It's all in your head

Prevent negative effects of biases in ICT project management decision-making.

Master Thesis report

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Abstract

Biases can significantly disrupt rational decision-making processes and in the ICT project management context derail projects. A mixed-methods approach was used to investigate the occurrence, impact, antecedents, and prevention of biases in project management decision-making. It concerned three studies, with each their own goal. Firstly, a series of existing project management cases (n = 15) was studied to identify the occurrence and impact of biases in decision-making. Secondly, a two-stage experiment (n = 117) was used to identify the effect of uncertainty, complexity, and an intervention on the occurrence of biases. Thirdly, a series of interviews with experienced project managers (n = 8) was conducted to validate the findings and the feasibility and value of the intervention as a method for project managers. The studies found evidence to support the notion that biases are both frequent and impactful in ICT project management and their occurrence is increased significantly when projects become more uncertain and complex. Moreover, a combined method focussing on awareness of common biases and a tool to confront complexity and uncertainty rationally, are found to significantly reduce the occurrence of biases in decision-making. Project managers can thus, through relatively simple interventions in their decision-making processes, improve decision-making quality and reduce preventable negative outcomes resulting from biased decision-making.

Acknowledgements

This master thesis – by itself a project that requires extensive management – was affected by both complexity and uncertainty. Ironic at this may be, this meant that the project was both a meaningful experience and a good lesson in project management. Along the way a lot of people chipped in, voiced their opinion, offered their advice, shared their knowledge and experiences. For that I am grateful. I first and foremost wish to thank my supervisors Dr. Fons Wijnhoven and Dr. Matthias de Visser. Fons, for his constructive criticism, continued support, a wealth of knowledge, great ideas and of course the many hours invested in this project. Matthias, for his conviction about the value of this work, his interest in helping a student explore this challenge and his time and support. Secondly, I would like to thank all my friends, family, classmates, and colleagues, to which I could turn with the challenges that would surface. They often graciously donated their time and thoughts to this project. Third, and finally, I would like to thank those who participated in the studies. First, the students, that served as participants, were an invaluable part of this study. They provided me with the insights in project management decision-making that were needed to write this report. Their enthusiasm and honest comments greatly improved the study. Second, the project managers, who so graciously sat down (digitally) and took their time to explain both the context in which they worked and the challenges they faced. They shared a wealth of knowledge and depth of understanding that has led to this final report. Their words and thoughts inspired me both professionally and personally.

1. Introduction

An increasingly digital society puts a growing emphasis on the success of its digital infrastructure. Digitalization through ICT projects is thus an important part of the development of modern society for both governments and businesses. The success of these projects is however not a given. In recent years there has been an increase of interest from the general public in ICT projects, their failure, scandals, and costs. This is perhaps to be expected, as failed ICT projects can have grave consequences for the real-world and the public. The repeated failure of ICT projects at the Dutch tax office, for example, were deemed a threat to the ability of the Dutch Government to collect taxes in future (Giebels & Leeuw, 2017). International studies amongst decision-makers in the business world revealed that over 50% of ICT projects can be considered a failure in some way (Bloch, Blumberg, & Laartz, 2012). The latter means that projects fail to meet expectations in regards to schedule, functionality or budget (Atkinson, 1999). ICT project failure is thus both frequent and truly impactful and the subject of this report.

The scientific literature offers some answers as to why projects fail. Common contributors to failure are the complexity of projects, uncertainty of events and outcomes, expectations of stakeholders, faulty communications and rework that leads to delays (Nelson, 2007). Most of these causes are related to human failure. Different researchers provide different methods to prevent some of these failures. For example, Mulder and Mulder (2013) describe a method that enables the early identification of project complexity based on a project's characteristics. Atkinson (1999), on the other hand, proposes a method with which to develop better measures of success, which enables faster and better identification of progress. New project management methodologies offer improvements as well. These methodologies, for example, offer a reduction of complexity and scale by dividing the project into smaller chunks with a shorter horizon (Kuchta & Skowron, 2016). Sterman (2002), instead, developed a whole toolset of methods that can be applied to any methodology. System Dynamics, as this toolset is known, leans on the use of visualization and simulation to map all involved factors, complexity and uncertainty and guide decision-making. The toolset contains scenario planning, simulation and process optimization (Wijnhoven, 2019). The effectiveness of such methods is however largely dependent on the competence of their user. Humans are thus not just a common theme in project failure, but also essential to their success. This is reflected in the central role of the project manager. The person who is overall responsible for the project's execution and essential for its success (Atkinson, 1999). The project manager is thus well supplied with tools to prevent project failure.

Decision-making errors are a specific category of human failure. Sociologists, psychologists, and behavioural economists, for example, found that people generally choose the option which looks or sounds most familiar (Volz et al., 2006). In addition, people tend to systematically underestimate their own workload and overestimate that of others (Kahneman, 2011). The mechanisms underlying these errors are called heuristics (Gigerenzer & Todd, 1999). They can be useful, as they help speed up decision-making. In a lot of cases, however, they lead to biases in decision-making, which can lead to erroneous decisions (Hertwig & Herzog, 2009). Considering that an ICT project consists for a large part of human evaluations and decisions, the role of these heuristics and biases is likely considerable in project management. However, research on this subject within project management is limited. Studies by McCray, Purvis, and McCray (2002) largely remain hypothetical in the potential impact biases could have on project management and produce no empirical evidence of their own. While Shore (2008), has studied the subject through a series of case studies on failures in landmark projects, such as the Discovery space shuttle crash. Both studies indeed found that biases in decision-making processes could be tied to the eventual project’s failure. Their studies left three opportunities which the current study builds on. Firstly, the scope of their research was limited to just the occurrence of biases. Their research, for example, did not include the factors or context which affect the occurrence of biases. Secondly, both studies proposed actions project managers could take both while on the job and in the organization of projects to prevent biases. Their proposed measures were however not tested for effectiveness. Thirdly, neither their findings regarding the occurrence of biases in project management nor their proposed measures were validated in actual project management. Their applicability and practical value thus remain an open question.

The scope of the current study was to identify the role of biases and the effect of a prevention method (referred to as “the intervention”) on the impact and occurrence of biases in the ICT project management context. It did so by supplementing the existing scientific literature in three distinct ways. First, the study identified the role and impact of a selection of biases in ICT project management cases. Past studies were limited both in representativeness for the current context and in scale. Shore (2008) selected and studied a very limited number of cases that were illustrative of certain biases in project management. Thus, there is a need to validate past findings. Second, the studies reported upon in this paper aimed to investigate the impact of uncertainty and complexity on the occurrence of biases. Both factors are commonly associated with both heuristic decision-making (Rieskamp & Hoffrage, 1999) and project management failure (Bodensteiner, Gerloff, & Quick, 1989). Moreover, the study aimed to design and test a method with which the negative effects of heuristics and biases can be mitigated, or their occurrence reduced. An effective intervention, according to the scientific literature (Rieskamp & Hoffrage, 1999), would likely need to combine elements of awareness creation and the encouragement of systematic thinking. It would have to be studied alongside factors like uncertainty and complexity, which were expected to affect the occurrence of biases. Third, this study aimed to validate its and earlier findings regarding biases in project management decision-making and the feasibility of the proposed method. The reasoning behind this was twofold. Firstly, to increase generalizability and acquire an added level of nuance and reflection. Secondly, to increase the practical value of the findings for the project managers who would potentially be affected by biased decision-making. The central research question of this study was:

How can the effects of heuristics and biases on project management outcomes be identified and mitigated for ICT projects?

2. Theoretical background and hypotheses

The second chapter is used to discuss the theoretical background and the hypothesis. It starts with a discussion of the project management scientific literature. Secondly, the study of heuristics and biases and their place in project management are described. Third, methods of remedying the effects of heuristics and biases in the project management context are discussed. Fourth and finally, the four hypotheses for the current study are listed.

2.1. A brief look at project management and its outcomes

Project management is an essential and multifaceted part of ICT projects. It consists of the planning, evaluation, control and steering of an ICT project towards an acceptable state for its deliverables (Fortune & White, 2006). Success in the ICT context is generally described as the delivery of a project within the allotted time and budget and with the predetermined features and quality, according to Fortune and White (2006) and Atkinson (1999). According to studies by Papke-Shields, Beise, and Quan (2010) and by McCray et al. (2002), project management is an active and contributing part in the success of both the project and the firm. Successful projects can, after all, lead to technological or service quality leads, competitive advantages, cost reductions or might be necessary to be compliant with legislation. The process of project management itself can, according to McCray et al. (2002), be divided into five sub-processes or phases. These sub-processes consist of initiation and planning phases; wherein initial needs trigger the forming of a project, the definition of the problem and the creation of a project planning to address the problem. This results in specifications after which the project can be executed in the third phase. The fourth phase consists of delivery and control in which the stakeholders use and evaluate the final product. Finally, there is a fifth and final closeout phase in which the project related activities are formally brought to a close or continue in a new project. Each phase brings its very own challenges, ranging from the recognition of the right problems to solve during the earlier phases, to adequately evaluating the quality of deliverables in the later phases. The project manager’s role is to safeguard the continuity of the project, continued progress according to the schedule and the state of deliverables. Both the project manager and project management are thus central to an ICT project’s success (Papke-Shields et al., 2010).

The outlook on the organization of projects, project management and decision-making in project management has been subject to change. New methods of project management, for example, move away from strict phasing and rigid decision-making processes to enable a shorter project management horizon by tackling the project in smaller bites. Shenhar (2001) writes that project complexity and uncertainty are the key factors that affect the challenges of a project. As a result, Kuchta and Skowron (2016) for example write that when the amount of uncertainty and complexity increase, one is often better off with more flexible project methodologies that allow for decision-making and planning while the project is ongoing. This allows project managers to manage the amount of complexity and uncertainty which they face at each point in the project. Examples of these methods include the AGILE, Scrum and Kanban. According to Serrador and Pinto (2015), the main added value of these methods resides in some of the practises that are part of these methods. Practises, such as close customer cooperation and intensive communication on expectations. These practises are however not uniquely tied to the more flexible methods and their way of handling phasing and decision-making (Nelson, 2007). Moreover, in ICT projects where the scope and outcomes are known, the more rigid and classical project management methods generally offer a better fit (Kuchta & Skowron, 2016). It is in these project management methods that the decision-making is more centralised and according to Purvis, McCray, and Roberts (2004) clustered in the earliest two phases. To limit the scope of the study and reduce variance in the projects and decision-making processes that could be studied, this study focused on the early phases of more traditional methods of project management.

2.2. Decision-making errors and biases in project management

The occurrence of decision-making errors in project management is not just commonplace, but logical as well. A perfect decision would include the search for all possible solutions, weighing these using all the relevant objective factors and then selecting the solution with the best fit (Rieskamp & Hoffrage, 1999). This process requires a lot of time and effort, which is often impractical and hindered by several factors. First, humans have a limited amount of cognitive energy and time that they are able and willing to invest to reach a decision (Shah & Oppenheimer, 2008). Second, complexity, risk, and uncertainty are properties of decision-making that increase the difficulty of decision-making. Where risk is a lack of knowledge of which one is aware and can estimate, uncertainty is hard to estimate because the decision-maker is partially or fully unaware of the absence of knowledge (Gigerenzer & Brighton, 2009). Complexity differs from both uncertainty and risk in that there does need to be any level of variability or lack of knowledge. Instead, it is part of the project’s problem and context. It is the sheer number of factors, nuances, and facets to take into account. Shenhar (2001) based three levels of ICT project complexity on this. He distinguished the assembly, system, and array levels of project complexity, based on the number of factors involved and the scale of the project. All three properties either impact the amount of cognitive energy required to solve a problem or decision or create a perception of increased requirements. This can bring the requirements of situations (real or perceived) above the threshold of cognitive energy and time that a decision-maker is able or willing to invest. In those cases, decision-making can become faulty.

2.2.1. Tackling decision-making constraints: the role of heuristics

The dual systems theory created by Tversky and Kahneman (Daiton & Zelley, 2011) describes how decision-makers might deal with a specific situation. It describes two modes or systems of operation for the human mind. System one, or the rational mode, is when one engages in conscious and rational decision-making. The available information is generally processed more elaborately, and a more complete decision-making process is followed with room for reflection and critical thought. A second, faster and more frugal mode of operation exists. This “system two” relies on more intuitive and heuristic decision-making. Examples of both extremely rational and extremely intuitive decision-making exist. For example, the extremely rational and long decision-making process associated with the procurement of military hardware versus the intuitive dislike for something that a hated celebrity endorses. The careful procurement process might however be disturbed by the intuitive decision that the organization’s buyer dislikes one of the suppliers during a meeting. Decision-makers adapt their decision-making process to the perceived situation and use elements of both systems. Their aim will generally be to reach the best decision possible to meet the requirements within the perceived constraints for an appropriate amount of effort (Hertwig & Herzog, 2009). A decision-maker might, for example, to not be halted by complexity, uncertainty, risk or a lack of time or energy simplify or skip aspects of the decision-making process using heuristics (Shah & Oppenheimer, 2008). They will, for example, stop searching for alternatives, limit the number of factors taken into account or bypass elaborate decision-making all together (Shah & Oppenheimer, 2008). Thus, decision-making is flexible, affected by the environment in which it takes place and a complex subject. Expectations for specific contexts can however be formed based on the dual systems theory and the scientific literature on heuristic decision-making.

The different modes of thinking apply to project management decision-making as well. A project manager might, for example, have to search for software to acquire a missing feature or might have to weigh options to solve a suddenly appearing software bug. Considering only the solutions presented by a close colleague or to use a solution that solved a similar bug in the past, are forms of heuristics that can be appealing. Heuristics are often practical, necessary, and valuable tools. They can however lead to biases that in turn lead to decision-making errors and failed projects, according to Shore (2008). This is the downside of system two thinking. Shore (2008) for example described that during the 2003 Columbia Space shuttle disaster, engineers neglected to investigate observations of foam falling off the spacecraft during launch as it had happened during previous launches. This time, however, the falling foam proved to be a sign of catastrophic failure. In their study, Purvis, McCray, and Roberts (2003) noted that project managers generally had the strong urge to ignore hard evidence that suggested the project was running off course and instead focussed on soft evidence that confirmed their assumptions. Heuristics can enable rapid decision-making when circumstances make it difficult but can lead to biases that distort decisions or lead to unforeseen negative outcomes as well. It is on these biases that the current study focussed.

2.2.2. Heuristics and biases in project management

Studies by McCray et al. (2002), Purvis et al. (2004) and by Shore (2008) have focused on heuristics and biases in project management. The researchers studied decision-making in ICT project management and identified the occurrence and impacts of biases. Both the studies by McCray et al. (2002) and by Shore (2008) resulted in lists of more than twenty common heuristics in project management. These lists are however not perfect, and their studies leave gaps. First, both lists overlap and supplement each other, using different names for the same biases or biases that result in the same effect. For example, both studies make mention of a heuristic that ensures new information that runs contrary to a current belief is ignored. One calls it “Narrow belief doctrine” (McCray et al., 2002) and the other “Conservatism” (Shore, 2008). Moreover, the lists also overlap internally and often present multiple biases that are similar in effect or present biases that are not generalizable examples of heuristic decision-making. For example “Reliance on profound events”, “Inappropriate comparisons” and “Misinterpretation of data” (McCray et al., 2002) all rely on past events that due to the ease of retrieval became more focal and dominant. This phenomenon is called the fluency heuristic in the study by Fukawa and Niedrich (2015). Secondly, the study of heuristic decision-making has evolved since the studies in the project management context by McCray et al. and Shore.

Researchers have since commented on the large amount of heuristics and biases identified by science and the lack of common workable definitions (Alter & Oppenheimer, 2009; Gigerenzer & Gaissmaier, 2011). More recent work in the field of decision-making has resulted in a better understanding of heuristic decision-making and definitions of the underlying mechanisms to which many of the biases identified by McCray et al. and Shore can be linked. We therefore constructed a list in which the biases identified by both studies in the early phases of project management with a similar definition are paired up, their effect on decision-making is described and the underlying heuristic named. This resulted in five heuristics, listed in Table 1., on which the current study focused its efforts. Their usefulness as workable definitions to identify biased decision-making in project management however had yet to be demonstrated. This is the first of the gaps in the scientific literature investigated in the current study.

Table 1. Biases in the various phases of project management and the underlying heuristics. Adapted from the article by McCray et al. (2002) and from Shore (2008). A description of each of the heuristics can be found in Appendix 1.

Descriptions of heuristics.

Heuristic	**Resulting Bias from McCray et al. (2002).**	**Resulting systematic bias from Shore (2008).**	**Effect on decision-making**
Availability heuristic (Gigerenzer & Gaissmaier, 2011)	Inappropriate comparisons		Limiting alternative and weighing-factor finding and event likelihood.
	Misinterpretation of data	Available data	Event likelihood
	Reliance on profound events/misapplied risk	Recency	Limiting alternative and weighing-factor finding and event likelihood.
One cue heuristic (Gigerenzer & Gaissmaier, 2011; Kahneman, 2011)	Use of intuition	Overconfidence	Limiting alternative and weighing-factor finding and event likelihood.
	Narrow belief doctrine	Conservatism	Limiting alternative and weighing-factor finding and event likelihood.
Misinterpretation of risk (Kahneman, 2011)		Illusion of Control	Influencing weighing factors and event likelihood.
Anchoring (Gilovich, Griffin, & Kahneman, 2002)	Anchoring	Sunk cost	Limiting alternative and weighing-factor finding and event likelihood.

Default choice heuristic (Gigerenzer & Gaissmaier, 2011)	Failure to consider alternatives	Limiting alternatives/complete inaction

The current study on biased decision-making in project management investigated two more gaps identified in the studies by McCray et al. (2002) and Shore (2008). First, both studies based their findings on cases that were selected for their ability to serve as clear-cut examples of ICT project management failure due to biased decision-making. Thus, there was no comparison possible between the different biases on their occurrence and impact in real ongoing projects. Second, as both McCray et al. and Shore noted, the scientific literature provides the project manager with tools to aid in important decisions. These decisions range from strategic to operational: From what expertise to acquire (Stevenson & Starkweather, 2010), to identifying and managing risk (Lefley, 2013). However, the tools to identify and deal with both uncertainty and the biases that are the result of the use of heuristics are underrepresented in scientific research (Purvis et al., 2016). They propose several remedies to limit the impact of the heuristics and biases in project management that they identified. These range from interdepartmental discussions and reviews of project management related decisions, to awareness creation for some of the heuristics that were studied. They, however, base their remedies on studies in the field of decision-making and psychology without adapting to or testing them in the project management context nor developing them into a complete and integrated method. The current study proposed and tested an integrated method for preventing biases in project management decision-making. This we will discuss more in-depth.

2.3. Preventing biases in project management

How to limit or prevent the harmful effects of biases in ICT project decision-making has been researched to some degree in other fields of study, such as in psychology and behavioural economics. These studies generally propose interventions that fall in one of two categories. First, there is awareness of the existence of heuristics and their resulting biases and how they might influence decisions. This is for example proposed in studies by Purvis et al. (2003) and in the books by Cialdini (2009) and Kahneman (2011). Being made aware of the fact that one tends to overestimate the likelihood of events that occurred recently has for example been proven effective. Second, there is the use of methods and techniques to facilitate elaborate and rational thinking. Elaborate thinking is described by Kahneman (2011) as the opposite of the fast and frugal thinking called “system one thinking” that facilitates the use of heuristics and occurrence of biases. Both interventions have their weak points and impracticalities. First, awareness of every heuristic and bias is highly unlikely to work on its own as it will need to be constant and complete. Neither of which is practical nor probable. Second, the rationalization according to a set method introduces the slower and more elaborate decision-making of what Kahneman (2011) calls “system two thinking”. This slows down decision-making when this might not be practical or feasible. Furthermore, while a study by Wijtenburg (2018) addresses dealing with uncertainty in project management, his focus is reactive and relies on early warning systems. Thus, potential remedies that limit the harmful effects of biases in project management decision-making exist. They, however, remain largely untested and have so far not yet been developed into a practical and integrated method or one that works preventatively.

Each of the two major proposed interventions against biases in ICT project management decision-making has some evidence to support its effectiveness, but also its limitations. As this study aimed to test an integrated variant upon the two interventions. Awareness or knowledge of the causes and effects of heuristics and their biases in project management can be achieved by both training and educational materials, as was proposed in articles by McCray et al. (2002) and Purvis et al. (2004). Methodologies for rational thinking have existed in the project management context and are actively used to aid decision-makers. Few offer the flexibility to include the effects of heuristic decision-making and thus allow for the integration of the first intervention into the second. System Dynamics is such a methodology. It centres around the complete modelling of projects (Mawby & Stupples, 2002), including risks and different scenarios (Wijnhoven, 2019). Moreover, one of its founders, Sterman

(2002), specifically appealed for the inclusion of uncertainty and for its use as a method in rationalizing decision-making. He, for example, described its qualities in finding and comparing alternatives and deciding upon the right weight for factors. Incidentally, these are the three ways in which heuristics simplify decision-making and where biases might occur. It thus serves as an excellent operationalization of the methodology described as part of the intervention and can be adapted to include heuristics and biases.

As Sterman (2002) noted, uncertainty and complexity are both important aspects and challenges in the successful modelling of projects using System Dynamics. It is perhaps fitting that they too play an important role in increasing the use of heuristic decision-making and the chance of biases in the decision-making process. As such, they were included in the current study. Risk, time limits and cognitive effort affect the amount of heuristic decision-making and resulting biases as well. Their influence is however well-known (Gigerenzer & Todd, 1999). Moreover, the scientific literature shows examples of successful interventions against these factors both in the project management context (Mawby & Stupples, 2002; Wijtenburg, 2018) and outside it (Rieskamp & Hoffrage, 1999). Therefore, risk, time limits and cognitive effort will not be included in the study itself. The current study instead focuses on the role of uncertainty and problem complexity both in its direct effect upon the use of heuristics and the resulting biases and on moderating the effectiveness of the intervention. The intervention focuses on the prevention of biases that negatively impact project management decision-making, rather than on the heuristics that are the underlying factor. This is because not all heuristics have a negative effect (Gigerenzer & Brighton, 2009) and because biases are tangible and measurable negative outcomes. The latter will be addressed more in-depth in the next chapter. An intervention using an approach that incorporates both awareness and systems thinking is likely to affect the negative influence of biases on project management decision-making. These expectations have been summarized in the theoretical model in Figure 1. and the hypotheses below.

2.4. Hypotheses and theoretical model

1. Increasing the awareness of biases in decision-making among decision-makers and providing them with a method to rationalize decisions, will decrease the amount of biases in future decisions.
2. The levels of uncertainty and complexity affect the amount of biases in decision-making.
   a. Higher levels of complexity increase the occurrence of biases in decision-making.
   b. Higher levels of uncertainty increase the occurrence of biases in decision-making.
   c. Higher levels of uncertainty and complexity interact to create a stronger increase in the occurrence of biases in decision-making.
3. The level of uncertainty moderates the effect of the awareness of biases in decision-making and the methods for rationalization upon the occurrence of biases, so that a lower level of uncertainty will lead to less biases when combined with awareness and the method for rationalization.

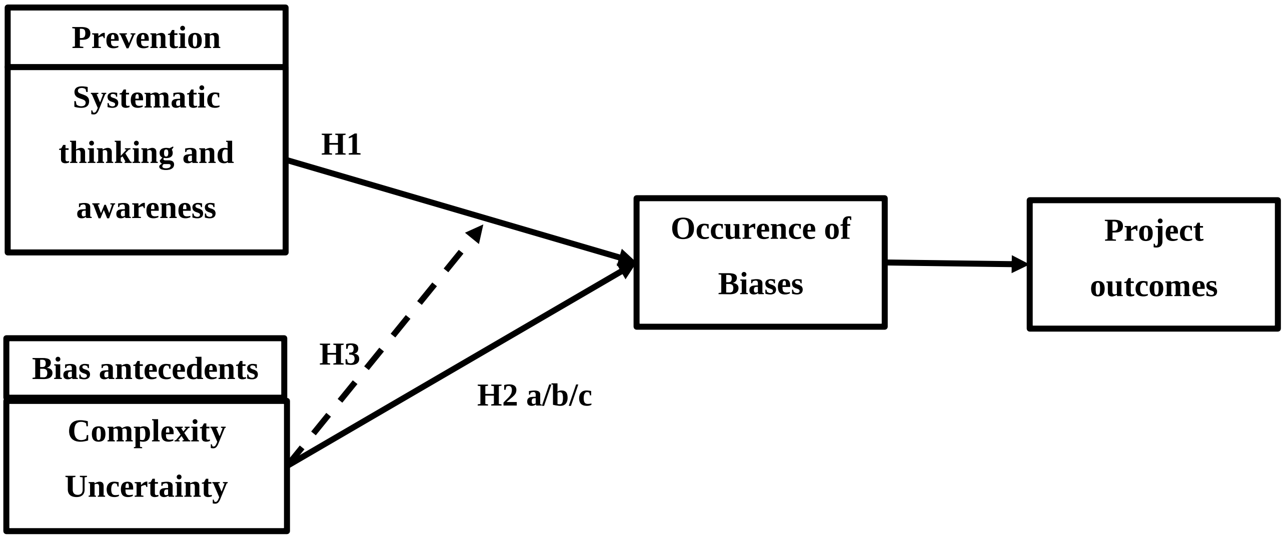

Figure 1. An overview of the theoretical model proposed in this chapter. Solid lines represent the main effects and dashed lines represent proposed moderator effects.

3. Methodology

This third chapter discusses the methodology, samples, procedures, and designs of each of the three studies that were conducted as part of the overall study for this report. It is divided into four main parts, starting with a description of the overall design and methodology, which is then followed by a separate section for each of the three studies that were conducted. The discussion of each separate study is done according to the same structure. First, it starts with an overall description of the rationale, purpose and design of the study. Second, the procedure for the study and analysis is detailed. Third, a description is given of the sample of each study. The theoretical model presented in Figure 1 will be adapted to show which part of the model is within the scope of each study and will be shown in each section.

3.1. Overall study design

A multi-part study was designed to answer the central research question and the gaps identified within the scientific literature. The overall study consisted of three sub-studies or parts and used a combination of qualitative and quantitative methods (mixed methods). In the first part, an analysis was done of fifteen project management cases written by a Dutch independent project management review board. The purpose of this study was to identify the occurrence and negative effects of biases in actual project management cases. Moreover, the context of each of the cases was studied to include the role of complexity and uncertainty in the decision-making process. The second part consisted of an experiment in which participants solved two project management cases spread out over two stages. In between both stages, an intervention took place. In both stages, various aspects of the cases were manipulated to create different experimental conditions. The purpose of the second study was to determine the occurrence of biases under different levels of uncertainty and complexity and to test the effectiveness of the proposed intervention. The third and last study consisted of a series of interviews with experts in project management. The interviews were used to evaluate the applicability and generalizability findings outside of lab conditions and the feasibility and practicality of the intervention. The combination of methods served to supplement each other and to provide a more complete and robust answer to the central research question than any one of the methods alone could. Each method is described in greater detail in its own section.

3.2. The case studies

The first study and first part of the overall study consisted of a desk research of project management cases. Its purpose was to identify biases in the decision-making process within these cases and the effect of biases on the overall project outcome. The analysis also included the project’s context, namely the complexity and uncertainty associated with the project. The subject of the analysis were 15 written and publicly available reports. The reports were written by an independent evaluation and advice board of the Dutch national government called “Bureau ICT Toetsing” (Bureau for ICT Evaluation) or “BIT”(Bureau ICT Toetsing (BIT), 2019), which we discuss more in-depth in section 3.2.2, found below.

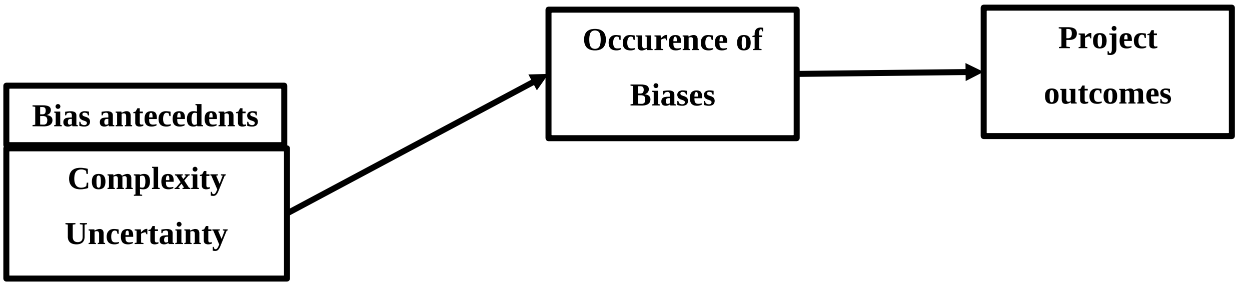

Figure 2. Overview of the scope of the first study, the analysis of fifteen project management cases. The figure is an adaption the theoretical model presented in chapter 2.

3.2.1. Procedure

The reports written by BIT commonly contained ten pages of content and varied from four pages to fifteen pages. The reports focussed on two major aspects (Bureau ICT Toetsing (BIT), 2019) of the projects that were analysed. Firstly, is the problem that provides a reason of existence for the project well-defined and does the project (whether proposed or in-progress) solve the problem? Secondly, is the project structured in such a way that there can be justified confidence that the project’s goals can be met within the limits of the project? Both aspects focus on the initiation and planning phases of project management and thus aligned with the scope of the current study. Each report indicates the likely causes and underlying mechanisms that cause the bureau to either have confidence or doubt in the project’s feasibility or assess its planned progress as severely threatened. In most cases, the evaluations contained a special section on the decision-making processes and the context of the ICT projects. Thus, the reports aligned with the scope of the first study.

The reports were read and analysed and the findings noted in a special matrix, similar to the methodology employed in the studies by Shore (2008). The matrix can be found in Appendix 2. Three things were sought in the texts that were analysed. Firstly, the text was searched for decision-making processes that contained hints of the heuristics listed in Table 1. The resulting decision would then be analysed to determine whether any of the biases could be recognized. By looking for recognizable heuristic decision-making first, a decision-making process would have needed to be described in-depth to allow for the recognition of a heuristic. This would potentially limit the danger of false-positive identifications that looms when one is actively searching for something in a text. Second, the decision-making analysis in the reports commonly contained a cause-effect description. It allowed the first study to link biased decision-making to the outcomes of the project. The impact was described as either affecting the progress or performance of the project, leading to failure, or having no impact at all. Third, the context of the ICT project was described in three ways that were relevant to this study. Firstly, the goal, motivation, schedule, and status of the project were described. Secondly, the stakeholders and key challenges were listed. Thirdly, the complexity and uncertainty in the project were described when applicable. These would be categorised based on the article by Shenhar (2001).

Recognizing the biases in decision-making employed by a third party based on a report by another party is both a complex and potentially subjective practise. When a section of the reports met the requirements described in the previous section it would be studied for the presence of biases. This was done based upon five sets of criteria, one for each of the heuristics within the scope of this study. While studying the evaluations, a search was conducted for the key mechanisms described in the definitions of the heuristics and biases that were given in Table 1. First, in the case of the erroneous evaluation of risks, the cases were searched for failures were either rare occurrences (both positive and negative) were, according to the reviewers, overestimated and thus valued wrongly. Second, in the case of decisions that were oversimplified, the text was searched for cases wherein a single cue (or piece of information) was at the basis of the decision. This could be an existing belief in case of conservatism or cases wherein intuition or opinions were leading. Thirdly, when a choice scenario was presented, the search would focus on how the choice sets were presented and constructed. False dichotomies in case of failure or further investment and inappropriate comparisons would be noted as biases. Fourth, the same choice sets would be scrutinized for the way they were constructed. Limited searches for alternatives could be based on past experiences or past successes and failures when making estimates. Depending on the type of information used these situations could be ascribed to one of the biases listed under the availability heuristic in table 1. The identification of biases was based on both the situation described in the evaluation and the evaluation of the actions themselves. For example, a decision might be described that was made based upon a single metric being the potential benefit of the action without considering its risks or impacts on the project. In other cases, BIT might note that the way in which risks were weighed was faulty and heavily favoured covering even the smallest risks. Both would be counted as examples of biases, but one was the situation described and the other an evaluation based upon research by BIT.

3.2.2. Origins and characteristics of the sample of reports

The “Bureau ICT Toetsing” or “BIT” was created after several high-profile ICT failures in the Dutch public and semi-public sectors. It was created to make up for the knowledge lacking in the organizations that manage the ICT projects. BIT has evaluated more than 50 ICT projects of the local and national Dutch governments as well as projects of agencies and firms indirectly or directly employed by those national and local governments since its inception in 2015. External independent expert reviewers have evaluated the evaluations and following reports as both thorough and reliable (StokmansMark & Adriaanse, 2019). Fifteen BIT reports were randomly selected for analysis from the last three years. In some cases (n = 2) multiple reports were written on the same project, but at different times in the project’s progress. In these cases, only the newest report was selected for this study’s analysis. Furthermore, some cases (n = 2) did not undergo a thorough analysis because either the state of the project meant that there was too little analyse or because the project was undergoing rapid and large changes at the time of the analysis. These reports were excluded, and new ones were randomly selected. The final list of 15 reports that this study analysed is listed in Bibliography of BIT reports on page number 61.

3.3. The experiment

The second part of the study consisted of a full experiment that used between-groups-comparisons and was deployed through Qualtrics’ survey application. It served to identify the impact and occurrence of biases in project management decision-making under different levels of project uncertainty and complexity in a lab environment. Moreover, the intervention proposed in section 2.3 and described in more detail in section 3.3.2 was tested. The lab environment was crucial as experimenting with real projects is both impractical and unfeasible, as the experiment would impact real running projects and would occur in an uncontrolled environment. Students from a Dutch research university served as a sample for this experiment. The experiment itself was conducted in two stages with each their own case. In the cases, the participants were asked to solve four project management decision-making questions. After the first stage, participants followed lectures containing the intervention. These consisted of an introduction to project management decision-making and biases and a lesson on the use of System Dynamics as a method of project mapping and scenario planning. After four weeks, the students solved a similar case. Both cases can be found in Appendix 3. The experimental conditions were manipulated through differences in the texts and specifications of the decision-making scenarios provided in the cases. Both cases were specifically designed for this experiment and its characteristics and limitations (see section 5.3) and were both tested in a pre-test to determine whether they were similar enough (see section 3.3.8). A schematic representation of the design of the experiment is shown in Figure 3., found below.

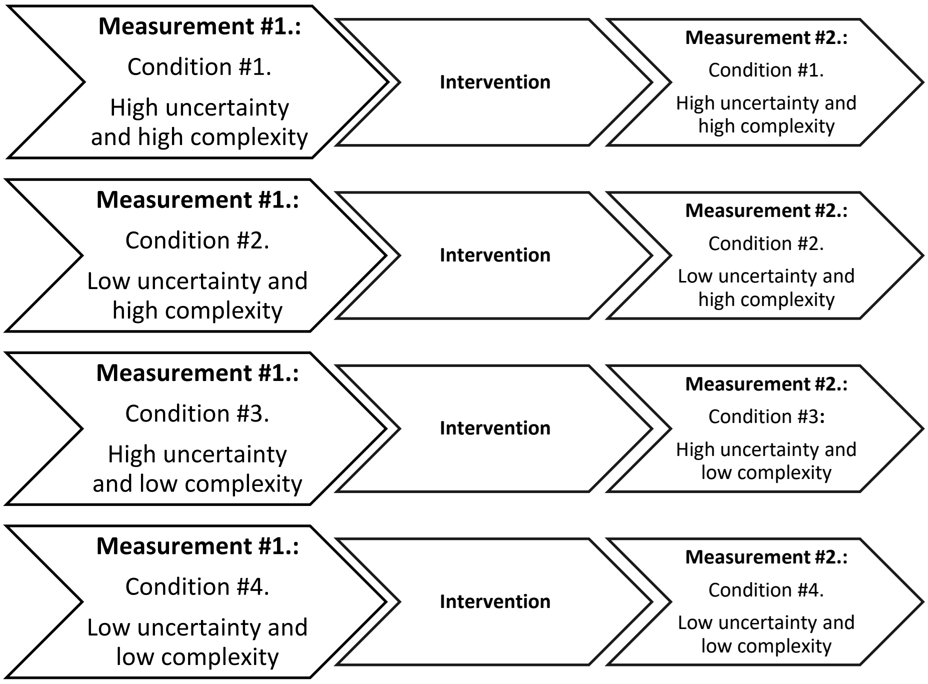

Figure 3. The design of the experiment with its four cells and two measurement points.

3.3.1. The independent variables and manipulation

The experiment featured two independent variables which served as manipulations within the experiment, namely the level of uncertainty and complexity. Both are manipulated within the cases the participants needed to solve. The text for each of the conditions was mostly identical to that of the others. Details and specifications provided to the participant were manipulated in accordance with the assigned experimental condition of the participant. Each of the variables and manipulations is described below.

The level of complexity was manipulated through the number of factors and stakeholder that the participant had to account for in solving the case. This operationalization was derived from the definition of complexity in the study by Shenhar (2001). We provide two examples of this manipulation. First, the participants in the high complexity condition had to select an insurance policy with double the number of clauses. Second, the high complexity condition featured a third more specifications that had to be met for the project to be successful. In both cases, neither the nature of the project nor the potential risk provided by the policy changed. Instead, the decision-making process was made more complex. The effectiveness of the manipulation was checked by a single questionnaire item asking to which degree they found the questions complex. This item was answered on a 5-point scale, anchored by extremely simple and extremely complex.

The level of uncertainty was manipulated in a similar fashion. In this study, uncertainty was represented by potential outcomes of which the contents nor their likelihood were fully known. Pich, Loch, and Meyer (2002) for example argue, that uncertainty in project management can occur in any aspect. It is the point where the current knowledge and capabilities cannot deal with a challenge or when knowledge of the challenge itself is absent. It thus requires imagination to solve. An example of this manipulation in practise could be found in one of the questions regarding risk mitigation strategies. The participants were asked to select the best mitigation strategy. In the high uncertainty condition, both the amount of potential impact (in Euros) from the risk and the likelihood of the risk materializing was presented as a bandwidth of possibilities. This ensured that participants had no real certainty or could calculate risks but were always dealing with a number of potential events. Some parts of this manipulation could be found in the case descriptions as well. An example might be the seemingly conflicting or incomplete description of a schedule or set of requirements that is conflicting. This ensured that participants had difficulty acquiring a firm grasp of the situation presented to them, in line with the definition presented before. Both approaches to manipulating uncertainty were intended to change risk into uncertainty. The effectiveness of the manipulation was checked through an item which contains a statement saying that the participant had enough information to answer each case. The single item is answered on a 5-point scale and anchored by completely disagree and completely agree.

3.3.2. The intervention

The intervention focussed on two aspects of decision-making, namely the common pitfalls of decision-making and dealing with complexity and uncertainty. Participants watched a lecture on each of the subjects as a form of intervention. The lectures were delivered over the course of two weeks through a digital learning environment that the participants were familiar with. In total, these sessions lasted two hours and were a requirement before participants could move onto the second stage. The first lecture concerned common decision-making pitfalls in project management that resulted from the use of heuristics. Participants were made aware of their existence and potential impact. Moreover, participants spent time learning about the conditions in which their decision-making was more likely to become biased. The second lecture and part of the intervention concerned a method with which decision-making could be rationalized. System Dynamics for this purpose. Participants learned how they could identify, analyse, map and schedule complex and uncertain projects. Furthermore, they learned how the basic method underlying System Dynamics could be applied in different settings and how it benefited their decision-making. Afterwards, participants practised with the System Dynamics methodology so to ensure they understood it.

3.3.3. Dependent variable measurements

Key in this experiment was the usage of heuristics and the resulting biases. This usage was measured through the answer options provided to the participants. Cases were designed to demand four decisions on an ICT project from the participant. Each decision was contained in a separate item with a small scenario that was part of the larger case. The parameters of the decision were dependent upon the randomly assigned condition and series of manipulations. Whether the participant reasoned through a heuristic and made a biased decision, was visible in the selected answer. The answers were converted into a decision-making score per item. A perfectly rational answer rewarded zero points. A faulty answer rewarded one point and a biased decision two points. The scores per item would be combined in an overall score, which ranged from zero to nine. The score reflected more rational decision-making when it was lower and biased decision-making when higher.

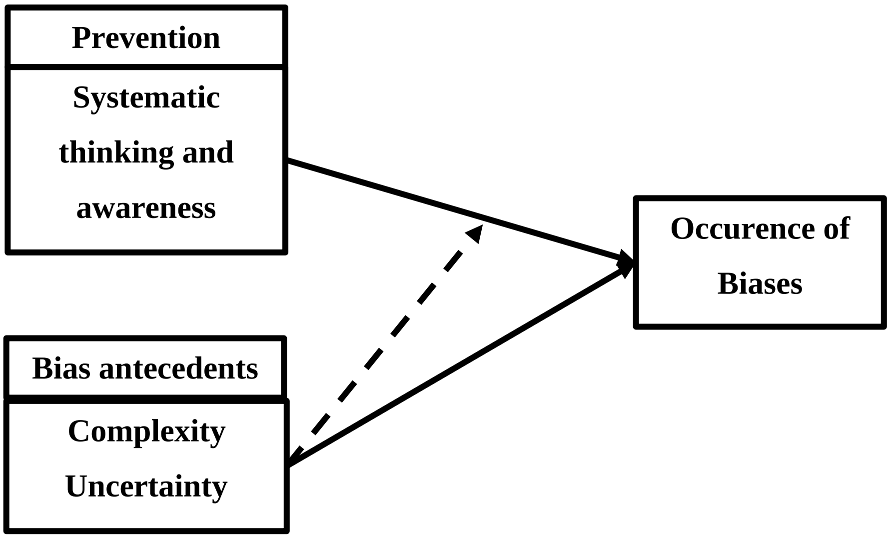

Figure 4. Showing the scope of the second study (the experiment) in an adapted version of the theoretical model presented in chapter 2.

3.3.4. Additional measurements

In addition to the measurements needed for the analysis of the results, two sets of measurements were taken. Firstly, there were three items concerning demographics and the educational background of the participants. These included age, gender, and level of understanding of the English language. Secondly, there were items intended to collect data on the participant’s experience with the cases. These items measured how realistic participants thought the cases were, how confident they felt in their own decision-making in general and during this experiment and inquired to what degree the participants applied the interventions.

3.3.5. Development of the cases and stimulus material

Two cases were used as the basis for the experiment. These cases served as the backstory to the decision-making challenges and dilemmas posed to the participants. Both cases were developed based on a formula and structure that was created using the cases analysed for the first part and case studies by McCray et al. (2002) and Shore (2008). Each case had four questions. Each question was adapted to fit with one heuristic, for example, one question included the opinion of a content expert. It thus encouraged blindly following that authority and encouraged the use of the authority heuristic. Participants were given requirements for the project’s timeline, budget, and decision-making in each of the two cases. For example, participants should see every transaction as an investment and only invest when it has an expected return equal to or higher than the cost. Moreover, some information was produced on the project outline and included the stakeholders, clients, suppliers and legal requirements. Cases and questions needed to meet three important criteria for the purposes of this experiment. First, they needed to be modular and adaptable to the experimental conditions. Second, no experiences outside of this experiment should be able to influence the outcomes significantly. This included anything from brand names to project descriptions that were too similar to well-known real-life projects. Moreover, this meant that heuristics based on memory could not be included. Third, each question should work with each of the heuristics and biases selected for this study. This ensured that the cases were similar by design while differing enough to not allow participants any benefit from having answered the first case.

3.3.6. Procedure

Participants were invited to the experiment through their course's electronic learning environment to a survey in the Qualtrics suite. They were informed that a researcher was interested in their decision-making in the project management context before they had any classes on the subject. Upon clicking on the invitation link, the participants were taken to an opening page explaining both the goals of the study and what was expected of participants. Each participant then had to give their informed consent and provide an email address to continue to the first stage of the experiment. The participants' email addresses were collected to ensure that the participants could be assigned to the same condition in both stages. Their answers were to the cases were however kept separate to ensure that the answers were truly anonymous. Participants then received an explanation about the case they worked with. It was explained that they had to make decisions as a project manager, meaning it is often under conditions of imperfect knowledge, differing levels of complexity and with a dose of uncertainty. They were then taken to the case description. The first case concerned an ERP implementation programme, wherein they served as a project manager. They were given a short backstory, project success requirements, an outline of the project and its participants and a number of risks that the "project team" identified for them. This information was provided to them in a PDF document as well. After reading everything, they could then continue to the first question.

Once participants passed the welcome screens, they were confronted with the first scenario and question. It asked them to select a supplier and they were provided with a shortlist of three suppliers for the project's hard- and software. Each supplier had its own conditions, up- and downsides. The first question was an example of the default heuristic, as it was never stated that these three suppliers were the only ones available and this their only offers. Moreover, it was a false comparison as the offers were made to as if they got better from one to the other, they were not. When participants inspected the conditions closely, they could have noticed that none of the suppliers could meet the requirements set out in the project descriptions and the offers themselves were otherwise similar. Thus, none of the suppliers met the critical requirements. Participants could opt to not select a supplier out of the three, which led to a scenario in which a new combined offer was made by two of the suppliers that did meet the requirements. Afterwards, the participants were asked on what basis they selected the supplier. This process was repeated for another three scenarios and questions within the case. After the last question, the participants visited the final set of questions.

In the final set of questions, the participants answered items concerning the case, their own demographics and their experience during the experiment. It for example included items that asked about their age and gender, to what degree they found answering the cases difficult and questions about their confidence in their own decision-making ability. Participants were then thanked for their time and effort and instructed to view the lectures that served as the intervention. These lectures were also included in the regular lecture schedule, as to maximize the possibility that the participants had viewed and listened to the lectures. Furthermore, participants were instructed to await an email invitation in four weeks for the second part of the experiment and were offered an opportunity to voice questions or complaints about the study to the researcher in the meantime. The second stage of the study was structured in the same way and featured the same heuristics as the first stage. However, the case this time was about the creation of a new customer platform for a service firm and both the outline and risks of the projects were different. The scenarios and questions that used different versions of the same heuristics in a different order to create a very similar case where none of the answers or lessons from the previous case applied. After answering four questions, like in the first stage, participants were again asked about their demographics, the cases and their experience. They were then debriefed and thanked for their participation for a final time.

3.3.7. Sample characteristics

The sample of the experiment consisted of students from a Dutch research university and was collected through convenience sampling. It was drawn from a pool of students that participated in a module taught during the second year of the undergraduate (Bachelor's) degree. Participants were approached through the online learning environment created for this module and asked for their voluntary participation. The source of the sample allowed for the assumption that the sample was homogenous in the level of understanding of the English language. Furthermore, the early stage of their education should have ensured that none of the participants had extensive previous knowledge or experience with project management. These assumptions were checked and confirmed within the experiment. The sample consisted of 107 participants who participated in the experiment. In the case of 24 participants, the participation was limited to the first stage, before the intervention and did not continue into the second stage. They were not excluded from the analysis as their presence does not majorly offset the sample's balance. Only participants that completed a stage fully were included. Out of the 107 participants, about 70% identified as male 25%, as female and 5% refused to indicate either. On average, the participants were 21 years old with a standard deviation of

3.915. They were randomly assigned to one of the four experimental conditions for the duration of the two stages of the experiment.

3.3.8. Pre-test

The experiment consisted of two stages with each its own case description and set of questions that were based on the same template and design logic. To ensure that both stages were sufficiently similar, a pre-test was run. During the pre-test 10 participants went through both stages in a random order. They were asked the same questions as the actual participants and score was calculated for them too based on the answers they gave, which served as the dependent variable. Moreover, the participants were asked to evaluate both cases. For each case they answered four items that were anchored on both ends with words representing complexity (Not complex/Complex), Certainty (Not certain/Certain), realism (Not realistic/Realistic) and difficulty (Not difficult/Difficult) on a five-point scale. Both these items and their final score were compared using Paired Sample T-tests in IMB's SPSS version 23. The results indicated that both cases did not differ significantly in terms of complexity (t = 0.000 p = 1.000), certainty (t = 0.000. p = 1.000), realism (t = 2.055. p = 0.067) and difficulty (t = 0.232. p = 0.821). Moreover, the scores across cases did not differ significantly (t = 0.711. p = 0.493). Thus, we can assume that the text of the cases themselves likely did not significantly affect the outcomes of the experiment. The results are summarized in Table 2, found below.

Table 2. Results of the paired sample t-test.

		Paired Differences					
		Mean	Std. Deviation	Std. Error Mean	t	df	Sig. (2-tailed)
Pair 1	Complexity	,000	,894	,270	,000	10	1.000
Pair 2	Certainty	,000	1.095	,330	,000	10	1.000
Pair 3	Realism	,636	1.027	,310	2.055	10	,067
Pair 4	Difficulty	,091	1.300	,392	,232	10	,821
Pair 5	Score	,27273	1.27208	,38355	,711	10	,493

3.4. The interview series

The last part of the study consisted of a series of interviews conducted with a sample of experienced project managers. Each of them has and is still active as a project manager. The goal of each interview was to determine the validity of the findings amongst experienced experts as opposed to the inexperienced starters from the experimental stage. Moreover, these experts offer an opportunity to study the feasibility and applicability of both the findings and intervention. It was a necessary addition to the lab experiment, as it provides feedback from the real-world. The output of the interviews will be used in a qualitative analysis.

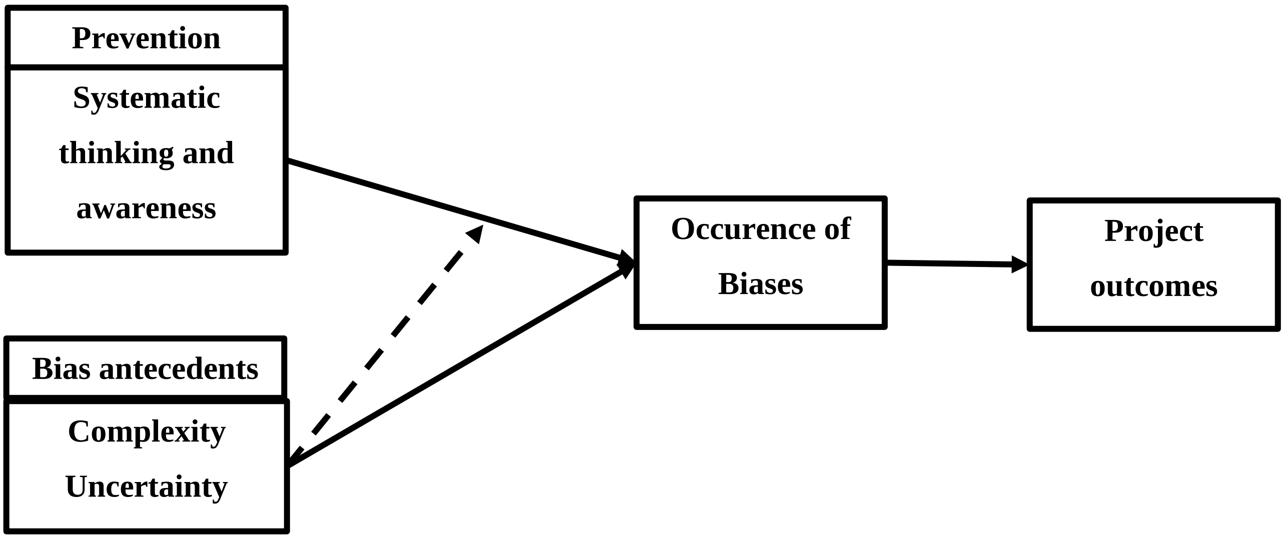

Figure 5. Showing the scope of the third study (the interviews) in an adapted version of the theoretical model presented in chapter 2.

3.4.1. Procedure

The interviews were conducted according to a semi-structured approach, whereby questions and subjects were defined beforehand, but participants were able to steer the process. Before the interviews, the research goals were translated into several subjects for the interviews, consisting of the role of complexity and uncertainty, the professional decision-making process, the use of heuristics, biased decision-making and improvements to the personal decision-making process. Each of the participants was emailed beforehand with information on the goals of the study, the subjects to be discussed, a procedure for the recording and analysis of the interviews and a method with which anonymity was ensured. Each participant was briefed before the interview and asked for verbal agreement with all the specified information and for the affirmation that they understood their rights. The interview was then to proceed according to the list of subjects and questions which can be found in Appendix 7. and the recording was started. The interview could be divided into three major parts. The first part was used to acquire the participant's experience with each of the subjects. Then, the second part was used to present the experiment's findings and inquire about the participant's evaluation and possible recognition of these findings. Third, the interview went on to discuss the intervention that was tested and how it could be applied in the participant's project management context. The recordings of the interviews were then be transcribed, and the recordings deleted. Afterwards, the interviews were coded using the scheme found in Appendix 3. This allowed for an analysis of consensus and overlap in experiences regarding the topics and the contrast between different positions.

3.4.2. The interview sample characteristics

Participants for the interviews were recruited through the International Project Management Association or IPMA for short. The sample needed to consist of project managers with a proven track record and experience. Both in the Netherlands and the wider world, IPMA educates, examines, and certifies project managers, their knowledge, and their experience level. The current study limited itself to the Dutch ICT project management context and thus only Dutch project managers were invited to participate. In total, eight interviews took place over three weeks. Each lasting around an hour. Out of the eight participants, five were certified at the second-highest level B-level for their experience and expertise. One individual was certified at the highest A-level. Two individuals were relatively young and experienced (in their thirties) project managers. They were included to acquire a more diverse sample and point of view while maintaining the sample's criteria of proven experience. All eight worked in ICT or ICT project management. Six of the participants' main task consisted of delivering software projects and Two of the participants' tasks revolved around hardware or manufacturing. Participants had various backgrounds. Slightly less than half (three participants) indicated that they had a mostly technical background in either software, ICT hardware or engineering. The others had a mixed background that most often centred around business or management. They all had at least 10 years of experience in project management, all but two had more than 20 years of experience.

4. Results

The analysis section consists of four parts, coinciding with the three main methods of study that were employed and a conclusion. First, the results of the case studies are discussed. Second, the experiment and its results are detailed. Third, we describe the findings of the interviews. Thirdly and finally, we determine the status of the proposed hypotheses based upon the results. In all cases, the threshold for significance or alpha was set at 5% ($\alpha = 0.05$). Only significant and near-significant finings ($p < 0.1$) are reported.

4.1. The case studies

The purpose of the case studies was to identify the occurrence and effects of biases in project management decision-making in real projects. This part of the study focused on 15 evaluations written on projects in the public and semi-public sector. The findings are summarized in Table 3. found below and a full schema for the analysis can be found in Appendix 2.

The analysis found that in 10 out of 15 evaluations there was evidence in support of a bias disrupting the decision-making. The biases resulting from the "one cue" heuristic (n = 5) and underestimation (n = 4) of risk bias were most often present. In those cases, decision-making either overly simplistic and optimistic or failed to account for risks. The default bias was most often employed when the amount of complexity was high. In these cases, decision-making was shortened to such a degree that there was no evidence of a proper decision-making process. Instead, in most cases, an earlier suggestion or unsupported opinion was followed. Project PHOENIX featured such decision-making. There the reviewers described that "Impactful design decisions were made on unclear grounds, which were not recorded and were of a highly ad-hoc nature". Later reviews by management assumed these decisions were made objectively and well informed. The underestimation of risks could be impactful as well. In one case a mismanaged risk was big enough to not just potentially threaten the project, but the organization's ability to perform its legally required activities as well. In case of the renewal of tax collection systems, the evaluation noted the severe underestimation of risks of system failure due to underestimated system complexity. The reviewers described that "The projects were made to be highly interdependent leading to high chances of delays and risks to the whole systems array." When decisions or evaluations were made based upon faulty information, retracing its source was complex. It was however often relatable to false assumptions or choice scenarios sketched in documentation (n = 5). In the "Vernieuwing

JDS" case BIT described an ambition to reach 99% reliability for a system to be without merit: "There is no need for a higher reliability" Later they describe a move towards a newer architecture that was described as more robust as "[one] wherein we see no discernible benefits". In most of the cases that were studied, the occurrence of biases directly or indirectly threatened the success of the ICT project and in two cases the ability of the organization to perform its core activities.

More generally (n = 15), incomplete or faulty decision-making processes led to decisions that had a loose connection to reality, failed to incorporate important risks or led to an increase in complexity or uncertainty. Most often both uncertainty and complexity. The evaluation of the Chamber of Commerce project (project "Kern Gezond") was one such case. Progress was hampered by sub-projects that increased complexity unnecessarily and achieved no extra capabilities. Instead of ending the sub-projects that contributed nothing to the overall objective, the management ended the only projects that did contribute. The reviewers described that "Even though an advice from 2015 recommended to keep the scale limited to the main goal of turning off "NMP" [thereby decreasing complexity], the project does seem to abide by this advice at all.". A common behaviour seen in failed projects (n = 12) was the avoidance of uncertainty and complexity during the decision-making process. The ministry of defence in project GRIT opted to leave a crucial technical analysis to inventory technical complexity until after the contract with the suppliers had been signed. This, the reviewers noted, led to both risks to the systems and the finances of the project.

In many of the cases that were analysed, the presence of biases in decision-making was likely. The cases however often did not provide conclusive enough evidence. In seven cases the project was solving something entirely different then its purpose was and was often increasing the organization's challenges. This and other examples where seemingly completely irrational decisions were made, were likely due to the project management using a different measure of success, as hinted upon in the evaluations. Overall, when decision-making was suboptimal, it often led to more complexity, more uncertainty, and unmanaged risks. This in turn resulted or was predicted to result in overruns in budget and time or the lack of functionality in the final product. In all the cases that were analysed, the researchers recommended to improve the decision-making process structurally and to improve or revise specific decision through the implementation of proper procedure, phasing, peer review and formal decision-making.

Table 3. An overview of the results per case studied.

Report data		**Factors with impact on project**			
Title	**Background**	**Complexity**	**Uncertainty**	**Biases**	**Effect of biases on project succes**
Boba Fryslan	Public infrastructure	Yes	Yes	Yes	Potential failure.
TransVIR		Yes	No	Yes	Running out of time and budget
Transitie Werk.nl	Employment	Yes	Yes	No	
Doelarchitectuur Inning	Tax office	Yes	Yes	Yes	Likely failure of the project and dependent projects, severe overruns in others and a threat to the core capabilities of the organization.
Verniewuing JDS	Judicial system	Yes	Yes	Yes	The bad decision-making likely leads to project failure.

Lerarenregister en voorportaal	Education	Yes	Yes	No	Decision-making leads to an overly complex and impractical solution that will likely not feature all the required functionalities and not be done in time.
Bevolgkingsregister	Administrative	Yes	Yes	Yes	Likely failure to deliver a working and complete project. Available time and funds insufficient.
GRIT	Defence	No	Yes	Yes	Potential failure of the project and future disruptions in organization's operational ability.
ICAS II	Civil aviation	Yes	No	Yes	Project likely not succeeding
Kern Gezond	Business/finance	Yes	Yes	Yes	Likely project failure.

PGB 2.0	Welfare	Yes	No	No	Failure of project likely
Centralisatie lucheverkeerdsleiding	Civil aviation	No	Yes	No	Project failure is likely or project goes over time and over budget.
Praeventis	Healthcare	No	No	Yes	Likely project failure.
Gemeenschappelijke centrale meldkamer	Security	Yes	Yes	Yes	Likely partial project failure.
Phoenix	Administrative	Yes	Yes	No	Likely overruns in time and budget.

4.2. The experiment

The analysis of the experiment was conducted using IMB's SPSS statistics package version 23. This section starts with a description of the data acquisition, cleaning, and preparation process, this is followed by a description of the assumptions that were checked and is closed off with the results of the actual data analysis. Effect sizes are reported upon and interpreted based on the overview provided by Watson (2018).

4.2.1. Data merging and cleaning

The data that was collected through Qualtrics' survey software and saved into different surveys. In total, 117 people partook in at least one part of the experiment and recorded a total of 226 sessions. They could be divided into two major groups. Those before and after the intervention. Every participant partook in the first part, but not every one of them in the second part. There were thus two data files based on the two stages of the experiment with slightly different numbers of sessions and thus participants (see section 3.5.1.) that needed to be merged. Before doing so, any session that amounted to an incomplete participation (n = 24) and sessions of participants that failed to pass items intended to measure whether they had understood the most important information and had taken their participation seriously (n = 8), were removed. After doing so, we arrive at the 108 participants of the first part and the 76 participants in the second stage of the experiment. The first and second session could not be tied to individual participants, due to technical and ethical constraints. This resulted in a dataset with 184 entries (sessions) that could be divided into conditions of high and low complexity, high and low uncertainty and with and without intervention. The data was thus treated as between-subjects instead of a hybrid of within-subjects and between-subjects.

4.2.2. Assumption checking for the ANOVA

The procedure that was chosen for data analysis was the N-way ANOVA, as it allowed for the comparison of multiple groups means across the four experimental conditions. It was the procedure that best fit with the data's characteristics as it is both robust and can handle categorical independent variables and scale type-dependent variables. Before applying the ANOVA procedure, three major assumptions underlying its use were checked. An inspection of the QQ plots (Figure 1.) shows the data's distribution to be normal or near normal. Furthermore, Levene´s test of Equality of Variance was employed to determine whether variance across experimental conditions was within the boundaries of the ANOVA´s assumptions. The test´s results ($F = 0.910$. $p = 0.5$) indicate that we cannot reject its null hypothesis and thus provides evidence that the variance across the conditions is indeed equal. Thirdly, it was tested whether any of the independent variables correlated to a significant degree with each other. The test showed that none of the independent variables correlated significantly and as such that all three major assumptions underlying the N-way ANOVA were met. The full analysis can be found in Appendix 6.

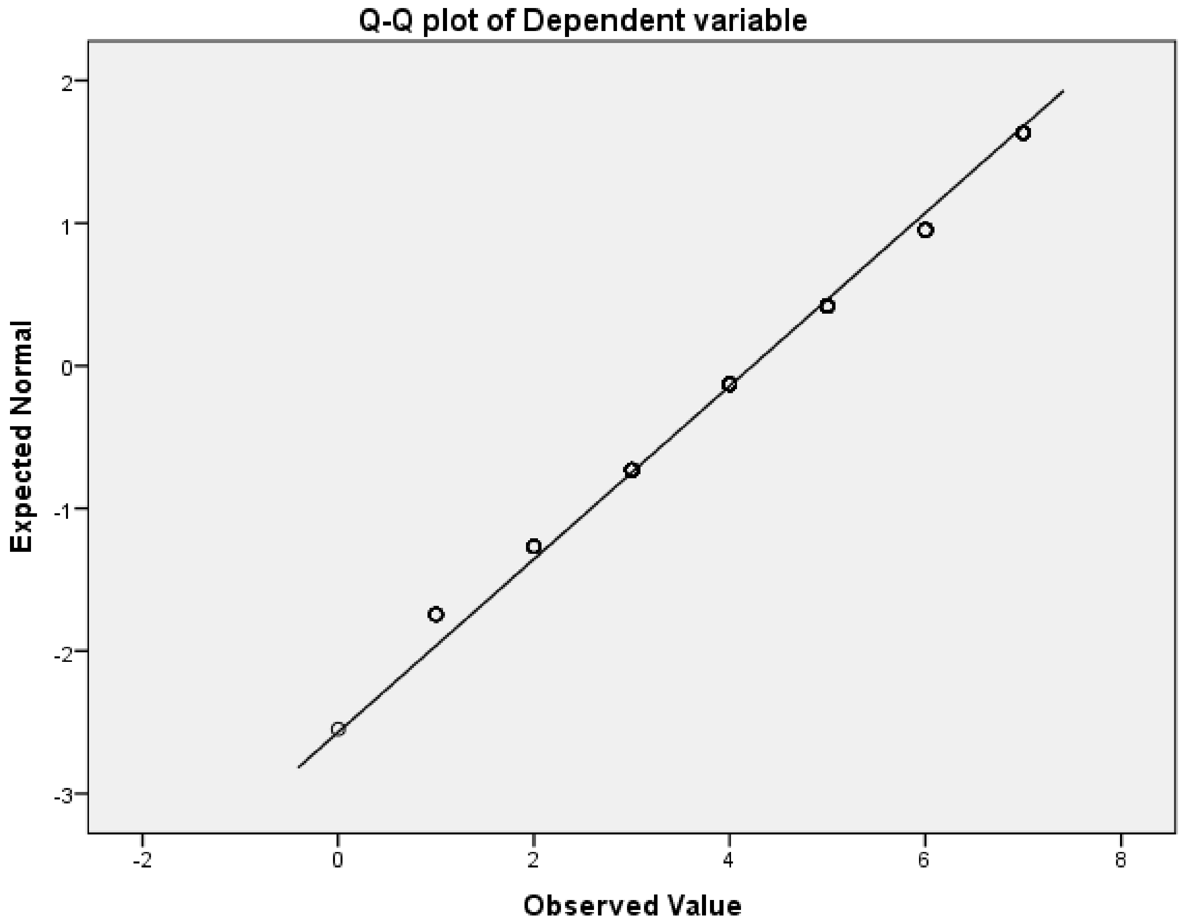

Figure 1. Q-Q plot showing the normality of distribution for the dependent variable as a score.

4.2.3. Data analysis

A single N-way (three-way in this case) ANOVA test of between-subject-effects was run on 184 cases (the sum of stage 1 and stage 2). The answers given to each of the cases were scored based on the type of decision-making; biased (high) or unbiased (low). These scores served as the dependent variables. Moreover, the model included the intervention (before and after intervention), amount of uncertainty (Little uncertainty/Much uncertainty) and amount of complexity (Little complexity/Much complexity) as independent variables. The results provide evidence in support of two significant relationships and one near-significant relationship and an overall model predictive capability of 19% (Adjusted R squared = 0.19). The results are elaborated upon in Table 4, found below. Non-significant results can be found in Appendix 6. Firstly, there was a significant positive effect of the intervention on the scores of the participants ($F = 36.44$. $p < 0.001$). The scores lowered, indicating that less biased decisions were made, when the intervention was applied (mean = 3.4324) as opposed to not (mean = 4.7963). The effect size ($\eta 2 = 0.172$) can be considered large. Secondly, there was a near-significant relationship ($F = 3.472$. $p = 0.064$) between the intervention, the amount of complexity and the dependent variable. Closer graphical inspection (see Figure 2) revealed that the level of complexity moderated the effect of the intervention in such a way that a higher level of complexity and the intervention resulted in higher (worse) scores and more biased decision-making. The size of this effect was very small ($\eta 2 = 0.019$). Thirdly, there was a significant relationship ($F = 3.926$. $p = 0.049$) between the level of uncertainty, level of complexity and the scores. Closer graphical inspection (see Figure 3) revealed that the biasedness of the decision-making process decreased sharply when both uncertainty and complexity were high. Meanwhile, the number of biases in the decision-making increased when the amount of complexity remained low but the amount of uncertainty increased. This effect size of this interaction was small as well ($\eta 2 = 0.022$).

Table 4. The results of the three-way ANOVA. $\alpha = 0.05$.

Variable	Type III Sum of Squares	Degrees of Freedom	Mean Square	F-score	P-value	Effect size in η2
Intervention	80.174	1	80.174	36.444	.000	.172
Intervention * Complexity	7.638	1	7.638	3.472	.064	.019
Uncertainty * Complexity	8.636	1	8.636	3.926	.049	.022

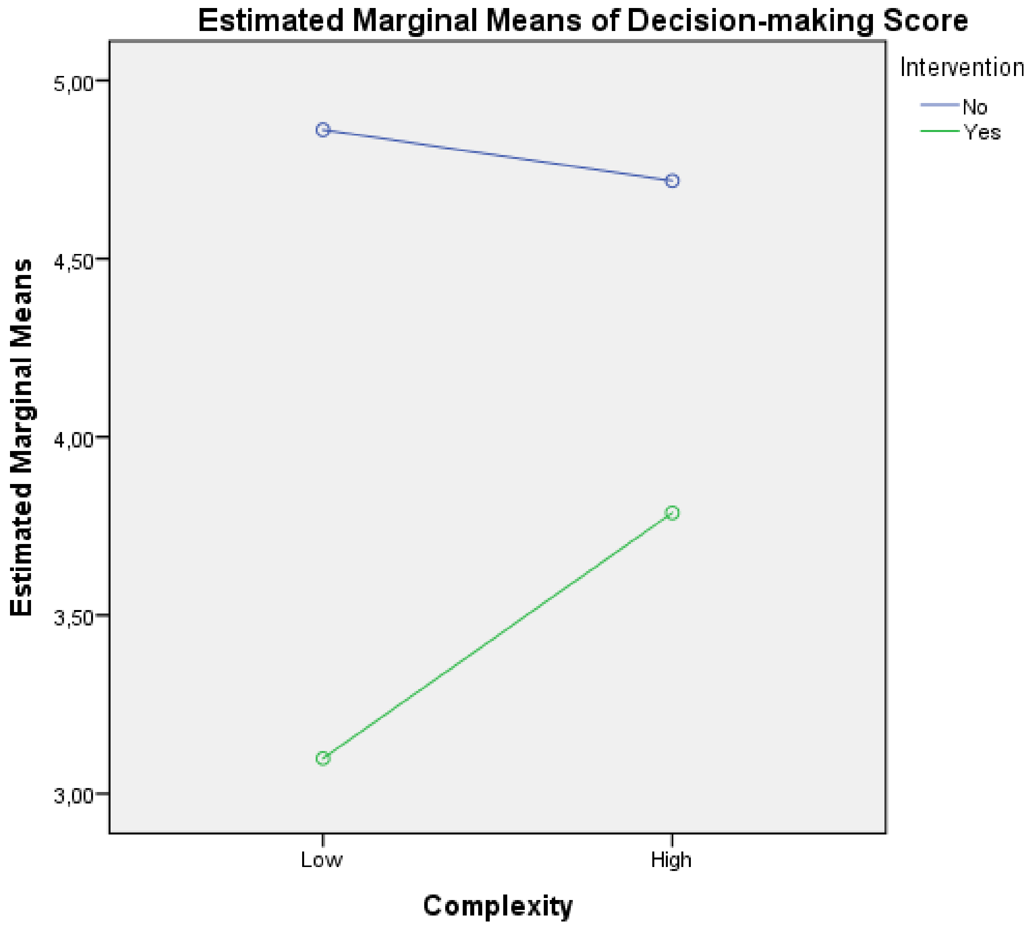

Figure 2. Showing the effect of complexity and the intervention on the dependent variable, the biased decision-making score. Lower scores represent a more rational decision-making process and higher scores a more biased decision-making process.

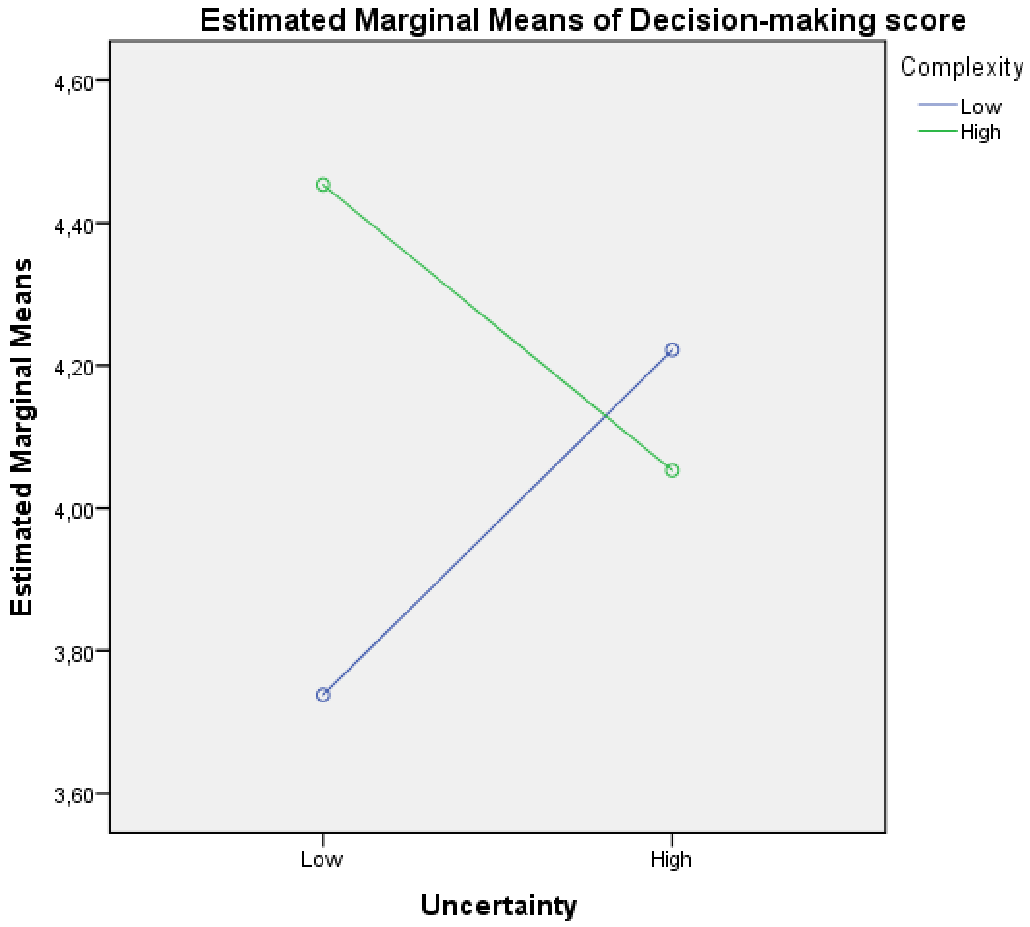

Figure 3. Showing the effect of both complexity and uncertainty on the dependent variable, the biased decision-making score. Lower scores represent a more rational decision-making process and higher scores a more biased decision-making process.

4.3. The interviews

The interviews served to both deepen the understanding of the subjects that were studied and reflect upon the hypothesis, literature, and experimental findings. We thus chose a general qualitative approach to the analysis that used both structured and unstructured elements. Firstly, a matrix was created (See Appendix 4.) for analysis in the form of a table with various positions and outcomes that align with or against the hypothesis. Each participant's position on each item was placed within the matrix. This allows for a more structured and quantitative-like analysis. Secondly, the talking points used during the interviews often led to introspection, reflection, and profound inferences from the participants. Some of these were used to supplement the more quantitative aspects of this analysis. They may be paired with opinions that were in contrast or might have aligned with the statement made and offer a deeper understanding of the subject matter. This section is split into two parts. One part for the discussion of the negative effects of biased decision-making and the decision-making process itself and another for the improvement of decision-making and the prevention of biases.

4.3.1. Decision-making and the decision-making context

One of the first questions posed to the participants was how they described their decision-making process in their professional life. All of the participants saw themselves more as the manager of the people and the context than as a central figure with a distinct decision-making agency. About half the participants commented later in the interview that there must be many decisions of which they were not aware of. Participants from a more business as opposed to technical context were far more inclined to have this realization. One participant noted, "There are likely many subconscious and implicit decisions taken during a project, of which you don't realize the impact." An example from practice came in the realization that the choice of problem-solver was likely already an implicit and quick decision on how the problem would be solved and what type of outcome reached. Moreover, a different participant remembered a week in which an intern noted all the decisions that the project manager made. The project manager was astounded at the number of decisions they had taken. Project managers from a heavily technical context did not share these insights and saw their decisions as part of a process. One noted, "No, my decision-making is always the natural result of a pre-determined process." Thus, while decision-making was central to each of the interviewee's professions, their own evaluation on their own role and agency differed greatly.

The next subject was the project's context and its impact on the decision-making and outcomes of projects. It focused on the effects of complexity and uncertainty on their decision-making. The understanding of both uncertainty and complexity was similar across participants. Each of the participants was recruited through the IPMA organization, which trains and educates its members intensively. This might account for the shared view of the factors involved. Six of the participants indicated that both complexity and uncertainty played distinct roles in increasing the difficulty of decision-making and the chance of error. One commented that "People often try to fence in problems, to reduce complexity. They then make a caricature of reality." Complexity was something that – particularly the participants with a technical background – were confident in tackling. Project managers with a more business-oriented background (n = 5) were more likely to feel threatened or challenged by complexity. They also put a heavier emphasize on the impact of stakeholders and organizational elements on the project's complexity. Those with a more technical background often saw complexity as a result of the amount of changes and factors involved in those changes. Uncertainty was often more difficult to grasp. Participants with a background more rooted in business or management were relatively comfortable with uncertainty and used to it. They described uncertainty as events that impact the project but of which the exact nature, impact and likelihood are unknown. They described being on guard for uncertainty and simulated possible outcomes. One participant noted that "Managing uncertainty is the most important aspect. You must be ready for uncertainty." Others thought the presence of these factors was so inherent to their work, that they were not active threats to the quality of decision-making. Project managers saw uncertainty more as a threat to the quality of their process, indicating that "Dealing with uncertainty takes priority and must be done as soon as possible". Overall, the role of complexity and uncertainty was considered great in the decision-making processes. The degree to which it was a threat differed greatly.

4.3.2. The occurrence of biases in decision-making

The view of the interviewees on biases in their decision-making differed, from person to person. Two of the participants were keenly aware of their biases and maintained a state of vigilance throughout their decision-making. Both were active in organizations that had political dimensions to them and noted that biases were something they could afford and the rationale behind decisions must always be traceable. Most participants (n = 6) indicated very little familiarity with heuristic and biased decision-making. Half (n = 4), when prompted, recognized some of the heuristics and biases, but were not aware of the ways their decision-making could be biased without being prompted. All but three of the participants indicated after further inquiry that they thought biases in decision-making posed real dangers to their project management. The divide could be traced back to their attitude towards their own agency in the decision-making. Those who ascribed a relatively large role to themselves, evaluated the danger of biases in their decision-making as more significant. found it useful to become more aware of their biases and the potential negative effects associated with them. Three of the participants recognized the biases that were used during the experiments as something they had encountered in real-life. They were keen to learn more as a result. Six out of the eight participants indicated that their decision-making process shielded them from much of the influences of biases in decision-making, indicating that “If your process checks out, then most of these biases get caught”. Overall, both the concern and awareness of biases in project management decision-making was minimal.

4.3.3. Limiting the impact of biases on decision-making

The last subject of the interviews concerned the intervention used during the interviews against biases in decision-making and the prevention of biases in general. All of the participants emphasized the importance of identifying both complexity and uncertainty. It was, according to one, “the core of what project managers do”. Their approach was one of dealing with both factors head-on. This would lower the chances of these factors negatively affecting decision-making. They used methodologies for rationalisation and decision-making, employed the help of experts and committees and relied heavily on peer reviews to avoid making mistakes. A distinction could be made here between those who described themselves as managing the project and making decisions formally and explicitly (n = 5) and those who described themselves as more implicit (n = 3). The earlier relying more on process and form and the latter relying more heavily on the people, context, and peer reviews. The practice that was at the core of each of the interviewee’s decision-making was preparation. Specifically, to create a context in which biases are less likely and the role of uncertainty and complexity cannot go unnoticed. Their individual methods and reliance on explicit versus implicit more intuition focused methods differed on an individual basis with a majority of five being more inclined towards the former.

The interviewees were open to learn more about and do more against biases in project management decision-making, as most recognized some form of need to it. Creating awareness was, according to six of the participants, the most important part of the intervention against biased decision-making. One indicating that “I did not know that I could be fooled this way". Those who thought of themselves as more explicit and formal in their decision-making leaned more towards a further improvement of the decision-making process. None wanted to use or adopt the specific method of System Dynamics. Four of the participants indicated that they had their own method for this. Others (n = 2) sought to increase the awareness of biases in their decision-making in different ways. Some came up with their own interventions. One of the recommendations by a participant was to train project managers in decision-making under bad circumstances. Thus, when both uncertainty and complexity were present. A participant commented "When under stress, like in an airplane crash or in combat surgery, people rely on very basic [and standardized] principles to manage the situation. This allows them to focus on the problem instead." A constant awareness to circumstances that would compromise decision-making was not deemed possible. Such a standardisation could help those project managers engage in more thoughtful decision-making through rehearsed routines. Furthermore, almost all participants indicated to have no recall level knowledge of the biases they might be prone to in decision-making, which likely hindered the effectiveness of preventative measures. Lastly, multiple participants commented that for any measure to be effective it had to be rooted in existing practises and procedures as biases were not a focal enough threat by themselves. Overall, participants were enthusiastic about increasing the knowledge and awareness of biases in their decision-making. However, for it to be effective, it had to fit within their context.

4.4. Relating the results to the hypotheses

This section reflects on the hypotheses posed in chapter 2. In it, we briefly discuss whether there was evidence in support of each hypothesis from each of the studies. We do so by providing the reader with Table 5,

Table 6, and Table 7. The next chapter is reserved for a full discussion of the findings and for conclusions.

Table 5. An overview of the hypotheses, the findings and results from the first study (case studies).

Number	**Hypothesis**	**Answer**	**Comment**
H1.	Increasing the awareness of biases in decision-making among decision-makers and providing them with a method to rationalize decisions, will decrease the amount of biases in future decisions.	Limited support provided by the study.	Cases with formalized and rationalized decision-making processes generally had less biases in decision-making.
H2.	The levels of uncertainty and complexity affect the amount of biases in decision-making.	Supported by the study.	All underlying relations were supported.
H2.a.	Higher levels of complexity increase the occurrence of biases in decision-making.	Supported by the study.	When cases were increasingly complex, so did the likelihood of there being biased decision-making.
H2.b.	Higher levels of uncertainty increase the occurrence of biases in decision-making.	Supported by the study.	A lack of dealing with uncertainty was often indicated as the underlying cause for biased and erroneous decision-making.
H2.c.	Higher levels of uncertainty and complexity interact to create a stronger increase in the occurrence of biases in decision-making.	Supported by the study.	Where cases were both uncertain and complex, decision-making was most often viewed as erroneous and biases

			were most likely to be identified.
H3.	The level of uncertainty moderates the effect of the awareness of biases in decision-making and the methods for rationalization upon the occurrence of biases, so that a lower level of uncertainty will lead to less biases when combined with awareness and the method for rationalization.	Could not be verified	Outside of the scope of the study

Table 6. An overview of the hypotheses, the findings and results from the second study (the experiment).

Number	**Hypothesis**	**Answer**	**Comment**
H1.	Increasing the awareness of biases in decision-making among decision-makers and providing them with a method to rationalize decisions, will decrease the amount of biases in future decisions.	Supported by the study.	The study showed a positive effect on the decision-making of the participants by the intervention.
H2.	The levels of uncertainty and complexity affect the amount of biases in decision-making.	Not supported by the study.	No evidence was found in support of this hypothesis.
H2.a.	Higher levels of complexity increase the occurrence of biases in decision-making.	Not supported by the study.	No evidence was found in support of this hypothesis.
H2.b.	Higher levels of uncertainty increase the occurrence of biases in decision-making.	Not supported by the study.	No evidence was found in support of this hypothesis.
H2.c.	Higher levels of uncertainty and complexity interact to create a stronger increase in the occurrence of biases in decision-making.	Not supported by the study.	An opposite effect was found, whereby a high level of both uncertainty and complexity would lead to fewer biases.
H3.	The level of uncertainty moderates the effect of the awareness of biases in decision-making and the methods for rationalization upon the occurrence of biases, so that a lower level of uncertainty will lead to less biases when	Not supported by the study.	No evidence was found in support of this hypothesis.

	combined with awareness and the method for rationalization.

Table 7. An overview of the hypotheses, the findings and results from the third study (the interviews).

Number	Hypothesis	Answer	Comment
H1.	Increasing the awareness of biases in decision-making among decision-makers and providing them with a method to rationalize decisions, will decrease the number of biases in future decisions.	Limited support provided by the study.	Participants generally thought awareness of fallibility was positively associated with less biased decision-making, however, no objective measure could be provided, as it was not part of this study.
H2.	The levels of uncertainty and complexity affect the number of biases in decision-making.	Limited support provided by the study.	This was only the case for uncertainty and the combination with complexity.
H2.a.	Higher levels of complexity increase the occurrence of biases in decision-making.	Not supported by the study.	Participants indicated that higher amounts of complexity would generally not affect their decision-making ability.
H2.b.	Higher levels of uncertainty increase the occurrence of biases in decision-making.	Supported by the study.	Participants indicated that uncertainty could increase the likelihood of erroneous decision-making and biases.
H2.c.	Higher levels of uncertainty and complexity interact to create a stronger increase in the occurrence of biases in decision-making	Supported by the study.	Participants noted that a highly complex and uncertain scenario would likely mean that more biased decisions are made.

H3.	The level of uncertainty moderates the effect of the awareness of biases in decision-making and the methods for rationalization upon the occurrence of biases, so that a lower level of uncertainty will lead to fewer biases when combined with awareness and the method for rationalization.	Not supported by the study.	Participants did not indicate anything to support this hypothesis.

5. Discussion

The discussion features five subjects. Firstly, we discuss the meaning of the results and draw inferences. Secondly, use the results to answer the main research question and this paper’s central thesis. Thirdly, we discuss the limitations of the studies that were conducted. Fourthly, we offer recommendations for practitioners in the field of project management. Fifthly and finally, we offer recommendations for future research based on the studies reported upon in this paper and their limitations.

5.1. The findings

The three studies combined managed to provide evidence in support of a significant portion of the hypothesis and an answer to the main research question. This answer is discussed through three main inferences. Firstly, the studies examined whether the occurrence and impact of biases in project management could be identified and how big this impact was. Both the case study of the BIT evaluations and the experiment provided evidence in support of this notion. The case studies demonstrated that biased decision-making could be identified, and its impact traced given consistent definitions and criteria and detailed source material. A series of scenarios were built upon these findings and used in the experiment to observe the occurrence and impact of biased decision-making in a controlled experimental setting. Both studies revealed that biases are subtle, often present themselves as easy solutions or quick fixes and can have a serious impact. Many of the participants in the experiments therefore fell for them. An observation reflected in the BIT cases studied. The case studies also demonstrated that in some cases the impact was big enough to threaten whole organizations. An inference reflected in the potential results of how participants solved the scenarios during the experiment. During the interviews, a more complex picture arose. Experienced project managers were often not explicitly aware of the potential occurrence and impact of biases in their decision-making. Upon being prompted, project managers often did think biased decision-making could occur in their work and endanger their project and remembered instances in which it did. Their awareness and past negative experiences with biased decision-making were however limited.

Secondly, the studies were designed to examine the effect of characteristic of the project and context on the occurrence of biases. The case studies provided evidence that both uncertainty and complexity had a real impact on the occurrence of erroneous and biased decision-making. When uncertainty or complexity increased, decision-making often suffered in quality and in some cases resulted in harmful decisions being made. No evidence in support of this notion was uncovered during the experiment and only limited evidence was found as a result of the interviews. The experiment showed that in some cases an increase in complexity or uncertainty led to a decrease in the occurrence of biases. For example, when both complexity and uncertainty were high, a sharp decrease in the occurrence of biases occurred. This could be similar to an incongruency or disfluency effect (Motyka, Suri, Grewal, & Kohli, 2016) seen in marketing-related decision-making literature where a noticeable increase in difficulty of solving a decision led to the participant ‘waking up’ and becoming more aware of the situation. Participants would then engage in more elaborate, critical and deliberate information processing and rational decision-making (Faber, Mills, Kopp, & D’Mello, 2017). Moreover, this was supported by the finding that in the condition without an intervention, an increase in complexity led to a decrease in the occurrence of biases. Another potential explanation could be that the causality in the case studies was reversed. That it was not uncertainty and complexity that led to biased decision-making but that biased decision-making, thus taking a decision-making shortcut, led to unresolved uncertainty and complexity. More research is required on this subject and its intricacies.

Thirdly, an intervention was created based upon awareness of biases in decision-making and a method for rationalization. Its aim was to decrease the occurrence of biases and lower their impact. The case studies provided examples of increasingly complex projects, uncertain futures and potential future catastrophe for projects and organizations when decision-making became irrational and erroneous. A picture confirmed by the interviews, wherein a heavy emphasizes was placed by the participants upon creating an environment wherein decisions could always be made rationally, and errors easily identified. The intervention proved effective during the experiment at this and a significant decrease in the occurrence of biases was observed. No significant interaction effect was however found with the amount of uncertainty or complexity of the scenario. This indicates, together with the lack of direct effects of uncertainty and complexity on the occurrence of biases, that the relationship between the context and the occurrence of biases is more complex. This coincides with the observation that experienced project managers did not feel threatened by either uncertainty or complexity. The interviews did provide evidence in favour of the adoption of the intervention by professionals. Professionals already viewed rationalization methods, such as System Dynamics, favourably and emphasized their importance in their work. The adoption of System Dynamics as that framework was less likely, as many of the interviewees had their own existing method. While their method of decision-making often included elements of rationalization methods, their awareness of biases in their decision-making was lacking. The lack of awareness of biases might be explained by a more general unawareness of the different factors in decision-making. Faran and Wijnhoven (2012) describe a type of unawareness or blindness to information outside of the expected spectrum. A rational approach might normally incorporate this information but might be obstructed by existing beliefs and goals. The potential effectiveness of the intervention when adopted is underlined by the case studies, wherein a method for rationalization and awareness of biases could have increased the quality of decision-making processes and prevented negative outcomes.

5.2. Answering the central research question

The main research question had two major aspects, namely the identification and the limitation of the negative effects of biases in decision-making in ICT project management. Both the case study and experiments offer answers to the first aspect. Case studies can, in line with the study by Shore (2008), in many cases help identify biased or erroneous decision-making. It is however a complex exercise and the nuanced effects of biases might often go unnoticed. Exercises that involve realistic cases can be used to show the impact of different biases in a controlled setting. It can serve as a diagnostic tool of sorts. Moreover, and as was suggested during the interviews, those exercises can be used to determine an individual's personal sensitivity to specific biases. A study by Kaptein and Eckles (2012) on an individual's susceptibility to different heuristics and biases in persuasion might offer some support for this notion, as they found that individual susceptibility varied greatly from heuristic to heuristic. The second aspect of the main research question focuses on the prevention of negative effects resulting from biased decision-making. The experiments showed that this is indeed feasible. During the experiment, the main tools deployed to achieve this was an awareness of the biases that exist and the use of a rational decision-making method, which offered the participant handle to grasp when decision-making was complex or uncertain. This method filled a role not too dissimilar to that of a heuristic. It was similar mental schematics were used by the experienced project managers. The awareness of the existence of heuristics and biases amongst this group of project managers was however very limited, which offers an opportunity for improvement. Overall, the combination of awareness and a decision-making methodology seems to provide an effective and feasible measure against the negative effects of biased decision-making.

5.3. Limitations of the studies

This study employed a variety of methods, which helped produce findings in different contexts and transcend limitations of a single method. This approach also introduced limitations of itself in both the methodology and the analysis. Firstly, the case studies were based on evaluations written by other researchers. This meant that the study was limited to the scope of the evaluation. Secondly, the experiment used two cases. While they were pre-tested to ensure similarity, they were neither randomly shown nor were they truly interchangeable. Secondly, the outbreak of COVID-19 and the resulting measures taken by both the Dutch government and the university prevented the interventions and experiments to take place in person. This had two main consequences. First, the lack of interaction with the participants likely led to a less optimal learning experience, as the intervention was designed for a classroom setting. Second, the design of the experiment aimed to capture what was in essence both within and between-subject-effects. Due to ethical and technical constraints, the ability to identify participants' sessions across the two stages was sacrificed and the two stages were treated as two samples instead. Thus, all effects were treated as between-subject-effects. This could have led to some effects being underreported or missed entirely. Thirdly, the researcher could not monitor the participants during the experiment, which meant the study had to rely on specially created items to check whether participants took their participation seriously. Fourthly, the interviews were undertaken with IPMA certified project managers to ensure a level of experience and consistency. This however might have also led the sample to be skewed towards a set of project managers with the skillset, experience, and characteristics that IPMA deems important. It is no guarantee that the project managers that were used as a sample in the current study are representative for experienced project managers in general. Fifthly, the sample of projects used in the case study was entirely focused on the public- and semi-public sector, as that is where the ICT auditing agency of the Dutch government operates. While no evidence was found that they differ significantly, the sample could suffer in representativeness because of it.

5.4. Recommendations for practitioners

This study used three different methods to investigate the occurrence, impact and prevention of biased decision-making in project management. It aimed to provide a realistic perspective through the use of interviews with experts in addition to literature studies and lab experiments. Thus, we can provide three recommendations for practitioners are likely to be both beneficial and feasible. Firstly, practitioners in all layers of project management should become aware of the fallibility of their decision-making. The knowledge that one could become biased is often described as a good prevention strategy against bias in itself by the participants of the interviews. This notion is supported by the results of the experiment. It is also one of the most elementary and easy steps to take. Moreover, it is recommended that project managers study their own decision-making and ways biases can occur, to see where they might be vulnerable in their practises and habits. Second, while awareness and a good level of the organization seem to improve the quality of decision-making and reduce the occurrence of biases, it is not foolproof. The interviews revealed a remarkable habit of experienced project managers that tended to register and review their decision-making and ensured their decision-making was audited by colleagues. Whether this happened consciously or not. It is a habit that we recommend practitioners copy. When one views decision-making as a process, it can be evaluated and improved upon. Thirdly, we recommend that project managers practise and train their decision-making under the bad conditions that high levels of complexity and uncertainty were often described to be. This is similar to how pilots train for emergency situations in which their decisions or actions might become flawed due to the difficult environment, project managers could remove some of the risks.

5.5. Recommendations for future research

Based on this study, we propose six recommendations for future research. These recommendations can be divided into two main subjects, namely the subject of biases in project management decision-making and the methodology used and developed for this study. First, the study did find evidence in support of the occurrence of biases in project management decision-making and a likely vulnerability amongst seasoned project managers. The sample of heuristics and biases used was however limited. Extending this to include different sets of heuristics and biases could not only help generalize this study’s findings but potentially also demonstrate where it is not generalizable. One example of this comes from the area of study that explores the vulnerability to heuristic decision-making as a tool for persuasion. Kaptein and Eckles (2012) found evidence that individuals are vulnerable to different heuristics to different degrees. This could potentially apply to the project management context, where one project manager could prove vulnerable to certain biases and not to others. Second, the interviews provided evidence that experienced project managers are proactive in dealing with uncertainty and complexity. In this might lie a remedy against biased decision-making, but the exact nature of their methodologies was outside the scope of this study. We, therefore, recommend that future researcher’s study how different project managers deal with uncertainty and complexity and when their methodologies are effective. This could provide valuable insights that could aid om improving decision-making in project management similar to the studies of the past on successful habits of successful managers which were written down in a bestseller book by Covey (2013). Thirdly, while it was briefly touched upon in the interviews, the effect of the project management environment on decision-making was outside the scope of this study. To what degree a high level of organization and centralization or leadership styles affect the environment's ability to improve decision-making is grounds for future studies.

As for the methodology we firstly recommend that researchers explore the possibility of using the methods used for the experiment as a diagnostic tool. The interviews demonstrated that most project managers are somewhat equipped to mitigate or prevent biased decision-making, but that they are mostly unaware of this. This could lead to them having blind spots in their decision-making process of which they are not aware. Some project managers indeed expressed a keen interest in using the setup for the experiments as a diagnostic tool of sort for themselves. The method needs to be developed further to be effective in this capacity. It needs to be expanded upon to include a wider selection of heuristics and biases and a greater variation of cases. Moreover, it needs validation. Second, while the qualitative analysis of the interview provided valuable insights, their scope and number were limited. Extending this research to include different project management contexts, fields, regions in the world and a more diverse group of project managers, could provide additional insights into project management decision-making and its pitfalls. Thirdly, future studies could extend the available scientific literature by studying biased decision-making in ongoing projects. This provides two benefits. Firstly, the way in which biases can manifest in project management were limited by the case studies used and the researchers themselves. Creating a richer source of the way in which biases manifest could help understand and prevent them. Secondly, the use of pre-existing case studies meant that the researchers could not study the projects as they were happening and could not determine the contents of the case. Focussed investigations in ongoing projects have the benefit of being less affected by memory biases and the narratives that form after the fact and have the ability to fully explore biased decision-making.

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Appendixes

The appendixes each start on a new page and are numbered.

Appendix 1.

Descriptions of heuristics

Availability heuristic (Gigerenzer & Gaissmaier, 2011) is the relative weight given by human cognition to recent events or events that are easily retrievable. It is a bias resulting from the phenomenon that the ease of retrieval gives credibility to whatever is retrieved and results from the natural tendency of people to like fluency. For example, a project manager might want to list the risks he knows a project runs and will use his experience to list the most likely risks for a project based on his own experience. Risks from his last projects will more easily come to mind and as a result be more focal, considered more likely and more impactful (Shah & Oppenheimer, 2008).

One cue heuristic (Gigerenzer & Gaissmaier, 2011) is a category of heuristics that is most commonly associated with a gut feeling or intuition. In those cases, a single factor will become the dominant factor in the decision-making process. One might consider the use of "if-this-then-that-rules" as a form of a one cue heuristic. Animals and humans alike might use it to determine when something is attractive, safe or dangerous. An example of this can be found in seafaring. When a sailor sees a flock of birds, they might deduce that there must be land nearby.

Misinterpretation of risk (Kahneman, 2011) can be especially dangerous to project managers. In his book, Kahneman, describes two major examples of this bias. First, there is the overestimation of risk when the chance of it occurring is low, but the potential impact is large. The same can be argued for the exact opposite and is the basis for many lotteries' profitability. When a chance of winning a huge price is very low, people still believe to be the exception. Moreover, risk and the value of items are tied to possession. Something that can be lost is always worth more to the possessor and the risk of losing it is inflated.

Anchoring (Gilovich, Griffin, & Kahneman, 2002) is based on the instinct of humans to compare. This instinct can also be abused. Anchoring is something humans do to almost everything they see or hear, they compare it to something they know. However, there are patterns in there that can lead to biases. Biases due to anchoring can occur when someone presents a false choice set. For example, someone presents a project manager with a choice out of 3 options. Humans are inclined to analyse and decide based upon those three, not to look further. Moreover, they will always perceive the options in comparison to the others, leading to potentially skewed decision-making when certain options perform remarkable in certain categories.

Default choice heuristic (Gigerenzer & Gaissmaier, 2011) is the absence of choice itself. It is the tendency to do nothing against a choice that is pre-made. A project manager might, for example, be presented with a choice from the past and has to make a new decision based on this. This can be a choice for a particular project management method or an ICT architecture. Rather than doubting or redoing this decision, people are more likely to accept it as is and work further from it.

Appendix 2.

Case study analysis matrix

Reports	Factor that impacted project:				Detailed description							
Title	Background	Complex	Uncertainty	Risk perception wrong?	Decision-making errors?	Biases	Bias 1.	Bias 2.	Comment	Proper decision-making process	Effect of biases on decision-making	Effect of biases on project succes
Boba Fryslan	Public infrastructure	Yes	Yes	No	Yes	Yes	Default bias	Underestimation of own work	Biases oversimplify decision-making and project complexity, which leads to incomplete and unrealistic decisions	Not at all present. Decisions are made poorly and with little supporting evidence. Moreover, complexity and uncertainty are avoided and underestimated.	Too simplistic view of the project.	Potential failure.
TransVIR		Yes	No	No	Yes	Yes	Under estimation of risks	Misjudgement of risks: way too optimistic.	The process suffers from a consistently lacking ability to startegize and decide. Decisions often miss the requirements or point. A possible explanation is a political reality.	No, decisions do not fit context or requirements.	irrational decisions are made that affect the project.	Running out of time and budget
Transitie Werk.nl	Employment	Yes	Yes	No	Yes	No			Not enough awareness of current situation in many decision-making processes. Biases could no be identified	No, decisions are made that avoid uncertainty and complexity	-	
Doelarchitectuur Inning	Tax office	Yes	Yes	Yes	Yes	Yes	Default bias/authority heuristic	Underestimation of own work	Heuristic models are applied so rigidly that they demonstrably lead to biases when deciding to replace an application. Work is struturally underestimated and decisions are presented as false dichtomoties.	Decision-making process is incomplete, biased and inconsistent. Furthermore, complexity is severely underestimated or even increased as a result of this process. Complexity is thus severely mismanagemed and led to an increase in ucertainty. Lastly, neither uncertainty nor complexity are actively	Increase in project scope without reason and unnesecary increases in complexity	Likely failure of the project and dependent projects, severe overruns in others and a threath to the core capabilities of the
Verniewuing JDS	Judicial system	Yes	Yes	Yes	Yes	Yes	Under estimation of own work.	Anchoring/default bias	Heuristics and biases are hard to properly define in this project. Decision-making quality is low and there are signs that decision-making was skipped. The reason is however not shown clearly in the report.	No, decision-making is done poorly and unstrtucted. The project increases compelxity and uncertainty and reduces the organization's operational ability.	Hard to define.	The bad decision-making likely leads to project failure.
Lerarenregister en voorportaal	Education	Yes	Yes	Yes	Yes	No	Under estimation of risks.		No clear biases could be identified from the tekst other than a clearly too optimistic view regarding risks.	No, decision-making was incomplete before the project started, missed important considerations regarding complexity and uncertainty and was driven by political motives in many cases.	-	Decision-making leads to an overly complex and impractical solution that will likely not feature all the required functionalities and not be

Bevolgkingsregister	Administrative	Yes	Yes	Yes	Yes	Yes	Default bias		-	Decision-making is of a poor quality. It misses important aspects, does not push the project towards its intended end and functionality and is poorly aware of risks, progress and future needs. The decision-making seems rushed and detached from reality, which the investigators note. Uncertainty and complexity are	Decisions are made too hastily and incompletely	Likely fai deliver a working complete project. Available and fund insufficie
GRIT	Defence	No	Yes	Yes	Yes	Yes	Sunk cost fallacy	Underestimation of risks	Financial risks are underestimated, complexity and uncertainty are not managed and decisions are postponed due to sunk cost fallacy.	Decison-making is not properly done, often incomplete and with too much uncertainty that is not actively confronted.	Incomplete and irrational decision-making	Potential failure of project a future disruptio organiza operation ability.
ICAS II	Civil aviation	Yes	No	Yes	Yes	Yes	Underestimation of own work.	Underestimation of risks	Work complexity, uncertainty and load is completely underestimated. Moreover, risks are not tackeled and underestimated.	Decision-making is often irrational and subjective. The programme follows a good structure, but derails its decision-making through the use of subjective criteria and an inability to actively mange the risks and uncertainty.	Too simplistic view of the project and an absense of risk management.	Project li not succeed
Kern Gezond	Business/finance	Yes	Yes	Yes	Yes	Yes	Default bias	Underestimation of own work	Biases are tough to identify clearly. There are however signs that decision-making was both irrational and biasedd.	Not at all. Decision-making is not proactively done and when done lacks proper scope and objective information.	Incomplete decision-making	Likely pro failure.
PGB 2.0	Welfare	Yes	No	Yes	Yes	No			Bias cannot be clearly identified.	Decision-making process lacked awareness of own capabilities and the risks the project faced. Moreover, the decision-making process was often incomplete.	-	Failure o project li
Centralisatie luchteverkeersleiding	Civil aviation	No	Yes	No	Yes	No			No biases could be identified	Decision-making was incomplete to a degree that there were whole decisions that were not made. Likely source seems to be an incomplete view of the project and an inability to tackle complexity, leading to uncertainty.	-	Project fa is likely c project g over time over bud

Praeventis	Healthcare	No	No	No	Yes	Yes	Anchoring		Results of current system are anchored to false projections and incomplete views of situations	The decision-making process works on unrealistic assumptions, wrong priorities and an alltogether incomplete view. The likely cause for this is an absense of knowledge on ICT projects and bad leadsership.	Unrealistic view of current project state	Likely pr failure.
Gemeenschappelijke centrale meldkamer	Security	Yes	Yes	Yea	Yes	Yes	Underestimation of risks.		Underestimation of risks related to supplier.	The decision-making processes were incomplete and created both uncertainty and complexity where none was needed. Moreover, risks that were present were ignored. Decision-making authority lay with a person far removed from the project and the overall organization made decision-making slow	Lack of risk management	Likely pa project fa
Phoenix	Administrative	Yes	Yes	Yes	Yes	No	Authority bias	Underestimation of risks	Biases were hard to identify. There was strong trust in authority that was unproven.	Decision-making was often incomplete and based on subjective or incomplete information. Moreover, in some cases a proper decision-making process lacked alltogether. The process likely suffered from other deficiences caused by biases, but these could not be identified.	Simplistic view of the project	Likely ov in time a budget.

Appendix 3.

Cases used during the experiment

Note: Below we show the two most extreme opposite conditions out of four per case.

Case #1. – Condition low complexity and low uncertainty

Imagine,
You are a project manager. You are hired by a firm that wants to implement a new ERP system. Your task is to get this ERP system implemented on time, within budget and with the right functionality for the end users. The project has a few phases. In each phase there is a crucial decision for you to be made.

The project team has already summarized the requirements for the project, they should guide your every decision and are as follows:

- Work processes can never increase in complexity or manual (human) actions.
- The ERP system will need to have at least a 99% uptime and a redundant (failure protected) data storage.
- Your implementation project should last no longer than 18 months and cost no more than 7.8 million Euros. The two main phases consist of developing a good version of the ERP system and the actual deployment and final implementation.
  - About 4 million Euros out of the 7.8 million Euro budget is allocated for the development of the ERP system itself (not every part is ready for deployment off the shelf).
  - You should expect to need about 4 to 6 months for the actual deployment and final implementation.
- System maintenance costs will need to decrease after taking the new ERP system in use.
- Data security will need to match the ISO 27001 standard at the minimum.

In this project you are working with a number of parties, they are:

- Executive management, to whom you report, and which supply you with the manpower and budget.
- The 8 different suppliers that work on getting various parts of the ERP system ready for use in your firm.
- Various groups of key users and end users.

Your project team did a risk assessment and found the following risks, likelihoods and impacts:

- Risk of stress and burnout related complaints amongst employees (10%, max. impact 80.000 Euros)
- Damages due to extra work resulting from data conversion problems and system failure (20%, max. impact 20.000 Euros).
- Claims from consumers due to data loss (5%, max impact 100.000 Euros).
- No significant problems

Please keep this text open in a seperate tab or window by clicking the following link:
Open case>>>

Case #1. – Condition high complexity and high uncertainty

Imagine,
You are a project manager. You are hired by a firm that wants to implement a new ERP system. Your task is to get this ERP system implemented on time, within budget and with the right functionality for the end users. The project has a few phases. In each phase there is a crucial decision for you to be made.

The project team has already summarized the requirements for the project, they should guide your every decision and are as follows:

- Work processes can never increase in complexity or manual (human) actions.
- The ERP system will need to have at least a 99% uptime and a redundant (failure protected) data storage.
- Your implementation project should last no longer than 18 months and cost no more than 7.8 million Euros. The two main phases consist of developing a good version of the ERP system and the actual deployment and final implementation.
    - About 4 million Euros out of the 7.8 million Euro budget is allocated for the development of the ERP system itself (not every part is ready for deployment off the shelf).
    - You should expect to need about 4 to 6 months for the actual deployment and final implementation.
    - A contol phase that does not count towards your project running time is added after deployment. This phase takes roughly 2 months.
- System maintenance costs will need to decrease after taking the new ERP system in use.
- Data security will need to match the ISO 27001 standard at the minimum.
- Exective management will want to be updated regularly.
- Your bonus is reduced for every month that the projects runs after the twentieth month.
- Insurance fees may never exceed 334.215 Euros.
- Your implementation time for the whole project, including control phase, should not exceed 21 months.

In this project you are working with a number of parties, they are:

- Executive management, to whom you report, and which supply you with the manpower and budget.
- The 8 different suppliers that work on getting various parts of the ERP system ready for use in your firm.
- Various groups of key users and end users.
- Regulators and the firm's lawyers that check whether the implementation meets compliance standards.
- Department managers that assign which users are key users.
- The communication department that takes care of internal communication
- A data transition officer

Your project team did a risk assessment and found the following risks, likelihoods and impacts:

- Risk of stress and burnout related complaints amongst employees (10%, max. impact 80.000 - 140.000 Euros)
- Damages due to extra work resulting from data conversion problems and system failure (15 - 25%, max. impact 20.000 - 25.000 Euros).
- Missing functionalities resulting from wrong problem analysis (10%, max. impact 12.000 Euros)
- Claims from consumers due to data loss (2 - 8%, max impact 100.000 Euros).
- Sick leave in your project or development team (5 - 45%, max. impact 6.500 Euros).
- Changes to use policies and product conditions of the ERP system (1 - 3%, max. impact 65.000)
- No significant problems

Please keep this text open in a seperate tab or window by clicking the following link:
Open case>>>

Case #2. – Condition low complexity and low uncertainty

Now imagine,
You are a project manager and you are hired by a firm to oversee the creation and launch of a new customer platform. The firm is a fairly large contractor that focuses on repairs and renovations in the Netherlands. It has both its own pool of employees and utilizes relationships with a wide range of local subcontractors to extend its capabilities and capacity. The platform enables the firm to connect its available workforce, expertise and capacity at subcontractors with customers throughout the Netherlands. There is currently a version of the platform running that will be replaced by the version that you are building and deploying.

During the project you have your own project team consisting of experienced professionals with a wide range of expertise. They have prepared a session for you in which they talk you through the project. During this introduction session they explain you the following:

- The project will follow the standard structure of planning and preparation, execution, delivery and control.
- The end product consists of both hardware and software.

The core capability of the platform is to produce offers that are both feasible for the firm and of sufficient quality to the customers. As a basis for the current project are three ambitions set out by the executive management:

- Reduce the amount of manual checks and corrections;
- Increase reliability, feasibility and quality of the offers;
- Be able to process a greater number of different projects (increase flexibility).

Furthermore, your team has compiled a list of requirements and constraints for the project set out by the executive management and department heads:

- The project should last no longer than 6 months and cost no more than 1.3 million Euros.
- Both the end users (consumers) and internal users (back-office personnel) should rate the new application higher on every separate aspect, including on the interface, usability and user satisfaction. On delivery, the final product should be tested by internal and end users.
- The platform will have to be very reliable. A guaranteed uptime of at least 99,98% is required by the subcontractors.
- Complexity of the tool for the end users and internal users should decrease while the flexibility is increased (see ambition #3).
- Additional investments outside of the scope of the project, but which are necessary for the project's success, are allowed up to 10% of the project's total budget. Furthermore, efforts to protect the firm from risk should be treated like investments when balancing risk and impact.

Your project team did a standard risk assessment for this project and found the following:

- Damages resulting from currency exchange rate fluctuations (25% at 12.250 Euro impact).
- Issues with customs and resulting damages (10% at 55.000 Euro)
- Legal issues resulting from supplier or end user conflicts (1% at 430.000 Euro impact).
- Supplier failure due to bankruptcy (10% at 52.000 Euro impact).
- Supplier performance failure like delays (2% at 100.000 Euro impact)
- External (digital) security threats (5% at 90.000 Euro impact).

Please keep this text open in a seperate tab or window by clicking the following link:

Case #2. – Condition high complexity and high uncertainty

Now imagine,
You are a project manager and you are hired by a firm to oversee the creation and launch of a new customer platform. The firm is a fairly large contractor that focuses on repairs and renovations in the Netherlands. It has both its own pool of employees and utilizes relationships with a wide range of local subcontractors to extend its capabilities and capacity. The platform enables the firm to connect its available workforce, expertise and capacity at subcontractors with customers throughout the Netherlands. There is currently a version of the platform running that will be replaced by the version that you are building and deploying.

During the project you have your own project team consisting of experienced professionals with a wide range of expertise. They have prepared a session for you in which they talk you through the project. During this introduction session they explain you the following:

- The project will follow the standard structure of planning and preparation, execution, delivery and control.
- The end product consists of both hardware and software.

The core capability of the platform is to produce offers that are both feasible for the firm and of sufficient quality to the customers. As a basis for the current project are three ambitions set out by the executive management:

- Reduce the amount of manual checks and corrections;
- Increase reliability, feasibility and quality of the offers;
- Be able to process a greater number of different projects (increase flexibility);
- Increase user satisfaction with the tool;
- Lower or equal maintenance costs;
- Creat durable competitive advantage.

Furthermore, your team has compiled a list of requirements and constraints for the project set out by the executive management and department heads:

- The project should last no longer than 6 months and cost no more than 1.3 million Euros.
- Both the end users (consumers) and internal users (back-office personnel) should rate the new application higher on every separate aspect, including on the interface, usability and user satisfaction. On delivery, the final product should be tested by internal and end users.
- The project should use suppliers that are rated in line with the internal procedure and paid according to the internal standards.
- The platform will have to be very reliable. A guaranteed uptime of at least 99,98% is required by the subcontractors.
- Complexity of the tool for the end users and internal users should decrease while the flexibility is increased (see ambition #3).
- Additional investments outside of the scope of the project, but which are necessary for the project's success, are allowed up to 10% of the project's total budget. Furthermore, efforts to protect the firm from risk should be treated like investments when balancing risk and impact.
- Developing overlapping functionalities is discouraged by the senior and executive management.
- The executive management will need to be made aware of any substantial changes to the plans and be updated regularly on progress.

Your project team did a standard risk assessment for this project and found the following:

- Damages resulting from currency exchange rate fluctuations (20% - 30% at 12.350 Euro impact).
- Damages resulting from data loss (11% at 33.150 to 42.200 Euros impact).
- Issues with customs and resulting damages (5% - 15% at 55.000 Euro impact)
- Legal issues resulting from supplier or end user conflicts (1% at 430.000 Euro impact).
- Software failures due to licensing issues (5% at 20.000 Euro impact).
- Delays and extra work due to sick or injured personnel (10% at 15.000 Euro impact).
- Supplier failure due to bankruptcy (7% - 15% at 52.000 Euro impact).
- Supplier performance failure like delays (1% - 3% at 100.000 Euro impact).
- Failure to meet data security regulatory standards and resulting claims (3% at 600.000 impact).
- Damages from malfunctioning equipment or software during the first 2 years (2% at 200.000 Euro impact).
- External (digital) security threats (2% at 80.000 to 100.000 Euro impact).

Appendix 4.

Matrix for analysis of the interviews

	Experiences projects affected by:				Deals with it through:			Intervention is:			
Interview number	Complexity	Uncertainty	Biases	Comment	Awarenesss	Strutucal thinking	Comment2	Feasible	Practical	Effective	Comment3
1	Yes	Yes	Yes	Awareness of biases in decision-making was limited. Thinks implciit decisions are threatened by biases. Battles all three through creating and maintaining a good context for decision-making	Yes	Yes	He tries to structure everything. He thinks no standard solution exists and uses peer review and a friendly context to acqurie critical insights.	N/A	N/A	Yes	Uses a variety the most impo aspects of the intervention f work.
2	Yes	Yes	Yes	Complexity and uncertainty are often two sides of the same coin or causal.	Yes	Yes	Generally tries to structure his decision-making. Is no neccesarily writing everything don. Confronts uncertainty and complexity.	Yes	Yes	Yes	Thinks a standarized approach and training PM-s effective unde circumstances airline pilots i beneficial. Moreover, ap many of the intervention's aspects himse
3	Yes	Yes	Yes	Tries to keep an overview of all the work, to expand his view and remove many of the pressures from uncertainty and complexity. Thinks many parts of decision-making occurs unconciously and thus is subject to bias.	Yes	Yes	Focuses on managing the context and the environment to create a structure in which success is likely. Heavily relies on scenarios, reflection and peer review.	Yes	Yes	Yes	Training professionals important par improving dec making. Recognition h avoiding traps mistakes.
4	Yes	Yes	Yes	Mainly assumptions are a major cause of misstakes and unforeseen circumstances. Complexity and ucnertainty are to be actively tackled.	Yes	Yes	Creating structures and relying on others in ways that promote rational decision-making. Moreover, heavily relies on learning and improving on past mistakes	Yes	N/A	Yes	Thinks trainin others and by others is likel most importa succesful app

5	Yes	Yes	No	Feels like they decide by intution quite often, however thinks his intuition is well developed. Attacks uncertainty and complexity head on. Has developed methods to deal with them on an emperical basis.	N/A	Yes	Has methods to deal with uncertainty and complexity that involve stuructured thinking and consultation with colleagues.	N/A	N/A	Yes	Training coulc serve as an important par improving dec making.
6	Yes	Yes	Yes	Biases in decision-making are a threat. Complexity and uncertainty heavily impact decision-making	Yes	Yes	Deals with it by taking both factors in account and making them part of the decision-making process. Moreover, intends to change context.	N/A	N/A	N/A	Thinks trainin sharing ideas this subject co help.
7	Yes	Yes	Not really	Complexity adds to the demands of decision-making and often requires more effort and time. Uncertainty is a constant in PM and is managed by managing stakeholders consistently and continously. Was not realy convinced of the occurence and impact of biases when maangement is done	Yes	Yes	Tries to formalize and rationalize his decision-making as a method against errors. Wants to remain in an overview/distant view perspective. Moreover, confronts factors that can cause errors.	Yes	Yes	YEs	Thinks assesm of personal subsceptibilit biases is incre useful. Creatin awareness is l this case.
8	Yes	Yes	N/A	Is more intuitive in his decision-making and uses reflection and hindsight to improve his intuition. Complexity and uncertainty are an inherent part of PM decision-making.	N/A	Yes	Relies heavily on processes to keep decision-making rational and allows them to fall back in case of pressure. Manages the people around them to maintain proper process and diversity in input	Moderately	No	Yes	Can help peop reflect on the decision-maki Should be par standard train programme to practical.

Appendix 6.

Full results of the ANOVA

Between-Subjects Factors

		N
Intervention	1.00	108
	2.00	76
Uncertainty	1.00	95
	2.00	89
Complexity	1.00	93
	2.00	91

Descriptive Statistics

Dependent Variable: Decision-making score

Part number	Uncertainty	Complexity	Mean	Std. Deviation	N
1.00	1.00	1.00	4.6429	1.47106	28
		2.00	5.2069	1.23576	29
		Total	4.9298	1.37399	57
	2.00	1.00	5.0800	1.52534	25
		2.00	4.2308	1.36551	26
		Total	4.6471	1.49430	51
	Total	1.00	4.8491	1.49867	53
		2.00	4.7455	1.37731	55

		Total	4.7963	1.43233	108
2.00	1.00	1.00	2.8333	1.61791	18
		2.00	3.7000	1.75019	20
		Total	3.2895	1.72279	38
	2.00	1.00	3.3636	1.70561	22
		2.00	3.8750	1.14746	16
		Total	3.5789	1.50012	38
	Total	1.00	3.1250	1.66699	40
		2.00	3.7778	1.49497	36
		Total	3.4342	1.61109	76
Total	1.00	1.00	3.9348	1.75629	46
		2.00	4.5918	1.63195	49
		Total	4.2737	1.71627	95
	2.00	1.00	4.2766	1.81422	47
		2.00	4.0952	1.28423	42
		Total	4.1910	1.58025	89
	Total	1.00	4.1075	1.78437	93
		2.00	4.3626	1.49456	91
		Total	4.2337	1.64790	184

Levene's Test of Equality of Error Variances[a]

Dependent Variable: Decision-making score

F	df1	df2	Sig.
.910	7	176	.500

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept + Intervention + Uncertainty + Complexity + Intervention * Uncertainty + Intervention * Complexity + Uncertainty * Complexity + Intervention * Uncertainty * Complexity

Test of Between-Subjects-Effects

Variable	Type III Sum of Squares	Degrees of Freedom	Mean Square	F-score	P-value	Effect size in η2
Corrected Model	109.768[a]	7	15.681	7.128	.000	.221
Intercept	2994.596	1	2994.596	1361.238	.000	.886
Intervention	80.174	1	80.174	36.444	.000	.172
Level of Uncertainty	.076	1	.076	.035	.852	.000
Level of Complexity	3.298	1	3.298	1.499	.222	.008
Intervention * Uncertainty	4.275	1	4.275	1.943	.165	.011
Intervention * Complexity	7.638	1	7.638	3.472	.064	.019
Uncertainty * Complexity	8.636	1	8.636	3.926	.049	.022
Intervention * Uncertainty * Complexity	3.091	1	3.091	1.405	.238	.008
Error	387.183	176	2.200			
Total	3795.000	184				
Corrected Total	496.951	183				

Appendix 7.

The list of questions and subjects for the interviews

Intro

- Introduction of interviewer and interviewee
- Brief description of the research goals and context and the previous studies
- State the end goal and role of the interviews in the process as a whole
- State expectations:
    - Need for introspection/reflection
    - Their own experiences and inferences are key
    - Focus on adding value to the existing literature through connection with practise and experience.

Their decision-making

- Describe their role in decision-making as a professional
- How do they normally make decisions in the project context?
- What type of decisions do they make?
- Describe their decision-making process?
- What are some key points within it?
- Which factors affect it?
- Which factors contribute to success?
- Which factors contribute to failure?
- How did you arrive at this decision-making process?
- How did it change over the years?
- What kind of experiences contributed to it?

The research model

- Can you describe complexity in your work?
- What role does it have?
- How do you deal with it?
- And uncertainty, can you describe that?
- How does that impact your work?
- How do you deal with it?
- How do these factors affect the overall project and the people working in it?
- -- Introduce heuristics and biased decision-making –
- Do you recognize the definitions employed here?
- How big is the impact of these heuristics and biases on your project management?

The intervention

- Would you say the intervention would be effective in your professional life?
    - When would it be effective?
    - When not?
    - For whom would it be effective?
- Would you adopt the practises incorporated in the intervention?

    - Why?/Why not?
    - What would you adopt and what not?
    - When would you adopt them?
- Do you recognize the intervention in your current practises?
- What would you adapt or improve in this intervention?