizational learning and team dynamics. It is recommended that the company introduces this serious game as an integral part of the onboarding process for new employees. This not only aids in familiarizing them with the company's culture and operations but also serves as a platform for sharing and integrating diverse perspectives from their previous experiences. Moreover, leveraging this game before risk assessment sessions could effectively heighten risk awareness and help in evaluating the diversity of viewpoints within project teams, ensuring a balanced approach to risk management.

Furthermore, the application of the serious game should not be restricted to project-related activities; it could also be employed as a continuous team-building and educational tool. An annual recurrence of the game could serve as a barometer for measuring shifts in employees' perceptions of specific risks over time, thus providing valuable insights into the evolving risk landscape. It is advised that Dura Vermeer explores these recommendations to strengthen their teams and enhance decision-making processes.

Literature

Aczél, B., Bagó, B., Foldes, A., & Lukács, B. (2015). Is it time for studying real-life debiasing? Evaluation of the effectiveness of an analogical intervention technique. *Frontiers in Psychology, 6*. https://doi.org/10.3389/fpsyg.2015.01120

Akintoye, A., & Macleod, M. (1997). Risk analysis and management in construction. *International Journal of Project Management, 15*(1), 31–38. https://doi.org/10.1016/s0263-7863(96)00035-x

Anderson, C. A., & Godfrey, S. S. (1987). Thoughts about actions: The effects of specificity and availability of imagined behavioral scripts on expectations about oneself and others. *Social Cognition,* 5(3), 238–258. https://doi.org/10.1521/soco.1987.5.3.238

Annetta, L. A. (2010). The "I's" have it: A framework for serious educational game design. *Review of General Psychology, 14*(2), 105-112.

Arkes, H. R. (1991). Costs and Benefits of judgment Errors: Implications for debiasing. *Psychological Bulletin, 110*(3), 486–498. https://doi.org/10.1037/0033-2909.110.3.486

Baker, S., Ponniah, D., & Smith, S. (1998). Techniques for the analysis of risks in major projects. *Journal of the Operational Research Society, 49*(6), 567. https://doi.org/10.2307/3010665

Bhandari, S., & Molenaar, K. R. (2020). Using Debiasing Strategies to Manage Cognitive Biases in Construction Risk Management: Recommendations for Practice and Future Research. *Practice Periodical on Structural Design and Construction, 25*(4). https://doi.org/10.1061/(asce)sc.1943-5576.0000521

Bing, L., Akintoye, A., Edwards, P.J., & Hardcastle, C. (2005). The allocation of risk in PPP/PFI construction projects in the UK. *International Journal of Project Management, 23*(1), 25-35

Birch, D. G., & McEvoy, N. A. (1992). Risk analysis for information systems. *Journal of Information Technology, 7*(1), 44–53. https://doi.org/10.1057/jit.1992.7

Blumenthal-Barby, J. S., and H. Krieger. (2015). Cognitive biases and heuristics in decision-making: A critical review using a systematic search strategy. *Medical Decision Making 35*(4): 539–57.

Blumenthal-Barby, J. S. (2016). Biases and Heuristics in Decision Making and Their Impact on Autonomy. *The American Journal of Bioethics 16*(5), 5-15.

Bosch-Rekveldt, M. (2011). Managing project complexity: A study into adapting early project phases to improve project performance in large engineering projects. The Hague, the Netherlands: Delft Centre for Project Management

Cosmides, L., & Tooby, J. (1994). Better than Rational: Evolutionary Psychology and the Invisible Hand. *American Economic Review, 84*(2), 327-332.

Dikmen, I, Birgonul, M. T. and Arikan, A. E. (2004). A critical review of risk management support tools. In: Khosrowshahi, F (Ed.), 20th Annual ARCOM Conference, 1-3 September 2004, Heriot Watt University. *Association of Researchers in Construction Management, Vol. 2*, 1145-54.

Dikmen, I., Birgonul, M. T., Anac, C., Tah, J. H. M., & Aouad, G. (2008). Learning from risks: A tool for post-project risk assessment. *Automation in Construction, 18*, 42–50

Dikmen, İ., Budayan, C., Birgönül, M. T., & Hayat, E. (2018). Effects of risk attitude and controllability assumption on risk ratings: Observational study on International Construction project risk assessment. *Journal of Management in Engineering, 34*(6). https://doi.org/10.1061/(asce)me.1943-5479.0000643

Duijm, D.J., 2015. Recommendations on the use and design of risk matrices. *Saf. Sci. 76*(1), 13–21.

Edwards, P. J., & Bowen, P. (1998). Risk and Risk Management in Construction: A review and Future Directions for research. *Engineering, Construction and Architectural Management, 5*(4), 339–349. https://doi.org/10.1108/eb021087

Elkington, P., & Smallman, C. (2002). Managing project risks: A case study from the utilities sector. *International Journal of Project Management, 20*, 49–57

Fan, M., Lin, N., & Sheu, C. (2008). Choosing a project risk-handling strategy: An analytical model. *International Journal of Project Management, 112*, 700–713.

Fischhoff, B. (1982). Debiasing. In Kahneman, D., Slovic, P., & Tversky, A. (eds.) *Judgment Under Uncertainty: Heuristics and Biases*. Cambridge University Press.

Flanagan, R., and Norman, G. (1993). Risk management and construction, Blackwell, Oxford.

Galavotti, I., Lippi, A., & Cerrato, D. (2021). The representativeness heuristic at work in decision-making: building blocks and individual-level cognitive and behavioral factors. *Management Decision, 59*(7), 1664–1683. https://doi.org/10.1108/md-10-2019-1464

Gjerdrum, D., & Peter, M. (2011). The New International Standard on the Practice of Risk Management - A Comparison of ISO 31000:2009 and the COSO ERM Framework. *Risk Management*, 8-12.

Godovykh, M., Pizam, A., & Bahja, F. (2021). Antecedents and outcomes of health risk perceptions in tourism, following the COVID-19 pandemic. *Tourism Review, 76*(4), 737–748. https://doi.org/10.1108/tr-06-2020-0257

Haselton, M. G., Nettle, D., & Andrews, P. W. (2005). The evolution of cognitive bias. *The handbook of evolutionary psychology,* 724-746.

Hayes, R.W., Perry, J.G., Thompson, P.A. & Willmer, G. (1986) Risk Management in Engineering Construction. Thomas Telford Ltd, London.

Heijer, F. D., Podt, M., Bosch-Rekveldt, M., De Leeuw, A., & Rijke, J. (2023). Serious gaming for better cooperation in flood defence asset management. *Journal Of Flood Risk Management, 16*(3). https://doi.org/10.1111/jfr3.12910

Hopkinson, M. (2010). The Project Risk Maturity Model: Measuring and Improving Risk Management Capability (1st ed.). Routledge. https://doi.org/10.4324/9781315237572

Hubbard, D., & Evans, D. (2010). Problems with scoring methods and ordinal scales in risk assessment. *IBM Journal of Research and Development*, 54 (3). doi: 10.1147/JRD.2010.2042914.

Hunt, D. & Naweed, A. (2023). The risk of risk assessments: Investigating dangerous workshop biases through a socio-technical systems model. *Safety Science*, *157*, 105918. https://doi.org/10.1016/j.ssci.2022.105918

Ika, L.A., Love, P.E.D., Pinto, J., 2022. Moving beyond the planning fallacy: the emergence of a new principle of project behavior. IEEE Trans. *Eng. Manag. 69*(6), 3310–3325.

Kähkönen, K. (2001), Integration of risk and opportunity thinking in projects. 4th European Project Management Conference, PMI Europe 2001. London, UK.

Kahneman, D., & Tversky, A. (1972). Subjective probability: a judgment of representativeness. *Cognitive Psychology, 3*(3), 430–454. https://doi.org/10.1016/0010-0285(72)90016-3

Kahneman, D., & Tversky, A. (1973). On the psychology of prediction. *Psychological Review, 80*(4).

Kangari, R. & Boyer, L. T. (1989). Risk management by expert systems. *Project Management Journal, 20*(1), 40–48.

KarimiAzari, A., Mousavi, N., Mousavi, S. F., & Hosseini, S. (2011). Risk assessment model selection in construction industry. *Expert Systems with Applications*, *38*(8), 9105–9111. https://doi.org/10.1016/j.eswa.2010.12.110

Katsikopoulos, K., Gigerenzer, G., 2013. Behavioral operations management: a blind spot and research program. J. *Supply Chain Manag. 49*(1), 3–7.

Larrick, R. P. (2004). Debiasing. In D. J. Koehler & N. Harvey (Eds.), Blackwell handbook of judgment and decision making (pp. 316–337). Blackwell Publishing. https://doi.org/10.1002/9780470752937.ch16

Laryea, S. (2008) Risk pricing practices in finance, insurance and construction. In: COBRA 2008 The construction and building research conference of the Royal Institution of Chartered Surveyors, 4-5 September 2008, Dublin Institute of Technology.

Love, P. E., Ika, L. A., & Pinto, J. K. (2023). Fast-and-frugal heuristics for decision-making in uncertain and complex settings in construction. *Developments in the Built Environment, 14*, 100129. https://doi.org/10.1016/j.dibe.2023.100129

MacCoun, R. J. (1998). BIASES IN THE INTERPRETATION AND USE OF RESEARCH RESULTS. *Annual Review of Psychology, 49*(1), 259–287. https://doi.org/10.1146/annurev.psych.49.1.259

Mak, S.W. & Raftery, J. (1992) Risk attitude and systematic bias in estimating and forecasting: an empirical study. *Construction Management and Economics, 10*, 303-320.

Mak, S.W. (1992) Risk management in construction: a study of subjective judgements. Ph.D. Thesis, University College, London.

Mak, S.W. (1995) Risk analysis in construction: a paradigm shift from a hard to soft approach. *Construction Management and Economics, 13*, 385-392.

McKim, R.A. (1991) Risk behaviour/risk allocation and contract strategy. In: Management, Quality and Economics in Building (eds A. Bezelga & P. Brandon), pp. 199-206. E. & F. N. Spon, London.

McKim, R.A. (1992) Risk behaviour of contractors: a Canadian study. *Project Management Journal, 23*(3), 51-55.

Mills, A. (2001). A systematic approach to risk management for construction. *Structural Survey*, *19*(5), 245–25

Montibeller, G., & Von Winterfeldt, D. (2015). Cognitive and motivational biases in decision and risk analysis. *Risk Analysis; 35*(7), 1230–1251. https://doi.org/10.1111/risa.12360

Morewedge, C. K., Yoon, H., Scopelliti, I., Symborski, C., Korris, J. H., & Kassam, K. (2015). Debiasing decisions. *Policy insights from the behavioral and brain sciences, 2*(1), 129–140. https://doi.org/10.1177/2372732215600886

Morgan, G. M. & Henrion, M. (1990) Uncertainty: A Guide to Dealing with Uncertainty in Quantitative Risk and Policy Analysis. Cambridge University Press, Cambridge.

Mousavi, S., & Gigerenzer, G. (2014). Risk, uncertainty, and heuristics. *Journal of Business Research, 67*(8), 1671–1678. https://doi.org/10.1016/j.jbusres.2014.02.013

Neth, H., & Gigerenzer, G. (2015). Heuristics: Tools for an uncertain world. In R. A. Scott & S. M. Kosslyn (Eds.), Emerging trends in the social and behavioral sciences an interdisciplinary, searchable, and linkable resource (pp. 1–18). Hoboken, NJ: Wiley. https://doi.org/10.1002/9781118900772.etrds0394

Nielsen, K. R. (2006). Risk management: Lessons from six continents. *Journal of management in engineering, 22*(2), 61-67.

Norzima, Z., Sorooshian, S., & Chow, K.W. (2011). *Effective project management*. Lambert Academic Publishing. Germany

Olcer, A. I., & Odabasi, A. Y. (2005). A new fuzzy multiple attributive group decision making methodology and its application to population/maneuvering system selection problem. *European Journal of Operational Research, 166*, 93–114

Paape, L., D.M. Swagerman, (2006). Risicomanagement - De Praktijk In Nederland. Amsterdam, PriceWaterhouseCoopers, Rijks Universiteit Groningen

Pronin, E., Gilovich T., & Ross, L. (2004). Objectivity in the eye of the beholder: Divergent perceptions of bias in self versus others. *Psychological Review, 111*(3), 781-799.

Pronin, E., Lin, D., & Ross, L. (2002). The Bias Blind Spot: Perceptions of Bias in Self Versus Others. *Personality & Social Psychology Bulletin, 28*(3), 369–381. https://doi.org/10.1177/0146167202286008

Raftery, J. (1994a). Risk analysis in project management, E&FN Spon, London.

Raftery, J. (1994b) Human aspects of project risk management. In: Proceedings: CIB (Conseil International du Bâtiment) International Symposium. Commission W92 Procurement Systems - 'East Meets West' (ed. S. Rowlinson), pp. 277-286. Department of Surveying, University of Hong Kong, Hong Kong.

Reimer, T., & Rieskamp, J. (2007). Fast and frugal heuristics. In R. Baumeister & K. D. Voss (Eds.), Encyclopedia of social psychology (pp. 347–349). Thousand Oaks, CA: SAGE.

Ruijter, H. (2019). Resilient Partnership - An interpretive approach to public-private cooperation in large infrastructure projects. The Netherlands.

Shah, A., & Oppenheimer, D. M. (2008). Heuristics made easy: an effort-reduction framework. *Psychological Bulletin, 134*(2), 207–222. https://doi.org/10.1037/0033-2909.134.2.207

Simkins, B. and S. A. Ramirez (2007). —Enterprise-Wide Risk Management and Corporate Governance. Loyola University Chicago Law Journal 39: 571.

Simon, H. A. (1957). Models of man; social and rational. Wiley.

Sprinkle, Z. J. (2018). Heuristics in Construction Project Management [Thesis]. Virginia Polytechnic Institute and State University.

Steiner, G. A. (1969). *Top management planning*. New York: Macmillan

Tabachnick, B. G., Fidell, L. S. & Ullman, J. B. (2018). *Using Multivariate Statistics*. Pearson.

Teneyuca, D. (2001). Organizational leader's use of risk management for information technology. *Information Security Technical Report, 6*(3), 54–59.

Tetlock, P. E., & Gardner, D. (2015). *Superforecasting: The art and science of prediction*. Crown Publishers/Random House.

Thompson, M., Ellis, R. and Wildavsky, A. (1990). *Culture Theory*. Westview Press, Oxford.

Todd, P. M., & Gigerenzer, G. (2012). Ecological rationality: Intelligence in the world. Oxford University Press.

Tversky, A., & Kahneman, D. (1974). Judgment under Uncertainty: Heuristics and Biases. *Science, 185*(4157), 1124–1131. http://www.jstor.org/stable/1738360

Uiterlinden, R. (2005). Het COSO Enterprise Risk Management - Integrated Framework.

Van Well-Stam, D., Lindenaar, F., Van Kinderen, S., & Van den Bunt, B. (2004). Project Risk Management. London: Kogan Page Limited.

West, R. F., Meserve, R. J. & Stanovich, K. E. (2012). Cognitive Sophistication Does Not Attenuate the Bias Blind Spot. *American Psychological Association 103*(3), 506-519. DOI: 10.1037/a0028857

Willams, T. M. (1994). Using a risk register to integrate risk management in project definition. *International Journal of Project Management, 12*(1), 17–22. https://doi.org/10.1016/0263-7863(94)90005-

Wood, G., & Ellis, R. C. (2003). Risk management practices of leading UK cost consultants. Engineering, *Construction and Architectural Management, 10*(4), 254–262. https://doi.org/10.1108/09699980310489960

Appendix A: Interview protocol

Intro (5 min)

- Introductie van geïnterviewde (functie, leeftijd, werkervaring (*bij Dura Vermeer*))
- *Benoemen doel van het interview en rol van geïnterviewden in onderzoek als geheel*
- *Verwachtingen benoemen*:
    - *Behoefte aan reflectie*
    - *Baseer antwoorden op eigen ervaringen*
    - *Waarde toevoegen aan bestaande literatuur door literatuurbevindingen en praktijk/ervaring te verbinden*

Besluitvorming risicoanalyse (15 min)

- Wat is uw rol in risicoanalyse bij Dura Vermeer?
- Hoe vindt risicoanalyse doorgaans plaats tijdens de aanbestedings- en uitvoeringsfase? Kunt u het proces beschrijven?
- Welke factoren beïnvloeden het proces van risicoanalyse?
    - Welke factoren dragen bij aan het succes van de analyse?
    - Welke factoren dragen bij aan het falen van de analyse?
- Hoe is het proces van risicoanalyse in de loop der jaren veranderd?
- Welke ervaringen hebben bijgedragen aan de ontwikkelingen van het proces van risicoanalyse zoals u dat uitvoert?

Heuristieken en biases in risicoanalyse (25 min)

- *Introduceer heuristieken en biases waar dit onderzoek op gericht is.*
- Herkent u het voorkomen van de heuristieken en biases zoals hier gepresenteerd in de praktijk?
- Hoe beïnvloeden deze heuristieken en biases uw risicoanalyseproces?
- Welke biases komen vanuit jouw ervaring het meest voor en ervaar je als meest problematisch voor de risicoanalyse?
- Welke biases zouden in potentie het meest problematisch zijn, ongeacht of je deze in de praktijk veel herkent?
- Zijn er nog andere heuristieken en biases die je in de praktijk ervaart waar we het nu niet over gehad hebben?

Interventiestrategieën (15 min)

- Bent u bekend met interventies om het optreden van biases te mitigeren? Past u deze interventies toe in de praktijk?
- Wanneer zouden bias-interventies effectief zijn?
- Wanneer zouden bias-interventies ineffectief zijn?
- Heeft u suggesties voor bias-interventies?
- Hoe zouden deze interventies het risicoanalyseproces helpen?

Afsluiting

- Welke vraag had je verwacht maar heb ik niet gesteld?
- *Tekenen formulier toestemming verwerking gegevens en antwoorden*

Heuristiek / bias	Definitie	Voorbeeld
Affectieve heuristiek	Bij het nemen van beslissingen vertrouwen op emoties in plaats van op concrete informatie	Beoordelen of iets goed of slecht is en je hebt daar een fijne, dan wel vervelende herinnering aan
Bevestigingsbias	Neiging om informatie te zoeken en te interpreteren en te herinneren op een manier die overeenstemt met iemands eerdere overtuigingen, waarden of meningen.	Je wil je voorgevoel / overeenstemming bevestigen
Representativiteits-heuristiek	We schatten de waarschijnlijkheid van een gebeurtenis in op basis van hoe vergelijkbaar deze is met een bekende situatie of stereotype dat we al in gedachten hebben	Er gebeurt x en x en dat voldoet aan het stereotype x, dus zal het wel zo zijn Hij draagt een pak en een aktetas, dus hij zal wel advocaat zijn
Ankerbias (ook bekend als referentie-effect)	Vertrouw te sterk op een stukje informatie (vaak het eerste stukje) dat ze over een onderwerp ontvangen, ongeacht de juistheid van die informatie	Als het eerste heel slecht is, lijkt het tweede wel mee te vallen. Eerst dure auto (standaard voor de rest van de onderhandeling), dan lijkt de tweede ineens heel goedkoop.
Status quo bias	Neiging om in een strategische interactie over het algemeen de standaardoptie (de gebruikelijke weg) te kiezen, omdat de nadelen van het verlaten ervan groter zijn dan de voordelen	Doen wat je altijd al doet voelt veilig
Verzonken-kosten effect	We blijven onze eerdere beslissingen steunen, ondanks nieuw bewijs dat erop wijst dat dit niet de beste handelwijze is	Je hebt voor iets betaald en weet dat het slecht is om ermee door te gaan, maar toch doe je het
Beschikbaarheidsbias	Mensen vertrouwen op directe voorbeelden die in de gedachten opkomen bij het evalueren van een specifiek onderwerp, concept, methode of beslissing / Beslissingen nemen op basis van informatie die we ons als eerste herinneren	Recent ongeluk met vliegtuig, waardoor je dat eng vindt, maar de kans dat je in een auto-ongeluk doodgaat is vele malen groter
Bandwagon effect	Neiging om bepaalde gedragingen of houdingen over te nemen, simpelweg omdat anderen dat doen	Verkiezingen: stemmen op wat de rest doet.
Winst- en verliesframingbias	Neiging om risicomijdende keuzes te maken wanneer opties een positief frame hebben, terwijl ze meer verliesmijdende opties	Men kiest voor de optie die ze als winst zien boven de optie die ze als

	selecteren wanneer ze met een negatief frame worden gepresenteerd	verlies zien, ook als de opties tot hetzelfde resultaat zouden leiden Van 600 mensen: A) je redt 200 mensen OF B) er gaan 400 mensen dood. Dan kiest men voor optie A als beste
Optimisme / overmoedbias	De neiging om de waarschijnlijkheid van positieve gebeurtenissen te overschatten en de waarschijnlijkheid van negatieve gebeurtenissen te onderschatten	Hoogmoed

Appendix B: Interview analysis

Table 3. Interview analysis (part 1)

	Interviewees (RM= Risk Manager; PM= Project Manager)					
Question (Q-xx)	RM-1	RM-2	RM-3	PM-1	PM-2	PM-3
1. Kunt u zichzelf introduceren en daarbij uw functie, afdeling en werkervaring benoemen?	Ik ben procesmanager voor de afdeling middelgrote projecten. Binnen de afdeling procesbeheersing ben ik verantwoordelijk voor verschillende processen waaronder risicomanagement. Ik ben 14 jaar in dienst bij DV. Aan het begin was ik betrokken bij de oprichting van de vakgroep projectbeheersing bij de afdeling beton- en waterbouw.	Werkzaam als procesmanager, waar risicomanagement onder valt. Ik ben ruim 5 jaar werkzaam bij Dura Vermeer waarvan 2 jaar bij afdeling Vastgoed en nu 3 jaar bij Haven & Industrie (onderdeel van divisie Infra). Ik ben veelal werkzaam op lopende projecten, maar soms ook in tenders. Rol op de projecten is veelal QA/QC-manager (quality assurance / quality control).	Ik werk 6 jaar bij DV. Momenteel in de functie verbetermanager/ manager procesbeheersing voor afdeling asset management.	Ik ben werkzaam als projectmanager bij een langdurige bodemsanering. Het is momenteel mijn tweede jaar als projectmanager. Daarvoor was ik werkzaam als procesmanager (financiën/risico/planning-manager).	Ik werk als projectmanager bij DV. Dat doe ik sinds 5 jaar en ben in totaal 14 jaar werkzaam bij DV. Daarvoor werkte ik als werkvoorbereider en uitvoerder.	Ik ben 43 jaar oud. Ongeveer 23 jaar werkzaam in de civiele techniek. Daarin heb ik onder anderen werkvoorbereiding gedaan en nu ben ik werkzaam als projectmanager sinds een jaar en daarvoor als bedrijfsleider en projectleider.
2. Hoe vindt risicoanalyse doorgaans plaats tijdens de aanbeste-dings- en uit-voeringsfase?	Geheel conform de RISMAN-methodiek analyseren we risico's binnen de gehele divisie infra. Als het lukt kijken we al in de tenderfase mee met risico's. Of we dat wel of niet doen hangt ook af van de contractvorm. Bij een RAW-contract blijft een groot deel van de verantwoordelijkheid en daarmee ook risico's bij de opdrachtgever. Bij een UAV-gc uitvraag is dat bijvoorbeeld andersom. Daarnaast is het afhankelijk van de EMVI-criteria die de opdrachtgever uitvraagt. Als we de projectscope in beeld hebben benaderen we risico's als factoren die een kans met zich meebrengen op het afwijken van de projectdoelstellingen. Daarbij maken we onderscheid tussen kansen en risico's, waarbij kansen een positieve afwijking brengen en risico's een negatieve. Bij complexere werken levert de opdrachtgever soms al een risicodossier aan met daarin risico's die zij al hebben geïdentificeerd. Daaropvolgend hebben we vaak één of twee plenaire sessies waarin we het risicodossier uitbreiden of opstellen als dit er nog niet was vanuit de aanbesteding.	We volgen de RISMAN-methodiek, waarbij we middels memo's brainstormen op de identificatie van de risico's op verschillende categorieën zoals veiligheid. Ik probeer de sessies laagdrempelig te houden, omdat niet iedereen ervaring of affiniteit heeft met risicomanagement. Men schrijft ieder voor zich risico's op en deze bespreken we plenair. Men vindt het moeilijk om risico's te beschrijven, omdat ze veelal bijvoorbeeld gevolgen benoemen. De kwantificatie doe ik in een later stadium individueel met de betrokken personen, waarbij ik gezamenlijk per individu de kwantificatie van de door hem of haar aangedragen risico's uitvoer. Veelal is dat ook de persoon vanuit hetzelfde specialisme als waar het risico toe behoort. Eventueel kan ik de kwantificatie ook uitvoeren met degene die het risico het beste kan beoordelen en/of beheersen.	Eigenlijk enkel wanneer de opdrachtgever risicovastlegging uitvraagt doen we dit. Binnen asset management zijn we er niet veelvuldig mee bezig. Het niveau van risicomanagement is daarmee bij asset management vrij laag. Als we niet gestructureerd de risico's vastleggen, is het enkel beperkt tot een beschouwing die ieder voor zich in zijn of haar hoofd maakt. Een risicosessie is bij ons altijd een gezamenlijke sessie, zowel de identificatie van risico's als de kwantificatie. Daarna houden we vaak eenmaal per jaar een opvolgende sessie waarin we de risico's beschouwen. Dat we dit slechts één keer per jaar doen, heeft er ook mee te maken dat we vaak langlopende onderhoudscontracten hebben (vaak 5+ jaar) die minder dynamisch zijn dan andere projecten. Je merkt daarbij wel dat de aandacht voor risico's een beetje wegzakt.	Voor grotere projecten is het risico- en kansendossier reeds in de tenderfase goed uitgewerkt. Voor kleinere werken is daar soms onvoldoende tijd voor of vindt men het onvoldoende belangrijk. Ook zie je dat er wel eens 'naar een vast percentage toe gewerkt wordt' als risicobudget dat we hanteren bovenop de andere projectkosten om te komen tot onze totale inschrijfprijs. De stuurgroep heeft daar lang niet altijd zicht op. Als de risico- en kansenbeschouwing goed is gedaan in de tenderfase, wijkt het percentage ook wel eens fors af van dat standaard percentage en wordt in het uiterste geval zelfs besloten niet in te schrijven.	Het vaststellen en vastleggen van risico's doen we vaak hoog over een keer in de aanbestedingsfase, vooral om te inventariseren waarvoor aandacht moet zijn. We leggen dit wel vast in een dossier. In de realisatiefase is vaak meer ruimte om per risico deze goed te beschouwen. Ik heb ervaring met zowel plenaire sessies als individuele sessies en met dat laatste heb ik de beste ervaring, omdat ik dan een bredere scope krijg qua risico's en beheersing.	We werken met een kansen- en risicodossier waarin we alle kansen en risico's benoemen. Lang niet in iedere aanbesteding leggen we kansen en risico's expliciet in dit dossier vast. Het belang dat de tenderleider hieraan hecht is bepalend voor of dit wel of niet gebeurt. In de uitvoeringsfase bouwen we dit dossier wel standaard op. Afhankelijk van de grote van het project, bouwt de projectleider het dossier zelf op (kleiner project) of doet een risicomanager dit (groter project). Hieropvolgend moet het dossier actueel gehouden worden. De projectleider dan wel risicomanager bouwt dit dossier naar mijn ervaring zelf op, op basis van individuele interviews met specialisten. Zowel identificatie als kwantificatie van risico's vindt daar plaats.
3. Wat is uw rol in risicoanalyse bij Dura Vermeer?	Ik faciliteer de plenaire risicosessies waarin we de risico's inventariseren en kwantificeren. Ik focus op de kwaliteit van het dossier (projectspecifieke risico's vastleggen) boven de kwantiteit van het dossier (waarbij veel standaard / globale risico's worden opgenomen). Het is dan belangrijk dat de risico's zuiver worden gedocumenteerd. Risico's beschrijven we vaak als oorzaak - risico - gevolg, maar de	Rol als QA/QC-manager is niet heel strak gedefinieerd, maar in risicomanagement organiseer en facilitair ik de risicosessies, evenals dat ik ze voorzit en het risicodossier uitwerk.	Mijn rol in risicosessies is het begeleiden van en/of deelnemen aan de sessie, afhankelijk van of wij of Rijkswaterstaat het faciliteert. Veelal werken we dan toe naar het opstellen vaan top 10 risico's, initieel	Projectmanagers krijgen tussen tender- en realisatiefase een kansen- en risicodossier overgedragen vanuit de tender. Daarbij zijn er aannames op met name tijd en geld gedaan voor kansen en risico's. De projectleider neemt het kansen- en risicodossier in de realisatiefase over, verbetert deze, werkt deze bij en borgt uitvoering van beheersmaatregelen. Als een tendermanager dit in de tenderfase heel opportunistisch	Ik zie mijn rol vooral als balans brengen tussen het optimisme uit de tender en het pessimisme (doemdenken) dat soms bij uitvoerders heerst. Die balans is voor mij natuurlijk echter ook weer gebaseerd op	Ik ben als projectmanager eindverantwoordelijk voor het beheerst uitvoeren van projecten dus ben ik eigenaar van het proces risicobeheersing. Ik zie mijn taak in het motiveren van het projectteam om potentiële risico's vroegtijdig onder de aandacht te krijgen. Daarna is ook de allocatie van risico's iets

	oorzaken hebben ook weer oorzaken. We moeten de scope van het risico duidelijk definiëren. Ook de beoordeling/kwantificatie van risico's doen we in de plenaire sessie(s). Juist door de interactie die dan ontstaat, is men kritisch op elkaars bevindingen. Zo help je elkaar aan een integraal goed dossier. Als iemand een risico benoemt waarvan de ander constateert dat dit al is afgedekt in het contract, kun je gezamenlijk conclusies trekken. Na de kwantificatie beschouwen we de top 10 risico's en evalueren we of dit ook de risico's zijn die volgens ons onderbuikgevoel tot de top 10 zouden behoren. Als er nog iets mist of iets hoort er niet, passen we ook wel eens de kwantificatie aan.		gekwantificeerd en het restrisico gekwantificeerd na beheersmaatregelen.	(onrealistisch) heeft gedaan, zie je wel eens dat alle kansen al 'verzilverd' zijn in de inschrijfprijs en de risico's niet zijn afgeprijsd of een heel lage kans van optreden zijn toegedicht.	onderbuikgevoel, maar het doel is realisme, in plaats van optimisme of pessimisme. Veelal leg ik de taak voor het faciliteren van sessies en documenteren van risico's weg bij de risicomanager.	waar ik me daarna mee bezighoud.
4. Welke factoren dragen bij aan het succes van de analyse en welke factoren dragen bij aan het falen van de analyse?	Een goeie voorbereiding van de sessie zelf, zoals een duidelijke agenda draagt bij aan de kwaliteit. Dat kan bijvoorbeeld gaan over eerst alle risico's beschouwen op dezelfde gevolgcategorie. Anders vliegt het alle kanten op en heb je na verloop van tijd nog geen kwalitatief goed dossier. Daarnaast moet er interactie ontstaan. Iedereen moet aan het woord komen, in plaats van dat degenen met het hoogste woord het voor het zeggen hebben. Ook doorvragen om de risicodefinitie (afbakening van risico's) duidelijk te krijgen. Bovendien moeten in de sessies de juiste specialisten aan tafel zitten (spreiding). Gedurende het project moet het risicodossier onder de aandacht blijven worden gebracht, zodat deze in verschillende fases van het project opnieuw beschouwd wordt. Teveel in details vervallen op ieder risico verstoort de analyse. Als het noodzakelijk is om het dossier meer diepgang te geven, kunnen we dit in individuele sessies verder uitdiepen. In die individuele sessies verschilt de kwantificatie echter niet veel van hoe we dit in de plenaire sessies al hadden gedaan. Bovendien gaat het mij meer om de top 10, dus risico's in relatie tot elkaar, in plaats van de kwantificatie per afzonderlijk risico.	Bij het ophalen van risico's is het belangrijk dat de juiste specialisten aangehaakt zijn. Het succes en falen van het kwantificeren hangt samen met het projectspecifiek beoordelen van de risico's. De scores voor gevolgcategorie geld moeten bijvoorbeeld bepaald worden als percentage van de aanneemsom. De kwantificering voer ik samen met de individuen uit, maar gebeurt dus niet geheel individueel, maar in gesprek/discussie met mij. Ik heb er vaak ook wel een eigen beeld bij en als mijn beoordeling enorm afwijkt van de beoordeling van de betrokkenen, vraag ik er op door. Zo voeren we een gesprek om overeenstemming te bereiken over de beoordeling en wordt men gedwongen er nog eens goed over na te denken.	De definitie van het risico is heel belangrijk. Vaak zie je dat sommigen het heel specifiek maken en anderen veel meer hoog over. We moeten een gemeenschappelijk begrip hebben van wat we nou daadwerkelijk gaan kwantificeren.	Als projectmanager kansen- en risicodossier overgedragen krijgt moet hij/zij hier ALTIJD nogmaals kritisch naar kijken. Roze bril vanuit de tender af zetten, maar puur realistisch bekijken. Vrijwel altijd moeten de kans van optreden en/of de impact bij optreden dan naar boven bijgesteld worden. De kwaliteit hangt ook af van de persoon die ervoor aan de lat staat als eindverantwoordelijke en hoe serieus deze risicomanagement neemt. Een projectmanager kan ook de stuurgroep een beetje misleiden over de ernst van de risico's of de mate waarin risico's überhaupt beschouwd zijn, om maar geen 'moeilijke vragen' te krijgen. Soms is er immers geen tijd voor de projectmanager om een compleet risicodossier goed uit te werken en ook niet altijd is er een risicomanager in het team. Dit geldt niet alleen voor de aanbestedingsfase, maar ook voor de realisatiefase; die tijdsdruk is er altijd. Specialistische disciplines (bv. sanering, spoor) moeten betrokken worden voor goede analyse, waarmee het ontbreken hiervan dus het falen van de analyse inleiden. Vaak sluiten deze specialisten pas in de realisatiefase aan, maar wenselijker is om ze al in de aanbestedingsfase te betrekken.	Het succes van de analyse is heel erg afhankelijk van de ervaring van mensen. Plenair zie je vaak dat dezelfde mensen altijd het woord nemen, terwijl je bij individuele analyse iedereen bevraagt en daarbij naar mijn idee een breder scala een risico's en beheersmaatregelen ophaalt. Ik denk echter wel dat iedereen vaak dezelfde toprisico's ziet.	Een heldere definitie van de gevolgklasse (bijvoorbeeld 1 staat gelijk aan €x) is noodzakelijk. Daarnaast is ook de definitie van het risico belangrijk en wat we tot risico's scharen (een ongewenste gebeurtenis die kan optreden) en wat onzekerheden/bandbreedtes zijn (bijvoorbeeld afwijkingen van aangenomen hoeveelheden in het ontwerp). Enkel die eerste categorie, de ongewenste gebeurtenis, moeten mijn inziens als risico's worden vastgelegd in een risicodossier.
5. Hoe is het proces van risicoanalyse in de loop der jaren veranderd?	Sinds ik binnen het bedrijf betrokken ben, volgen we de RISMAN-methode. Daar is niet veel in veranderd. De technieken die we daarbovenop soms gebruiken zijn er in de loop der jaren bijgekomen. Dit gaat bijvoorbeeld om een Monte Carlo-analyse voor het vaststellen van een totale risicopot voor het project.	In de afgelopen vijf jaar en ook in mijn werkleven daarvoor hebben we altijd de RISMAN-methodiek toegepast. Voor de risicosessies kun je wel verschillende werkvormen hanteren, waarin je nog wel eens kunt innoveren. Echter, het hele proces volgens RISMAN is in de sector wel uniform toegepast en in de laatste jaren niet veranderd.	Risico's krijgen tegenwoordig binnen de directie meer aandacht, bijvoorbeeld in de operationele plannen. Op de contracten (projecten) zie ik er niet veel ontwikkeling in. Wel vindt vastlegging steeds vaker plaats in Relatics. Dat helpt je risico's op een gestructureerde manier vast te leggen en te kwantificeren.	Vroeger werd er veel meer met lef en overmoed ("cowboygedrag") naar risico's gekeken. Traditioneel werkte opdrachtgever hele projectplan, inclusief ontwerp uit en stond de aannemer enkel aan de lat om het te bouwen. De aannemer bouwde enkel exact volgens de tekeningen van de opdrachtgever en alles wat bezweek/faalde, was risico van de opdrachtgever. Nu maken we zelf vaker een ontwerp op basis van enkel de gegevens dat er op locatie x een weg moet komen. Wanneer dan bijvoorbeeld geen gegevens beschikbaar zijn over de draagkracht van de bodem, moeten we dit zelf onderzoeken. Het risico van het eventueel falen van de constructie ligt daarna ook bij de aannemer, wat ervoor zorgt dat deze nu de prikkel krijgt om óók de risico's te beschouwen, evenals de opdrachtgever dat doet. Onwerkbaar weer (lage temperatuur, wind, onweer) was vroeger het	RISMAN doen we altijd al, maar de manier van gestructureerd vastleggen (dossiervorming) is sterk verbeterd. Het krijgt simpelweg meer aandacht. Vroeger werd enkel gefocust op geld, maar nu bekijken we risico's veel breder, bijvoorbeeld ook op tijd en kwaliteit.	Vroeger (tot aan ca. 2005) bestond het procesmatige risicomanagement en kwaliteitbeheer helemaal niet. Er werd wel over risico's nagedacht, maar dit bleef beperkt tot "gezond verstand" gebruiken. Het procesmatig documenteren van risico's is sindsdien steeds belangrijker geworden.

				toprisico voor aannemers, omdat zij enkel aan de lat stonden voor het bouwen. Binnen een bepaald tijdsbestek moest de aannemer dat doet en onwerkbaar weer was het voornaamste risico om dat te verhinderen. Tegenwoordig draait het ook sterk om ontwerp en veiligheid (omdat dat ook in het ontwerp al komt kijken).		
6. Welke ervaringen hebben bijgedragen aan de ontwikkeling van het proces van risicoanalyse zoals u dat nu uitvoert?	Vanuit de coronatijd zijn digitale sessies belangrijker geworden. Die houd ik tegenwoordig nog wel eens, waarbij ik aan het begin van de sessie het format van het risicodossier al klaar heb staan. Tijdens de sessies vullen we deze dan. Dit heeft als voordeel dat je tijdens de sessie direct snel kunt filteren door het dossier heen in plaats van dat je alle papieren memo's moet ordenen. Dit is voornamelijk vanuit praktische overwegingen. Niet zo zeer dat de kwaliteit van de analyse hier beter van wordt.	Op kleinere werken wordt niet procesmatig volgens RISMAN gewerkt, omdat daar onvoldoende tijd of kennis zit. Het is dan beperkt tot enkel het identificeren en vastleggen van enkele beheersmaatregelen in Excel. Zelf ben ik wel wanneer het mogelijk is in tijd, altijd procesmatig gaan werken volgens RISMAN. Dit proces borgt dat je compleet bent.	Jaren terug nam ik het opstellen van risico's inclusief beheersmaatregelen volledig op me en maakte ik een actielijstje voor wie de maatregelen zou uitvoeren. Tegenwoordig maken we gezamenlijk het dossier, zodat ook iedereen betrokken is en betrokkenheid voelt. Dan hoef ik geen acties op te leggen.	De functie manager procesbeheersing (waar risicomanagement een onderdeel van is), is pas iets van de laatste 15 à 20 jaar. Nu heeft deze functie een vaste plaats in een projectteam, zowel van opdrachtgeverskant als van aannemerskant. Deze dient risicosessies te plannen en te faciliteren, er op toe te zien dat beheersmaatregelen worden uitgevoerd, etc. Deze is als het ware naast de projectmanager een tweede stuurwiel van het project. Vroeger werden deze taken belegd bij de projectmanager, MITS deze hiervoor tijd had naast zijn/haar andere werkzaamheden.	Er is steeds meer aandacht voor risicoanalyse en risicobeheersing gekomen binnen de gehele sector. Ik kan geen persoonlijke ervaringen bedenken waardoor ik anders ben gaan werken.	Ik ben me meer gaan richten op het (laten) uitvoeren van beheersmaatregelen in plaats van enkel het identificeren van risico's. Soms zijn we veel bezig met het in kaart brengen van de risico's, maar laten we na de focus op de beheersing te leggen. Dat komt ook doordat we focussen op enkel een lijstje toprisico's en met de rest doen we niets meer. Als je een fout hebt gemaakt in de kwantificering, kunnen ook risico's die oorspronkelijk buiten je lijst toprisico's vallen problematisch worden doordat je daarvoor geen beheersmaatregelen hebt getroffen. Ik monitor nu ook steeds meer die risico's om alsnog beheersmaatregelen te kunnen treffen als we signaleren dat risico's toch groter zijn of worden dan vooraf ingeschat.

Table 4. Interview analysis (part 2)

	Interviewees (RM= Risk Manager; PM= Project Manager)					
Question (Q-xx)	**RM-1**	**RM-2**	**RM-3**	**PM-1**	**PM-2**	**PM-3**
7. Welke biases komen vanuit jouw ervaring het meest voor en ervaar je als meest problematisch voor de risicoanalyse?	Ik herken ze allemaal wel uit de praktijk. Sommigen zie ik echter niet als iets problematisch. Tussen de *representativiteitsheuristiek* en de *affectieve heuristiek* zie ik een oorzaak-gevolg relatie: als je iets herkent vanuit een ander project (representativiteit) kun je daar mogelijk met emotie uit dat vorige project (affectief) over oordelen. De *bevestigingsbias* is niet meer dan menselijk en er schiet me niet direct een voorbeeld te binnen dat dit ooit een issue is geweest. De *ankerbias* komt wellicht voor doordat we het eerste risico als eerste stukje informatie krijgen en alle daaropvolgende risico's relatief ten opzichte van de eerste en daaropvolgende risico's beoordelen. Ik zie dit echter niet als probleem, omdat we uiteindelijk gewoon toewerken naar een top 10. Als er aan het einde van de analyse nog iets mist in de top 10 of iets hoort er niet, passen we ook wel eens de kwantificatie aan. (opmerking onderzoeker: dit is mogelijk juist de	Ik denk dat beoordeling veelal op emotie gebeurt. De *affectieve heuristiek* ken ik daarmee zeker. De *bevestigingsbias* herken ik niet zo. In een plenaire sessie worden risico's van verschillende kanten belicht en door discussie wordt deze bias denk ik ondervangen. De *representativiteitsheuristiek* komt veel voor. Men baseert een beoordeling op eerdere ervaringen. De *ankerbias* herken ik, maar vind ik niet heel problematisch. De *status quo bias*, *verzonken-kosten effect* en de *beschikbaarheidsbias* herken ik allen niet uit de praktijk. Het *bandwagon effect* herken ik ook niet. Dat komt ook, omdat ik risico's doorgaans één op één met individuen kwantificeer en dit naar mijn idee een bias is die voorkomt als je gezamenlijk kwantificeert. De *winst/verliesframingbias* herken ik niet. De	De *affectieve heuristiek* herken ik zeker. Er zit vaak ook wantrouwen tussen de opdrachtgever en opdrachtnemer (bij gezamenlijke risicosessies). De *bevestigingsbias* herken ik zeker ook. Dat geldt ook voor de *representativiteitsheuristiek*. In onderhoudscontracten werken we aan verschillende wegen en dan wordt vaak gezegd: "dit risico is op weg x van toepassing en zal daarom ook wel op weg y en weg z van toepassing zijn". De *ankerbias*, *status quo bias*, en *verzonken-kosten bias* denk ik ook wel te herkennen, maar kan daar niet zo snel een voorbeeld van geven. Bij die laatste hangt het er ook vanaf of je bij een (tweede) analyse met dezelfde mensen zit die de 'verzonken kosten' hebben gemaakt. Zij zouden daar wellicht niet vanaf willen wijken, maar 'nieuwe' beoordelaars zullen daar wellicht minder aan	Ik herken ze allemaal in de praktijk, op de ankerbias in wellicht heel kleine mate na. Bandwagon herken ik sterk. Als een projectmanager met een sterke persoonlijkheid een sterke mening heeft overtuigt hij de rest van het team om op een bepaalde manier te handelen. Ook als andere mensen een risico beoordelen en je hebt zelf de kennis niet, denk je eerder "dat zal wel kloppen". Als vier mensen vanuit de tender zeggen "de kans van optreden van dit risico is niet groot", ook al heb jij het idee van wel, laat je je toch beïnvloeden door wat de 'massa' vindt. De **optimismebias** komt het vaakst voor. Bijvoorbeeld wanneer we een inschatting maken van onze dagelijks productie, denk aan het aantal ankers dat je per dag boort of het aantal palen dat je per dag heit. Soms zijn er dagen dat het werkelijke aantal ver beneden de inschatting ligt. Daarnaast	De *affectieve heuristiek* komt veel voor en is belemmerend als dit heel dominant wordt in een discussie. Ik vertrouw daarom liever op getallen in plaats van op emotie door slechte ervaringen. In de *bevestigingsbias* herken ik mezelf soms. Ik vind hem echter minder problematisch dan de vorige. De *representativiteitsheuristiek* komt heel veel voor. Iedereen put zijn/haar kennis uit eerdere ervaringen. Ik zie deze echter meer als positieve bijdrage en dus niet problematisch. De *ankerbias* herken ik bij het relatief beoordelen van de risico's. Echter is dat naar mijn idee ook wat ik vanuit mijn rol moet doen: kijken naar de grote lijnen. De *status quo bias* herken ik, omdat sommige risico's altijd voorkomen in 'standaardlijstjes' die worden opgesomd bij ieder project. Daardoor ga je	De *affectieve heuristiek* herken ik zeker. Dat kan om emoties uit het verleden gaan als iemand ergens iets heel erg mis heeft zien gaan. Kan functioneel zijn, maar ik zie dit meer als valkuil. De *bevestigingsbias* is heel herkenbaar. Je hebt dan eigenlijk een tunnelvisie en staat niet meer open voor andere informatie. De *representativiteitsheuristiek* is er altijd. De waarschijnlijkheid inschatten blijft heel subjectief. Dit doe je uiteindelijk toch met wat je in je 'rugtas' hebt zitten aan ervaring. Het *ankereffect*, de *status quo bias* en het *verzonken kosten effect* herken ik eigenlijk allen niet zo in de praktijk. Bij de status quo bias geldt wel dat we iets doen zoals we het altijd doen, maar dat doen we volgens mij niet per se, omdat de nadelen van iets anders doen groter zijn. De

	bevestigingsbias; score aanpassen op basis van onderbuikgevoel ten aanzien van de top 10). De status quo bias, *verzonken-kostenbias* en *beschikbaarheidsbias* herken ik wel, maar zie ik allen niet als problematisch. Het *bandwagon effect* zie ik niet vaak ontstaan, maar kan wel voorkomen als één of enkelen constant het hoogste woord hebben en anderen met die ene persoon of de groep meegaan. De *winst- en verliesframingbias* herken ik niet zo, omdat we in risicosessies niet veel stilstaan bij een positieve of negatieve framing van het risico. Een risico is in essentie iets wat tot een negatieve afwijking van de projectdoelstelling leidt, dus zal een risico vaak negatief geformuleerd zijn. De *optimismebias* herken ik niet enorm in de praktijk. Volgens mij kan je pas echt achteraf bij een evaluatie beoordelen of je vooraf overmoedig was en dit evalueren doen we te weinig. Als meest voorkomend zie ik de **representativiteitsheuristiek**, maar deze zie ik tegelijkertijd juist als een functionele heuristiek: je beoordeling baseren op eerdere ervaringen. Het meest problematisch vind ik de **affectieve heuristiek** waarbij men meer beoordeelt op gevoel/emotie dan dat men objectief beoordeelt. Dit kan juist wel een gevolg zijn van de representativiteitheuristiek doordat je door een vorig project met emotie naar een risico kijkt.	*optimismebias* herken ik zeker wel. Het meest voorkomend en in potentie meest problematisch vind ik de **representativiteits-heuristiek**. Deze kan ook functioneel zijn, maar kan je ook zeer beperken in je denken. Je beschouwt dan immers een risico op basis van eerdere positieve of negatieve ervaring, maar je zou het eigenlijk opnieuw met een open blik moeten beschouwen.	vasthouden. De *beschikbaarheidsbias* komt continu voor en is denk ik ook heel menselijk. Het *bandwagon effect* komt zeker voor. Ook als mensen geen gevoel hebben bij een risico, gaan ze maar mee met iemand die er wel iets over kan zeggen / durft te zeggen. De *winst- en verliesframingbias* heeft te maken met hoe je een risico beschrijft. Een risico wordt altijd in negatieve richting beschreven, want anders is het een kans. Daarom herken ik deze niet als iets waardoor we biased beoordelingen maken. De *optmismebias* herken ik ook. Je wil 'zo goed mogelijk' uit een risicosessie komen. Dat betekent dat je risico's initieel hoog beoordeeld en na je beheersmaatregelen kwantificeer je ze lager om te doen overkomen alsof je de risico's effectief beheerst, terwijl dit niet per se de realiteit is met de genoemde maatregelen. De **beschikbaarheidsbias**, **bevestigingsbias** en het **bandwagon effect** vind ik het meest problematisch. Die laatste komt ook veel voor wanneer de energie bij mensen wegzakt, want dan gaan ze maar mee met de rest, omdat ze geen zin/energie hebben er tegenin te gaan.	geldt dat ook voor de **representativiteitsheuristiek** (oordelen op ervaring): "op dat project kwam dit en dit voor en dat is dus ook voor dit project een risico), **bandwagon** en **winst- en verliesframing bias.** Bandwagon creëert echt een tunnelvisie voor het hele team. Als ook je stuurgroep hierin meegaat, vertrouw je enkel op de projectmanager met de sterke mening.	deze wellicht op den duur niet meer zo speciaal vinden en denk je dat dit risico wel mee zal vallen. Het *verzonken-kosten effect* is zeer problematisch als het optreedt. De *beschikbaarheidsbias* herken ik in ieder geval niet bij mezelf, omdat ik meer vertrouw op cijfers en minder op emoties/gedachten die opkomen. Het *bandwagon effect* herken ik zeker wel. Als een aantal mensen zeggen dat de ernst van een risico wel meevalt, gaan veel daar in mee. De *winst- en verliesframingbias* treedt op in groepsdynamiek, omdat mensen een risico gaan framen op hun discipline. Een ontwerper zal bijvoorbeeld een ontwerprisico negatief framen zodat deze meer aandacht krijgt. De *optimismebias* herken ik ook. De **affectieve heuristiek**, het **verzonken-kosten effect** en de **optimismebias** dragen in mijn optiek het meest negatief bij een risicomanagement. Commission bias voorgelegd: Deze herken ik ook. Een risico moet altijd effectief beheerst worden. In onze beoordeling sturen we dus ook dat het restrisico altijd significant lager is dan het initiële risico. We willen onszelf altijd laten denken dat we risico's effectief moeten beheersen, terwijl de kosten van een risico als deze optreedt, wellicht zelfs lager zouden kunnen zijn dan het treffen van de voor dat risico specifieke beheersmaatregelen.	*beschikbaarheidsbias* herken ik zeker wel. Bijvoorbeeld alle PFAS-risico's of alles wat gerelateerd is aan de nieuwe omgevingswet is ineens een groot risico, omdat dat actueel is. Ook het *bandwagon effect* herken ik in de praktijk. Mensen praten elkaar toch gewoon na. Het is afhankelijk van met wie je aan tafel zit. De *winst- en verliesframingbias* herken ik niet. De *optimismebias* behoort wel tot de meest herkenbaren. Het meest voorkomend en in potentie problematisch vind ik **optimismebias**, omdat het losstaat van feitelijkheden op het project. Ook de **affectieve heuristiek** in combinatie met de **representativiteitsheuristiek** is problematisch. Dat is dus het geval wanneer iemand op emotie handelt op basis van eerdere gebeurtenissen in een eerder, vergelijkbaar project. Gebeurtenissen uit het verleden, bieden geen garanties voor de toekomst, maar dat is wel vaak wat we denken. Ik zie altijd paalbreuk bij heien terugkomen in risicodossiers, maar ik heb het nog nooit meegemaakt. Waarschijnlijk heeft iemand anders dit ooit eens desastreus meegemaakt en blijft dit nog altijd ophalen. Commission bias voorgelegd: Dit herken ik zeker. Door acties te nemen (bijsturen/strategie wijzigen) kunnen we complexiteit introduceren waardoor nieuwe risico's optreden met gevolgen die groter zijn dan wanneer we niks zouden hebben gedaan.
8. Hoe beïnvloeden deze heuristieken en biases uw risicoanalyse-proces?	Veel biases herken ik wel, maar acht ik niet zo problematisch doordat we ze in een plenaire sessie al ondervangen. Wel denk ik dat op emotie handelen ervoor zorgt dat risico's niet realistisch beschouwd worden.	Sommige biases sturen of beperken je denkrichting en zorgen ervoor dat je daarom een verkeerde beoordeling maakt of in ieder geval een beoordeling die beïnvloed wordt, bijvoorbeeld door je ervaringen op andere projecten. Dat kan functioneel zijn, maar ook voor problemen zorgen.	Het kan leiden tot vertekende beoordelingen, doordat de beoordeling 'gestuurd' wordt naar hoe men zou willen dat het is.	Op drie manieren. 1. Bij het inschatten van de kans denk je al aan hoe hoog de kosten zullen zijn als het optreedt, terwijl je sec de kans en sec de gevolgen (worst case) als het optreedt zou moeten beschouwen. Bijvoorbeeld wanneer we bij de bodemsanering gaan ontgraven en we komen puin tegen kun je bedenken 'de hele bodem moet eruit' of 'dit komt op slechts een paar plekken voor. Als je zowel in je effect bij optreden van het risico rekening houdt met dat laatste en dan ook nog eens de kans laag inschat, is het aannemelijk dat je het risico onderschat hebt en een ontoereikend budget hebt meegenomen voor het risico als het worst case scenario toch optreedt. 2. Bij het	Risicobeoordeling wordt minder objectief.	Het zorgt ervoor dat we risico's op een project niet beschouwen zoals ze in de realiteit zijn en daarmee is ook de beoordeling niet reëel.

				inschatten van de kans en de gevolgen van een risico, neemt men al in beschouwing dat beheersmaatregelen worden uitgevoerd, terwijl je eigenlijk het initiële risico zou moeten beoordelen, ZONDER rekening te houden met het uitvoeren van de beheersmaatregelen. Het kan immers ook voorkomen dat je een beheersmaatregel vergeet uit te voeren of niet kan uitvoeren door tijdgebrek, etc. 3. De winst- en verliesframing bias creëren wij soms zelf juist voor de opdrachtgever om te voorkomen dat zij gaan ingrijpen. Daarbij zou je een risico dus juist positief kunnen framen ipv negatief terwijl het effect hetzelfde is.		
9. Zijn er nog andere heuristieken en biases die je in de praktijk ervaart waar we het nu niet over gehad hebben?'	De branche is financieel gedreven met veel techneuten. Veiligheid staat in theorie op één, maar in de praktijk herken ik wel dat men bewust risico's neemt of risico's negeert om maar door te kunnen werken ("het moet snel, het moet af"), waardoor risico's soms geaccepteerd worden, terwijl ze eigenlijk hoog beoordeeld zouden moeten worden en beheerst moeten worden. De focus ligt eerder op andere accenten zoals technische haalbaarheid, etc. omdat men daar ook affiniteit mee heeft. Overkoepelende zaken zoals veiligheid worden dan soms minder beschouwd. Je neemt dan een risico voor lief.	Nee	In groepsdynamiek kan het voorkomen dat er 'machtsspelletjes' worden gespeeld.	Je ziet vaak ook dat mensen gelijk willen acteren bij een gebeurtenis in plaats van eerst goed de gebeurtenis beschouwen. Ze willen accelereren in plaats van eerst even vertragen en goed het probleem analyseren. Iets doen is beter dan niets doen, omdat dit het gevoel geeft dat je ergens grip op kunt uitoefenen. Juist door die actie zou je ook een extra risico kunnen creëren. (opmerking onderzoeker: dit lijkt op de neiging dat mensen altijd willen acteren, ook als niets doen tot eenzelfde of zelfs beter resultaat zou leiden (= commission bias)).	Men hecht waarde aan de autoriteit van mensen (hij/zij is hier specialist in dus zal wel gelijk hebben).	Het blinde vlek principe: we baseren onze mening op wat we zien, maar het is goed om eens daaruit te stappen om te beoordelen of we alles nou wel in beeld hebben. De kracht van wat je niet ziet.

Table 5. Interview analysis (part 3)

	Interviewees (RM= Risk Manager; PM= Project Manager)					
Question (Q-xx)	RM-1	RM-2	RM-3	PM-1	PM-2	PM-3
10. Bent u bekend met interventies om het optreden van biases te mitigeren? Past u deze interventies toe in de praktijk?	Dat zit hem wat mij betreft in een gezamenlijke sessie houden, zodat ze elkaar vanuit verschillende disciplines kritisch kunnen bevragen en corrigeren, zodat de risico's niet door een eenzijdige bril beoordeeld worden.	Eigenlijk niet. Ik ben al zeer tevreden als ik een volledig dossier kan opbouwen, waarin we risico's hebben geïdentificeerd. Ik denk dat interventies te 'zwaar' zijn doordat ze nog een element aan risicoanalyse toevoegen, terwijl veel het al moeilijk vinden.	Ik probeer zelf kritisch te zijn tijdens risicosessies die ik faciliteer, maar ben niet 'bekend' met speciale interventies	Ik laat de specialisten altijd eerst aan het woord en laat anderen daar vervolgens op reageren. Ik faciliteer met name en vraag door i.p.v. zelf de leiding nemen in de analyse. Zo probeer ik objectiviteit en volledigheid (volledigheid betekent ook dat ik alle betrokkenen wil horen over de risico's) te borgen.	Nee	Goed doorvragen op wat iemand zegt om feiten boven tafel te krijgen. Ik zie daarin een taak voor mij om meningen en zorgen te vertalen naar feiten.
11. Wanneer zouden bias-interventies effectief zijn? Wanneer zouden bias-interventies ineffectief zijn?	Effectief is het als de discussie ontstaat zodat de risico's kritisch beschouwd worden. Niet effectief is het als de sessie niet goed begeleid wordt en er een aantal het hoogste woord voeren in plaats van dat iedereen gehoord wordt.	Het zal effectief zijn als we daarmee met onze risicopot beter in de buurt komen van de werkelijke situatie. Dat gaat nu ook al wel redelijk goed.	Je wil een positieve 'flow' houden, in plaats van constant discussies, waardoor het teamgevoel, het "samen naar de oplossing zoeken" wegvalt. Een interventie zou dus ineffectief zijn als het demotiverend werkt. Kritisch zijn mag natuurlijk wel. Degene die de risicosessie leidt speelt een cruciale rol in hoe dit geleidt wordt en daarmee van belang voor de kwaliteit van de analyse. De facilitator moet kritisch durven zijn, maar wel positief blijven.	Bij een initiële risicosessie zoveel mogelijk risico's op te halen en daarna in kleinere setting de risico's analyseren. Niet volledig de risico's uitkristalliseren, maar in korte tijd efficiënt de risico's beoordelen, zodat men scherp blijft. Op individueel niveau de mensen 'debiasen' doe ik niet. Ik zie het meer als een taak voor mezelf om biases te voorkomen i.p.v. individuen met training te belasten, want ze vinden risicoanalyse op zichzelf staand vaak al lastig. Ik treed dan op als een soort advocaat van de duivel als ik denk dat mensen foute beoordelingen maken.	Het is heel effectief als er af en toe een checkvraag wordt gesteld, dus doorvragen op wat iemand noemt. De facilitator van de risicosessie speelt hierin een belangrijke rol.	Het is effectief als men zich bewust wordt van mogelijke biases en daarmee zichzelf ervan weerhoudt om biased beoordelingen te maken. Ik denk ook dat men met een positieve focus (niet focus op wat mis kan gaan, maar juist focussen op hoe het goed kan gaan) op risicobeheersing tot een realistischere beoordeling kan komen.
12. Heeft u suggesties voor bias-interventies?	Je kunt de aanwezigen in groepjes verdelen, zodat de risico's toch meer afzonderlijk beschouwd worden en daarna pas plenair of dat de groepjes elkaars beoordeling controleren.	Ik zou risico's wel eens op een andere manier willen inventariseren.	Nee	Ik stel vaak wel eens voor om mensen van verschillende disciplines op elkaars stoel te laten zitten. Bijvoorbeeld een uitvoerder en ontwerpen kijken op een andere manier naar de ruimtelijke inrichting van een bouwplaats. Voor een ontwerpen moet het passen op de tekening (statische situatie). Een uitvoerder weet dat hij op de bouwplaats ook beweging van materieel en materiaal gaat krijgen en dat dit elkaar knelt als de ruimte krap is. Daarnaast de 'glazen-bol-methodiek'. Men de risico's laten beschouwen als het misgaat. Ze gaan het dan in hun hoofd visualiseren en moeten vervolgens terugdenken aan de oorzaken. Door te visualiseren krijgt men meer 'gevoel' bij risico's, dan door enkel getalletjes te beschouwen waar aan de hand van we de risico's beoordelen.	Bewustwording van biases als introductie van de sessie zou kunnen helpen. Ik denk wel dat je dat iedere keer opnieuw moet aanhalen, want anders zakt het bewustzijn weg en zijn mensen overgeleverd aan invloeden van de waan van de dag. Het zou ook fijn zijn als een moment om even te 'landen' voorafgaand aan de sessie.	Een positieve setting in risicomanagement creëren (*zie bovenstaand*)
13. Hoe zouden deze interventies het risicoanalyse-proces helpen?	Je krijgt meer diepgang. Zo komen meer mensen aan het woord.	Mensen meer bewust maken van risico's in het dagelijkse werk.	Het maakt de analyse objectiever. Het verbetert het proces niet per se, maar kan het zelfs juist verstoren.	Als ze 'op elkaars stoel' gaan zitten, kijken ze buiten hun gebaande, gebruikelijke visie.	Het maakt de analyse objectiever en daarmee beter.	Het helpt door ons te stimuleren het doel van risicomanagement voor ogen te houden: we doen risicomanagement niet omdat het een proces is dat we altijd uitvoeren, maar om het optreden van faalkosten te voorkomen.
Final question:						

14. Welke vraag had je verwacht maar heb ik niet gesteld?	Ik dacht dat we meer stil zouden staan bij het onderscheid tussen initiële risico's en restrisico's en de definitie van risico's. Meer de theorie achter risicoanalyse en de beschouwing ervan, inclusief preventieve en correctieve beheersmaatregelen.	Ik had geen heel specifieke verwachtingen.	Ik dacht dat het meer in zou gaan op welke specifieke technische risico's we kennen.	We hebben het niet gehad over het effect van risicomanagement op het acteren van de projectmanager als persoon. Het is belangrijk om te bedenken wat het doel is van het risicodossier. Enerzijds kun je het gebruiken om risico's correct te beschouwen om een passend budget mee te nemen. Anderzijds kun je het ook gebruiken als sturingsmiddel richting je stuurgroep of opdrachtgever om bijvoorbeeld intern om meer menseninzet te vragen en de opdrachtgever bijvoorbeeld ook aan te zetten tot het acteren op risico's. Ik gebruik het risicodossier soms dus als middel om de noodzaak tot handelen door ons bedrijf intern of door de opdrachtgever duidelijk te maken. Dit is dus eigenlijk ook het rechtvaardigen van de te nemen of genomen beheersmaatregelen.	Ik dacht dat het meer zou gaan over risico's in de praktijk, dus voorbeelden daarvan en van goede en slechte voorbeelden van eerdere risicobeoordeling en beheersing. Ik herken dit alles wat we nu besproken hebben wel uit de praktijk, maar ben er normaal niet zo mee bezig.	Ik had geen verwachtingen. Wel denk ik dat het interessant is binnen de aannemerij om ook actief te sturen op kansenmanagement, in plaats van enkel op risicomanagement.

Appendix C: Serious game risks and dilemmas

Risks:

1. Uitvoeringsontwerpen zijn niet tijdig gereed voor het aanvragen van benodigde vergunningen door opdrachtnemer.
2. Benodigde materialen zijn onvoldoende of niet tijdig beschikbaar in de markt.
3. We treffen de beschermde zandhagedis aan in het projectgebied na het kappen van bomen.
4. De impact op de planning ten gevolge van werkzaamheden aan kabels en leidingen is groter dan verwacht.
5. De welstandscommissie van gemeente X zorgt voor vertraging in het verkrijgen ven de omgevingsvergunning.
6. Bouwpercelen zijn bij geplande aanvang van de werkzaamheden niet in het bezit gekomen via minnelijke verwerving waardoor onteigeningsprocedure opgestart moet worden (gem. doorlooptijd 8 maanden).
7. Weggebruikers en/of omwonenden ervaren meer hinder dan verwacht ten gevolge van werkzaamheden.
8. Onze uitvoeringswerkzaamheden veroorzaken dermate trillingen dat deze leiden tot schade aan trillingsgevoelige objecten zoals de nabijgelegen tunnelconstructie.
9. Aanliggende bedrijven (stakeholders) zijn beperkt of niet bereikbaar met financiële schade tot gevolg.
10. We beschadigen kabels en leidingen bij het realiseren van de steunpunten voor onze constructie (bv. inbrengen grondverdringende palen).
11. De bestaande grondkeringsconstructie voor de spoorbaan bezwijkt, dan wel deformeert buiten de toleranties als gevolg van onze werkzaamheden.
12. De stalen brugboog en aanbruggen die we aanbrengen passen niet op de onderbouw door marges in maatvoering en uitvoering.
13. Gevaar door vallend materiaal op werkwegen tijdens hijswerkzaamheden in zeer beperkte werkruimte.
14. Verkeershinder tijdens onze realisatiefase neemt toe door uitloop van nevenprojecten, waar afsluiten en omleiden naar nabij ons werkgebied benodigd is.
15. Er ontstaat schade aan ons materieel bij het inbrengen van fundaties in ondergrond door de aanwezigheid van onvoorziene obstakels.
16. Tijdens uitvoering worden onvoorziene (hoeveelheden) verontreinigde grond aangetroffen.
17. De werkelijke zetting wijkt af van de vooraf berekende zettingscurve waardoor er bij geplande start werkzaamheden nog geen stabiel en zettingsarm grondlichaam is.
18. Nacht- of weekendwerkzaamheden lopen uit, waardoor de geplande openstelling mogelijk niet gehaald wordt.

Antwoordcombinaties:

Representativiteitsheuristiek:

1. Objectief + Risicobereid (A) <> Biased + Risicobereid (B)

Je bent verantwoordelijk voor het beoordelen van een risico: *Uitvoeringsontwerpen zijn niet tijdig gereed voor het aanvragen van benodigde vergunningen door opdrachtnemer*. Je hebt twee benaderingen waaruit je kunt kiezen. Welke heeft je voorkeur?

Optie A: We zullen een gedetailleerd stappenplan volgen en alle fasen van het ontwerpproces nauwkeurig analyseren. We zullen de benodigde tijd voor elke fase inschatten en mogelijke vertragingen identificeren. We zijn bereid om het risico te accepteren met het geloof dat eventuele vertragingen in de uitvoeringsontwerpen binnen aanvaardbare grenzen zullen blijven.

Optie B: We vertrouwen op onze ervaring en eerdere projecten om een schatting te maken van het tijdsbestek voor het gereed maken van de ontwerpen. We geloven dat we op het huidige project vergelijkbare prestaties zullen leveren als bij vorige projecten, zelfs als er beperkte gegevens beschikbaar zijn. We vertrouwen erop dat eventuele vertragingen in uitvoeringsontwerpen aanvaardbaar blijven.

2. Objectief + Risicobereid <> Objectief + Risicoavers

Je bent verantwoordelijk voor het beoordelen van een risico: *Benodigde materialen zijn onvoldoende of niet tijdig beschikbaar in de markt.* Je hebt twee benaderingen waaruit je kunt kiezen. Welke heeft je voorkeur?:

Optie A: We voeren een gedetailleerde analyse uit van potentiële leveranciers en alternatieve materialen. Hierbij wordt rekening gehouden met verschillende scenario's en de mogelijkheid van marktfluctuaties. Het besluit wordt genomen op basis van een zorgvuldige afweging van risico's en kansen, waarbij we bereid zijn om een iets hoger risico te accepteren in ruil voor mogelijke kostenbesparingen of andere voordelen.

Optie B: We beoordelen het risico door een analyse uit te voeren naar betrouwbare leveranciers, waarbij strikte naleving van leveringstermijnen wordt geëist. We minimaliseren het risico door vast te houden aan bewezen leveranciers en voorzorgsmaatregelen te nemen, zelfs als dit mogelijk hogere kosten met zich meebrengt. We streven naar een risicomijdende benadering om de betrouwbaarheid van de materiaalvoorziening te waarborgen.

3. Objectief + Risicobereid <> Biased + Risicoavers

Je bent verantwoordelijk voor het beoordelen van een risico: *We treffen de beschermde zandhagedis aan in het projectgebied na het kappen van bomen.* Je hebt twee benaderingen waaruit je kunt kiezen. Welke heeft je voorkeur?:

Optie A: We kiezen voor een grondige, systematische aanpak waarbij alle beschikbare gegevens over de habitat van de zandhagedis worden verzameld en geanalyseerd. We zijn daarna bereid een zekere mate van risico te nemen door aan te nemen dat de mogelijke aanwezigheid van de zandhagedis in dit geval minder waarschijnlijk is.

Optie B: We baseren onze risicobeoordeling op eerdere projecten waarbij het kappen van bomen gevolgen kon hebben voor het aantreffen van beschermde diersoorten. We zijn daarna risicomijdend en laten een ecoloog ter plekke de mogelijke aanwezigheid beoordelen waarmee definitief uitsluitsel gegeven kan worden over de mogelijke aanwezigheid van de zandhagedis.

4. Biased + Risicobereid <> Objectief + Risicoavers

Je bent verantwoordelijk voor het beoordelen van een risico: *De impact op de planning ten gevolge van werkzaamheden aan kabels en leidingen is groter dan verwacht*. Je hebt twee benaderingen waaruit je kunt kiezen. Welke heeft je voorkeur?:

Optie A: We baseren de inschatting van het risico op recente gevallen waarin soortgelijke werkzaamheden werden uitgevoerd. We vertrouwen erop dat verlegging van kabels en leidingen meestal wel goed gaat en de impact zeer beheersbaar is.

Optie B: Het team voert een gedetailleerde analyse uit van de specifieke factoren die van invloed kunnen zijn op de planning bij de werkzaamheden aan kabels en leidingen. De nadruk ligt op het vermijden van risico's en het nemen van voorzorgsmaatregelen om eventuele onverwachte complicaties te beperken.

5. Biased + Risicobereid <> Biased + Risicoavers

Je bent verantwoordelijk voor het beoordelen van een risico: *De welstandscommissie van gemeente X zorgt voor vertraging in het verkrijgen ven de omgevingsvergunning*. Je hebt twee benaderingen waaruit je kunt kiezen. Welke heeft je voorkeur?:

Optie A: We baseren onze beoordeling op eerdere ervaringen met deze welstandscommissie waarbij de ervaringen wisselend zijn. We gaan ervan uit dat ze dit keer soepel zullen zijn en kiezen ervoor om het gekozen proces voort te zetten zonder aanpassingen te maken om eventuele vertraging te verminderen, in de hoop dat de commissie de vertraging minimaliseert.

Optie B: We herinneren ons dat er door beoordeling van de welstandscommissie van deze gemeente eerder ook wel eens vertragingen waren. We houden rekening met het slechtste scenario en kiezen voor het uitgebreid voorbereiden van documentatie en het proactief betrekken van de commissie om mogelijke bezwaren te voorkomen, om zo het risico van verdere vertraging te minimaliseren.

6. Objectief + Risicoavers <> Biased + Risicoavers

Je bent verantwoordelijk voor het beoordelen van een risico: *Bouwpercelen zijn bij geplande aanvang van de werkzaamheden niet in het bezit gekomen via minnelijke verwerving waardoor onteigeningsprocedure opgestart moet worden (gem. doorlooptijd 8 maanden)*. Je hebt twee benaderingen waaruit je kunt kiezen. Welke heeft je voorkeur?:

Optie A: We voeren een uitgebreide gegevensverzameling en analyse uit om de kans op vertraagde onteigening in dit project te beoordelen. We analyseren alle relevante juridische, financiële en historische informatie grondig. De focus ligt op het vermijden van onzekere situaties, door vooraf het risico te minimaliseren.

Optie B: We vertrouwen bij de beoordeling van het onteigeningsrisico voornamelijk op ervaring op vergelijkbare eerdere projecten in de regio. We nemen aan dat de situatie vergelijkbaar zal zijn met die van eerdere projecten zonder een grondige analyse van alle specifieke factoren. Wel gaan we uit van het slechtste scenario en stellen we alles in het werk om het risico vooraf te minimaliseren.

Affectieve heuristiek

7. Objectief + Risicobereid <> Biased + Risicobereid

Je bent verantwoordelijk voor het beoordelen van een risico: *Weggebruikers en/of omwonenden ervaren meer hinder dan verwacht ten gevolge van werkzaamheden.* Je hebt twee benaderingen waaruit je kunt kiezen. Welke heeft je voorkeur?:

Optie A: We maken een uitgebreide analyse van verwachte hinder voor weggebruikers en omwonenden door onder andere een hindercontourkaart op te stellen. Alle relevante gegevens worden zorgvuldig geanalyseerd. We gaan ervan uit dat de hinder in de uitvoeringsfase wel mee zal vallen en/of we die dan wel zullen beheersen.

Optie B: We maken onze beoordeling op basis van gevoelens en intuïtieve inschattingen van het team. We kiezen ervoor om bepaalde werkzaamheden uit te voeren zonder extra maatregelen voor hinderbeperking op basis van de veronderstelling dat de overlast niet buitengewoon ernstig zal zijn.

8. Objectief + Risicobereid <> Objectief + Risicoavers

Je bent verantwoordelijk voor het beoordelen van een risico: *Onze uitvoeringswerkzaamheden veroorzaken dermate trillingen dat deze leiden tot schade aan trillingsgevoelige objecten zoals de nabijgelegen tunnelconstructie.* Je hebt twee benaderingen waaruit je kunt kiezen. Welke heeft je voorkeur?:

Optie A: We stellen een uitgebreide, gedetailleerde trillingsanalyse op met behulp van geavanceerde modelleringstechnieken om het exacte risiconiveau te bepalen. We kiezen ervoor om uitvoeringswerkzaamheden met aanvullende maatregelen te handhaven op een niveau dat net binnen de vastgestelde grenzen van aanvaardbaar risico valt, terwijl we tegelijkertijd ruimte laten voor optimalisatie van efficiëntie en kosten.

Optie B: We implementeren een gestandaardiseerd, systematisch beoordelingsproces dat rekening houdt met uitgebreide technische gegevens en modellering. We willen extra zekerheid voordat we doorgaan, om mogelijke schade aan trillingsgevoelige objecten volledig uit te sluiten. Door strikte grenswaarden vast te stellen en ruime veiligheidsmarges toe te passen, verminderen we het risico op schade aan trillingsgevoelige objecten aanzienlijk, ook als dit leidt tot forse kosten en het nemen van voorzorgsmaatregelen die mogelijk niet noodzakelijk zijn.

9. Objectief + Risicobereid <> Biased + Risicoavers

Je bent verantwoordelijk voor het beoordelen van een risico: *Aanliggende bedrijven (stakeholders) zijn beperkt of niet bereikbaar met financiële schade tot gevolg.* Je hebt twee benaderingen waaruit je kunt kiezen. Welke heeft je voorkeur?:

Optie A: We voeren grondig onderzoek uit naar de bereikbaarheid van aanliggende bedrijven in verschillende scenario's. We zijn bereid om een bepaald niveau van risico te accepteren en zetten niet overmatig in op bereikbaarheid van stakeholders in ruil voor efficiëntie en kostenbesparing.

Optie B: We laten de beoordeling beïnvloeden door emoties en onderbuikgevoel. Uit een sterke angst voor mogelijke financiële schade als gevolg van onbereikbare stakeholders, zijn we geneigd om conservatieve maatregelen te nemen en financiële schade voor stakeholders en onszelf te minimaliseren, zelfs als dit betekent dat er meer middelen moeten worden geïnvesteerd om de bereikbaarheid te waarborgen.

10. Biased + Risicobereid <> Objectief + Risicoavers

Je bent verantwoordelijk voor het beoordelen van een risico: *We beschadigen kabels en leidingen bij het realiseren van de steunpunten voor onze constructie (bv. inbrengen grondverdringende palen).* Je hebt twee benaderingen waaruit je kunt kiezen. Welke heeft je voorkeur?:

Optie A: We beoordelen het risico door te vertrouwen op intuïtie. We neigen naar het minimaliseren van kosten en tijd bij het realiseren van de steunpunten, zelfs als dit betekent dat er meer risico wordt genomen op het beschadigen van kabels en leidingen.

Optie B: We voeren een uitgebreide analyse uit van de bodemgesteldheid, de locatie van bestaande kabels en leidingen, en de specificaties van de grondverdringende palen. We maken uitgebreide plannen om het risico op beschadiging van kabels en leidingen tot een minimum te beperken. Hoewel deze aanpak mogelijk meer tijd en middelen vergt, vermindert het de kans op onvoorziene complicaties en schade.

11. Biased + Risicobereid <> Biased + Risicoavers

Je bent verantwoordelijk voor het beoordelen van een risico: *De bestaande grondkeringsconstructie voor de spoorbaan bezwijkt, dan wel deformeert buiten de toleranties als gevolg van onze werkzaamheden.* Je hebt twee benaderingen waaruit je kunt kiezen. Welke heeft je voorkeur?:

Optie A: We laten ons in de beoordeling leiden door intuïties. We neigen naar de aanname dat de huidige grondkeringsconstructie voldoende robuust is om de verwachte werkzaamheden te weerstaan.

Optie B: Emoties en intuïtie van het team worden in overweging genomen, waarbij we neigen naar het focussen op worst-case scenario's, voorzichtigheid en het vermijden van risico's.

12. Objectief + Risicoavers <> Biased + Risicoavers

Je bent verantwoordelijk voor het beoordelen van een risico: *De stalen brugboog en aanbruggen die we aanbrengen passen niet op de onderbouw door marges in maatvoering en uitvoering.* Je hebt twee benaderingen waaruit je kunt kiezen. Welke heeft je voorkeur?:

Optie A: We maken een gedetailleerde analyse van alle technische specificaties en voeren nauwkeurige metingen uit. Hierbij wordt gestreefd naar een zo nauwkeurig mogelijke matching

tussen de brugboog/aanbruggen en de onderbouw, met het doel om het risico op misfit tot een minimum te beperken.

Optie B: Zonder exacte berekeningen en analyses te maken, wordt vertrouwd op de intuïtie van betrokken vakmensen en het team om de juiste maatvoering en uitvoering te bepalen. We houden er ernstig rekening mee dat maatvoering en uitvoering wellicht problemen kunnen veroorzaken. We nemen voor de zekerheid extra voorzorgsmaatregelen.

Optimism bias

13. Objectief + Risicobereid <> Biased + Risicobereid

Je bent verantwoordelijk voor het beoordelen van een risico: *Gevaar door vallend materiaal op werkwegen tijdens hijswerkzaamheden in zeer beperkte werkruimte.* Je hebt twee benaderingen waaruit je kunt kiezen. Welke heeft je voorkeur?:

Optie A: We voeren een gedetailleerde risicoanalyse uit waarbij elke fase van de hijswerkzaamheden systematisch wordt beoordeeld. We maken gebruik van gestandaardiseerde protocollen en procedures om mogelijke risico's te identificeren. We zijn bereid om een zeker niveau van risico te accepteren als alle criteria binnen de vastgestelde normen vallen.

Optie B: We vertrouwen op de bestaande veiligheidsmaatregelen en een lange geschiedenis zonder ernstige incidenten. Zonder extra maatregelen te nemen accepteren we een zekere mate van risico met inachtneming van bestaande veiligheidsmaatregelen.

14. Objectief + Risicobereid <> Objectief + Risicoavers

Je bent verantwoordelijk voor het beoordelen van een risico: *Verkeershinder tijdens onze realisatiefase neemt toe door uitloop van nevenprojecten, waardoor langer afsluiten en omleiden naar nabij ons werkgebied benodigd is.* Je hebt twee benaderingen waaruit je kunt kiezen. Welke heeft je voorkeur?:

Optie A: We voeren een uitgebreide analyse uit van de nevenprojecten om de waarschijnlijkheid van uitloop en de mogelijke impact nauwkeurig te voorspellen. We gaan ervan uit dat eventuele vertragingen kunnen worden opgevangen zonder extra middelen en met de huidige planningsopties.

Optie B: We kiezen voor een systematische benadering waarbij we gedetailleerde analyses en prognoses maken om de potentiële verkeershinder nauwkeurig te kwantificeren. We nemen conservatieve schattingen in overweging bij het plannen van de realisatiefase en houden rekening met worst-case scenario's, zelfs als de waarschijnlijkheid van uitloop bij nevenprojecten niet heel hoog lijkt.

15. Objectief + Risicobereid <> Biased + Risicoavers

Je bent verantwoordelijk voor het beoordelen van een risico: *Er ontstaat schade aan ons materieel bij het inbrengen van fundaties in ondergrond door de aanwezigheid van onvoorziene obstakels.* Je hebt twee benaderingen waaruit je kunt kiezen. Welke heeft je voorkeur?:

Optie A: Het team kiest ervoor om een gedetailleerde systematische analyse uit te voeren, waarbij alle mogelijke obstakels in kaart worden gebracht. Hieropvolgend worden in de uitvoering geen bijzondere maatregelen genomen om ons materieel te beschermen. Het team is bereid om een zeker risico te nemen in het belang van efficiëntie en kostenbesparing.

Optie B: Zonder een uitgebreide analyse van mogelijke obstakels uit te voeren, zijn we optimistisch over het vermijden van obstakels en schatten de kans op schade als laag in. We nemen voor de zekerheid extra voorzorgsmaatregelen om mogelijke obstakels te minimaliseren. De focus ligt op het vermijden van risico's, zelfs als dit leidt tot hogere kosten.

16. Biased + Risicobereid <> Objectief + Risicoavers

Je bent verantwoordelijk voor het beoordelen van een risico: *Tijdens uitvoering worden onvoorziene (hoeveelheden) verontreinigde grond aangetroffen.* Je hebt twee benaderingen waaruit je kunt kiezen. Welke heeft je voorkeur?:

Optie A: We kiezen ervoor om de positieve inschatting van ons team te volgen en beschouwen het risico op onvoorziene verontreiniging als beheersbaar. We nemen geen extra maatregelen en vertrouwen erop dat eventuele verhoogde kosten en vertragingen beheersbaar zullen zijn.

Optie B: We kiezen ervoor om een grondige analyse uit te voeren van de omvang en de aard van de verontreiniging, waarbij alle mogelijke risico's in kaart worden gebracht. Er worden passende maatregelen genomen waarbij een extra reservering in het budget en buffer in de planning wordt opgenomen om de impact van een eventuele verontreiniging te minimaliseren.

17. Biased + Risicobereid <> Biased + Risicoavers

Je bent verantwoordelijk voor het beoordelen van een risico: *De werkelijke zetting wijkt af van de vooraf berekende zettingscurve waardoor er bij geplande start werkzaamheden nog geen stabiel en zettingsarm grondlichaam is.* Je hebt twee benaderingen waaruit je kunt kiezen. Welke heeft je voorkeur?:

Optie A: We vertrouwen op positieve aannames en gunstige vooruitzichten. We gaan ervan uit dat eventuele afwijkingen binnen aanvaardbare grenzen vallen, en dat er geen significante problemen zullen ontstaan bij de geplande start van de werkzaamheden. We nemen geen aanvullende maatregelen.

Optie B: We houden rekening met positieve aannames en hopen dat de werkelijke zetting aan de gunstige kant van de berekening zal zitten. Voor de zekerheid nemen we een buffer op in de planning om tegenvallers op te kunnen vangen.

18. Objectief + Risicoavers <> Biased + Risicoavers

Je bent verantwoordelijk voor het beoordelen van een risico: *Nacht- of weekendwerkzaamheden lopen uit, waardoor de geplande openstelling niet gehaald wordt.* Je hebt twee benaderingen waaruit je kunt kiezen. Welke heeft je voorkeur?:

Optie A: We maken een zeer nauwkeurige analyse van de planning in de weekendafsluiting waarbij we diverse scenario's middels Monte Carlo-analyse laten doorrekenen. We nemen extra maatregelen om kritieke activiteiten versneld uit te kunnen voeren en bouwen buffers in.

Optie B: Zonder het uitvoeren van een uitgebreide analyse gaan we ervan uit dat mogelijke vertraging slechts tijdelijk zijn en later in de afsluiting kunnen worden ingehaald. Om zekerheid in te bouwen, nemen we buffers op in de planning.