Learning from our projects

Evaluating and Improving Risk Management of the Flood Protection Program (HWBP)

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Learning from our projects

Evaluating and Improving Risk Management of the Flood Protection Program (HWBP)

Erfan HOSEINI

Learning from our projects

Evaluating and Improving Risk Management of the Flood Protection Program (HWBP)

Proefschrift

ter verkrijging van de graad van doctor aan de Technische

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voorzitter van het College voor Promoties,

in het openbaar te verdedigen op

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To the loves of my life

Fatima and Mandana

Summary

The Netherlands has a long history of protecting against flooding and high water levels. Due to the climate change and the sea level rise, the next flood could have a high impact on this small country. Hoogwaterbeschermingsprogramma (HWBP), the current largest flood defence program in the Netherlands, makes sure that all the flood defence facilities (dike, pomp, dune) in the Netherlands comply with the safety norms. HWBP has two objectives:

1. Increasing the pace of improving the flood defence facilities to 50 km per year.
2. Reducing the average costs of the flood defence improvement to 7 million euro per kilometre.

To reach these objectives, special attention should be given to the management of risks in HWBP projects.

Current risk management literature mentions that risk management contributes to project success. Despite the benefits of risk management, projects still lack a proper application of risk management. This highlights the importance of improving risk management application, not just in the case of HWBP, but also generally.

HWBP is a running program without any defined end date. The older program, HWBP-2, is almost finished. The focus of this dissertation is, for a great deal, on HWBP-2 projects. The objective of this research is to improve the risk management practices in HWBP. Evaluating risk management practices, and the processes for estimating the project costs and cost contingency in HWBP-2 can provide Program Directorate of HWBP (PD-HWBP), waterboards and individuals involved in the realization of the flood defence projects insight about the current situation and possible improvements. The lessons learned in risk management of HWBP-2 projects can be collected and used in HWBP projects. To summarize, the research objective is:

To improve risk management application in HWBP projects by identifying the areas of improvement and providing an overview of the common risks and the percentages of cost contingency in the projects.

The main research question is:

What are the lessons learned of applying risk management in HWBP-2 projects and how can these lessons be used to improve the risk management application in HWBP projects?

The research is performed in four phases. Before starting phase I, Chapter 1 and Chapter 2 discuss the importance of this doctoral research and the role of risk management in the success of the projects.

In chapter 1, background information about HWBP and HWBP-2 is given and the research questions and the research approach are defined. In chapter 2, the impact of risk management on project success is investigated by performing a literature survey. The available literature confirms the link between risk management and project success: even a moderate risk management application had positive effects on the project outcomes.

Phase I is about measuring risk management maturity of the projects. Phase I of the research contains two chapters: Chapter 3 and Chapter 4. In Chapter 3, the concept of Risk Maturity Models (RMMs) as a tool to improve risk management application is discussed. To address the deficiencies in the other risk maturity models, a generic Risk Maturity Model (called RiskProve) is developed and validated to help improving risk management in construction projects. RiskProve uses a list of statements extracted from risk management literature using Qualitative Content Analysis (QCA). These statements are divided into two main categories (as shown in Figure I): 'Organizational' and 'Application and Process'. The Organizational category contains four aspects: 'Policy and Strategy', 'Top-management Commitment', 'Culture and Personnel Knowledge'. The category 'Application and Process' contains the aspects: 'Risk Assessment', 'Risk Treatment and Mitigation', and 'Monitor and Review'. The statements and the model are validated employing two focus group sessions. The experts agree with the aspects and statements in RiskProve and evaluate it as an easy to use tool that provides projects a clear picture of potential improvements regarding risk management.

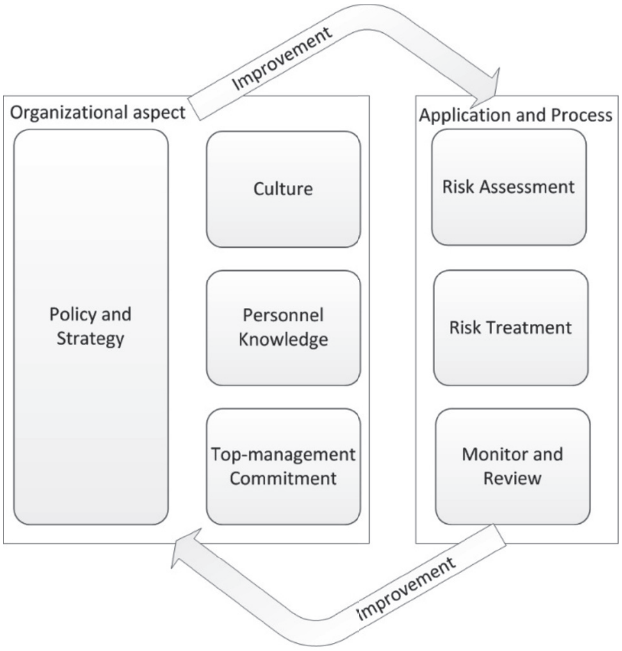


Figure I The RiskProve framework

In Chapter 4, RiskProve has been applied in 16 projects of two public organizations. The objective was to help the projects improve their risk management practices. The aspects Risk Assessment has received the highest and Top-management Commitment the lowest risk management maturity scores. Both organizations see possibilities to improve in defining the objective of risk management, defining the risk appetite, and evaluating and collecting the lessons learned. Based on the results, recommendations are drawn for improving risk management application that are further validated in Chapter 8.

Phase II of the research investigates the identified and occurred risks in projects (Chapter 5). Learning from risks in previous projects could be a way to improve risk management, therefore, the identified and occurred risks in 16 HWBP-2 projects from several waterboards are examined. Using a case study approach, the identified risks are collected from the risk registers during the whole project lifecycle (Exploration phase, Plan Development phase, Tender & Award, and Execution phase). Occurred risks in these projects are collected by means of interviews with the project manager or the project controller of the projects. In total, 2157 risks were collected. The risks were divided into the seven categories of the RISMAN method: Organizational, Political, Financial, Zoning, Technical, Legal, and Social. The results revealed that more risks were identified in the preparation phases (Exploration, Plan Development, and Tender & Award) than in the execution phase. In total, about 13% of identified risks have occurred, mostly in the execution phase. Most identified and occurred risks are related to the Organizational and Zoning categories. This information can help future similar projects better manage their risks by getting insight into the most common type of risks, the phase in which most risks are identified and have occurred and the risks that are identified and have never occurred.

In phase III (Chapter 6 and Chapter 7), the cost and cost contingency (risk reservation) of HWBP-2 projects were investigated. Chapter 6 investigates the cost and cost contingency evolvement of the projects in the pre-construction phase of HWBP-2 projects. Applying a case study approach, the estimated total project costs in the pre-construction phases (Exploration, Plan Development and Tender & Award) of 29 HWBP-2 projects were investigated. On average, the cost estimates increased 11.51% compared to the initial estimates. According to literature, this increase can be due to 'technical' reasons, 'political' reasons, 'strategic misrepresentation', and 'optimism bias'. The outcome of the research was that the increase in the cost estimates of the flood defence projects can be explained by 'technical' reasons rather than 'optimism bias' or 'strategic misrepresentation'. When the examined projects started, they were relatively new for the responsible waterboards and they had limited experience with the cost estimation of this type of projects. Mistakes caused by a lack of historical data or lack of experience were unavoidable. The investigation of 'known unknown' and 'unknown unknown' contingencies of these projects shows that the percentage of 'unknown unknown' contingency has increased throughout the pre-construction phase while a reduction was expected. This increase suggests that the projects were not confident about their estimates and the increase can be explained by a lack of experience, organizations' culture or the phenomenon of 'pessimistic bias'. 'Pessimism bias' is when the estimator is conservative and underestimates the opportunities. The concept of 'pessimism bias' comes in contrast with 'optimism bias' as explained by Bent Flyvbjerg.

In chapter 7, the cost and cost contingency performance of projects in the execution phase from the perspectives of client and contractor were studied. The projects of the contractor were also studied since the contractor is also involved in the execution phase. Similar to Chapter 5 and Chapter 6, this chapter benefits from a case study approach.

In total 95 projects are investigated: 44 client projects (HWBP-2) and 51 contractor projects. The research investigated the realized costs (after project execution) and the estimated costs (before project execution). Comparing the total realized and estimated costs, the HWBP-2 projects faced about 16% cost underrun meaning that estimated costs were more than what actually was needed. In the 51 contractor projects, overruns up to 2% were faced. In the HWBP-2 projects, the estimated cost contingency was on average 2.64% more than the required cost contingency while the estimated cost contingency in the contractor's projects was on average 5.41% less than the required cost contingency. In general, it seems that the contractor was more optimistic in the estimates and has overestimated the opportunities while the client was more pessimistic with a tendency for overestimating the costs and underestimating the opportunities. These differences can be explained by 'pessimism bias' and 'technical' reasons at the client's side. At the contractor side, 'optimism bias', 'technical' and 'political' reasons play a role.

Phase IV of the research (Chapter 8) presents the validation of the recommendations for improving risk management in HWBP projects. Based on the results of the previous chapters, a list of 20 recommendations is drawn. The importance and feasibility of these recommendations are tested by three expert sessions: one session with project controllers from the waterboards, one session with experts from the PD-HWBP who are involved in risk management, and one session with experts who have strategic and directorate roles in HWBP. It was observed that the experts from the waterboards and the PD-HWBP see opportunities for improving risk management. A Risk Management Map (RM-Map) is defined with five milestones including the role and responsibility of the PD-HWBP and the waterboards. (Figure I).

The way to improve risk management should be followed by both the PD-HWBP and the waterboards, while each party has its own responsibilities. The RM-Map contains five milestones:

1. Defining the strategy of RM by the PD-HWBP and the waterboards
2. Creating the conditions to apply recommendations
3. Translating the defined strategy to objectives at waterboards and showing commitment
4. Improving the RM application in projects
5. Support, facilitate, and share the knowledge

From these five milestones, milestones one and two are the responsibility of both the waterboards and the PD-HWBP, milestones three and four are the responsibility of the waterboards, and milestone five is the responsibility of the PD-HWBP. The infinity form of the RM-Map emphasises the continuous process of evaluating and improving. Without a defined strategy for risk management (milestone 1), reaching the other milestones would be difficult.

This study resulted in an answer to the main research question:

What are the lessons learned of applying risk management in HWBP-2 projects and how can these lessons be used to improve the risk management application in HWBP projects?

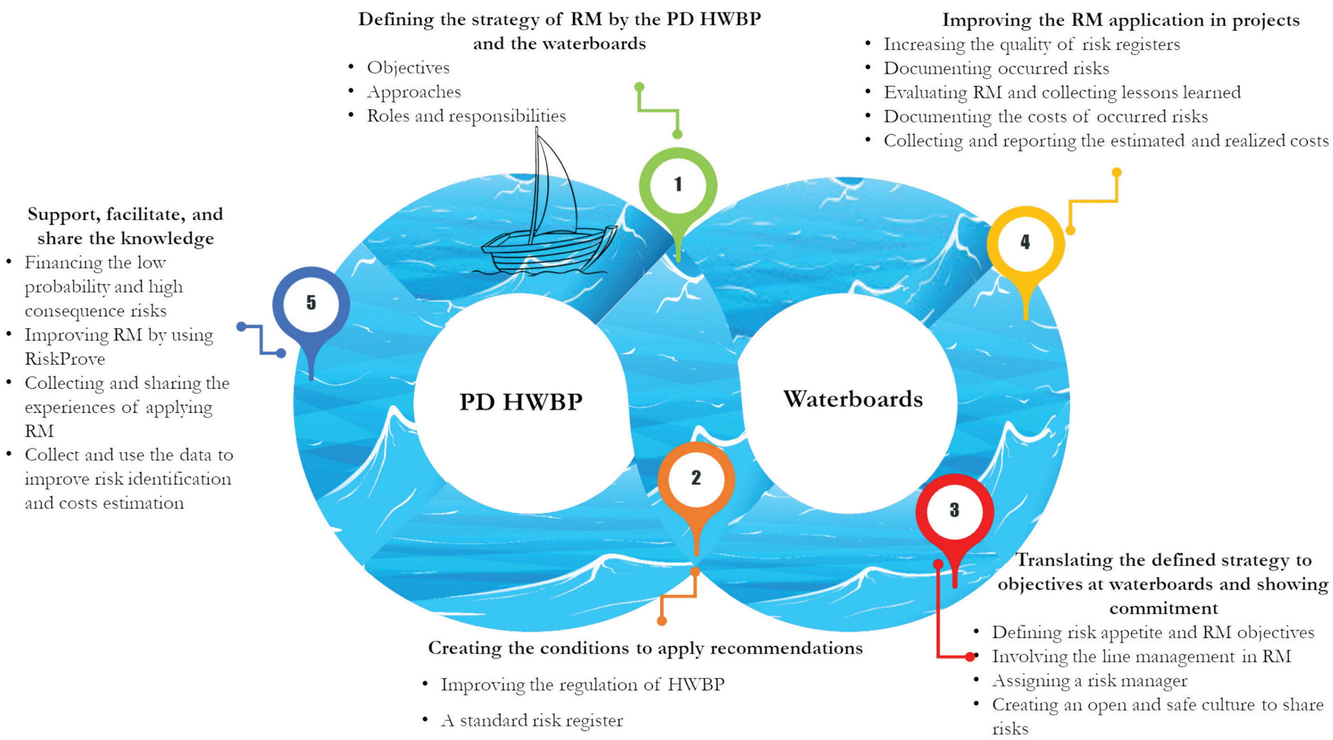


Figure II The RM-Map to improve risk management practices in HWBP projects

Different lessons can be learned from the risk management application in HWBP-2 projects. Regarding the risk management maturity of the projects, it is concluded that the projects are more mature in risk assessment while risk treatment and review of projects still needs attention. Project teams must realize that 'managing risks' is about taking actions. Project members should give special attention to applying the control measures and evaluating the usefulness of them. Giving more attention to these steps and especially reviewing and collecting the lessons learned of the projects can improve the risk management application in HWBP projects. This information can be used in future projects. Periodic measurement of risk management maturity using RiskProve can check whether the HWBP projects are on the right path.

Regarding the identified and occurred risks (Chapter 5), several lessons can be learned from the HWBP-2 projects. Firstly, most identified and occurred risks are related to the categories Organizational and Zoning. These two risk categories should receive extra attention in HWBP projects. An important lesson learned is that the projects should better document the occurred risks. The costs related to the occurred risks should be recorded as well. The database of risks made in this research can be used in the HWBP projects to check the completeness of their risk registers. A generic risk register containing the possible risks in each phase of HWBP projects can be drawn up. Practitioners can also learn from the control measures taken in other projects. Future projects could base their work on this generic risk register, carefully considering the specific applicability.

Regarding the cost and cost contingency estimate of the projects (Chapter 6 and Chapter 7), an important lesson learned is that such information should regularly (e.g. at the end of each project phase) be collected and evaluated. Cost performance of the projects (comparing the realized and estimated costs) should be recorded and any reason for the deviation should be investigated. The consequences for overestimating the budget due to 'pessimistic bias' behaviour should be communicated to the waterboards and the importance of efficiently using public money should be emphasized. It is essential that the estimated and realized costs of the finished projects are collected, analysed and made available to the projects in the HWBP program. Future HWBP projects should strengthen the predictability of their estimates using the historical data. This is a way to make the cost estimate of the projects more objective.

An important observation from investigating the HWBP-2 projects is that it was enormously difficult to collect the information. It took the author a long time to find the

data of the projects. One of the eye-opening conclusions was that for about one-third of the projects no trace of the risk registers or cost estimation documents could be found. Let us remember that these projects are not from the last centuries, but from the past few years.

Fortunately, HWBP projects follow a better regime for collecting information, although this is not enough. Information of the realization phase is only available (if properly collected) in a single waterboard. This makes the process of evaluating all program's projects, learning and sharing the knowledge gained very difficult. The other issue is that there is no insight in the realized costs of the projects because in the current regulation of the HWBP the waterboards do not need to report the realized costs. The author flags a risk in this situation:

Because the correct information is not collected, there would be insufficient information to evaluate future HWBP projects.

The directors of HWBP and the board of the waterboards should be prepared to mitigate this risk.

Regardless of the strategy of HWBP for financing the project (reimbursable or lump sum), project performance information should be collected properly, evaluated and shared regularly among the waterboards. The author believes that the current approach of HWBP for financing the projects, pre-financing the project costs, is better than the approach in HWBP-2, post-calculation of the costs, as pre-financing is an incentive for the waterboards to think in advance about the risks. Pre-financing, however, does not mean that the project should not report their realized costs. In the regulation of the HWBP is mentioned that: after finishing each phase, there will be no recalculation of the costs[1]. This part must be removed from the regulation of the projects. For learning purposes and transparency of the realized costs, projects should report their costs in any case.

Attention should be given to the 'use' of the collected information from projects, not just 'collecting' the information. In the HWBP program, there is currently no process to collect and use the lessons learned of projects. In the past years, the TU Delft has taken important steps to help projects collecting and using their lessons learned. HWBP is a continuous program and investing in collecting and using the lessons learned can significantly help HWBP. It is time to learn from our projects.

1 Method for determining subsidised and not subsidised costs, based on the subsidy regulation of Flood Protection Program 2014 (version 2017), page 6: After completion of each phase, no settlement will take place based on recalculation of the costs. This working method limits the administrative burden and also provides an incentive for efficiency.

Samenvatting

Nederland heeft een lange geschiedenis van bescherming tegen overstromingen en hoge waterstanden. Door de klimaatverandering en de zeespiegelstijging kan een volgende overstroming grote gevolgen hebben voor dit kleine land. Het Hoogwaterbeschermingsprogramma (HWBP), het grootste waterkeringsprogramma van Nederland op dit moment, zorgt ervoor dat alle waterkeringen (dijk, gemaal, duin) in Nederland voldoen aan de veiligheidsnormen. Het HWBP heeft twee doelstellingen:

1. Het versnellen van de verbetering van de waterkeringen tot 50 km per jaar.
2. Het reduceren van de gemiddelde kosten van de verbetering van de waterkeringen tot 7 miljoen euro per kilometer.

Om deze doelstellingen te bereiken, moet speciale aandacht worden besteed aan het beheersen van risico's in de HWBP-projecten.

De huidige literatuur over risicomanagement vermeldt dat risicomanagement bijdraagt aan het succes van projecten. Toch ontbreekt een juiste toepassing van risicomanagement in veel projecten. Dit benadrukt het belang van het verbeteren van de toepassing van risicomanagement, niet alleen in het geval van HWBP projecten, maar ook in het algemeen.

Het HWBP is een lopend programma zonder gedefinieerde einddatum. Het oudere programma, HWBP-2, is bijna afgerond. De focus van dit proefschrift ligt voor een groot deel op HWBP-2 projecten. Het doel van dit onderzoek is het verbeteren van de toepassing van risicomanagement in het HWBP. De evaluatie van de HWBP-2 projecten wat betreft toepassing van risicomanagement en inschatting projectkosten en onvoorziene kosten, kan inzicht geven in de huidige situatie. Ook geeft het de programmadirectie van HWBP (PD-HWBP), waterschappen en individuen, die betrokken zijn bij de realisatie van de waterkeringsprojecten, inzicht in mogelijke verbeteringen. De geleerde lessen op gebied van risicomanagement in HWBP-2-projecten worden verzameld en kunnen worden gebruikt in toekomstige HWBP-projecten. Samenvattend is het onderzoeksdoel:

Het verbeteren van de toepassing van risicomanagement in HWBP-projecten door de verbeterpunten te identificeren en een overzicht te geven van de gemeenschappelijke risico's en de percentages van onvoorziene kosten in HWBP-2 projecten.

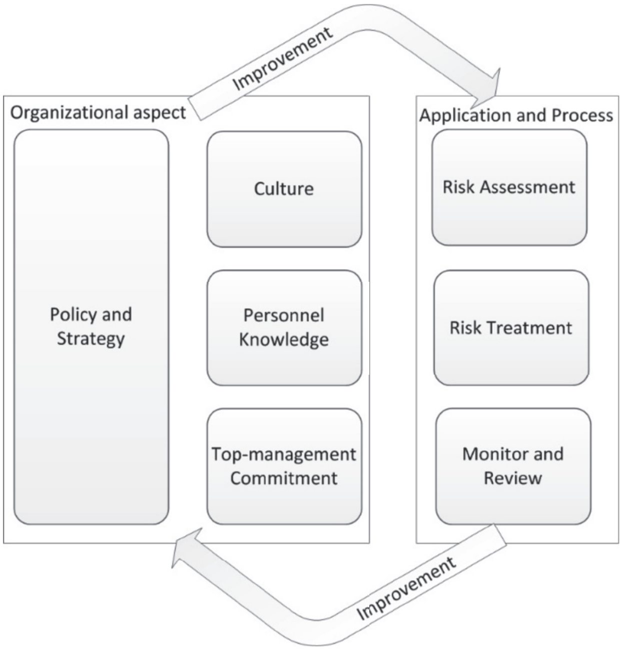
De hoofdvraag van dit onderzoek luidt:

Wat zijn de geleerde lessen van het toepassen van risicomanagement in HWBP-2-projecten en hoe kunnen deze lessen worden gebruikt om de toepassing van risicomanagement in HWBP-projecten te verbeteren?

Het onderzoek is opgedeeld in vier fasen. Voordat we beginnen met fase I, beschrijven hoofdstuk 1 en hoofdstuk 2 het belang van dit onderzoek en de vermeende rol van risicomanagement in het succes van projecten.

In hoofdstuk 1 wordt achtergrondinformatie gegeven over HWBP en HWBP-2 en worden de onderzoeksvragen en de onderzoeksaanpak gedefinieerd. In hoofdstuk 2 wordt de impact van risicomanagement op projectsucces onderzocht door middel van een literatuuronderzoek.. De beschikbare literatuur bevestigt het verband tussen risicomanagement en projectsucces: zelfs een matige toepassing van risicomanagement had positieve effecten op projectresultaten.

Fase I gaat over het meten van de volwassenheid van risicomanagement van projecten. Fase I van het onderzoek bestaat uit twee hoofdstukken: Hoofdstuk 3 en Hoofdstuk 4. Hoofdstuk 3 beschrijft het concept van Risk Maturity Modellen (RMM's) als een tool om toepassing van risicomanagement te verbeteren. Om de tekortkomingen in bestaande RMM's aan te pakken, wordt een generiek RMM (genaamd RiskProve) ontwikkeld en gevalideerd.. RiskProve bevat een lijst met stellingen/vragen met betrekking tot risicomanagement. Deze zijn middels kwalitatieve inhoudsanalyse (QCA) verkregen uit een literatuurstudie.. De stellingen/vragen zijn onderverdeeld in twee hoofdcategorieën (zoals weergegeven in figuur I): 'Organisatorisch' en 'Toepassing en proces'. De categorie Organisatie omvat vier aspecten: 'Beleid en Strategie', 'Topmanagement commitment', 'Cultuur & Persoonlijke Kennis'. De categorie 'Toepassing en Proces' bevat de aspecten: 'Risicobeoordeling', 'Risicobeheersing' en 'Monitoring & Review'. De stellingen en het model zijn gevalideerd aan de hand van twee sessies met experts. De experts herkennen de aspecten en de stellingen in RiskProve en zien RiskProve als een eenvoudig hulpmiddel dat projecten een duidelijk beeld kan geven van mogelijke verbeteringen met betrekking tot risicomanagement.



Figuur I RiskProve

In hoofdstuk 4 is RiskProve toegepast in 16 projecten van twee publieke organisaties. Het doel was om de toepassing van risicomanagement in deze projecten te onderzoeken. Het aspect Risicobeoordeling kreeg de hoogste volwassenheidsscore, het aspect Topmanagement Commitment kreeg de laagste risicomanagement volwassenheidsscores. Beide organisaties zien verbeteringsmogelijkheden in het definiëren van de doelstelling van risicomanagement, het definiëren van de risicobereidheid en het evalueren en verzamelen van de geleerde lessen. Op basis van de resultaten worden aanbevelingen gedaan om de toepassing van risicomanagement te verbeteren. De aanbevelingen en de validatie daarvan worden besproken in hoofdstuk 8.

Fase II van deze study onderzoekt de geïdentificeerde en opgetreden risico's in HWBP-2 projecten (hoofdstuk 5). Leren van risico's uit eerdere projecten zou een manier kunnen zijn om risicomanagement te verbeteren. Daarom worden de geïdentificeerde en opgetreden risico's in 16 HWBP-2-projecten van verschillende waterschappen onderzocht. Met behulp van een casestudy aanpak worden de geïdentificeerde risico's uit de risicoregisters verzameld gedurende de hele levenscyclus van het project (verkenningsfase, planontwikkelingsfase, aanbesteding en toekenning en uitvoeringsfase).

Opgetreden risico's bij deze projecten worden verzameld door middel van interviews met de projectmanager of de projectcontroller van de projecten. In totaal zijn er 2157 risico's verzameld. De risico's zijn onderverdeeld in de zeven categorieën van de RISMAN-methode: Organisatorisch, Politiek, Financieel, Ruimtelijk, Technisch, Juridisch en Maatschappelijk. Uit de resultaten bleek dat in de voorbereidingsfasen (Verkenning, Planontwikkeling en Inschrijving & Toekenning) meer risico's zijn geïdentificeerd dan in de uitvoeringsfase. In totaal is ongeveer 13% van de geïdentificeerde risico's opgetreden, meestal in de uitvoeringsfase. De meeste geïdentificeerde en opgetreden risico's vallen in de categorieën Organisatie en Ruimtelijk. Deze informatie kan soortgelijke, toekomstige projecten helpen om hun risico's beter te beheersen.

In fase III (hoofdstuk 6 en hoofdstuk 7) zijn de begroting en risicoreservering van de HWBP-2-projecten onderzocht. Hoofdstuk 6 richt zich op de ontwikkeling van de begroting en risicoreservering van de HWBP-2 projecten in de voorbereidingsfase. Met behulp van een casestudy aanpak zijn de geschatte totale projectkosten in de voorbereidingsfase (Verkenningsfase, Planstudiefase en Gunning) van 29 HWBP-2-projecten onderzocht. Gemiddeld zijn de kostenramingen met 11,51% gestegen ten opzichte van de oorspronkelijke schattingen. Volgens de literatuur kan deze toename te wijten zijn aan technische redenen, politieke redenen, strategische verkeerde voorstelling van zaken of 'optimism bias'. De uitkomst van het onderzoek was dat de stijging van de kostenramingen van de waterkeringsprojecten kan worden verklaard door technische redenen, er lijkt geen sprake van 'optimism-bias' of strategische verkeerde voorstelling van zaken. Toen de onderzochte projecten van start gingen, waren ze relatief nieuw voor de verantwoordelijke waterschappen. De waterschappen hadden beperkte ervaring met de kostenraming van dit soort projecten. Fouten veroorzaakt door een gebrek aan historische gegevens of gebrek aan ervaring waren daarom onvermijdelijk. Het onderzoek naar 'bekende onbekende' en 'onbekende onbekende' onvoorziene gebeurtenissen van deze projecten toont aan dat het percentage van 'onbekende onbekende' onvoorziene omstandigheden tijdens de pre-constructiefase is gestegen terwijl een afname werd verwacht. Deze toename suggereert dat de projecten geen vertrouwen hadden in hun schattingen. De toename kan worden verklaard door een gebrek aan ervaring, de cultuur van de organisatie of het fenomeen van 'pessimism bias'. 'Pessimism bias' ontstaat wanneer de schatter conservatief is en de kansen onderschat. Het concept van 'pessimism-bias' staat in contrast met 'optimism-bias'.

In hoofdstuk 7 is gekeken naar de gerealiseerde kosten en de risicoreservering voor onvoorziene gebeurtenissen bij projecten in de uitvoeringsfase vanuit het perspectief van opdrachtgever en aannemer. De projecten van de aannemer zijn ook bestudeerd omdat juist de aannemer betrokken is bij de uitvoeringsfase. Net als Hoofdstuk 5 en Hoofdstuk 6 profiteert dit hoofdstuk van een casestudy aanpak. In totaal worden 95 projecten onderzocht: 44 vanuit het perspectief van de opdrachtgever (HWBP-2 projecten) en 51 projecten van een aannemer. De studie onderzocht de gerealiseerde kosten (na uitvoering van het project) en de geschatte kosten (vóór uitvoering van het project). Uit de vergelijking van de totaal gerealiseerde kosten en geschatte kosten blijkt dat de HWBP-2-projecten 16% goedkoper zijn gerealiseerd. Bij de 51 projecten van de aannemer zijn er juist lichte overschrijdingen gerapporteerd, tot 2%.. In de HWBP-2-projecten waren de geschatte risicoreservering gemiddeld 2,64% hoger dan de gerealiseerde onvoorziene kosten, terwijl de geschatte onvoorziene kosten in de projecten van de aannemer gemiddeld 5,41% lager waren dan de gerealiseerde risicoreservering. Over het algemeen lijkt de aannemer dus te optimistisch en heeft hij de kansen overschat, terwijl de opdrachtgever pessimistischer was met een neiging tot overschatting van de kosten en onderschatting van de kansen. Deze verschillen kunnen worden verklaard door 'pessimism bias' en 'technische' redenen aan de kant van de klant. Aan de kant van de aannemer spelen een opportunistische houding (optimism bias), 'technische' en 'politieke' redenen een rol.

Fase IV van het onderzoek (hoofdstuk 8) presenteert de validatie van de aanbevelingen ter verbetering van het risicomanagement in HWBP-projecten. Op basis van de resultaten van de voorgaande hoofdstukken wordt een lijst met 20 aanbevelingen opgesteld. Het belang en de haalbaarheid van deze aanbevelingen worden getoetst door drie expertsessies: één sessie met projectcontrollers van de waterschappen, één sessie met experts van de PD-HWBP die zich bezighouden met risicomanagement, en één sessie met experts met strategische en directierollen. in het HWBP. Geconstateerd is dat de experts van de waterschappen en de PD-HWBP kansen zien om het risicomanagement te verbeteren. Een 'Risk Management Map' (RM-Map) is gedefinieerd met daarin vijf mijlpalen en een beschrijving van de rol en verantwoordelijkheid van de PD-HWBP en de waterschappen. (Figuur I).

Zowel de PD-HWBP als de waterschappen zouden de weg van verbetering van het risicomanagement moeten volgen, waarbij elke partij zijn eigen verantwoordelijkheden heeft. De RM-Map omvat vijf mijlpalen:

1. Het definiëren van de strategie van RM door de PD-HWBP en de waterschappen
2. Het creëren van de voorwaarden om de aanbevelingen toe te kunnen passen
3. Het vertalen van de gedefinieerde strategie naar doelstellingen bij waterschappen en het tonen van commitment
4. Het verbeteren van de RM-toepassing in projecten
5. Ondersteunen, faciliteren en kennisdelen

Van deze vijf mijlpalen zijn nummer één en twee de verantwoordelijkheid van zowel de waterschappen als de PD-HWBP, mijlpalen drie en vier vallen onder de verantwoordelijkheid van de waterschappen en mijlpaal vijf is de verantwoordelijkheid van de PD-HWBP. De oneindige vorm van de RM-Map benadrukt het continue proces van evalueren en verbeteren. Zonder een gedefinieerde strategie voor risicobeheer (mijlpaal 1) zou het moeilijk zijn om de andere mijlpalen te bereiken.

Deze studie geeft een antwoord op de belangrijkste onderzoeksvraag:

Wat zijn de geleerde lessen van het toepassen van risicomanagement in HWBP-2-projecten en hoe kunnen deze lessen worden gebruikt om de toepassing van risicomanagement in HWBP-projecten te verbeteren?

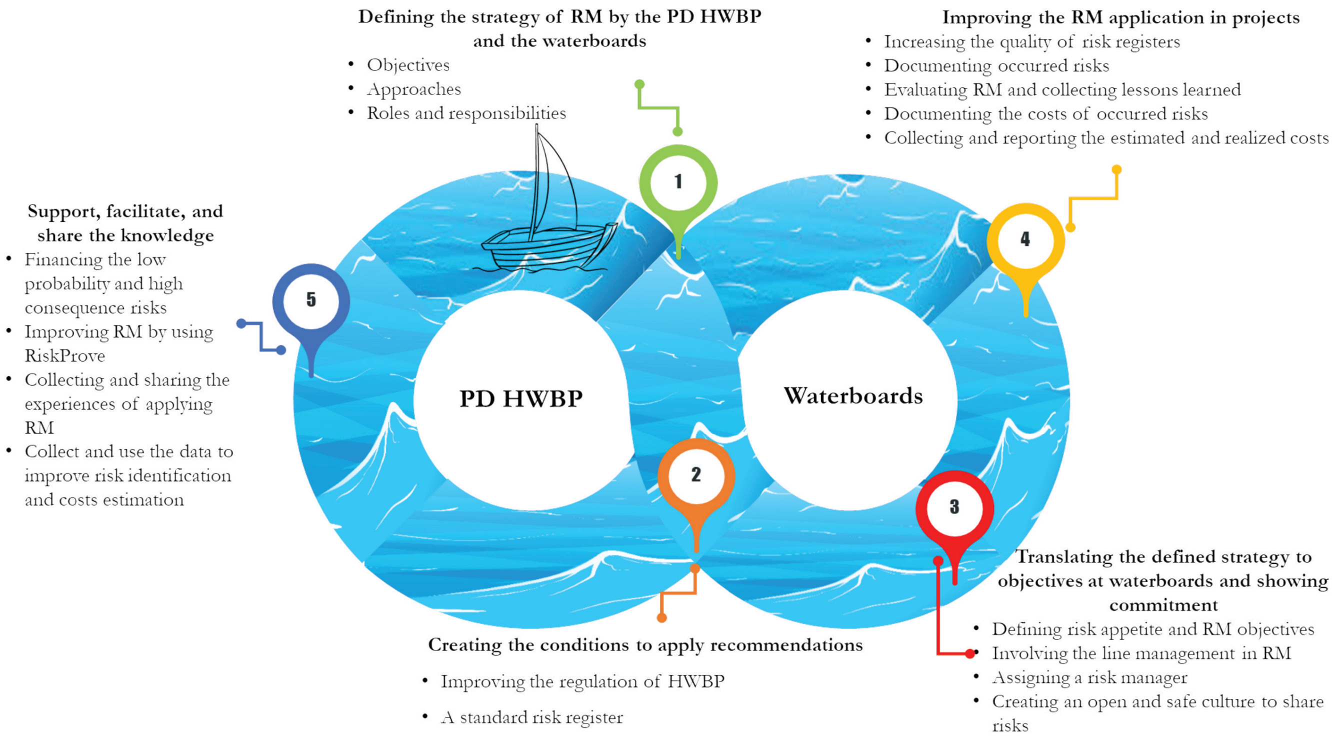


Figure II De RM-Map voor het verbeteren van risicomanagement toepassing in HWBP projecten

Uit de toepassing van risicomanagement in HWBP-2-projecten kunnen verschillende lessen worden getrokken. Wat betreft de volwassenheid van het risicomanagement van de projecten wordt geconcludeerd dat de projecten volwassen zijn in risicobeoordeling, terwijl de risicobeheersing en monitoren en review meer aandacht behoeven. Projectteams moeten beseffen dat 'risicomanagement' over een proactieve houding gaat. Projectleden moeten speciale aandacht besteden aan het toepassen van de beheersmaatregelen en het evalueren van het nut ervan. Door meer aandacht te besteden aan deze stappen en vooral de geleerde lessen te verzamelen en te gebruiken kan de toepassing van risicomanagement in HWBP-projecten worden verbeterd. Deze verzamelde informatie kan worden gebruikt in toekomstige projecten. Periodieke meting van de volwassenheid van risicomanagement met behulp van RiskProve kan aangeven of de HWBP-projecten op de goede weg zijn.

Wat betreft de geïdentificeerde en opgetreden risico's (hoofdstuk 5) kunnen uit de HWBP-2-projecten verschillende lessen worden getrokken. Ten eerste houden de meeste geïdentificeerde en opgetreden risico's verband met de categorieën Organisatie en Ruimtelijk. Deze twee risicocategorieën verdienen extra aandacht in HWBP-projecten. Een belangrijke les is dat de projecten de opgetreden risico's beter moeten documenteren. De kosten in verband met de opgetreden risico's moeten ook worden geregistreerd. De database van risico's die in dit onderzoek is gemaakt, kan in de HWBP-projecten worden gebruikt om de volledigheid van risicoregisters te controleren. Er kan een generiek risicoregister worden opgesteld met de potentiele risico's per projectfase. Het projectteam kan leren van de beheersmaatregelen die bij andere projecten zijn genomen. Toekomstige projecten zouden hun werk kunnen baseren op dit generieke risicoregister, zorgvuldig rekening houdend met de specifieke toepasbaarheid.

Een belangrijke les omtrent de kostenrealisatie en de kostenramingen van de onderzochte projecten (hoofdstuk 6 en hoofdstuk 7) is dat dergelijke informatie regelmatig (bijvoorbeeld aan het einde van elke projectfase) moet worden verzameld.. Kostenprestaties van de projecten (de vergelijking van de gerealiseerde en geschatte kosten) moeten worden geregistreerd en geëvalueerd en elke reden voor afwijking moet worden onderzocht. De gevolgen voor het overschatten van het budget, als gevolg van 'pessimism bias', moeten worden gedeeld met de waterschappen en het belang van efficiënt gebruik van overheidsgeld moet worden benadrukt. Het is essentieel dat de geschatte en gerealiseerde kosten van voltooide projecten worden verzameld, geanalyseerd en beschikbaar gesteld aan de projecten in het HWBP-programma. Toekomstige HWBP-projecten moeten de voorspelbaarheid van hun schattingen versterken op basis van historische gegevens. Dit is een manier om de kostenraming van de projecten objectiever te maken.

Tijdens het onderzoek van de HWBP-2-projecten bleek dat het verzamelen van de informatie enorm moeilijk was. Het kostte de auteur veel tijd om de gegevens van de projecten te vinden. Een van de in het oog springende conclusies is dat er voor ongeveer een derde van de projecten geen spoor van de risicoregisters of kostenramingsdocumenten is gevonden. Laten we niet vergeten dat deze projecten niet van de afgelopen eeuwen zijn, maar van de afgelopen jaren.

De huidige HWBP-projecten volgen gelukkig een beter regime voor het verzamelen van informatie, hoewel het toch nog onvoldoende is. De informatie over de realisatiefase is namelijk alleen beschikbaar (mits goed verzameld) in het betreffende waterschap. Dit maakt het proces van het evalueren van alle programmaprojecten, het leren en het delen van de opgedane kennis erg moeilijk. Een ander probleem is het gebrek aan inzicht in de gerealiseerde kosten van de projecten, omdat de waterschappen in de huidige regeling van het HWBP de gerealiseerde kosten niet hoeven te rapporteren. De auteur markeert een risico in deze situatie:

Omdat de juiste informatie niet wordt verzameld, zou er onvoldoende informatie zijn om toekomstige HWBP-projecten te evalueren.

De directeuren van HWBP en het bestuur van de waterschappen moeten bereid zijn dit risico te mitigeren.

Ongeacht de strategie van HWBP voor de financiering van het project (op basis van gemaakte kosten of op basis van vaste prijs), moet informatie over de projectprestaties correct worden verzameld, geëvalueerd en ook regelmatig worden gedeeld tussen de waterschappen. De auteur is van mening dat de huidige aanpak van HWBP met betrekking tot de financiering van de projecten (voorfinanciering van de projectkosten) beter is dan de aanpak in HWBP-2 (vergoeding op basis van nacalculatie), aangezien voorfinanciering een prikkel is voor de waterschappen om vooraf na te denken over de risico's. Voorfinanciering betekent echter niet dat het project de gerealiseerde kosten niet hoeft te rapporteren. In de HWBP-regeling wordt nu vermeld dat na het beëindigen van elke fase er geen herberekening van de kosten gedaan hoeft te worden[2]. Er wordt

2 Werkwijze bij het vaststellen van subsidiabele en nietsubsidiabele kosten, behorend bij de Regeling subsidies hoogwaterbescherming 2014 (versie 2017), pagina 6: Na afronding van de fase vindt geen verrekening op basis van nacalculatie plaats. Deze werkwijze beperkt de administratieve lasten en houdt tevens een prikkel tot doelmatigheid in.

aangeraden om dit deel te verwijderen uit de regeling. Voor leerdoeleinden en transparantie van de gerealiseerde kosten dienen projecten in ieder geval hun kosten te rapporteren.

Er moet aandacht worden besteed aan het gebruiken van de verzamelde informatie van projecten, niet alleen aan het verzamelen van de informatie. In het HWBP-programma is er momenteel geen proces om de geleerde lessen van projecten te verzamelen om deze verder te kunnen gebruiken. De TU Delft heeft de afgelopen jaren belangrijke stappen gezet om geleerde lessen van projecten te helpen verzamelen en gebruiken. Het HWBP is een continu programma en investeren in het verzamelen en gebruiken van de geleerde lessen kan het HWBP aanzienlijk helpen. Het is tijd om te leren van onze projecten.

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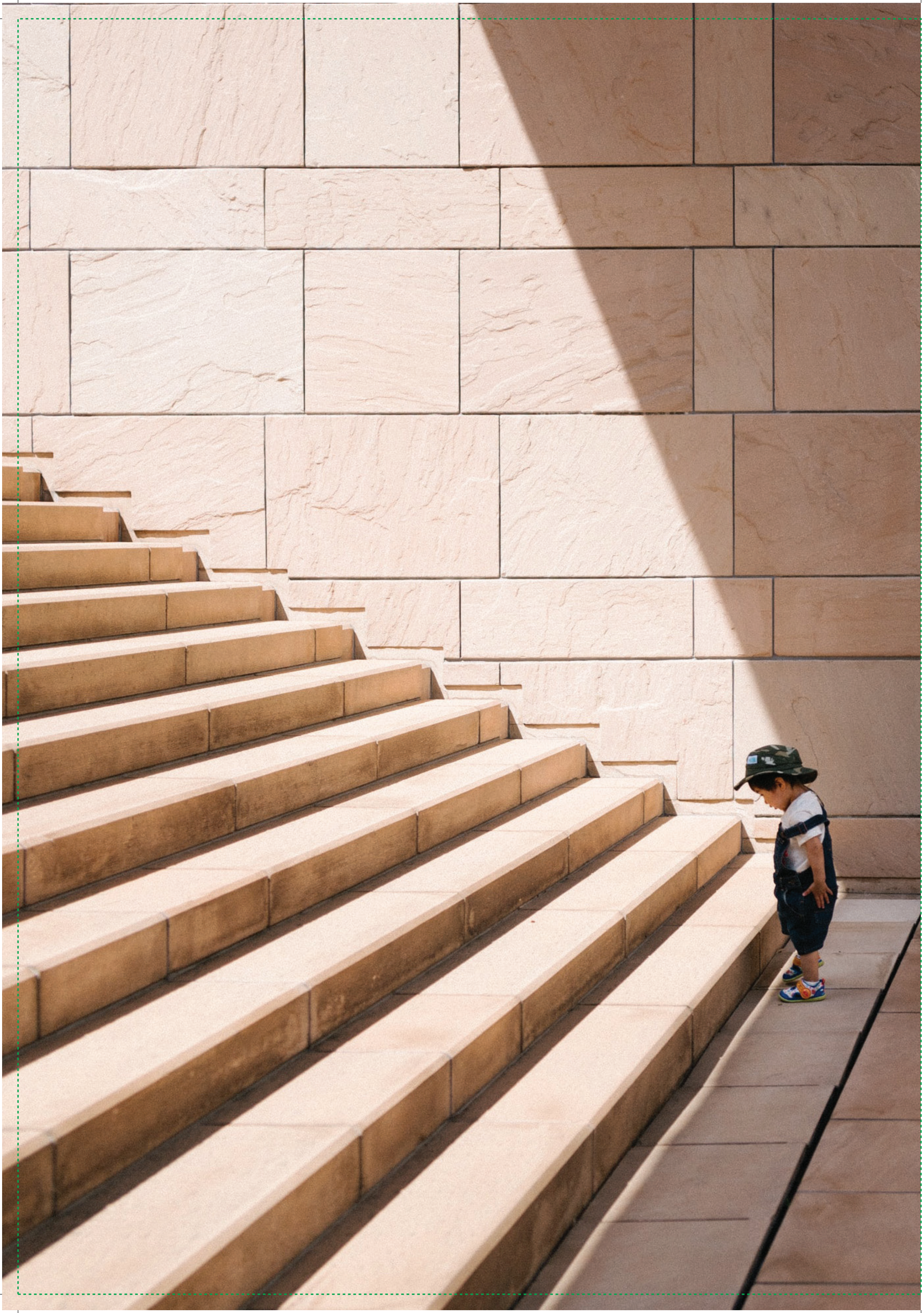

CHAPTER 1

Introduction and Setting the Scene

Abstract

Risk, as an inevitable part of human's life, is any uncertain event that can negatively or positively influence activities and objectives. The importance of managing risk is emphasized and some scholars call it as the most important activity in managing the project's objectives.

The Netherlands has a long history of flooding. Flooding in the Netherlands has decreased because of strong governmental responsibility and proactive improvement of flood protection facilities (such as dikes and dunes). However, the climate change and sea level rise increase the chance that a next flood could have high impact on this small country. The Netherlands needs to be prepared, maybe more than ever. The Hoogwaterbeschermingsprogramma (HWBP) is one of the flood defence programs in the Netherlands that makes sure that all the flood defence facilities in the Netherlands comply with the safety norms. HWBP has two ambition objectives:

1. Increasing the flood defence improvement to 50 km per year.
2. Reducing the average costs of the flood defence improvement to 7 million euro per kilometre.

To reach these objectives, special attention should be given to the management of risks in the projects of the program.

The current risk management literature mentions that risk management contributes to better decision making, less time and cost and therefore to project performance. Despite the benefits of risk management, projects still lack a proper application of risk management. International projects such as the Panama Canal, the Airbus 380, and in the Netherlands the new see-lock IJmuiden and the Juliana canal are among examples of projects which suffered from a lack of proper application of risk management. This highlights the importance of improving risk management application, not just in the case of HWBP, but generally. Apart from practice, we also notice a scientific knowledge gap in the areas such as objective measurement of the risk management maturity of the projects and the amount of cost contingency (risk reservation) during the pre-construction as well as the execution phases of projects. The knowledge gap observed in the current literature and the need for better risk management application from practice prove the importance of research about improving risk management application.

This first chapter is devoted to explaining the importance of risk management and sketching the scope and objective of this research. The chapter provides background information regarding the Hoogwaterbeschermingsprogramma (HWBP), the current largest flood protection program in the Netherlands that has sponsored this research. It explains the research approach for investigating and evaluating risk management in HWBP, as the main focus of this research.

1.1 Risk

Looking closely around us, risk is everywhere. The world in which we live is unpredictable, strange, incomprehensible, surprising and mysterious, which forces us to accept the fact that we neither know nor understand everything, and we cannot, therefore, control everything. Therefore, risk is inherent in every aspect of human activities, from riding a bicycle, managing a project, dealing with clients, to deciding not to take any action at all (Flyvbjerg, Bruzelius, & Rothengatter, 2003; AS/NZS, 2004). In general, risk can be any uncertain event that its occurrence can positively or negatively affect an individual, a group of people or the outcome of an event or an activity (D. Hillson & Simon, 2007). Risk can be seen from a strategic (higher level in an organization, or society) or operational (project and programs) perspective (BSI, 2000; Zou, 2010). The focus of this research is, however, on managing risk on the project level.

Risk in a project is considered as an uncertain event with possible positive or negative deviations from defined project goals (Bufaied, 1987; Morris, 2011; APM, 2012; PMI, 2013; Lehtiranta, 2014; Staveren, 2015; Eaton, Dikmen, & Akbiyikli, 2016). In this definition, risk is no longer something that must be prevented from happening but depending on its outcome, it can be exploited. In this research, the latter definition of risk is considered; risk can have both positive and negative consequences on the project's outcomes. Threats and opportunities are both important to project success (Hertogh, Baker, Staal-Ong, & Westerveld, 2008; Johansen, Olsson, Jergeas, & Rolstadås, 2019)), although it is noted that the majority of authors focus on the negative consequences, the threats.

From a management theory perspective, risk is seen as exposure to specific factors that can threaten the expected project goals. Based on this perspective, risk exposure can be calculated by multiplication of the probability of the undesirable event and the impact or magnitude of the loss if the event occurs. In classical decision theory, risk was viewed as reflecting variation in the probability distribution of possible outcomes, negative or positive, associated with a particular decision (March & Shapira, 1987; Bannerman, 2008). Hence risk is equal to the probability of occurrence of loss or gain multiplied by its respective magnitude (Jaafari, 2001, p. 89). It should be taken into account that merely looking at the impact of risk (probability multiplied by the consequence) is not always enough to assess the importance of a risk. That is because a risk with a high probability and low consequence has the same impact as a risk with low probability but a high consequence. Aven (2010) argues that the definitions of risk are too narrow since probabilities are not always perfect tools for expressing uncertainties. The probabilities are conditioned on a number of assumptions, are depend on the background knowledge, and are subject to individual's perception. The drawback of using probability to define risk is that uncertainties are often hidden in the background knowledge (Aven, 2010).

According to an organizational perspective, a risk arises when organizations pursue opportunities in the face of uncertainty (Bannerman, 2008). Each project is different and involves some degree of uncertainty, hence there is no risk-free project (Raz, Shenhar, & Dvir, 2002). Project risks may come from external or internal of the project and can be characterized by uncertainty, complexity, and urgency, or from lack of resources or other constraints such as skills, or policy (Raz et al., 2002). Taking risk in projects (or in any aspect of human's life) is unavoidable.

A 'not occurred risk', by definition, is not something that is real. It is the anticipation of a future event with a possible (positive or negative) consequence in the presence (De Bakker, Boonstra, & Wortmann, 2011). Risk is not an absolute situation, it is something that may happen and, therefore, might be predicted.

The predictable nature of risks makes it subject to individual's perception, experience, culture, situation and opinion which is known as risk attitude. David Hillson and Murray-Webster (2012) define risk attitude as the chosen response to perception of a specific uncertainty. Risk attitude has to deal with individual's behaviours. Certain possible attitudes in equal situations could lead to different behaviours and consequences (David Hillson & Murray-Webster, 2012). Research reveals that different actors in a project have different perspectives of risks and risk management (Zhang, 2011; De Bakker, Boonstra, & Wortmann, 2012; Willumsen, Oehmen, Stingl, & Geraldi, 2019). The differences in perceptions can be explained by differences in interests, knowledge expertise and responsibilities (Keil, Tiwana, & Bush, 2002).

David Hillson and Murray-Webster (2012) define three main risk attitudes:

- Risk-averse attitude: when the individual (or organizations) avoids the uncertain event.
- Risk-seeking attitude: when the individual (or organizations) chooses for the uncertain event.
- Risk-tolerant: when the individual (or organizations) has no strong desire to respond to threats or opportunities.

A risk-averse strategy can limit distinctive achievement while a risk-seeking strategy can increase project losses. It is, therefore, important to find a balance between each of these dimensions that, in combination, represents a risk profile that is appropriate and acceptable to internal and external stakeholders (Bannerman, 2008).

While risks cannot be eliminated from projects, it can be acknowledged explicitly and with accountability (Flyvbjerg et al., 2003; Staveren, 2015). During the last decades, there has been a major interest in improving abilities to deal with risks and especially its negative impact (Raz & Hillson, 2005). Indeed, the awareness to project risks and the need to manage them has become one of the main topics of interest for researchers and practitioners (e.g. Asadi and Rao (2018), Nishaant Ha (2018), and Willumsen et al. (2019)). Just as the presence of risks is recognized and accepted, there is a matching drive to manage risks as far as possible (David Hillson, 2006).

1.2 Project risk management

While project risks cannot be avoided, one can be prepared by adding mechanisms, backups, and extra resources, to protect the project objectives in case something goes wrong. This is called project risk management (Raz et al., 2002). Risk Management is defined as the coordinated activities to direct and control an organization with regard to risks (ISO31000, 2009). Risk management must be seen as an iterative and continuous process in the whole duration of a project (PMI, 2013). In Chapter 3 of this dissertation, a thorough comparison of risk management activities based on several risk management guidelines is provided.

Projects are unique and bounded with uncertainties, making risk management a key activity in managing them (Murray, 2009). Risk management is crucial in complex projects where uncertainties due to long timescales, multi-ownership, involving substantial resources, and significant political issues play a more significant role (Chapman & Ward, 2003; Yeo & Ren, 2009; Bosch-Rekveldt, 2011; Hopkinson, 2012; Schwindt & Zimmermann, 2015). The objectives of risk management are to intensify the probability and impact of positive events and to reduce the probability and impact of negative events (PMI, 2013; Schwindt & Zimmermann, 2015).

Project risk management literature acknowledges a universal acceptance about the importance of risk management within all sectors (BSI, 2000; IRM, 2002; AS/NZS, 2004; D. Hillson & Simon, 2007; Merna & Al-Thani, 2011; Becker & Smidt, 2015; Ahmadi, Behzadian, Ardeshir, & Kapelan, 2017). Many researchers and practitioners believe that managing risk is the single most important factor in ensuring successful project management since risks are measured by their potential impact on the achievement of project objectives (Ren & Yeo, 2004; Yeo & Ren, 2009; Schwindt & Zimmermann, 2015). Burtonshaw-Gunn (2009) introduces risk-driven project management as a new concept. He argues that if there were no risks in the project, there would be no need for project management and, as a consequence, the main purpose of project management is to manage the risks. Burtonshaw-Gunn (2009) and Yeo and Ren (2009) explain the importance of integration of risk management and other project management processes. Risk management should be a core process within strategic management of any business or organization (BSI, 2000; FERMA, 2002; IRM, 2002) and should be an integral part of project management since the roots of risks are related to other project management aspects (Nicholas & Steyn, 2012; Zou et al., 2010).

Literature on risk management names several advantageous of applying risk management. For example, risk management helps projects to be completed on time, within the budget, to the required quality and with proper provision for safety and environmental issues (Burtonshaw-Gunn, 2009; Murray, 2009; Öngel, 2009; Yeo & Ren, 2009; Merna & Al-Thani, 2011; Schwindt & Zimmermann, 2015; Eaton et al., 2016; Ziyu, Tahir, Dharm, & Guru, 2017). Furthermore, the hard and soft benefits of risk management are: a better basis for decision-making and negotiation, more realistic business and project planning, increased involvement of stakeholders, reduced finance costs, increased reliability and quality of services and products, reduced claims and legal costs, and enhanced competitive advantage (BSI, 2000; Loosemore, Raftery, Reilly, & Higgon, 2006; D. Hillson & Simon, 2007; Merna & Al-Thani, 2011; Becker & Smidt, 2015).

1.3 Flood protection in the Netherlands

Flooding is a major natural hazard affecting 520 million people every year, claiming the lives of about 25,000 worldwide, and causing global economic losses between $50 and $60 billion annually. Therefore, it is essential to manage the risk of flooding in an effective and appropriate way (Van Alphen et al., 2011).

The Netherlands is a low situated country where the lakes such as the IJsselmeer and the North Sea provide an abundance of water. Geographically speaking, the Netherlands is located in a delta and about one-third of its area is under the sea level. Unsurprisingly, the history of the Netherlands shows the occurrence of several floodings among which the floods in the years 1836, 1916, and 1953. In the flooding disaster of 1953, only the major cities of Amsterdam, Rotterdam, and The Hague were safe, while large areas in the southwest of the country were flooded, causing more than 1800 deaths and major damages (Wesselink, 2007). After this disaster, the government invested significantly in flood protection structures to bring existing flood defences (dikes, locks, and dunes) up to date. As a result, all tidal outlets were closed off, except the northern and southern waterways, which provided access to the harbours of Rotterdam and Antwerp, as well as the Eastern Scheldt. Additionally, it was decided that the dikes, which did not meet the safety norms, were to be strengthened (Wesselink, 2007; Van Alphen et al., 2011).

In 2010, the Delta Program was designed to protect the Netherlands against flooding and to secure freshwater supplies. The goal of the Delta Program is to (Delta Programme Commissioner, 2019):

"Collectively addressing common goals within the national framework of the Delta Program; rather than waiting to be hit by a new (flood) disaster, keeping ahead of disaster, major damage, and social disruption" (p.13.)

There are several programs under the Delta Program among which are Room for the River program (In Dutch: Ruimte voor de Rivier (RvR)) and the Flood Protection Program (In Dutch: Hoogwaterbeschermingsprogramma (HWBP)). The RvR program is almost finished while HWBP is still ongoing. HWBP is often compared with RvR regarding the regulation and financing. Therefore, the RvR program is explained next. The HWBP program is also elaborated as this program is the main focus of this doctoral research.

1.3.1 Room for the River program

In 1993, the water of the major rivers rose to an alarming level and in 1995, the risk of flooding increased to such an extent that for the security reasons, the authorities decided to evacuate 250,000 residents and a livestock of one million animals. These events prompted the RvR program. The focus of this program is to build over-dimensioning measures in order to make space for water and flexibility to cope with climate change (Wesselink, 2007). The RvR goals were to achieve the required protection level along the Rhine tributaries and the downstream section of the Meuse by the end of 2015, whilst enhancing the associated spatial quality. These goals were achieved by executing 34 measures: flood plain excavations, dike relocations, lowering of groins and embankments, dike improvements, removal of obstacles, depoldering, and the construction of a flood channel (Delta Programme Commissioner, 2019). Rijkswaterstaat (RWS)[3], waterboards (the regional public organizations responsible for water management in each area), provinces and some municipalities were responsible for realization of these measures.

In 2006, the Room for the River Program Directorate (In Dutch: programmadirectie Ruimte voor de Rivier (PDR)) was established. The PDR formed an independent entity within RWS. The PDR consisted of a program office that acted as assessor, facilitator and program director for the entire program. The PDR consisted of a unit of RWS projects, which was responsible for part of the implementation of the RvR projects (Martine Olde Wolbers, Leonore Das, Jesse Wiltink, & Fritjof Brave, 2018).

The evaluation report published recently (Martine Olde Wolbers et al., 2018) shows that the program has achieved its dual goals (flood risk management and spatial quality) while finished within budget and time. The program has made the area around the major rivers safer and stronger from economic, ecological, and landscape perspective, whilst added value has been created for residents, leisure facilities, the business community and nature (Martine Olde Wolbers et al., 2018; Delta Programme Commissioner, 2019).

1.3.2 Flood Protection Program

The Flood Protection Program (in Dutch: Hoogwaterbeschermingsprogramma (HWBP)) is currently the largest execution program of the Delta Program, and in the

3 Rijkswaterstaat is part of the Dutch Ministry of Infrastructure and Water Management and responsible for the design, construction, management and maintenance of the main infrastructure facilities in the Netherlands.

coming years the financial share of it will be half of the Delta fund (Programmaplan, 2019). HWBP covers the improvement of 943 kilometres of dikes and 468 engineering structures (Delta Programme Commissioner, 2019). Similar to RvR, HWBP has its own Program Directorate (PD-HWBP) which has the role of director, facilitator and audit in the realization of HWBP projects. The program goal is that all flood defence facilities meet the new water safety standards which will ensure a minimum protection level of 10-5 per annum for every resident of the Netherlands living behind a primary dike or dam not later than 2050 (Delta Programme Commissioner, 2019).

In HWBP, the waterboards and Rijkswaterstaat work together to reinforce the flood defence facilities which do not satisfy the current safety norms (Programmaplan, 2019). The waterboards and RWS test the flood defence facilities periodically to check whether they satisfy the safety standards and norms. If the flood defences are rejected based on the periodic test rounds, the waterboards are obliged to improve the flood defences to meet the current standards. The rejected flood defence facilities are then considered for subsidy for improvement. The waterboards, responsible for the flood defence facilities, have to submit their estimated budgets to the program. The required subsidy should be approved by the PD-HWBP. The PD-HWBP evaluates the plan for improvement/reinforcement of these flood defence facilities based on an efficient, plain and simple design (15e Voortgangsrapportage, 2018). The PD-HWBP provides the waterboards with the required subsidy, given the approval of the plan for improvement/reinforcement.

Based on the first tests performed in the period of 1996-2001, part of the flood defence facilities did not meet the safety standards and hence required improvements. The projects defined based on these first tests are realized under a program called HWBP-1.

The second test to check the flood defence facilities was performed in the period of 2001-2006. The results revealed that some water defences plus a few places along the North Sea did not satisfy the safety norms and required attention. The projects that were defined based on the result of the second test are categorized under HWBP-2. HWBP-2 has in total 87 projects including 69 (362.4 km) dikes and 18 coastal projects (15e Voortgangsrapportage, 2018). The execution period for this program is 2007-2017 and the total budget is 2.7 billion euros. Until the end of December 2018, out of the 69 dike projects, 64 are ready and five projects are still in execution. In addition, all 18 coastal projects are finalized (15e Voortgangsrapportage, 2018). Figure 1-1 presents an overview of the progress of the projects in HWBP-2.

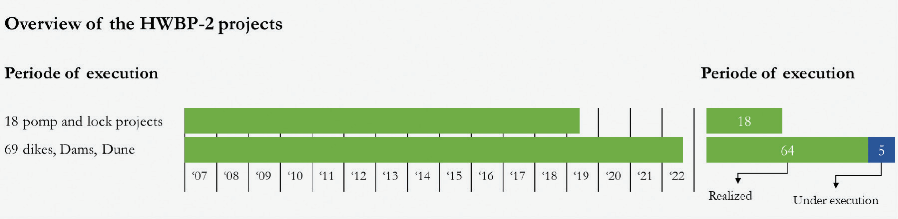

Figure 1-1 An overview of the progress of the projects in HWBP-2 (retrieved from 15e Voortgangsrapportage)

The third test round, performed in the period of 2006-2011, resulted in new projects that are named under the 'new HWBP' (15e Voortgangsrapportage, 2018). Since naming the program after the test name could cause confusion and the tests are supposed to be performed periodically for a long time, it was decided to name the program just 'HWBP' and the number of the performed tests is no longer considered. HWBP is now an ongoing program and in contrast to HWBP-2, it has no specific end date. Each year, HWBP is designed for a period of 6 years with a perspective of 12 years. The planning of the projects for the first 6 years is detailed while the planning for 12 years is more indicative. In this way, the program has more room to manoeuvre and the projects can be executed more effectively and with more flexibility (Programmarapportage, 2015). Based on the yearly tests of the flood defence structures, new projects are added to the program. The HWBP has 34 projects based on the test during 2014-2019. These numbers are increased by the tests performed in the period 2015-2020 to 62 and in the period of 2016-2021 to 72 projects. The total scope of these 72 projects contains 748 km dike reinforcement and 1650 km coastal project with the estimated budget of 5.3 billion euro (Projectenboek, 2015, 2016).

The programs HWBP-2 and HWBP are the main focus of this doctoral research and most of the cases studied in this research are selected among the HWBP-2 projects. The differences between these programs are explained next.

1.3.3 The differences between HWBP-2 and HWBP

In 2010 the parliament of the Netherlands was informed that the HWBP-2 shows deviation from the planning and was facing cost overrun. Through the evaluations performed by KPMG and Netherlands Court of Audit, it was revealed that HWBP-2 was missing efficiency incentives (Programmarapportage, 2015). As a result, a task force under the guidance of Prof. mr. dr. E.F. Ten Heuvelhof (known as Taskforce

Ten Heuvelhof) was established for the improvement of the program. The taskforce provided recommendations in three levels which became the fundamental differences between HWBP and HWBP-2 (Programmarapportage, 2015):

1. Structure: the program is established as a common responsibility between Rijkswaterstaat and the waterboards, both of these organizations pay 50 % of the expenses. Additionally, the decision based on the test results should be the responsibility of Rijkswaterstaat instead of the provinces.

2. Process: assigning more time on research regarding alternative methods of projects execution in the early phases of the project.

3. Organization and Governance: the managers should invest more in knowledge and skills of the personnel. To do so, a common knowledge and execution organization should be established between the waterboards and the Rijkswaterstaat.

The Taskforce Ten Heuvelhof advised, in addition, that risk management performed by the waterboards should be developed as part of project control (Taskforce, 2010).

These modifications resulted in an intensive collaboration between Rijkswaterstaat and the waterboards in areas such as knowledge exchange and exchanging personnel, learning and helping each other, new approaches to risk management, new governance, joint financing of the projects by Rijkswaterstaat and waterboards, and a continuous program (Programmarapportage, 2015). On 22 March 2011, the HWBP-2 was designated as a Major Project, meaning the PD-HWBP should regularly report the progress of the program to the parliament of the Netherlands.

The two major differences between HWBP and HWBP-2, financing of the projects and the approach of risk management, are the building blocks of this doctoral research and are elaborated next.

1.3.4 Finance of HWBP and HWBP-2

The finance of HWBP-2 was based on so-called post-calculation (reimbursable) system. After the project budget was estimated and the project was ready for execution, the responsible waterboard could ask for the subsidy. The requested subsidy, after the evaluation by the PD-HWBP, would be provided to the waterboard. The PD-HWBP paid then 80% of the accepted subsidy plus 15% of project preparation costs to the projects as pre-finance of the project.

After project completion, the realized costs of the projects were calculated. In case the realized project costs were less than the estimated costs, the waterboards would pay the remaining budget back to the PD-HWBP. In case the actual project costs were higher than the estimated project costs, PD-HWBP would pay the extra costs to the waterboard. This means that the waterboards did not need to have an accurate estimation of the costs since they were paid for all the realized costs.

Based on the recommendations of the Taskforce Ten Heuvelhof, two changes were made in the finance strategy. First, both waterboards and RWS are responsible for financing HWBP. As a result, in HWBP, in contrast to HWBP-2, the funding required to execute the projects is provided by both RWS and waterboards. A bank account, known as 'Dike account', is established and RWS and waterboards (even the waterboards that have no projects in HWBP) pay their share to the Dike account. The required budget for the projects in HWBP is paid from this account. Each project receives only 90% of the project costs from the Dike account as a subsidy and the rest, 10% (project-related share) should be paid by the waterboard itself as an incentive for efficiency. Figure 1-2 presents the financing of HWBP. The second row presents that 90% of the project execution costs are paid from the Dike account, while 10 % of the costs are paid by the responsible waterboard. The lowest row in Figure 1-2 presents the composition of the funds in the Dike account.

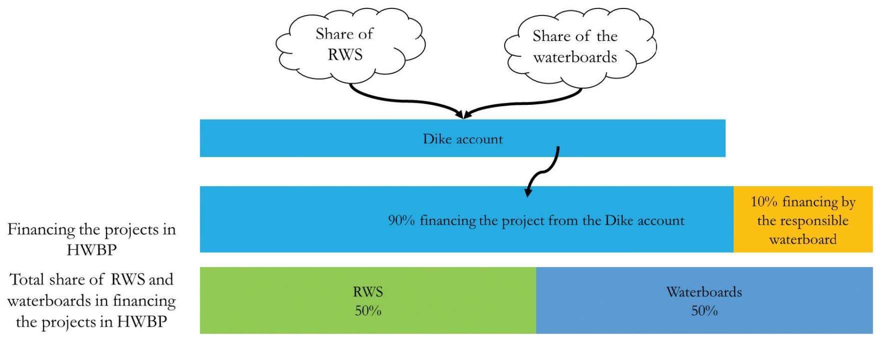

Figure 1-2 Financing of HWBP, own illustration based on Projectenboek (2015)

In HWBP, in contrast with HWBP-2, the preparation costs of the projects are not considered for subsidy (Deel B, 2017). The financing of the projects in HWBP is changed from post-calculation (reimbursable) to pre-calculation (lump sum). The budget of each phase is paid at the beginning of that phase and at the end of the phase, no post-calculation of the costs takes place. This means that the waterboards are responsible for dealing with the lack or remaining budget at the end of each phase. The remaining budget (cost underrun) at the end of each phase can be kept by the waterboards as a reward for efficiently executing the project. In contrast, in the case of shortage of the budget (cost overrun), the waterboards should pay the expenses themselves. Applying these modifications, it was hoped that the efficiency of the HWBP projects would increase as a result of less administrative work and the incentive for better estimating the costs (Deel B, 2017). So to summarize this section, the financing regime of projects in HWBP-2 was based on post-calculation while the financing regime of the projects in HWBP is based on pre-calculation.

1.3.5 Risk allocation and cost contingency in HWBP

Another difference between the projects in HWBP and HWBP-2 is the way the risks are allocated between the waterboards and the PD-HWBP. In HWBP-2, the PD-HWBP was responsible for the risks since all project costs were paid based on post-calculation. In HWBP, however, the party who can manage a risk best is responsible for that risk (Deel B, 2014, 2017). Therefore, all project related risks that can be controlled by the waterboards are born by them and the risks related to, for instance, change in the laws and regulations (known as exogenous risks) are born by the PD-HWBP.

In HWBP, a budget should be assigned in the cost estimate of the project for the foreseen risks (known unknowns) and the unforeseen risks (unknown unknowns). The amount of contingency to address the foreseen risks is defined based on the quantified amounts of the identified risks in the risk register. The unforeseen risks are determined based on a percentage of the Base Costs (in Dutch: totale voorziene kosten). To ensure that the projects do not reserve cost contingency more than needed, ranges are defined for the amount of risk reservation per phase. Ranges are required since different projects have different levels of complexity and, as a result, different cost contingency is required. Table 1-1 presents the relation between the percentage of foreseen and unforeseen cost contingency in each phase of an HWBP project (Deel B, 2014, 2017). These percentages are suggested based on the experiences of experts in RWS. PD-HWBP uses the concept of 'comply or explain' meaning that the projects which deviate from these ranges in their estimates should clarify these deviations (Deel B, 2017).

Table 1-1 The percentage of cost contingency in different phases of an HWBP project (Deel B, 2014)

Project Phase	Unforeseen part	Minimum percentage of cost contingency	Maximum percentage of cost contingency
Exploration	70%	25%	40%
Plan Development	70%	20%	35%
Tender & Award	50%	10%	25%
Changes after the tendering	30%	5%	20%

In the phases Exploration and Plan Development, the projects may ask 5% of the Base Cost of that phase as the unforeseen cost contingency (Deel B, 2017). As shown in Table 1-1, the allowed percentage of unforeseen reservation in the Exploration and the Plan Development phases is 70% of total risk reservation. In the Tender & Award phase, the unforeseen reservation is 50% of total risk reservation (Deel B, 2014). The minimum and maximum percentages of cost contingency per phase (shown in Table 1-1) are a proportion of the total project Base Costs.

There is a remark regarding the percentages of cost contingency in Table 1-1. The percentages show the amount of foreseen and unforeseen contingency for the total project budget while the projects have to determine the cost contingency for each phase based on the budget of that phase (and not the total project budget). This has made Table 1-1, as a reference for the amount of cost contingency, less relevant in the practice.

1.4 Research design

This section explains the research design for this doctoral research. First the research objectives and the research questions are explained. Then, the purpose of social science and the different research paradigms within social science are expounded. Next, the research methods applied to answer each research question are presented.

1.4.1 Research necessity

In the Netherlands, flooding has become very rare, as a result of strong governmental responsibility and high protection standards, but the potential impact of a major flood may be disastrous to this relatively small country (Van Alphen et al., 2011), that is densely populated. Research shows that due to the circumstances such as sea level rise, more periods of (heavy) rainfall and increase in the temperature, the flooding may have a bigger impact now compared to 50 years ago. As the Dutch population is increasing, there would be more potential victims in case of a flooding (Delta Programme, 2016). The Netherlands needs to be prepared for the consequences of the rising sea level, land subsidence and rising temperatures. This means looking further ahead and making effective long-term plans. The HWBP objectives of improving all flood defence facilities (that do not meet the safety norms according to the standards) until 2050 are significant and vital. Therefore, two ambitions are defined (Programmaplan, 2019):

1. Increasing the flood defence improvement to 50 km per year.

2. Reducing the average costs of the flood defence improvement to 7 million euro per kilometre.

The special location of the Netherlands, climate change and the ambitions of HWBP make the importance of risk management evident. These ambitions cannot be achieved without special attention to risk management.

Despite the suggested benefits of risk management (see section 1.2), the study of Raz et al. (2002) reveals that risk management practices are not widely used. A similar conclusion is drawn by Bannerman (2008). In a recent study, Olechowski, Oehmen, Seering, and Ben-Daya (2016) state that despite the recognition of risk management as a means to improve the chance of success within projects, many organizations lack the application of risk management practices. Empirical research about project performance data of major organizations across a variety of industries shows that wherever risk management is insufficiently applied, projects fail more often (D. Hillson & Simon, 2007). Well-known examples of ineffective risk management are: Panama Canal, the Airbus 380, and nuclear waste depository in Yucca Mountain, Nevada (Kendrick, 2006; Shore, 2008; Alarcon, Ashley, de Hanily, Molenaar, & Ungo, 2011; Swift, 2015). In case of the Netherlands, projects such as North/South metro Amsterdam, Zeesluis IJmuiden, and the Juliana canal can be named.

There is, therefore, a need, from both academia and practice, to improve risk management application in projects. The ambitions of HWBP and the examples of lack or poor application of risk management rises the concerns regarding the importance of improving risk management applications in the projects. This concern forms the core of this doctoral research and is deliberated from several aspects (such as improving risk management application and improving estimating cost contingency) in this dissertation. By successfully implementing risk management in projects, meeting the ambitious goals of HWBP seems to be more realistic.

1.4.2 Research objective, research scope, and research questions

By the time of writing this dissertation (mid-2019), the projects in HWBP-2 are almost finished (except the project Markermeer dikes) and the projects in HWBP have been started. An evaluation of risk management in HWBP-2 can provide PD-HWBP, waterboards and anyone involved in the realization of the flood defence projects insights in the current situation of risks management and the possible improvements. Moreover, next to the process of risk management, the practices for determining the cost contingency, as the buffer to use in case of occurred risks, should be investigated and optimized. The many lessons learned in risk management of HWBP-2 can be collected and used in HWBP projects. These statements are summarized as the following research objectives:

To improve risk management application in HWBP projects by identifying the areas of improvement and providing an overview of the common risks and the percentages of cost contingency in the projects.

The most important assumption in this doctoral research is that risk management contributes to achieving project success. Although investigating the contribution of risk management to project success is not the main subject of this dissertation, it cannot be neglected due to its influences on the topic of improving the application of risk management. Chapter 2 of this dissertation, therefore, investigates the role of risk management in achieving project success.

The scope of this research is on HWBP projects. However, other public and private organizations, where suited, are researched as well. The research focuses mainly on the uncertainties in estimating costs and uncertainty on time is not considered. Based on the research objectives, the main research question is formulated as:

What are the lessons learned of applying risk management in HWBP-2 projects and how can these lessons be used to improve the risk management application in HWBP projects?

To answer the main research question, six sub-questions are formulated:

1. How can the risk management maturity of construction projects be measured?
2. What are the improvement areas of risk management in projects of public organizations?

3. What can be learned from risk identification of HWBP-2 projects?

4. What can be learned from the cost contingency of HWBP-2 projects in the preparation phase?

5. What can be learned from the estimated and realized cost and cost contingency of HWBP-2 projects in the execution phase?

6. How can the application of risk management in HWBP projects be improved based on the observed results in HWBP-2 projects?

The research is performed in four phases. By finishing each phase, a step is taken to answer the main research question. These four phases are:

I. Risk management maturity of projects (sub-question 1 and 2).

II. Type of risks and identified and occurred risks (sub-question 3).

III. Estimated and realized cost (contingency) of the projects (sub-questions 4 and 5).

IV. Recommendations to improve the application of risk management in the projects (sub-question 6).

The first three phases are distinct from each other and the outputs from these phases create the input for phase four.

1.4.3 Social science's purpose and research paradigms

McQueen and Knussen (2002) state "research is carried out in order to describe, understand, explain, and predict a progressively sophisticated function" (p.4). Simply stated, research on any subject aims to describe a phenomenon or a process that has previously been inaccessible or vaguely understood. The major aim of studying social sciences is to increase understanding of forces that exist in the world. (McQueen & Knussen, 2002). Social science researches are performed under different circumstances. These circumstances lead to the formation of major and different perspectives in the social sciences paradigms (Kuhn, 1970). Paradigms are "worldviews or belief systems that guide researchers" (Tashakkori & Teddlie, 1998) (p.3).

According to Kumar (2011), there are mainly two paradigms that create a foundation for social science studies. The first paradigm, which has roots in physical studies, is the positivist/empiricist approach (Tashakkori & Teddlie, 1998; Kumar, 2011). The positivism paradigm declares that only statements which reflect reduction to an observation can claim a meaningful knowledge (Garner, Wagner, & Kawulich, 2009). The second paradigm is a naturalistic approach called interpretivism or constructivism (Tashakkori & Teddlie, 1998; Dash, 2005; Kumar, 2011). While the positivist paradigm is based on senses and the idea that knowledge can be obtained by observation and experiment, the constructivism paradigm explains that social realities are interpreted according to individual's ideology and thoughts (Kothari, 2004). The positivist paradigm is deductive and highlights an objectivist approach for social studies and focuses on quantitative methodology (Kothari, 2004; Kumar, 2011). The interpretivist paradigm, contrarily, is inductive and stresses subjective approaches, implementing qualitative methodology (Tashakkori & Teddlie, 1998; Dash, 2005; Kumar, 2011). Qualitative research is concerned with qualitative phenomenons, subjective assessment of attitudes, opinions and behaviour and is a function of the researcher's insights, the chosen research strategy and the nature of collected data (Kothari, 2004; Kumar, 2011).

History of social science shows a huge debate, named by Tashakkori and Teddlie (1998) as "war", among the supporters of these two fundamental perspectives (Kuhn, 1970). From the ashes of this "war", a third paradigm emerged which is called pragmatism (Sayer, 1992; Tashakkori & Teddlie, 1998; Johnson & Onwuegbuzie, 2004; Easton, 2010). This paradigm has common features with positivism and interpretivism, that have been imagined incompatible before, and it encourages a multidisplinary research that contains both quantitative and qualitative methods (Sayer, 1992; Tashakkori & Teddlie, 1998). With the emerge of the pragmatism as a new paradigm, a mixed-methods approach is formed (Tashakkori & Teddlie, 1998).

Mixed-methods focus on combining or mixing both quantitative and qualitative research approaches into a single study (Johnson & Onwuegbuzie, 2004; Creswell, 2013). A key feature of mixed-methods research is its methodological pluralism, which, frequently, leads to a superior research (compared to mono-method research). Mixed-methods research does not replace either qualitative or quantitative approaches but rather benefits from the strengths and minimizes the weaknesses of these methodologies in a single research (Johnson & Onwuegbuzie, 2004).

1.5 Research methods applied in this research

Kumar (2011) mentions: "differences in philosophical perspective in each paradigm combined with the aim of a study, to a large extent, determine the focus, approach and mode of enquiry which determine the structural aspect of a study design" (p.104). The different characteristics of the research questions in this research require different research methods for data collection and analysis. Investigating the risk management implementation would be limited if the focus of research is put merely on one paradigm. Investigating the maturity of risk management in projects, for example, needs a more constructivism approach while to investigate the amount of cost contingency in projects, a positivist approach is more suited. For each research question, a specific approach is chosen, which is elaborated here.

1.5.1 SQ1: How can the risk management maturity of construction projects be measured?

The research question is answered following a constructivism approach and applying qualitative methods. To measure the maturity of risk management in projects, it was necessary to develop a new and generic risk maturity model. Creating this new risk maturity model began with an intensive literature review. The literature review included a study of Best Practices of risk management, several risk management frameworks and guidelines, and available risk maturity models. By using Qualitative Content Analysis (QCA), the risk management statements mentioned by most of these sources are extracted. QCA is a method which describes the meaning of qualitative data systematically. The method is performed by breaking the qualitative data down to coding frames which cover the features of the qualitative data (Schreier, 2014). This essential and preliminary task provides the most important risk management aspects, addressed by risk management literature, which is required for a comprehensive risk maturity model. Based on this step, a conceptual Risk Maturity Model (RMM) is developed. This RMM, named RiskProve, is tested and improved using two focus group sessions. A focus group is a qualitative research approach in which attitudes, opinions or perceptions towards an issue are investigated by a group of experts (Langford & McDonagh, 2003). A focus group allows the participants to be triggered by one another's opinions and build upon each other's viewpoint. Based on the comments provided by the experts, the conceptual model was improved and ready to be tested in practice. The results of these steps are presented in Chapter 3 of this dissertation.

The model developed as an answer to the first research question is used to answer the second research question.

1.5.2 SQ2: What are the improvement areas of risk management in the projects of public organizations?

The selected research approach for this question is pragmatism using mixed methods with a sequential design where the qualitative method is more dominant than the quantitative method (Tashakkori & Teddlie, 1998; Johnson & Onwuegbuzie, 2004; Creswell, 2013). The project members of more than 30 projects in nine organizations are asked to evaluate the maturity of risk management in their projects using RiskProve. To make the results more homogenous and comparable, only the results from the risk management maturity of two public organization are presented in this dissertation.

Using RiskProve, the experts in the projects were asked to evaluate the maturity of their project in risk management (quantitative step). Subsequently, group discussions and focus group sessions were held per project to discuss the results. The experts in each project elaborated on their scores for risk management maturity and mentioned the possible recommendations for improving risk management in their projects. The results of this research question are presented in Chapter 4. By answering the first and second research question, the first phase of the research is completed.

In the second phase of the research, the type of risks, identified and occurred risks in the HWBP-2 projects are investigated.

1.5.3 SQ3: What can be learned from the risk identification of HWBP-2 projects?

To answer this research question, the risk registers of the projects should be investigated. The research has an exploratory feature and, therefore, case study method is selected. A case study is characterized by a flexible form of data collection and is useful when exploring an area where little is known or where the researcher wants to gain a holistic overview. It is relevant when the focus of the study is in depth rather than breadth (Kothari, 2004; Kumar, 2011). In this research question, multiple case study design with several embedded units of analysis are chosen (Yin, 2014). Each case is a separate project and, in each case, different dimensions are explored: type of risk, phase of risk etc. The risk registers of 18 projects of HWBP-2 during the whole project lifecycle are collected and investigated. Investigating the risk registers was, however, not sufficient to collect the occurred risks, therefore, in-depth interviews were held with the project managers (or project controller) of each project to collect the occurred risks. This phase has a pragmatism approach where the investigation of the cases, are quantitatively oriented and the interviews are qualitatively oriented. The results of this research question are presented in Chapter 5. Answering this research question, the second phase of the research is fulfilled.

1.5.4 SQ4: What can be learned from the cost contingency of HWBP-2 projects in the preparation phase? And SQ5: What can be learned from the estimated and realized cost and cost contingency of HWBP-2 projects in the execution phase?

The estimated and required cost contingency of HWBP-2 projects are investigated using a case study design. In total, 44 projects of HWBP-2 are selected as the cases in this research and the estimated and realized costs are collected from the cost documents (SSK estimate and the reports of final cost settlement in Dutch: eindafrekeningsverslag) of the projects. These cases are analysed for percentage and amount of estimated and required cost contingency, estimated and realized budget. This phase follows a positivist approach and the results are quantitatively discussed. Chapter 6 and Chapter 7 of this dissertation explain the result of the fourth and fifth research questions respectively.

Based on the outcomes of the phases I, II and III, recommendations are drawn for both the waterboards and the PD-HWBP to improve their risk management practices.

1.5.5 SQ6: How can the application of risk management in HWBP projects be improved based on the observed results in HWBP-2 projects?

These recommendations based on phases I, II and III are validated in three focus group sessions with experts from both PD-HWBP and waterboards. This phase has a more constructivist approach. Chapter 8 presents the results of this research question.

1.6 Scientific and social relevance

There are three types of research in management: theory building, theory testing, and problem centred/practical research (Crowther & Lancaster, 2012). This doctoral research falls under the third category, problem centred/practical research, which aims to investigate a problem or an issue in an organization and provide recommendations for improvement. Problem centred/practical research can at the same time be used for theory building and theory testing (Crowther & Lancaster, 2012). Even though the research is more of a problem centred/practical research, its outcomes are scientifically relevant as well. The research answers practical problems and, at the same time, contributes to the current literature using new approaches. To elaborate, the studies by Wendler (2012) and Tarhan, Turetken, and Reijers (2016) show that theoretical reflections of the maturity models are mostly missing and that risk maturity models are not empirically validated. RiskProve (the risk maturity model developed in this research) covers these deficiencies as it is based on in-depth literature and as it is validated by several experts, familiar with risk management (scientific relevance). During the research, RiskProve is applied by more than 30 projects in nine organizations to test it and to improve risk management practices in these organizations (social relevance).

The database of risks (Chapter 5) is another deliverable of this research with both social and relevance contributions. Most available literature investigates only the opinions of experts about the type of risks. Regarding the scientific relevance, this research uses a new approach by investigating the identified and occurred risks in real construction projects and discussing the type of risk and the phases in which risks are identified and occurred risks. In this sense, the research is novel and provides new insights to the current literature. Regarding the social contribution, the risk database developed in this research can be used for benchmark, as well as for cross-project analysis for learning purposes.

Another deliverable of the research comprises the results of the investigation of estimated and realized cost and cost contingency (Chapter 6 and Chapter 7). Scientifically seen, there are few studies discussing the accuracy of cost contingency in projects. The magnitude of cost overrun in the construction projects (e.g. Cantarelli, Molin, van Wee, and Flyvbjerg (2012)), is merely discussed from the perspective of one of the main project parties; either client or contractor. Also the evolvement of cost contingency in the pre-construction phases of construction projects is underexposed in literature. All these research gaps are covered in this research. The results of investigating the estimated and realized costs of the projects are supposed to be used to improve the current regulation of HWBP. The recommendations drawn in this research (Chapter 8) will be used as an input to develop the Program Management Plan (in Dutch: Programmabeheersplan)

1.7 Dissertation outline

Figure 1-3 shows the relation between the different chapters of this dissertation and the four phases of the research. This dissertation starts with Chapter 1 (this chapter) followed by Chapter 2 which explains the contribution of risk management to project success. The first phase of the research (shown by the green circle) includes Chapter 3 and Chapter 4. Chapter 3 explains the development of RiskProve while Chapter 4 discusses the results of implementing it in projects of public organizations. The second phase of the research (shown by the yellow circle) is presented in Chapter 5 which is about the investigation of the risk registers of projects. The third phase (shown by the red circle) includes Chapter 6 and Chapter 7 which are respectively about the cost and cost contingency performance of the project in the preparation and execution phases. The drawn recommendations to improve risk management, based on the previous chapters, are validated in Chapter 8 which is the fourth and final phase of the research. Chapter 9 is the final chapter. In this chapter, the research questions are answered and recommendations for future research are given.

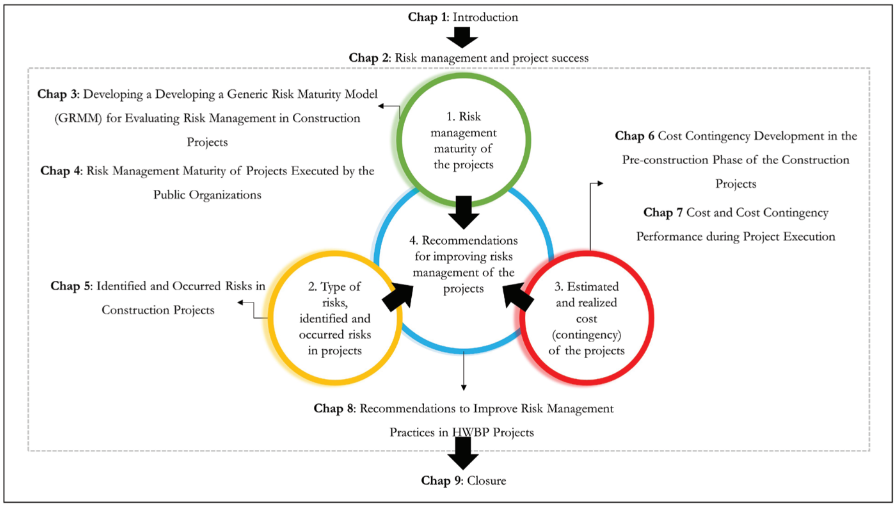

Figure 1-3 The different phases and the related chapters in this research

To conclude, Table 1-2 shows an overview of the data collection in this research.

Table 1-2 An overview of data collection in each chapter and phase of the research

Chapter	Phase	Data collection
3	I	Literature review and two focus group sessions with 16 experts from diverse companies
4	I	Nine HWBP projects of one waterboard and 7 projects of one department of Rijkswaterstaat
5	II	16 HWBP-2 projects of different waterboards
6	III	29 HWBP-2 projects of different waterboards
7	III	44 HWBP-2 projects of different waterboards and 51 projects of one contractor
8	IV	Three focus group sessions with 17 experts from different waterboards and experts from PD-HWBP

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CHAPTER 2

Does Risk Management Contribute to Project Success?

Abstract

Contribution of risk management to project success is usually taken as given. There are, however, some doubts about the role risk management plays in the success of projects. This chapter discusses the impact of risk management on project success by reviewing the literature. The relevant publications discussing the contribution of risk management to project success are found in the databases of Scopus and Google Scholar. The examined literature shows that there is a link between risk management and project success. Literature concludes that even a moderate risk management application has positive effects on the project outcomes. Risk management improves decision-making, increases stakeholder satisfaction and delivery according to requirements. Risk management creates an overview of the current situation, creates risk acceptance by establishing trust and helps the stakeholders reaching common actions more efficiently and effectively. Applying risk management does not necessarily lead to project success. A common failure mode for risk management is to perform it as a tick-the-box exercise or as an administrative process. Risk management can probably lead to project success if it is applied based on 'risk-based thinking and acting'. This mind-set emphasizing on soft skills, culture, and organizational context considers risk management as a routine component in any project activity. As risk management contributes to project success, it is rational to investigate the application of risk management in projects and identify the possible improvement areas in applying risk management in projects.

2.1 Is performing risk management really useful?

Currently, due to the increased competition and globalization, project success becomes even more critical to organizations, and yet many projects still suffer delays, overruns, and even failure (Raz, Shenhar, & Dvir, 2002). Many research efforts have been done to define the project success. For example, A. J. Shenhar, D. Dvir, O. Levy, and A. C. J. Maltz (2001b) develop a multidimensional framework for assessing project success. They measure the success of project bases on four dimensions of: (1) project efficiency, (2) impact on the customer,(3) direct business and organizational success, and (4) preparing for the future (Shenhar et al., 2001b). While a project can be considered a failure in the short-term while, it is a success in the long run (for example Sydney opera house. Literature on risk management indicates that applying risk management increases the possibility of project success (Flyvbjerg, Bruzelius, & Rothengatter, 2003; Nicholas & Steyn, 2012). Despite all mentioned advantages of risk management, authors such as Staveren (2015) mention, that the benefits of risk management are never proven and that there is no clear cause and consequence relation between risk management and organization or project success. Similarly, the study of Bakker (2011) shows that there is little evidence that risk management contributes to IT project success. He further concludes that: "risk management can contribute to IT project success if the project has clear and fixed requirements, uses a strict method of system development, and has historical and applicable data available, collected from previous projects" (Bakker, 2011, p.143).

In this regard, two questions come to the mind:

1. Does risk management contribute to project success?
2. How does risk management contribute to project success?

These questions are the core topics of this chapter, which are answered by reviewing the literature.

Search for relevant articles is performed using Scopus and Google Scholar. Keywords used for searching the articles included 'risk management' and 'project success' in title, abstract, and keyword. The keywords are selected from the previously published studies such as De Bakker, Boonstra, and Wortmann (2014). The search is limited to English journal or conference papers within the subject areas of 'Engineering' and 'Business, Management and Accounting' without limiting the search to a specific period. As a result, 192 articles are found. The abstracts of these articles are studied and the relevant researches investigating the role of risk management in project success are investigated. The investigated articles are further elaborated.

Regarding the link between risk management and project success, two main streams can be found in the literature: Instrumental and Empirical approaches. These streams are elaborated.

2.2 Instrumental approach of risk management towards project success

The Instrumental approach includes publications which state that risk management should be done because it is mentioned in the handbooks of project and risk management (ISO31000, 2009; PMI, 2013). This approach is called 'normative' or 'instrumental' approach (De Bakker, 2009; De Bakker, Boonstra, & Wortmann, 2010; Willumsen, Oehmen, Stingl, & Geraldi, 2019). There is an assumption within the normative literature that risk management creates value for project outcomes and, thereby, increasing the probability of project success. Authors such as Kutsch, Browning, and Hall (2014) name these guidelines as being self-evidently correct and entirely sufficient (Kutsch et al., 2014). For example, Lam, Wang, Lee, and Tsang (2007) state that risk management helps to assess and ascertain project viability, analyse and control the risks to minimize loss, and avoid dissatisfaction and enhance profit margins. Similarly, Hillson and Simon (2007) state that where risk management is properly implemented, more projects meet their objectives. Likewise, Kishk and Ukaga (2008) mention that risk management contributes to project success by increasing team involvement, creating a process for the reporting of potential problems and increasing the team's support. These publications, however, do not include any empirical evidence that supports their assumptions nor evidence to show the link between project risk management and project success (De Bakker, 2009; De Bakker et al., 2010; Oehmen, Olechowski, Kenley, & Ben-Daya, 2014; Willumsen et al., 2019).

The instrumental approach is, criticized by several authors. De Bakker et al. (2010) (p.495) indicate that: "project management handbooks assume that the application of processes and procedures "according to the rules of the handbook" automatically will lead to project success. In case a project fails, the project processes and procedures have to be better executed or improved." For example, Hillson and Simon (2007) mention that the low score of risk management in terms of effective deployment (compared to other project management techniques) suggests that the problem, probably, lies in the application of risk management in practice. De Bakker, Boonstra, and Wortmann (2011) state that the instrumental approach assumes that the world around us is objective, can be explained by causal relationships, stakeholders act as one actor who can influence the world, stakeholders are fully informed and act rationally when making decisions. By taking the right actions, risk management can influence project success. In the context of the instrumental approach, the success of a project is objectively measurable based on success criteria such as time and budget. Further, the success of a project is assumed to be the same for all stakeholders, and it can be determined when its deliverables are realized (De Bakker et al., 2011). Investigating the literature, De Bakker et al. (2010) and De Bakker (2009) conclude that the assumptions supporting the contribution of risk management to project success are not always correct. For example, the sequence of the risk management process (identification, analysis, responses, and monitoring and review) is often not followed or quantitative risk analysis is not always considered as valuable in projects. In addition, the knowledge of risks does not automatically imply that this knowledge is used for managing these risks.

Similar to De Bakker et al., Kutsch et al. (2014) criticize the instrumental approach mentioning that the overarching premise of risk management is a reductionist, predictive analysis in which a large and complex problem is reduced to smaller problems that can be managed in isolation. This reductionist approach works properly if linearity exists, but such situations are rare in the real world. As another critic to the instrumental approach, Raz et al. (2002) state that one cannot expect that a single, universal risk management process and its supporting set of tools and techniques would be applicable to all types of projects and lead to similar results in all projects. Doubts about the correctness of the assumptions taken in the instrumental approach have introduced a new stream known as empirical approach.

2.3 Empirical approach of risk management towards project success

The empirical approach seeks empirical evidence to prove the relation between risk management and project success. Kishk and Ukaga (2008) studied the relation between risk management and project success in two projects (the sector is not mentioned) considering the success criteria according to the iron triangle (cost, time quality). Using interviews and document study, they concluded that the causes of the projects' failure could be directly related to the extent of risk management applied. In addition, the level of risk management performed had a direct impact on the success of the project. They suggest that effective risk management should be continuously undertaken throughout the project lifecycle to enhance project success (Kishk & Ukaga, 2008). They do not elaborate, however, what is meant by 'effective risk management'.

Elkington and Smallman (2002) investigated the influence of risk management on project success in the utility sector, measuring the status of project completion, level of benefits delivered, project manager satisfaction, schedule and budget as success criteria. Using a questionnaire, they asked the project managers in one organization about the amount of risk management undertaken, the stage of the project in which risk management is applied and how successful the projects are. They concluded that there is a strong link between the amount of risk management undertaken in a project and the level of success of the project; more successful projects had used more risk management. They showed, in addition, that the project had a higher chance of succeeding if risk management was used earlier in a project (Elkington & Smallman, 2002).

Raz et al. (2002) present the results of an empirical study, answering the questions of whether and how risk management helps the projects. Investigating the data of more than 100 projects in different industries, they examine the impact of risk management practices such as risk identification, probabilistic risk analysis, planning for uncertainty and trade-off analysis on various dimensions of project success (Raz et al., 2002). The success dimensions are measured based on the four criteria of functional, technical, time, and cost. Their study revealed that risk management practices are effective and are related to project success (Raz et al., 2002). Risk management practices were more applicable to higher-risk projects meaning that risk management tools and techniques were more helpful in projects with higher risks, by improving project performance on more dimensions than for lower-risks projects. Raz et al. (2002) mention that high-risk projects are not less successful than low-risk projects, but high-risk projects are often managed more carefully, resulting in an improved outcome. Furthermore, they claim that all projects (small or big) will benefit from regular application of risk management. Based on their results, the impact of risk management is mainly on better meeting the time and budget goals and less on product performance.

Zwikael and Ahn (2011) examine the effectiveness of risk management practices in reducing project risk, conducting a survey to 701 project managers in a multinational, multi-industry study. They consider project success using traditional measures of time, cost and quality (known as iron triangle) including customer satisfaction as well. Results of this study show that there is a link between project context (industry and country wherein a project is executed) and the perceived levels of project risk, and the extent of risk management application. Their findings suggest that “risk management moderates the relationship between risk level and project success” Zwikael and Ahn (2011) (p.35). They conclude that risk management contributes to project success by reducing uncertainty and improving project success rates. Even a moderate application of risk management decreases the negative effect risks have on project success. In line with Raz et al. (2002), the study by Zwikael and Ahn (2011) suggests that there is no direct link between the level of project risk and project success meaning that it cannot be concluded that a project with high-risk profile is less successful than a project with less risk profile. Similar to Raz et al. (2002), they found that risk management is more effective in the projects with the medium-to-high level of risk.

Oehmen et al. (2014) and De Bakker et al. (2011) argue that risk management success cannot be measured by only overall project success. De Bakker et al. (2011) further state that a broader view (beyond iron triangle) to measure the role of risk management on project success is needed.

De Bakker (2009) proposed and validated a new model regarding the contribution of risk management to (IT) project success. In his model, De Bakker (2009) assumes that each of the risk management practices of risk management planning, risk identification, risk registration, risk analysis, risk allocation, risk reporting, and risk control may have influence on project success. He identified six indicators for project success: 1. Delivery on time, 2. Delivery within budget constraints, 3. Delivery according to requirements, 4. Stakeholder satisfaction, 5. Project member work satisfaction, and 6. Future potential of the project result for the organization with stakeholder communication and stakeholder collaboration. Based on his study, 'stakeholder satisfaction' and 'delivery according to requirements' were the two important contributions of risk management to project success. The results indicated that the following risk management practices influenced the project result: risk allocation, risk management planning, risk identification, and risk analysis, and risk reporting. Risk identification creates a common view between the project actors towards the project risks. Risk analysis creates awareness about the situation, and a feeling of urgency to take actions to manage risks. Risk allocation and risk reporting stimulate people to take action. In general, risk management can create an overview about the current situation, and it defines the direction for efficient actions. Furthermore, the risk management application creates possibilities for reflection and evaluation of project at specific moments in the project. (De Bakker, 2009).

De Bakker et al. (2011) mention that the effects of risk management on project success are not only caused by the results of rational problem-solving methods, but the actions taken by participants in (one or more) risk management activities can have effects on project success. They investigate the relationship between project risk management and (IT/IS) project success in two Enterprise Resource Planning (ERP) system implementation projects. The study shows that the stakeholders use risk management to communicate with each other, and to influence other stakeholders' behaviour. Risk management application influence on the risk perception of the stakeholders by creating positive feelings, creating acceptance of risks and through establishing trust. Risk management contributes to project success by influencing the stakeholders' risk perception by conforming their perception and making them more conscious of the context of their responsibilities (De Bakker et al., 2011).

In another study, De Bakker, Boonstra, and Wortmann (2012) investigate seven ERP projects. They indicate that risk identification followed by risk reporting, risk registration, risk allocation, risk control and risk analysis have the highest impact on project success. (De Bakker et al., 2012). They conclude that risk identification and risk reporting have more contribution to project success than the other risk management activities. They state further that their results may have some implication upon the use of specific risk management activities in projects. This conclusion by De Bakker et al. (2012), however, does not mean that some steps of risk management may be excluded.

Teller (2013) emphasizes on the risk management culture as a soft skill of risk management. Risk management culture encompasses the general awareness about the importance and the potential contribution of risk management, the acceptance and commitment to risk management application, communication of risks between stakeholders, trust and openness toward risks, and risk tolerance. It is suggested that a strong risk management culture has a significant influence on the effectiveness of the risk management process (Teller, 2013).

Oehmen et al. (2014) investigate the role of risks management in project success in several sectors (mostly in aerospace & defence sector). They define five success dimensions: 1. Quality Decision Making, 2. High Program Stability 3. Open, problem-solving organization, 4. Overall new product development project success, and 5. Overall product success. They identify six categories of risk management: 1. Develop risk management skills and resources. 2. Tailor risk management to and integrate it with new product development, 3. Quantify impacts of risks on your main objectives, 4. Support all critical decisions with risk management results, 5. Monitor and review your risks, risk mitigation actions, and risk management process, and 6. Create transparency regarding new product development risks. Oehmen et al. (2014) investigate the association of the six risk management practices with five dimensions of project success. The results reveal that the risk management practices directly influence on improved decision-making, program stability and problem-solving but only indirectly influence project and product success.

Carvalho and Rabechini Junior (2015) distinguish the soft and hard sides of risk management, mentioning that the hard side of risk management (such as risk planning, risk identification, risk analysis qualitative and quantitative, etc.) covers only part of risk management aspects. The hard side can help to manage foreseeable uncertainties and variability. Dealing with unforeseeable uncertainties, however, needs the focus on the soft side (context, strategic approach to risks and uncertainties, risk communication, attitude, assignment, and relationship with stakeholders). Carvalho and Rabechini Junior (2015) show that the soft side of risk management has relation with both the hard side of risk management and project success. They conclude that focusing on the hard side of risk management is not enough to effectively managing the risks.

Pimchangthong and Boonjing (2017) explore the influence of risk management practices (including risk identification, risk analysis, risk response planning, and risk monitoring and control) on IT project success, measured by process performance and product performance. Similar to De Bakker (2009) they found that risk identification and risk response planning positively influence the process performance and the total IT project success.

In an attempt to attribute project success to risk management application, De Bakker et al. (2014) conduct an experiment involving 53 project groups of four members each. In this experiment, some project groups do not conduct any risk identification before executing their project. Other project groups identify the risks with the support of a risk identification prompt list. In the groups that perform risk identification supported by a prompt list, project members of some groups were also asked to discuss the risks with each other, while other groups did not discuss the risks. They measure the project success in timely delivering the project and by asking individual project members for their opinions on the outcomes of their project. The results of this experiment revealed that the use of risk identification and discussing the risks positively influences objective and perceived project success (De Bakker et al., 2014).

Kutsch et al. (2014) use an entirely different approach and explain why risk management was ineffective in IT projects. Literature attributes risk management ineffectiveness to factors such as lack of knowledge, confusion about the word risk, unavoidable human errors, and subjective methods (Hubbard, 2009). Kutsch et al. (2014) investigated 19 information system projects that experienced one or more critical incidents in spite of complying with risk management practices. They identified 26 critical incidents in these projects. These critical incidents were researched retrospectively. They asked the respondents to identify the risks that led to the incident. In total, 208 risks were identified. Afterwards, they explored the knowability of each risk, asking the respondents whether they knew about the risks before the incidents. Their study revealed that only two percent (four risks) of the 208 identified risks (contributing to the 26 critical incidents) were unknown to the respondents and the respondents knew about 204 risks. Most incidents, therefore, were not originated from a lack of knowledge or unknown risks, but from the way known risks were managed (or not). The study of Kutsch et al. (2014) revealed that of the 204 known risks, 94 percent (192 risks) were identified in the formal risk management process. A further 18 percent of the 192 identified risks (34 risks) were excluded from the risk assessment process, dropping out of the management process. A further 28 percent (44 risks) of the risks that made it through the earlier stages (158 risks) were not actively managed, even though managers had already invested effort in identifying and assessing them. Their results show that, on average, 44 percent of all known risks were not actively managed. Their findings suggest that inefficient risk management was the main reason for the critical incidents and failure of the projects.

2.4 Discussion

From the investigated literature, it can be concluded that either risk management as a whole or each risk management activity separately contributes to project success. Except Oehmen et al. (2014), all explored literature concluded that risk management directly influences the project success. Based on the studied literature, risk management influences project success through improved decision-making, program stability and a proactive open organization. Risk management contributes to project success by increasing stakeholder satisfaction and delivery according to requirements. Risk management creates an overview of the current situation and helps the stakeholders to reach common actions more efficiently and effectively. It creates acceptance of risks through establishing trust. Furthermore, risk management creates the common view of project members towards project risks, creates awareness among the stakeholders about the situation, and a feeling of urgency to react on risks and it stimulates taking actions.

The investigation of the literature shows, at the same time, the limitation that the researches face proving the link between risk management and project success. In total, four limitations can be named which are further expounded.

First, the investigated literature shows that measuring project success merely using the iron triangle criteria is not enough and a broader view on project success is required. Some authors such as Oehmen et al. (2014) and De Bakker et al. (2011) expand their research to more dimensions of project success (such as quality decision making and open, problem-solving organization), however, the effects of risk management on other dimensions of project success (A. J. Shenhar, D. Dvir, O. Levy, & A. C. Maltz, 2001a) are still unknown.

Second, previous research shows that the question whether risk management contributes to project success requires more specification by defining which aspect of risk management and which dimensions of project success. Different aspects of risk management can have different impacts on different dimensions of project success. The limitation of current literature is that only a few dimensions of risk management are investigated.

Third, due to the nature of projects, the success of a project cannot be merely accredited to risk management. Bannerman (2008) indicates that if a major project is successful, it can be difficult to unequivocally attribute any part of that outcome to risk management. He argues that success is usually attributed to good fortune (even luck). Furthermore, individuals tend to attribute success as resulting from their own skills and unique contributions to the project. Willumsen et al. (2019) mention that due to the complexity of project management, it is difficult to know whether risk management activities have led to project success, or if there are other compounding factors that have played a role. Furthermore, repeatability is difficult because of the unique characteristics of each project. Since a project is a series of activities over a longer period of time, consisting of numerous interactions between stakeholders, it is impossible to isolate and investigate the effects of one particular activity on project outcomes in a real project (De Bakker et al., 2014).

Fourth, success and the link between risk management and project success are dependent on the perception of the stakeholders. This important limitation is mentioned as a research limitation by De Bakker et al. (2012) and De Bakker et al. (2011) and concluded by Willumsen et al. (2019) as well. Interestingly, De Bakker et al. (2014) reflect on their early work by De Bakker et al. (2012) and De Bakker et al. (2011) mentioning that this evidence (the link between project success and risk management) remains rather weak, primarily due to being solely based on project stakeholder's opinions. Bannerman (2008) shows that success is differently perceived by different roles. Project stakeholders may use various project success definitions or may have different perceptions of risk, based on their beliefs, attitudes, judgments, and feelings and influenced by group thinking and trust (Lehtiranta, 2014). In addition to stakeholder's perceptions, the context and the situation in which the success is measured should be considered. According to Willumsen et al. (2019), risk management practice does not create value independently and risk management value creation depends on the objectives and circumstances and the content that the stakeholder perceives as important. The results by Willumsen et al. (2019) revealed that, in some cases, the stakeholders perceived risk management created value by doing the opposite of what literature suggests. For instance, while the literature on risk management suggests that transparency might have added value for risk management (Teller & Kock, 2013), the results by Willumsen et al. (2019) mentioned that "sometimes the best way to manage the risk was to avoid creating transparency" (p.741). Likewise, the level of transparency was sometimes dependent on the project phase; in the tender phase, the projects were less open to share the information. This makes the whole subject regarding the contribution of risk management to project success more complicated because it leaves little possibility (if not no possibility) for a general conclusion. The fact that examined researches focus primarily on the opinions of the stakeholders, makes an 'objective' validation of these perceptions impossible. Willumsen et al. (2019) suggest that "instead of trying to establish causation and statistically proving the effects of risk management on project success, the complexity, ubiquity, impreciseness and contextual nature of the value creation of risk management should be embraced" (p.747).

De Bakker et al. (2010) state that just having knowledge about risk management alone or just performing risk management by following the steps is not enough to contribute to project success. A research by Boulding et al. (1997) revealed that performing risk analysis and disclosing the probability of failure does not necessarily stop the managers supporting a product or project. Boulding et al. (1997) mention: "a risk analysis decision aid, by itself, does not appear to overcome the effects of an ambitious information environment" (p.172). Hence, next to the question of whether risk management contributes to the project success, there is an important question: when does risk management contribute to project success? This question has led to a topic in risk management known as 'risk-based thinking and acting' (In Dutch: risico gestuurd denken en handelen). This mind-set distinguishes risk management from being merely an administrative work, and emphasises on the culture of risk management in an organization. 'Risk-based thinking and acting' is about explicitly discussing risks and considering risk management not as a separate activity but as a mind-set, by all the project members, that is cautious about uncertainties in a natural way. The same as crossing a street or walking on a high edge, when one naturally looks left and right, or when one considers the situation and act accordingly. DE MEYER, Loch, and Pich (2002) mention that to deal with extreme uncertainties, in case of innovative projects, managers should go beyond traditional risk management and more toward flexibility and learning. De Bakker et al. (2010) conclude that "the fact that project management practitioners pay attention to project risks is likely to have more impact on project success than following the steps prescribed in the risk management process" (p.502).

The mind-set of 'risk-based thinking and acting' has been acknowledged by several scholars as well. Raz et al. (2002) state that project risk management should become part of the culture of projects and a routine part in any project activity. Risks should be seen as normal and expected, and good risk management as prudent practice and not doom-saying activity (Kutsch et al., 2014). Risk management should be more than a process alone. It should be a capability, developed within an organization through learning and practiced over a long period. Risk management is not just about identifying and assessing risks and assigning mitigation measures and contingencies but it is the ability to respond quickly and effectively to threats as they arise (Bannerman, 2008). A popular failure mode of risk management is to merely execute it as a tick-the-box exercise or as an administrative process (Kutsch et al., 2014; Willumsen et al., 2019).

Risk management impacts on project success when it creates awareness and shapes the expectations. In this view, risk management contributes to project success, because the stakeholders are aware of the fact that there are risks, and they adjust their expectations and behaviour accordingly (De Bakker et al., 2010). The process of risk management must allow for a certain amount of ambiguity, uncertainty, and subjectivity and the organizations must be aware, question, and be open about risks (Lehtiranta, 2014). To have an impact on the project success, the organisational context (e.g. culture) as well as individual aspects (e.g. expectations, intuition and judgement, biases, power conflicts, trust and learning), should be considered in risk management. Effective project risk management requires broad involvement and collaboration across all segments of the project team and its environment (Thamhain, 2013). Effective risk management requires more attention to soft skills, and a combination between the hard and soft skills (Söderlund & Maylor, 2012; Carvalho & Rabechini Junior, 2015). In unforeseeable situations, using soft skills, such as intuition and judgement to provide fast responses and adapt to the new situation, creating a balance between anticipation or preparedness and resilience can be crucial (Carvalho & Rabechini Junior, 2015).

2.5 Conclusion and implication for this research

This chapter has investigated the role of risk management in project success. Despite the aforementioned research limitations in defining a link between risk management and project success, literature confirms that risk management application contributes to project success. Literature sketches the situations wherein risk management contributes to project success as well. Investigating the literature, it can be concluded that even a moderate application of risk management positively influences project outcomes. Risk management contributions to project success are, among others, by improving decision-making, increasing stakeholder satisfaction and delivery according to requirements. Attention to both soft and hard factors of risk management can contribute to more project success.

As risk management contributes to project success, it is, therefore, important to investigate the application of risk management in projects and identify the possible improvement areas in applying risk management. Understanding the influence of risk management on project success, the rest of this doctoral research will be devoted to investigating the possible improvements in the application of risk management.

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CHAPTER 3

Developing a Generic Risk Maturity Model for Evaluating Risk Management in Construction Projects

Abstract[4]

The literature on risk management acknowledges a growing number of Risk Maturity Models (RMM). However, for the construction sector, there is no validated risk maturity model that is based on both theory and experts' opinions. In this paper, a generic Risk Maturity Model (called RiskProve), inspired by the EFQM model, is developed and validated to remedy this shortcoming. RiskProve uses a list of statements extracted from risk management literature by means of Qualitative Content Analysis. The statements and the model are both validated by means of two focus group sessions, based on which the statements and the model are improved. According to the experts, RiskProve is easy to use and provides projects with a clear picture of potential improvements regarding risk management. Project managers can use RiskProve for planning and improving risk management, as well as for cross-project analysis for learning purposes. Further research on application of RiskProve in real projects is recommended.

Keywords: Project risk management, Risk Maturity Model, Evaluation of risk management, Threat and opportunity, Construction management

3.1 Introduction

The occurrence of risks, either positive (opportunity) or negative (threat), is unavoidable in projects because projects are surrounded with uncertainties (Murray, 2009). Many researchers and practitioners believe that risk management increases the possibility of project success (Chapman & Ward, 2003; Flyvbjerg, Bruzelius, & Rothengatter, 2003; Global, 2004; Ren & Yeo, 2004; D. Hillson, 2006; Yeo & Ren, 2009; Holzmann & Spiegler, 2011; Cagliano, Grimaldi, & Rafele, 2015; Schwindt & Zimmermann, 2015; Olechowski, Oehmen, Seering, & Ben-Daya, 2016). Over the past decades, risk management has increasingly received attention (Raz & Hillson, 2005; D. Hillson, 2006; Verbano & Venturini, 2011; Yaraghi & Langhe, 2011). Despite this, risk management practices are either not implemented thoroughly, or can still be improved in several ways (Yaraghi & Langhe, 2011; Mu, Cheng, Chohr, & Peng, 2014; Dyer, 2016; Olechowski et al., 2016). Those organizations that have tried to integrate risk management into their business processes have reported various degrees of success (Bosler, 2002).

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Organizations wishing to implement a formal approach to risk management (or to improve their existing approaches) require a clear definition of objectives, proper planning and resourcing, and effective monitoring and control. Additionally, these organizations need a tool that can help them to identify the areas of improvement and to measure the progress in improving risk management (Bosler, 2002; Yeo & Ren, 2009). A Risk Maturity Model (RMM) is such a tool that can be used for this purpose.

An RMM aims to measure the maturity of risk management in projects and/or organizations. Maturity in terms of risk management means an evolution towards the full development of risk management processes (RIMS, 2015a). RMMs help to improve the risk management processes in projects (Schiller & Prpich, 2014). A major benefit of an RMM is the possibility to identify the areas of strengths and weaknesses in risk management (Bosler, 2002; Loosemore, Raftery, Reilly, & Higgon, 2006; Strutt, Sharp, Terry, & Miles, 2006; Macgillivray, Sharp, Strutt, Hamilton, & Pollard, 2007; Yeo & Ren, 2009; Zou, 2010; Wendler, 2012). Yeo and Ren (2009) state that there is a close link between risk management maturity and success of projects. Identifying the maturity of risk management can contribute to minimizing costs and improving profitability (Zou, 2010; Oliva, 2016).

Despite the suggested capabilities of RMMs, the development of RMMs is still subject of discussion (Jia et al., 2013). Wendler (2012) studied 237 articles in maturity models in more than 20 domains. The results reveal that, despite the increasing number of maturity models, most models are not empirically validated. A similar conclusion is drawn by Tarhan, Turetken, and Reijers (2016). Furthermore, Wendler (2012) mentions that the theoretical reflections of the maturity models are mostly missing. Therefore, there is a need for an RMM that is based on sound theoretical and empirical foundations. Such an RMM is presented in this paper and its applicability and approach are validated.

This paper is structured as follows. Section 3.2 discusses the research background and formulates the research objectives. In Section 3.3, a description of the methods used in the research is given. Next, in Section 3.4, the development of a new RMM for the construction projects is presented. Section 3.5 explains the validation of the model based on two focus group sessions. Next, in Section 3.6, the improved model is discussed and compared with other models. Finally, in Section 3.7, conclusions are drawn, and in Section 3.8, recommendations are given for further research and the use of the model in practice.

3.2 Research background and problem formulation

The term maturity for a project is known as a measurement concept that demonstrates progress in development (Loosemore et al., 2006; Öngel, 2009; Cienfuegos Spikin, 2013; Minsky & Fox, 2015). Maturity in terms of risk management indicates an evolution towards full development and application of the risk management process. Linked closely with continuous improvement, risk management maturity expresses the degree of formality and application of risk management activities (Minsky & Fox, 2015).

The concept of maturity models is rooted in the field of quality management and can be traced back to the quality revolution of the 1970s (Strutt et al., 2006; Macgillivray et al., 2007; Wendler, 2012). Two early maturity models are Nolan's model and Crosby's Quality Management Maturity Grid (QMMG) (Wendler, 2012; Mu et al., 2014). During the last decade, several maturity models were expanded to other domains (Wendler, 2012; Kwak, Sadatsafavi, Walewski, & Williams, 2015). The European Foundation for Quality Management (EFQM), the INK (the Dutch version of the EFQM) model, and the Project Excellence Model (Westerveld, 2003) are some examples of maturity models.

The past decade also saw the development of several risk maturity models (RMMs). Table 3-1 compares 13 RMMs in terms of type and number of the maturity levels. Despite the differences among the available RMMs, they all consist of two common components. First, RMMs define a set of levels that describe the evolvement of a project in risk management. These levels present sequential and hierarchical progression, which are connected. A project achieves a new level of maturity when a new system of practices, not present at lower levels of maturity, has been established. The second component refers to the measured objects: the capabilities or attributes. This means RMMs have to define criteria for measurement such as conditions, processes, and application targets (Wendler, 2012; Cienfuegos Spikin, 2013). The models in Table 3-1 contain either four or five levels of maturity. The models are either in the form of an attributes-maturity level matrix, a questionnaire or a combination of an attributes-maturity level matrix and a questionnaire. The attributes-maturity models are in the form of a table in which the attributes are presented in the first column and the levels in the first row. The table provides explanations for each attribute in each level. The user can select a level of maturity based on the explanations provided for each attribute.

Table 3-1 List of Risk Maturity Models

Source	Maturity levels	Type
Risk Maturity Model (D. A. Hillson, 1997)	Four	Attributes-maturity level matrix
Project Management Maturity Model (J. Kent Crawford, 2006)	Five	Attributes-maturity level matrix
Risk Management Maturity Model (RMMM) (Bosler, 2002)	Four	Attributes-maturity level matrix
IACCM Business Risk Management Maturity Model (IACCM, 2003)	Four	Questionnaire and attributes- maturity level matrix
Risk Management Capability Maturity Model (Yeo & Ren, 2009)	Five	Questionnaire
PMI's Risk Management Maturity Model (Loosemore et al., 2006)	Four	Attributes-maturity level matrix
Project Risk Maturity Model (Hopkinson, 2012)	Four	Questionnaire
Risk Management Capability Maturity Model (Macgillivray et al., 2007)	Five	Attributes-maturity level matrix
Risk Management Maturity Model (Zou, 2010)	Four	Questionnaire
Construction Risk Management Maturity Model (Öngel, 2009)	Four	Questionnaire
The Alarm National Performance Model for Risk Management in the Public Services (Alarm, 2009)	Five	Questionnaire and attributes-maturity level matrix
Risk Maturity Model for Dutch municipalities (Cienfuegos Spikin, 2013)	Five	Questionnaire
RIMS Risk Maturity Model for ERM (Minsky & Fox, 2015; RIMS, 2015)	Five	Questionnaire

A project achieves a certain level if all processes have reached or exceeded a certain level (Schiller & Prpich, 2014).

The models with questionnaires request detailed questions to be answered. The user can select a score between 1 to 4 or 1 to 5, depending on the level of maturity. In the combined models, the attributes-maturity level matrix is used to better score the questions in the questionnaire. The more mature a project is in risk management, the more steps of risk management are implemented (Cagliano et al., 2015).

Most of the RMMs examined in this research do not clarify in which industry the model should be used. Among the studied models in Table 3-1, only three models explicitly mention the sector in which the model may be used; the models by Öngel, (2009) Loosemore et al. (2006) and Zou (2010) were designed specifically for construction projects. In addition, the origin of the statements or the aspects used in the models in Table 3-1 is indistinct. Most of the available RMMs are merely based on the experience of the authors and suffer from a lack of theoretical background (Wendler, 2012). Some RMMs do not cover all risk management steps. This is an important shortfall of the RMMs, as they are supposed to check the extent to which risk management is applied in projects. Furthermore, as also addressed by Wendler (2012) and Tarhan et al. (2016), most RMMs are not validated. Together, this results in weaknesses in these models, which in turn could result in a skewed picture of a project's risk maturity. To overcome these shortcomings, this research develops a generic risk maturity model (RiskProve) for the construction sector, based on sound theoretical and empirical bases. Furthermore, expert opinions from those involved in construction projects are used to validate the model. The objective of this study is twofold:

- To develop a generic risk maturity model on solid theoretical and empirical bases, covering the most important activities of risk management.
- To have the model and its benefits validated by risk management experts.

The research aims to answer the following research question:

What are the validated elements of a Generic Risk Maturity Model for construction projects?

This research contributes to the current literature by developing an RMM that addresses the shortcomings of other models. It covers all relevant activities of risk management and adopts a more holistic view on risk management. The practitioners can use RiskProve for improving risk management and cross-project analysis for learning purposes.

3.3 Method

To achieve the research objectives, the research was performed in two parts: a Theoretical part consisting of Qualitative Content Analysis on selected literature and an Empirical part by means of focus groups. The Theoretical part deals with the first research objective while the Empirical part deals with the second one. The results of the Theoretical part are inputs for the Empirical part. The overall research design is presented in Figure 3-1

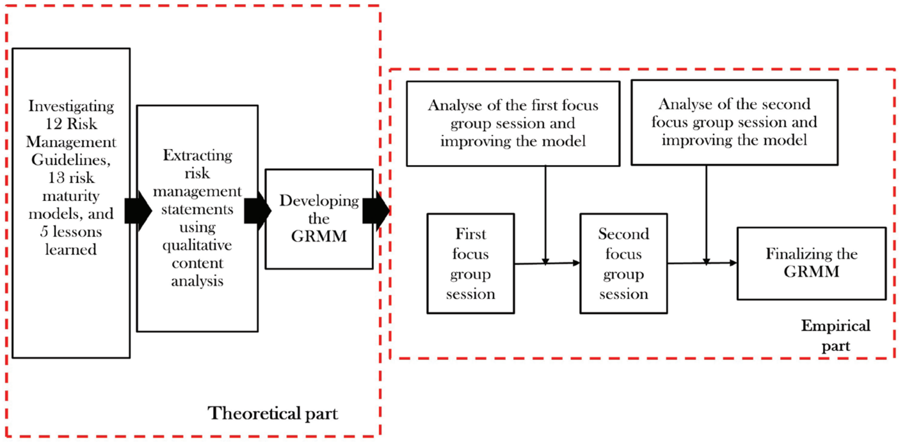

Figure 3-1 Research design

In the Theoretical part of the research, 12 risk management guidelines (RMG), 13 Risk Maturity Models (RMMs), and 5 articles dealing with Lessons Learned (LL) about applying risk management were examined. By using Qualitative Content Analysis (QCA), the risk management statements mentioned by most of these sources are extracted. QCA is a method, which describes the meaning of qualitative data systematically. The method is performed by breaking the qualitative data down to coding frames which cover the features of the qualitative data (Schreier, 2014). Next, RiskProve was developed as an interactive Excel file using the extracted statements from the literature.

In the Empirical part of the research, the statements as well as RiskProve were tested by performing two focus group sessions. In the first focus group, only the statements extracted from the literature in the Theoretical part were tested. In the second focus group, in addition to evaluating the statements, the experts were asked to evaluate the model design. The purpose of performing focus groups is to check the extent to which the statements in RiskProve cover the reality of risk management practice. A focus group is a research approach in which attitudes, opinions or perceptions towards a matter are tested in interaction within a group (Asbury, 1995; Langford & McDonagh, 2003). A focus group is chosen because it enables the gathering of rich qualitative data.

The focus group sessions were held in the Netherlands with participants from diverse groups of experts. Morgan (1993) discerns two group definition characteristics: 1. *break* characteristics, those that differentiate groups from each other and 2. *control* characteristics,

3

those that groups have in common (Morgan, 1993). To fulfil the control characteristic, the participants for both focus groups are selected based on their familiarity with risk management in projects. For the first focus group session, the researchers contacted a group of experts in the Netherlands known as the Special Interest Group in Probabilistic Risk Analysis (SIGPRA). The experts in this group work in both public and private companies and meet regularly to discuss the experiences and developments in risk management. The participants in the first focus group session were selected from both clients and contractors to fulfil the *break* characteristic of the group. For the second focus group session, the participants are selected among the risk managers of a consultant company, which provides risk management services to both client and contractor companies (and hence are familiar with the requirements of both groups regarding risk management).

In the first focus group session, the experts' opinions were asked about the *clarity* and *completeness* of the statements in RiskProve. The experts were provided with printed statements of the models in two forms: *Individual* and *Group* forms. The experts were asked to work individually first and give their comments in the *Individual* form about the statements they felt were unclear or should be removed. In addition, the experts were asked to add statements if needed in the space provided on the *Individual* forms. In this way, statements which the experts felt were missing could be added. Next, the experts were divided into sub-groups of three persons and asked to select a list of the most important statements they felt should be added or removed and write them down in the *Group* form. In this way, the experts had to argue within their groups as to why a statement should be added or removed. This step was followed by a plenary session during which the experts were asked to discuss the comments they had written down on the *Group* forms. Each sub-group read the list of selected statements, followed by discussions between the sub-groups about their comments on the statements.

The second focus group session included the same steps as the first focus group session, and in addition, the experts were provided with the RiskProve Excel file. The experts were asked to work individually with RiskProve in Excel. They were asked to score a recent project in which they were involved and, while doing so, to examine the model with regard to clarity and completeness of the statements as well as convenience and ease of use. The experts were given the *Individual* form so they could provide their opinion about the clarity and completeness of the statements. In addition, they were given the *Group* form so they could decide for each sub-group whether a statement should be added or removed. This process had also been used in the first focus group. In addition, a list of questions was provided to each expert, based on criteria defined by Kolfschoten (2007), to check RiskProve for completeness, usefulness, understandability, ease of use, willingness to use RiskProve again, and need for improvement. At the end, plenary discussions were held, and the experts' opinions were gathered about the statements and the model.

For both sessions, the experts were informed beforehand that they were supposed to examine an RMM, without being provided with further information. Both sessions started with a short presentation about risk management maturity and RMMs in general, followed by a brief introduction about the newly developed RiskProve. In both presentations, only the framework of the model was provided; the statements were not explained. Afterwards, the experts were instructed how to examine the model. Each focus group session took about one hour, with two facilitators present for each session. The first focus group session was held with nine experts and the second one with seven experts. During the first session, one of the facilitators wrote down the important discussion points. During the second session, besides taking notes, the session was also recorded (audio only). All forms (i.e. *Individual* form, *Group* form, and the list of questions), notes, and audio recording were analysed afterwards.

3.4 Theoretical part: model development

First, the development of RiskProve is explained. Next, the selection of the statements is explained. Finally, the proposed application of RiskProve is discussed.

3.4.1 Developing a Generic Risk Maturity Model

RiskProve is inspired by the European Foundation of Quality Management (EFQM). The EFQM model is established to assess a project organization's progress towards excellence (Qureshi, Warraich, & Hijazi, 2009). The EFQM model has the same intention as RMMs, despite their different focus areas. Several scholars have shown that the EFQM can also be adjusted for projects (Westerveld & Walters, 2001; Bryde, 2003; Westerveld, 2003). Moreover, the EFQM follows the Plan, Do, Check and Act (PDCA) cycle, which insists on repeatable implementation of the model. This characteristic is comparable to the continuous application and improvement characteristic of risk management.

Figure 3 2 presents a schematic model for RiskProve, which is a customized model of the EFQM. Risk management literature shows that two conditions should be in place in order to successfully apply risk management in a project. The first condition addresses any activities that ensure that risk management can be performed in a project (e.g. training, culture, policy and strategy and commitment towards risk management) (BSI & IEC, 2001; ISO31000, 2009). These activities fall under the *Organizational* category in RiskProve. The second condition addresses the activities related to applying risk management (e.g. identifying risks, applying control measures, monitor and review). These activities are addressed by the *Application and Process* category in RiskProve. The *Organizational* category in RiskProve is comparable to the *Enablers* area in the EFQM. Activities in this category are the steps a project needs to take in order to implement risk management. The *Application and Process* category is comparable to the *Results* area of the EFQM model, since it measures the results of risk management application.

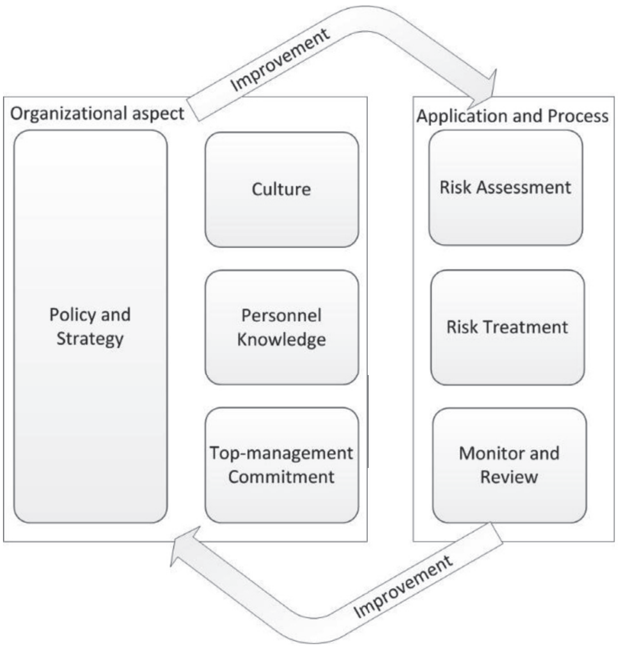

Figure 3-2 The RiskProve framework

On a deeper level, the *Organizational* category of RiskProve contains four aspects, adjusted from the EFQM model:

- Policy and Strategy, which is comparable to Strategy aspect in the EFQM model. The aspect focuses on the availability of a risk management policy in a project. This enables effective implementation of risk management. Risk management policy specifies the processes, methods, and tools to be used for managing risks (Global, 2004; ISO31000, 2009).

- Culture, which can be compared to Partnership and Resources in the EFQM. The aspect emphasises building a risk-aware culture within a project and by all the stakeholders (FERMA, 2002). Hillson and Simon (2007) mention the individuals' attitudes toward risks, organization risk culture, and combination of theoretical knowledge, and effective behaviours and attitudes as success factors for risk management.

- Personnel Knowledge, comparable to the People aspect in the EFQM. This aspect focuses on the availability of skilled and competent staff, training, and allocation of appropriate resources (BSI & IEC, 2001; COSO, 2004; Van Well-Stam, Lindenaar, & van Kinderen, 2004).

- Top-management5 Commitment, comparable to the Leadership aspect in the EFQM. This aspect highlights the role of top-management in the introduction of risk management and ensuring its on-going effectiveness (Loosemore et al., 2006; D. Hillson & Simon, 2007; ISO31000, 2009).

These four aspects cover the 19 risk management success criteria as mentioned by Yaraghi and Langhe (2011).

The *Application and Process* category contains the steps of the risk management process as mentioned by several standards and guidelines (ISO31000, 2009; PMI, 2013). This category checks the application of risk management given the availability of the aspects in the *Organizational* category. This category has three aspects:

- *Risk Assessment.* This aspect covers all activities related to identifying, quantifying, formulating, and prioritizing risks etc.

5 By the top-management the line management of an organization is meant.

- *Risk treatment.* This aspect contains activities such as selecting a response strategy, implementing the control measures, considering residual and secondary risks etc.
- *Monitor and Review.* This aspect is about controlling previous steps, identifying new risks and updating the status of risks, and control measures.

The feedback loops between the two categories in RiskProve reflect on the continuous improvements based on the result of RiskProve application in both categories (*Organizational and Application and Process*).

3.4.2 Extracting the statements for RiskProve

A list of Risk Management Guidelines (RMG) was selected to extract the important statements in risk management (Table 3-2). These resources are well-known risk management guidelines, selected based on studies by Raz and Hillson (2005), Koutsoukis (2010), and RIMS (2011), who compared several RMGs. Furthermore, a list of articles dealing with Lessons Learned (LL) of successfully applying risk management in construction projects was selected through a scan of recent literature (Table 3-2). The LLs are investigated to extract the activities that can lead to successful application of risk management. In addition to these resources, the RMMs provided in Table 3-1 are further examined to extract the statements, in case any were not mentioned in RMGs and LLs.

Table 3-2 List of 12 RMG sources and 5 LL sources selected

RMG sources	LL sources
(PMI, 2013)	(Marcelino-Sádaba, Pérez-Ezcurdia, Lazcano, & Villanueva, 2014)
(ISO31000, 2009)	(Hertogh, Baker, Staal-Ong, & Westerveld, 2008)
(FERMA, 2002)	(Greiman, 2013)
(COSO, 2004)	(Staveren, 2009)
(D. Hillson & Simon, 2007)	(Staal-Ong, 2016)
(Van Well-Stam et al., 2004)	
(Chapman, 1997)	
(Murray, 2009)	
(Canadian Standards, 1997)	
(Global, 2004)	
(BSI, 2000)	
(BSI & IEC, 2001)	

By means of Qualitative Content Analysis (QCA), the statements mentioned by most of these references were selected. Table 3-3 provides the statements with their reference to the literature. Table 3-4 and Table 3-5 provide the list of risk management statements for each aspect. To remove some duplications and to resolve ambiguity, the formulation of the statements was adjusted. RiskProve consists of 58 statements in total.

Table 3-3 List of the statement extracted based on RMMs and RMGs, and LLs

Aspect	Extracted statements	References
Policy and strategy	Understand and define internal context	1*,2*,3*,4*,5*,6*,7*,8*,9*,10*, 11*,1**
	Understand and define external context	1*,2*,3*,4*,5*,6*,7*,8*,9*,10*,11*, 12*,1**
	Organization Commit resources for Risk Management	1,3,4,7,8,9,10,11,12,1*,2*,3*,4*, 5*,6*,7*,8*,9*,10*,11*,12*,1**, 3**,4**
	Risk management purposes in line with organization/project purposes	4,7,13,1*,2*,3*,4*,5*,6*,7*,8*,10*, 11*,12*,1**,3**
	Decide the appropriate level of RM (risk thresholds)	4,8,11,12,1*,2*,3*,4*,5*,7*,8*,10*, 12*,1**,3**
	Appropriate mechanisms for sharing risk amongst those best placed to manage them	7,11,1*,2*,2**,4**
	A documented framework of risk management processes	2,3,5,6,7,8,9,10,11,13,1*,2*,5*,6*, 7*,8*,10*,11*,12*,1**,5**
	Define RM tools and techniques	3,12,1*,2*,5*,6*,7*,8*,12*,4**
	Availability of a clear mechanism for external/internal communication and reporting	3,1*,2*,3*,4*,5*,6*,8*,10*,11*,12*, 1**,3**,4**
	Availability process for deciding the project reserve	2,10,11,1*,3*,7*,8*,9*,10*,11*,12*, 2**,3**,5**
	Database for collecting historical information about risk management	2,10,1*,2*,10*,11*,12*,2**,5**
	Define the frequency of monitor, reviewed and reporting	7,9,1*,2*,3*,4*,5*,6*,8*,10*,12 *,1**
Top-management commitment	Risk Management is encouraged and supported by the top management	1,3,4,5,6,7,9,10,11,12,13,3*,4*,8*, 10*,11*,2**,4**,5**
	Communication of goals and strategies of risk management	4,13,1*,10*
	Top management reviews risk management reports actively to make decisions	2,3,6,7,9,10,11,12,8*
	Establishing clear accountability and responsibility of roles for managing risks	11,13,1*,2*,3*,4*,5*,6*,7*,8*,9*, 10*,11*,12*,2**,4**
	Availability of a Risk management plan	7,1*,2*,5*,6*,7*,9*,10*,11*,12*, 1**,3**
	Integration of risk management with other project management processes	2,4,6,7,10,11,1*,2*,3*,4*,5*,6*,7*, 10*,11*,12*,2**,3**,5**

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Personnel knowledge	Regular (internal or external) training to enhance skills	1,3,4,5,6,7,10,11,12,2*,3*,4*,10*,11*,3**,4**
	Availability of experienced team responsible for risk management	1,3,4,10,12,2*,4*,9*,10*,11*,12*,2**
	Use of external experts and services in risk management	1,3,6,8,10,12,4*,9*,11*
	Involved staff exhibit an appropriate level of competence in application of risk management	3,4,8,9,2*,4*,7*,9*,10*,11*,12*,4**
Culture	Personnel's understand and belief in the benefits of risk management	1,3,4,5,6,9,10,11,3*,4*,4**,5**
	Project is flexible and willing to change	1,3,5,6
	No blame culture and accepting that people make mistakes	3,6,11,10*,11*,2**
	Team members trust and openness in reporting risks to internal and external stakeholders	6,7,9,1*,10*,12*,2**,3**,4**,5**
	Alignment of risk management attitude and goals of personnel with the organization	4,1*,3*
	(Strong) teamwork (with internal and external partners)	2,3,5,6,7,8,9,10,11,12,13,1*,2*,3*,4*,6*,7*,8*,9*,10*,11*,12*,2**,3**,4**
Risk assessment	Risks and opportunities are identified proactively based on different objectives and methods	2,3,5,6,7,8,9,10,11,12,1*,2*,3*,4*,5*,6*,7*,8*,9*,10*,11*,12*,1**,2**,3**,4**,5**
	Dividing risks based on different classification	1*,3*,5*,6*,7*,8*,9*,11*,12*,2**
	Key external stakeholders as well as company professionals participate in risk identification	2,3,6,7,8,9,10,11,12,13,1*,2*,3*,4*,6*,7*,8*,9*,10*,11*,12*,2**,3**,4**
	Qualitative and quantitative risk analysis	3,5,6,8,9,10,12,13,1*,2*,3*,4*,5*,6*,7*,8*,9*,10*,11*,12*,1**,2**,3**,5**
	Comparing the estimated risk against risk criteria and prioritizing risks	2,6,9,11,1*,2*,3*,4*,5*,6*,7*,8*,9*,10*,11*,12*,2**,5**
Risk treatment	Identify list of potential responses	1*,3*,4*,5*,6*,7*,8*,9*,10*,11*,12*,1**,3**
	Selection of an appropriate risk strategy for each risk	2,4,7,11,12,1*,2*,3*,4*,5*,6*,7*,8*,9*,10*,11*,12*,1**,2**,3**
	Nominate risk owner with authority and responsibility for each risk	2,5,6,7,9,11,13,1*,2*,3*,4*,5*,6*,7*,8*,9*,10*,11*,12*,1**,2**,5**
	Sharing risks (both internally and externally)	4,5,6,1*,2*,4*,8*,10*,11*,12*,2**,3**,5**
	Preparing risk treatment plan	7,1*,2*,4*,5*,6*,7*,8*,9*,10*,11*,12*,1**,3**
	Implications of planned risk responses	7,1*,2*,4*,5*,6*,7*,8*,9*,10*,11*,12*,1**,4**
	Considering residual and secondary risks	7,1*,2*,3*,4*,5*,6*,7*,8*,9*,10*,11*,12*,1**,2**

Monitor and review	Regular evaluating and improving Risk management process	1,3,5,6,7,8,9,11,12,1*,2*,3*,4*,5*,6*,7*,8*,9*,11*,12*,3**
	Post- project assessment and Capturing lesson learned	2,4,5,6,7,11,1*,2*,3*,4*,5*,6*,7*,8*,10*,11*,12*,1**,3**,4**
	Routine and consistent application of risk management	1,3,7,9,11,13,1*,2*,3*,4*,5*,6*,7*,8*,9*,10*,11*,12*,1**,2**,3**
	Check actual progress against risk treatment plan and update of risk management plan	1,2,3,7,9,10,11,12,1*,2*,3*,4*,5*,6*,7*,8*,9*,10*,11*,12*,1**,2**,4**
	The whole process is documented	1,2,4,5,7,11,12,13,1*,2*,3*,4*,5*,6*,7*,8*,9*,10*,11*,12*,1**,2**,3**,4**
	Regularly communicating and reporting relevant risk information to the key stakeholders	1,2,3,4,6,7,9,10,11,13,1*,2*,3*,4*,5*,6*,7*,8*,9*,10*,11*,12*,1**,2**,3**
	Regularly communicating and reporting relevant risk information to the organization management	1,3,4,6,7,9,10,11,13,1*,2*,3*,4*,5*,6*,7*,8*,9*,10*,11*,12*,1**,2**,3**

RMM sources: 1= (D. A. Hillson, 1997), 2= (J. Kent Crawford, 2006), 3= (Bosler, 2002), 4= (IACCM, 2003), 5= (Yeo & Ren, 2009), 6= (Loosemore et al., 2006), 7= (Hopkinson, 2012), 8= (Macgillivray et al., 2007), 9= (Zou, 2010), 10= (Öngel, 2009), 11= (Alarm, 2009), 12= (Cienfuegos Spikin, 2013), 13= (Minsky & Fox, 2015; RIMS, 2015)
RMG sources:1*=(PMI, 2013), 2*=(ISO, 2009), 3*= (FERMA, 2002), 4*= (COSO, 2004, Moeller, 2007), 5*= (Hillson and Simon, 2007), 6*= (Van Well-Stam, Lindenaar, and van Kinderen 2004), 7*= (Chapman, 1997), 8*= (OGC, 2009), 9*= (Canadian Standards, 1997), 10*=(Global, 2004), 11*= (BSI, 2000), 12*= (BSI and IEC, 2001),
LL sources: 1**=Marcelino-Sádaba et al. (2014), 2**=(Hertogh et al., 2008), 3**= Greiman (2013) 4**= Staveren (2009)

Table 3-4 Extracted statements for the category Organizational

Aspect	Statements
Policy and Strategy	Understand and define internal context
	Understand and define external context
	Project organization Commit resources for Risk Management
	Risk management purposes in line with organization/project purposes
	Decide the appropriate level of RM (risk thresholds)
	Appropriate mechanisms for sharing risk amongst those best placed to manage them
	A documented framework of risk management processes
	Define RM tools and techniques
	Availability of a clear mechanism for external/internal communication and reporting
	Availability process for deciding the project reserve
	Database for collecting historical information about risk management
	Define the frequency of monitor, reviewed and reporting

Top-management Commitment	Risk Management is encouraged and supported by the top management
	Communication of goals and strategies of risk management
	Top management reviews risk management reports actively to make decisions
	Establishing clear accountability and responsibility of roles for managing risks
	Availability of a Risk management plan
	Integration of risk management with other project management processes
Personnel Knowledge	Regular (internal or external) training to enhance skills
	Availability of experienced team responsible for risk management
	Use of external experts and services in risk management
	Involved staff exhibit an appropriate level of competence in application of risk management
Culture	Personnel's understand and belief in the benefits of risk management
	project is flexible and willing to change
	No blame culture and accepting that people make mistakes
	Team members trust and openness in reporting risks to internal and external stakeholders
	Alignment of risk management attitude and goals of personnel with the organization
	(Strong) teamwork (with internal and external partners)

Table 3-5 Extracted statements for the category Application and Process

Aspect	Statements
Risk Assessment	Risks and opportunities are identified proactively based on different objectives and methods
	Dividing risks based on different classification
	Key external stakeholders as well as company professionals participate in risk identification
	Qualitative and quantitative risk analysis
	Comparing the estimated risk against risk criteria and prioritizing risks
Risk Treatment	Identify list of potential responses
	Selection of an appropriate risk strategy for each risk
	Nominate risk owner with authority and responsibility for each risk
	Sharing risks (both internally and externally)
	Preparing risk treatment plan
	Implications of planned risk responses
	Considering residual and secondary risks
Monitor and Review	Regular evaluating and improving Risk management process
	Post- project assessment and Capturing lesson learned
	Routine and consistent application of risk management
	Check actual progress against risk treatment plan and update of risk management plan
	The whole process is documented
	Regularly communicating and reporting relevant risk information to the key stakeholders
	Regularly communicating and reporting relevant risk information to the organization management

3.4.3 The RiskProve application

RiskProve is presented as an interactive Excel document, with a separate sheet for each of the aspects (Policy and Strategy, Culture, etc.). The extracted statements for each aspect (as shown in Table 3-3 and Table 3-4) are linked to the corresponding aspects. The user scores the statements in each aspect by awarding it a score of 10, 7, 4, or 1. The final score of a specific aspect is equal to the average of the scores of the statement in each aspect.

There is a long discussion in literature regarding the optimal number of response categories or scale points. A key consideration in the number of response categories is whether the scale should be odd or even (Darbyshire & McDonald, 2004). Garland (1991) shows that presenting a midpoint in the Likert Scale causes distortion since the respondents have a tendency to select this middle point. Earlier, Matell and Jacoby (1972) advised on minimising the usage of a mid-point category and propose to either not include it at all or use scales with many points so respondents feel less inclined to choose the middle point. Following Matell and Jacoby, we propose an even point scale avoiding a middle point for RiskProve.

The nature of responses in a scale can be divided to agreement, evaluation, and frequency (Spector, 1992). The statements in RiskProve fall under the category evaluation. For evaluating the risk management implementation, four response choices were selected in this study. Each statement in risk management can be evaluated by applying one of the following descriptions: not applied, limitedly applied, to a large extent applied, or totally applied. Having fewer than four response choices does not cover risk management implementation completely, whereas more than four does not have sufficient added value. These response choices are used to make a verbal four-point scale with the above possibilities as the definition of each score. A verbal scale prevents ambiguity with regard to the actual meaning of each point (Spector, 1976).

For assigning values to the four-point scale, two criteria are considered. Spector (1976) shows that in a Likert Scale, response categories with equal intervals should be used (criterion 1). The second criterion is that if the information is gathered at the interval level of measurement, a two-sided, balanced scale must be used (either with or without a mid-point), so that the negative points on the scale mirror positive points on the scale (Spector, 1976). We decided to show the score of the statements in RiskProve between

1-10 in a verbal four-point scale. To fulfil the criteria, the scale of 1 to 10 is divided into three equal intervals, with the negative points mirroring the positive points as follows: 1 (not applied), 4 (limitedly applied), 7 (to a large extent applied), 10 (totally applied).

3.5 Empirical part: RiskProve validation

This section describes the results of the empirical part of the research, which is the validation of the RiskProve. This section elaborates on the results of each focus group session, the experts' remarks and the consequent improvements in RiskProve.

3.5.1 Analysis of the first focus group

In the first focus group session, the statements of RiskProve were validated with nine experts. Details about the experts are provided in Appendix A, Table 3-8. First, the comments provided in the Individual forms, filled by each participant, were examined and the remarks and feedback were recorded. Next, the Group forms were analysed, and the comments recorded, and afterwards, the comments made during the plenary discussion were reviewed. If the experts indicated a statement should be removed while that statement was mentioned in several pieces of literature, we did not apply the experts' comments.

Based on the comments received, the experts agreed with most of the statements. Only some of the statements were modified and a few were removed. An example of a removed statement is 'risks are shared with external parties' from the Risk Treatment aspect, which received the most comments; six out of nine experts stated that this statement was not necessary. Examples of remarks among the comments are 'depends on the goal of your risk management' or '[it] depends on the contract [and] not always possible'. During the plenary session, the contractor group explicitly mentioned that they will not share their risks with other parties: 'we will share top 5 or top 10 risks, but not all of the risks'. However, the client groups had no problems in sharing the risks. This statement was replaced with the statement 'the risk register containing the risks related to the project is shared between client and contractor' (see Table 3-5).

Some of the statements were modified based on the first focus group. For example, with regard to the statement 'the risk appetite of the organization/project is communicated to the external and internal stakeholders', both the client and the contractor participants indicated that they would not share their risk appetite with other parties. Treasury (2004, p.49) defines risk appetite as 'the amount of risk that an organization is prepared to accept, tolerate or be exposed to at any point in time'. One participant responded, 'internally [sharing the risk appetite] yes, but externally sharing is not necessary' or 'I do not know if I would tell my contractors about my risks appetite'. Therefore, this statement was modified to '… communicated internally'. Similarly, regarding the statement 'there is an internal or/and external training to enhance skills', one of the experts said: 'not as necessary, though external input is often refreshing' or 'it does not need to be external per se and it can be internal as well'. Based on the comments, this statement was adjusted to 'the personnel receive training for enhancing risk management skills'. Some comments were also made with regard to the statement 'risk and opportunities are identified'. One expert stated: 'Whether or not this is needed, depends on your definition of risk management. Strictly, thus, it is not needed'. PMI (2013) indicates that risk can be both positive (opportunity) and negative (threat). To clarify this statement, the word 'opportunity' was removed and instead, we mentioned in the introduction sheet of the model that the model deals with negative (threat) as well as positive (opportunity) risks.

Besides these changes, six statements were added to the model based on the experts' inputs (Table 3-6).

Table 3-6 List of added statements to the model

Aspect	Added statements
Policy and Strategy	The organization/project has a defined risk matrix for quantifying probability and consequence of risks (in time, cost, quality)
Risk Treatment and Mitigation	The cost/time of the most important rest risks (after applying the control measures) are considered as cost/time contingency
	A cost/time contingency is assigned for the unforeseen risks based on the complexity and size of the project
	The risk register containing the risks related to the project is shared between client and contractor
Monitor and Review	Cost/schedule documents are updated based on the status of risks
	Probability and consequences of active risks are updated based on the risk matrix of the organization

In addition to the statements, the experts were also asked (in both the Individual and Group forms) whether an aspect needed to be removed or changed. The only comment about the aspects was about Risk Treatment. One of the experts suggested that this aspect should be changed to Risk Treatment and Mitigation. This comment was applied, since the combination of 'treatment and mitigation' reflects the statements in this aspect better. The experts recognized all aspects in RiskProve without further remarks.

During the plenary session, the experts confirmed that RiskProve seems helpful in improving risk management.

3.5.2 Analysis of the second focus group

During the second focus group session, seven participants tested the statements - which had been revised based on the first focus group session - as well as RiskProve. Details about the experts are provided in Appendix A. The comments regarding the statements and the model were analysed separately following the same procedure as was used for the analysis of the first focus group session.

Compared to the first focus group session, the experts provided few comments about the statements, mainly about clarity and certainty of a few statements. No suggestions were done to remove a statement. Like the first focus group, the experts did not provide any remarks regarding the two categories, and as such, no remarks regarding the aspects in each category. Only the statement 'the project is flexible and willing to change' received some comments. The experts felt that the words 'flexible' and 'change' are ambiguous, and a project might not be flexible but could nevertheless perform well in applying risk management. This statement was removed from the final list. Table 3-7 provides the validated statements of RiskProve after the two focus group sessions. The final number of statements is 51.

Table 3-7 Validated statements of the RiskProve

Aspect	Statements after the focus group sessions
Strategy and policy	The project commits resources (tools, personnel, training, etc.) to risk management
	Risk management objectives are defined and documented
	Risk management objectives are in line with project objectives
	The risk appetite of the project is defined and documented
	The risk appetite document of the project is internally communicated and available
	The project has a documented process for risk management
	The risk management tools and techniques to be used in the project are defined and documented
	The project has procedures to report risk management to external and internal stakeholders
	The project has a database for collecting the information about risk management
	The project has a defined risk matrix for quantifying probability and consequence of risks (in time, cost, quality, etc.)
	Risk management is integrated in project management approach of the project
	There is a procedure for deciding risk reservation in the project
	The procedure for deciding risk reservation is based on the defined risk appetite of the project

Top-management commitment	Management encourages and supports risk management within the project
	Management communicates goals and strategies of risk management within the project
	Management asks for risk management information and reports
	Management uses risk management reports to make decisions
	Management defines roles (with authority and accountability) to perform risk management process within the project
Culture and personnel knowledge	The project team understands the necessity of risk management (risk management is not seen as an additional burden)
	There is no blame culture and the project organization accepts that people make mistakes
	The project team has trust and openness in reporting risks
	The project team is aware of his risk attitude
	The personnel receive training (if needed) to improve risk management skills
	There is an experienced team/person responsible for risk management
Risk assessment	Risks are identified and the type, cause, possible consequences and phase of the risks are described in the risk register
	Key external stakeholders (besides the key internal stakeholders) participate in risk identification
	Probability and consequences of identified risks are quantified based on the risk matrix of the project
	Quantitative risk analysis (for both time and cost) is performed
	There is a risk owner (either internally or externally) for each risk who is responsible for that risk
	Important risks for treatment and mitigation are identified based on the risk appetite of the project
	The entire risk assessment process is performed based on the project risk management process
	The risk assessment outcome is documented and communicated to internal and (if needed) external stakeholders
Risk treatment and mitigation	Per risk a control measure based on different strategies (reduce, avoid, transfer, and accept) is defined
	Secondary risks after applying control measures are considered
	The costs of control measures are considered in the project costs
	The time of control measures are considered in the project schedule
	Residual risks after applying control measures are quantified and considered
	The cost/time of the most important residual risks are considered as cost/time contingency
	A cost/time contingency is assigned for the unforeseen risks based on the complexity and size of the project
	Control measures are applied
	The whole risk treatment and mitigation process is based on the project risk management process
	The risk treatment outcome is documented and communicated to internal and (if needed) external stakeholders
	The contractor risks, identified by the client, are communicated to the relevant contractors
Monitor and review	Status of the control measures are updated (in progress, applied, not applied yet)
	Status of risks are updated in the risk register (active, managed, occurred)
	New risks are added to the risk register and the previous steps are repeated for the new risks
	Cost/schedule documents are updated based on the status of risks
	Probability and consequences of active risks are updated based on the risk matrix of the organization
	Lessons learned (occurred risks, performing risk management, etc.) are recorded
	The entire monitor and review process is based on the project risk management process
	The outcome of monitor and review process is documented and communicated to internal and (if needed) external stakeholders

3

Regarding the use of RiskProve, we received positive feedback and some experts began discussing the scores they had awarded to the same project. Based on the answers to the questions about the method and use of the model, most of the experts acknowledged that RiskProve is easy to work with. Moreover, the experts mentioned that RiskProve provides a good picture of the status of risk management in a project. Most of the experts confirmed that the model helps with better application and improvement of risk management. One of the experts stated: "[RiskProve] provides insight about where the possibilities are to improve in [risk management] maturity". One of the experts declared that "the model opens the subject for discussion". Another participant stated that "[RiskProve] quickly provides an insight [with regard to risk management] and helps with steering [risks]". Similarly, another participant said that "[RiskProve] provides possibilities for discussion and suggestions for improvement".

We also asked the experts about the system of scoring, and most of them agreed that the scoring accurately expresses the situation of risk management application in a project. The experts indicated that they would be willing to implement the model in their projects.

In addition to the positive comments, the experts provided two additional remarks regarding weight factors and ambition in risk management improvement. In both focus group sessions, experts mentioned that the importance of the statements should not be considered equally, since not all statements are equally important for all projects. To address this concern, a column called Importance was added to the model. The user can select the importance of each statement for the project using the same scoring method as for evaluating the maturity of the statements (10 (very important), 7 (important), 4 (less important), and 1 (not important)). The score of importance adds a weight factor to each statement: the statements with a higher importance have more impact on the final score of each aspect in RiskProve. The following formulae are used to calculate the maturity score for each aspect (Equation 1 and 2).

$$\mathrm{N} = \sum_{i=1}^{j} \mathrm{importance}_i \tag{3-1}$$

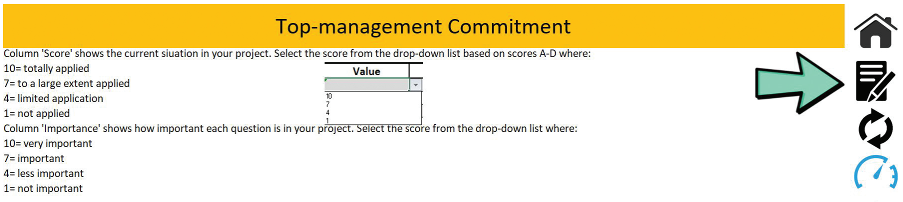
$$\text{Total maturity score} = \sum_{i=1}^{j} \mathrm{Score}_i \times \frac{\mathrm{importance}_i}{\mathrm{N}} \tag{3-2}$$

Where N represents the summation of the score for the importance, j is the number of statements. The scorei looks at the maturity score of statement i.

Another comment that was made, related to the ambition of a project in improving risk management. The expert mentioned that the model only looks at the current situation of risk management, while the ambition of a project to improve in risk management is overlooked. To address this concern, a column named *Ambition* was added to the model, again to be scored with 1, 4, 7 or 10 (with higher scores reflecting more ambition).

In this way, RiskProve can also measure the ambition level of risk management in a project, in addition to the current level. The ambition score of each aspect is calculated in the same way as explained in Equation 1 and 2 with the scorei showing the ambition score of statement i.

As an example, Figure 3-3 shows an overview of RiskProve for the aspect *Top-management Commitment*. Some symbols are provided on all pages of the model to help the user to navigate through the model. The home symbol takes the user back to the starting page, where an explanation about the model is provided. The dashboard symbol takes the user to the results of the model and the green arrows can be used for navigating to the previous and following pages.



ID	Top-management Commitment*	Value	Importance	Ambition
1	Management encourages and supports risk management within the project	10	10	10
2	Management communicates goals and strategies of risk management within the project	7	7	7
3	Management asks for risk management information and reports	4	7	7
4	Management uses risk management reports to make decisions	7	7	10
5	Management defines roles (with authority and accountability) to perform risk management process within the project	4	7	7
		Maturity score	6.7	
		Ambition Score	8.3	

Figure 3-3 Appearance of RiskProve

3.6 Discussion

RiskProve presented in this paper aims to help practitioners in construction projects by evaluating and improving risk management. In addition, it can be used for cross-project analysis for learning purposes. The results of both focus group sessions confirmed that

RiskProve provides insight about the current situation of risks management in a project. In addition, it facilitates a discussion about risk management improvement between the project members.

RiskProve covers the limitations of other RMMs, i.e. the lack of theoretical and/or practical background and the lack of validation of the models. Because of the weight factors per statement, RiskProve is suitable for use in all types of construction projects regardless of their size. RiskProve measures the ambition of projects in risk management application. This feature enables projects to create a clear picture about their desired risk management status, in addition to understanding the current situation of risk management. This way, by evaluating and benchmarking risk management, the projects' ability to plan for improvements is enhanced. In addition, RiskProve focuses explicitly on both positive and negative risks. These features make RiskProve a generic risk maturity model.

RiskProve contains risk management statements extracted from 12 RMGs, 13 RMMs and 5 LLs, and the opinions of practitioners are considered in its development as well. This is a clear difference with the existing RMMs examined in this paper, which do not mention the origin of their statements. Wendler (2012) indicates that not all models have a theoretical background and the attributes decided on for these models are based on the experiences of their developers. Bosler (2002) states that an RMM should appreciate the nature of the risk management process. Some of the examined models (e.g. models number 1, 3, 4, 6, 7 and 8 in Table 3-1), however, only consider parts of the risk management process. Therefore, these models cannot thoroughly identify weaknesses and strengths of applying risk management in projects.

Furthermore, the current RMM models do not present a realistic picture of the implementation of risk management. For example, the aspects considered in the highest level of maturity in the attributes-maturity models do not contain exactly the aspects in the lower levels (e.g. in the model by Bosler (2002), the concern of 'risk budget allocation' is considered in level three but not in level four). It seems that there is an unwritten rule applied in these models that a higher maturity level can only be achieved when the lower levels have already been achieved (only model no. 7 explicitly mentions this concern). With this 'rule', it is difficult for the projects to find their position in these maturity models, which complicates the real situation of risk management application. A similar argument is applicable to the models that use a questionnaire. In these models, again, hidden 'rule' applies and, hence, the user is not provided with a valid picture of risk management application. In addition, the results in these models are not always an integer number. Usually, the models come with another unwritten rule to round off the non-integer number and provide the user with a level of maturity that does not fully reflect the project's true situation. In fact, in both types of the models, the model's make-up presents the user with a level of maturity that the user is forced to choose a level of maturity that might not reflect the reality of a project.

Many models try to specify a set of fixed situations for each level and explain the situation of all projects based on these specific descriptions. But: projects are unique, and the same situation might not be applicable to all projects. Since the main goal of an RMM is aiding projects in identifying their strong and weak areas of performing risk management, we argue that the existence of a specific level does not add value. Instead, the projects need to know their current risk management situation and compare it to the desired situation for continuous improvement. Therefore, unlike other models, RiskProve, does not have any maturity level, and instead uses an explicit scoring system. Hence, RiskProve does not limit the user to one of four or five levels of maturity. Instead, the maturity score can be any number between 1-10. Based on the maturity and ambition scores gained for each aspect, the user decides whether the score is considered sufficient, and whether or not an improvement is required.

The examined RMMs in this paper consider all statements as being equally important. However, not all of the statements may be applicable to a project, or some may be more important than others given the context of the project. Hillson and Simon (2007) mention that not all projects require the same level of risk management and a 'one size fits all' approach does not apply to all projects. This concern was explicitly mentioned during the first focus group session where the client and contractor expressed different opinions about a number of statements. Therefore, RiskProve uses an adjustable weighting factor so that the user can decide which statement is more important and applicable to a particular project. This capability of RiskProve makes it a generic model applicable in small, medium and large construction projects.

It is important for a project to know where it stands regarding risk management, but it is also important to know what it wants to reach. RiskProve's ability of measuring ambition is another point that distinguishes it from other models. J Kent Crawford (2006) explains that the final level of maturity is not desired for every project. Each project needs to determine the minimum level of maturity at which the desired value is achieved and determine the value associated with achieving the next level (J Kent Crawford, 2006). The same situation is applicable to RiskProve. Before implementing the model in a project, the appropriate score for that particular project should be decided upon. The project team should decide where they want to be in risk management by filling out the ambition score in RiskProve, and next, they should strive for continuous improvement until the desired goal is reached. Selecting a specific score as the goal of a project is crucial, because a project cannot come up with proper improvement measures if it does not have a goal.

3.7 Conclusion

This paper presents the development and validation of a generic risk maturity model, called RiskProve, for the construction industry that can help projects gain a full, realistic picture of their risk management application. This research has contributed to the available literature by bridging the research gap in the field of Risk Maturity Models (RMM): there was a lack of an RMM based on both theory and experts' opinions, validated on the statement level as well as the overall model level.

With regard to answering the research question, the statements for RiskProve were extracted by means of Qualitative Content Analysis, from different risk management resources. These statements have been divided into two main categories of Organizational and Application and Process. The Organizational category contains four aspects of Policy and Strategy, Top-management Commitment, Culture and Personnel Knowledge. The category Application and Process contains the aspects of Risk Assessment, Risk Treatment and Mitigation, and Monitor and Review. The aspects, the statements, and the model were tested in two focus group sessions. The aspects (Policy and Strategy, Top-management Commitment, etc.) and the statements are elements of a generic risk maturity model. Experts stated that RiskProve helps projects by identifying strong and weak areas of risk management, and felt it provided a realistic picture of risk management in a project. They also indicated that it facilitates discussion about improvement of risk management in a project. The firm theoretical background of RiskProve and inclusion of the practitioners' views make it different from other, currently available RMMs.

3.8 Recommendation for future research

The research creates need for future research. A limitation of this study is the fact that only the opinions of professionals in the construction industry of the Netherlands have been considered, therefor, expanding the research to cover an international scope could be considered. Another recommendation for future research is the application of RiskProve in real construction projects and to compare the risk management improvement areas across different projects.

3.9 Acknowledgment

The authors would like to express their appreciations to the participants in the focus groups and their contribution to this research.

3.10 Appendix A

Table 3-8 Role and years of experience of experts participated in the first and second focus group sessions

First focus group session		**Second focus group session**	
Role	Years of experience	Role	Years of experience
Senior adviser risk manager	18	Risk manager	20
Functional project control	9	Risk manager	3
Manager cost Engineer	40	Risk manager Senior adviser	12
Senior contract manager	10	Risk manager	8
Risk manager	5	Risk manager	13
Cost Engineer/business analyst	2	Risk manager adviser	2.5
Risk manager	16	Risk management adviser	5
Cost Engineer	17		
Cost manager	30		

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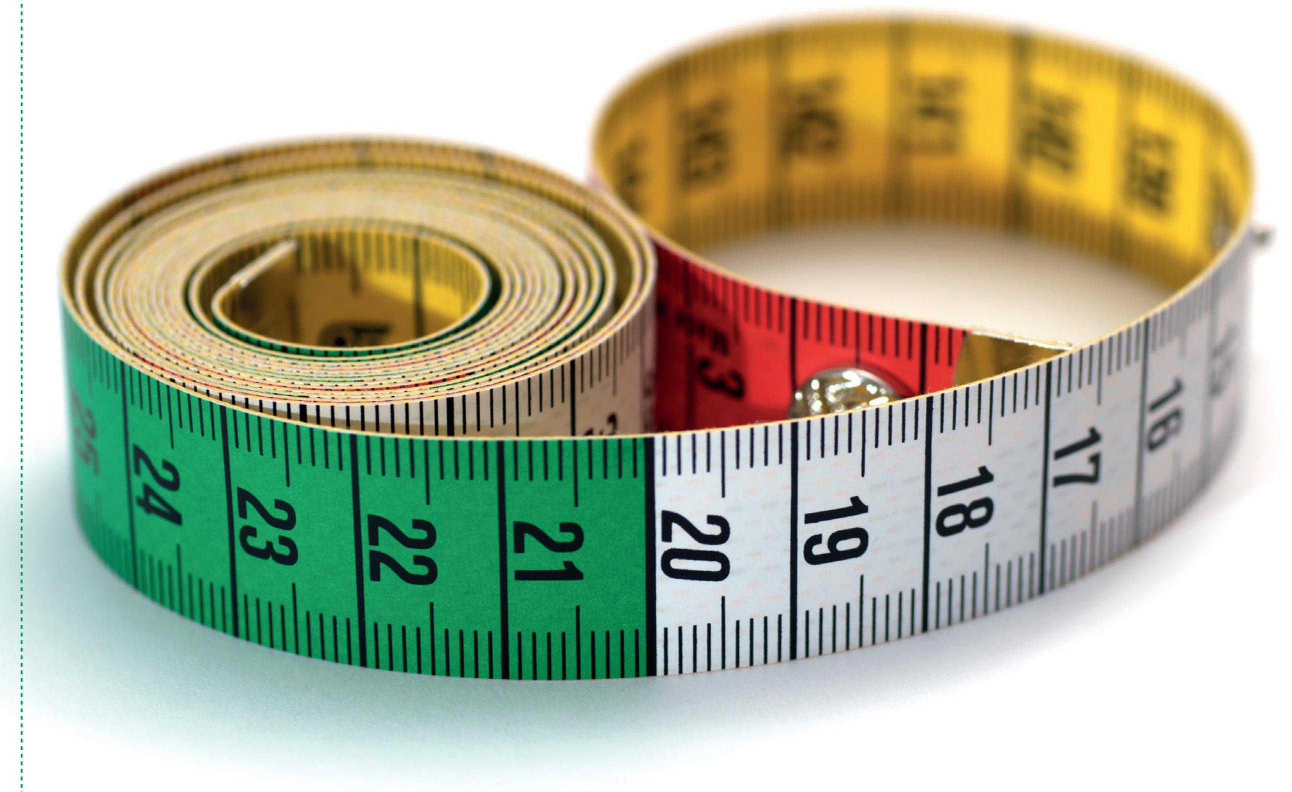
The cover photo is taken from https://bpmredux.wordpress.com/2013/04/05/bpm-maturity-models-youll-grow-old-trying-to-get-ahead-of-the-curve/



CHAPTER 4

Risk Management Maturity of Projects Executed by the Public Organizations

Abstract[6]

RiskProve, developed in Chapter 3, was applied in 16 projects of two public organizations (nine HWBP projects of one waterboard and seven projects of one department of Rijkswaterstaat). The objective of this research was to help the projects improve their risk management practices. Risk Assessment and Top-management Commitment has received respectively the highest and lowest risk management maturity scores in both organizations. Results show that Organization 1 is more advanced in applying risk management. Regardless of the scores of risk management maturity, both organizations see possibilities to improve, among other things, defining the objective of risk management, defining the risk appetite, and evaluating and collecting the lessons learned. Based on the results, recommendations are drawn for improving the risk management application.

4.1 Introduction

Construction projects are bounded with uncertainties, and as a result, occurrence of risks, either positive (opportunity) or negative (threat), in these projects is unavoidable (Murray, 2009). Despite the increasing consensus on the importance of risk management (Merna & Al-Thani, 2011; Becker & Smidt, 2015; Ahmadi, Behzadian, Ardeshir, & Kapelan, 2017), effective implementations of risk management processes into organizations and projects are not common and risk management application still needs improvement in the projects (Bosler, 2002; Yaraghi & Langhe, 2011; Mu, Cheng, Chohr, & Peng, 2014; Dyer, 2016; Olechowski, Oehmen, Seering, & Ben-Daya, 2016). Empirical research shows that risk management is the lowest scoring process among all project management processes (D. Hillson & Simon, 2007). The first step to improve the risk management application in a project is to identify the weak areas of performing risk management. As explained in Chapter 3, a risk maturity model (RMM) is a tool that can be used for this purpose.

The term 'maturity' for an organization means progress in development and applying processes that are documented, managed, measured, controlled and continuously improved (Loosemore, Raftery, Reilly, & Higgon, 2006; Öngel, 2009; Cienfuegos Spikin, 2013). Maturity in terms of risk management means the evolution towards full development and application of the risk management process (Loosemore et al., 2006;

6 Part of this chapter is published in ARCOM conference 2018: Hoseini, E., Bosch-Rekveldt, M., & Hertogh, M. (2018). Risk management maturity of construction projects in the Netherlands. In Proceeding of the 34th Annual ARCOM Conference, ARCOM 2018 (pp. 657-666). ARCOM, Association of Researchers in Construction Management.

K. Yeo & Ren, 2009; Zou, Chen, & Chan, 2010; Wendler, 2012; Schiller & Prpich, 2014; Hoseini, 2019).

According to Wendler (2012), the 'maturity' concept is increasingly utilized by organizations to measure the quality of their processes. The idea and the concept of maturity models and maturity measurement was initiated in the field of quality management (Strutt, Sharp, Terry, & Miles, 2006; Macgillivray, Sharp, Strutt, Hamilton, & Pollard, 2007a; Wendler, 2012). Afterwards, the concept has expanded to the other fields such as project management (Ibbs & Kwak, 2000; Kwak & Ibbs, 2002) and risk management maturity measurement (D. A. Hillson, 1997). Maturity measurement provides ways to evaluate, benchmark, control, and improve organizations' practices (Alashwal, Abdul-Rahman, & Asef, 2017). Research shows a direct connection between the higher level of maturity and improved organizational performance (Grant & Pennypacker, 2006).

Measuring the maturity of risk management in an organization is a useful starting point when commencing on a review of current risk management practices, systems and culture (Loosemore et al., 2006). RMMs help organizations to understand their current level of risk management capabilities, as well as their strengths and weaknesses in the application of risk management, to take appropriate actions to improve their risk management performances (Jia et al., 2013). Risk management maturity of an organization reflects the organization's superiority in understanding and managing risk (Zou et al., 2010). Improving the maturity of risk management can contribute to minimizing costs and improving profitability (Zou et al., 2010; Young, 2013; Oliva, 2016). In short, an RMM can assess and provide an overview of the current risk capability of an organization. Based on this assessment, the weak areas of applying risk management can be identified and actions can be taken to improve those areas.

Given this introduction, in section 2, literature is reviewed and then in section 3, the research problem and the research objectives are described. Next, in section 4 the research method is explained. In section 5, the results and analysis are presented and afterwards, the results are discussed and recommendations are given for the practice in section 6.

4.2 Literature review about the application of RMMs

In the past decade, there has been an increasing interest in developing and applying the risk management maturity models (RMMs) in practice (IACCM, 2003; Grant & Pennypacker, 2006). Macgillivray et al. (2007a) explains the implementation of a Risk Management

Capability Maturity Model in the water utility sector. Using a survey research design, MacGillivray, Sharp, Strutt, Hamilton, and Pollard (2007b) compare the risk management maturity of eight water utilities in the USA, the UK, and Australia. They conclude that the long-term processes of education and training in risk management and risk knowledge management are not mature yet.

Öngel (2009) explains the development and implementation of an RMM in construction projects in Turkey. By means of interviews, the risk management maturity of five construction companies in Turkey is investigated. He concluded that the level of risk management varies per project and between local and international projects. In addition, companies that do not allocate a budget to risk management activities, encounter an immature risk management process. Similarly, Zou et al. (2010) describe the development, validation and application of a web-based RM3 (Risk Management Maturity Model). Zou et al. (2010) assign a specific number to each of four levels of maturity. By means of a survey, a sample size of 300 construction organizations in Australia was approached. They conclude the Australian construction industry's overall risk management maturity level was relatively low (where 32% rated at Level 2 and 52% rated at Level 3).

Jia et al. (2013) developed a framework of Risk Management Maturity System (RMMS) with three drivers of capabilities, evaluation and evolution. They calculate the score of risk management maturity based on the principles given in the OPM3 (PMI (Project Management Institute), 2013), and an evaluation system with a two-stage evaluation process. The evaluation system takes the correlation between different risk management capabilities into account and utilizes a weight oriented evaluation process, which embeds an analytic network process (ANP) model. The data were then processed by the Super Decisions software, and the score of maturity is calculated. Applying the method in a construction contractor in China, the results revealed that the maturity score of most of the risk management activities is at low level. In another study, Mu et al. (2014) assess the risk management capability of subway project contractors in China. Investigating the literature on RMMs, they develop a Risk Management Capability (RMC) assessment model containing 21 indices to measure risk management capability. A survey was conducted to collect information regarding the risk management maturity of the projects. The study concludes that the overall risk management capability levels of contractors in subway projects in China is between low and medium (Mu et al., 2014).

Zhao, Hwang, and Low (2014) assess the Enterprise Risk Management (ERM) maturity in Chinese construction firms using a fuzzy Enterprise Risk Management Maturity Model (ERMMM). By means of a survey, the respondents were asked to rate the implementation levels of 66 ERM best practices on a five-point scale by comparing the similar current practices in their firms with the best practices. Their research indicated that the 25 Chinese construction firms had a low score of risk maturity, while the remaining 10 obtained a medium-level risk maturity score. The overall risk management maturity score was low. K. T. Yeo, Ren, and Ren (2016) describe the development and application of a project risk management capability maturity model in the rail projects in Singapore. The developed model is applied in a client organization by means of a case study. Their research assessed the organization overall risk management capability maturity as high.

Alashwal et al. (2017) investigated the influence of organizational learning on risk management maturity of 132 contractor firms in Malaysia. By means of a survey, OPM3 (Organizational Project Management Maturity Model) (PMI (Project Management Institute), 2013) was used to measure the maturity of risk management. Using partial least-squares structural equation modelling (PLS-SEM) and multi-group moderation analysis, Alashwal et al. (2017) concluded that more construction firm acquires and interprets information and knowledge related to project risks, the higher the level of maturity the firm can achieve. They also conclude that the firm size has an influence on the risk management maturity score.

Cienfuegos Spikin (2013) studied the risk management maturity of 72 municipalities in the Netherlands using a survey. He uses a five point Likert scale to define the maturity level of the municipalities. By using Cronbach‘s alpha test he shows the reliability of each risk management stage. The mean value is used to calculate the maturity score. He concludes that there are large differences between the risk management maturities of the municipalities. The smallest municipalities (regarding the number of inhabitants) have the lowest score of maturity while the biggest municipalities are more advanced in the risk management application.

4.3 Problem formulation and research objectives

The previous section explained risk management maturity measurement as described in the literature. Through this investigation, shortcomings in the applied methods and approaches of previous articles can be observed. The arguments to support this inference are given as follows.

First, authors such as Jia et al. (2013), Zhao et al. (2014), and Alashwal et al. (2017) measure risk management maturity, focusing on the complex methods. These methods, although valuable, are too complex to be applied by the project team for the evaluation of risk management in projects. These complex methods make the applicability of the RMM less attractive, and difficult to be applied without the presence of the authors. In the author's view, the articles using complex methods to measure the maturity of risk management seems to have misunderstood the ideas of RMM. The main goal of risk management maturity measurement should be: simply giving a project an overview of the weak and strong areas of applying risk management so that the team can plan for improvement. The author argues that for measuring the maturity of risk management, no complex calculations or methods are needed. The method to measure risk maturity should be pertinent, giving the project team the possibility and motivation to apply the model by their own.

Second, authors such as Zhao et al. (2014) Mu et al. (2014) and Cienfuegos Spikin (2013) conclude the maturity of the projects/organization as high or low in their researches. The terms such as 'low' and 'high' are, however, subjective; a low maturity score for a project can be considered as a high sore for another project. A low or high score of maturity can only be concluded if they are compared with the goal of the projects and their desired position in applying risk management. The shortcoming of the current maturity measurements approaches is that they do not consider the ambition level of risk management in projects. The ambition level defines the desired level of risk management that a project/organization aims to reach in the future.

Third, measuring merely the maturity level of a project is not enough but the reasons for a weak performance in risk management should be examined as well and the required measures to improve the risk management application should be taken. Collecting data within projects on what happened is not enough, and it is important to understand what exactly went wrong and why (Williams, 2003). Determining the root cause of a problem is very important because the issue may repeat if the cause of the problem is not eliminated (Myszewski, 2013; Rosenfeld, 2013). Most of the examined researches do not investigate this step. The authors such as Cienfuegos Spikin (2013) and Mu et al. (2014) use a survey to measure the risk management maturity of the project without a deep investigation of the problem. While a survey is suitable when the opinions of many participants about a subject should be collected, it lacks the depth to investigate the subject under study. Therefore, no specific recommendations could be given per project and, as a result, the planning for improvement of risk management would not be possible.

Based on the abovementioned arguments, the author argues that:

A risk management maturity approach should be simply applicable, be able to measure the ambition as well as the current level of risk management maturity and provide the possibility to deeply investigate the reasons of poor performance.

None of the investigated researches address all these arguments. Therefore, in this chapter the results of an empirical study, performed to benchmark the risk management application in the projects, are presented.

The research objectives of this research are:

I. To investigate the current and the ambition level of risk management maturity in construction projects, and

II. To identify improvements areas and provide recommendations for improving risk management in projects.

The research questions formulated to fulfil the research objective are:

1. *What are the current and ambition levels of risk management maturity in projects?*

2. *What are the improvement areas of risk management in the projects?*

The research answers these questions, investigating the projects executed by public organizations in the Netherlands.

4.4 Methodology

To investigate the risk management maturity, the projects of two public organizations in the Netherlands are selected as the cases. The research characteristic is exploratory and, therefore, a case study approach is preferable to explore the risk management maturity of the projects (Kothari, 2004; Yin, 2014). These organizations are selected based on their availability and interest to measure their risk management maturity. Organization 1 is a regional public organization responsible for water management in an area in the Netherlands. Organization 2 is a national public organization. The risk maturity measurement was performed as a reference measurement (in Dutch: nulmeting) to assess the current situation of risk management and plan for improvements in these organizations. From each organization, two risk management advisors were involved in the research. From Organization 1 nine projects, and from Organization 2 seven projects are selected. In each of the organizations, the projects are selected by the risk advisors from a department in each of the organizations. The selected projects from Organization 1 are flood defence protection, while the projects in Organization 2 are about installation and testing of devices that collect the traffic information. Ongoing projects (at the time of writing this dissertation) were selected since gathering data from ongoing projects is easier, and the project members of these projects are easier to approach. Investigating the finished projects, in this case, would have less added value since the planning for improvement is not possible anymore. From each project, the project team has participated in the study. Table 4-1 presents the number of participants in each project.

Table 4-1 Number of participants per project in each organization

Organization 1	
ID project	Number of participants
1	5
2	4
3	5
4	5
5	4
6	5
7	5
8	5
9	4
Total	42

Organization 2	
ID project	Number of participants
1	5
2	4
3	4
4	4
5	5
6	3
7	3
Total	28

To answer each of the research questions designed for this chapter, the research is performed in two steps:

I. Determining the risk management maturity of the projects.

II. Investigating the reasons for poor risk management performance and identifying the possible improvements.

In the first step, the risk management maturity of the organizations was measured using RiskProve (Chapter 3). The results of the first step are used in the focus group sessions (Langford & McDonagh, 2003) with each project to investigate the possible improvement in risk management. The first step has a more quantitative approach, while the second step is more qualitative. In fact, the research benefits from a mixed-methods approach

(Tashakkori & Teddlie, 1998; Johnson & Onwuegbuzie, 2004), applying both qualitative and quantitative methods. Figure 4-1 presents the research design of this research.

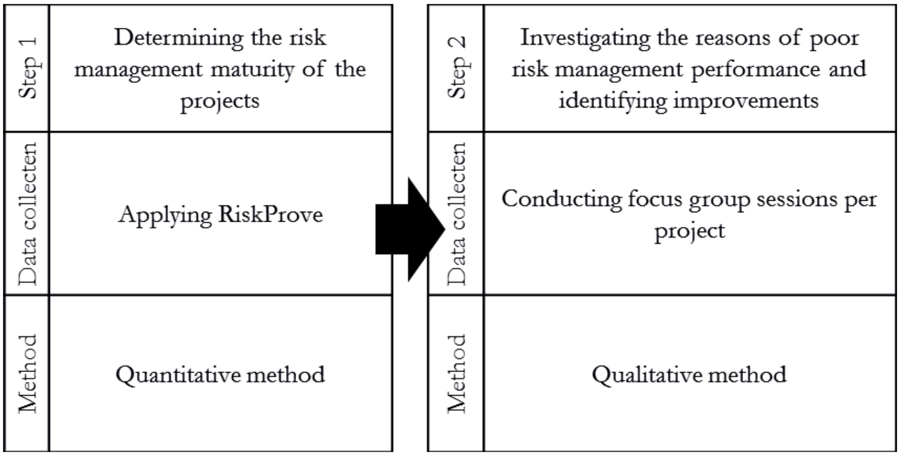


Figure 4-1 Research design of this research

The risk advisors in each organization sent RiskProve via email to the project team members of each project. In the first step, the experts from each organization were asked to individually evaluate the risk management maturity of their projects by applying RiskProve. The results were then returned to the researcher for analysis. Figure 4-2 presents an example of a filled aspect in RiskProve.

ID	Culture and Personnel Knowledge	Maturity	Importance	Ambition
1	The project team understands the necessity of risk management (risk management is not seen as an additional burden)	4	10	10
2	There is no blame culture and the project organization accepts that people make mistakes	4	7	10
3	The project team has trust and openness in reporting risks	4	4	4
4	The project team is aware of his risk attitude*	4	4	10
5	The project team receives training (if needed) to improve risk management skills	1	7	10
6	There is an experienced team/ person responsible for risk management	7	7	7
		Maturity score	4.0	
		Ambition score	8.8	

Figure 4-2 An example of the scores and the colours of each statement in one of the aspects

The maturity and the ambition scores for each aspect (Figure 3-2) calculated based on Equation 4-1, Equation 4-2 and Equation 4-3:

$$N = \sum_{i=1}^{j} \mathrm{importance}_i$$

Equation 4-1 The summation of the score for the importance, j is the number of statements (for one participant)

$$\text{Maturity score of each aspect} = \sum_{i=1}^{j} \text{Score } M_i \times \frac{\mathrm{importance}_i}{N}$$

Equation 4-2 Total maturity score of each aspect where Mi is the Maturity score of statement i (for one participants)

$$\text{Ambition score of each aspect} = \sum_{i=1}^{j} \text{Score } A_i \times \frac{\mathrm{importance}_i}{N}$$

Equation 4-3 Total ambition score of each aspect where Ai is the Ambition score of statement i (for one participants)

The total scores of maturity and ambition for the categories Organizational and Application & Process are equal to the average score of maturity and ambition of the aspects in each category as shown in Equation 4-4 and Equation 4-5.

$$\text{Maturity score per category} = \text{Avergae of maturity score of each aspect in a category}$$

Equation 4-4 Maturity score per category for one participant

$$\text{Ambition score per category} = \text{Avergae of ambition score of each aspect in a category}$$

Equation 4-5 Ambition score per category for one participant

In RiskProve a colour (red, orange, yellow, and grey) is assigned to each statement (Figure 4-2). The colour for each statement is determined, automatically, based on the differences between the scores of maturity, ambition, and importance of each statement as shown in Equation 4-6:

$$F = (Ambition - Maturity) * Importance$$

Equation 4-6 Determining the colour for each statement

Based on Equation 4-6 the following scores are possible for F:

- A high difference between the scores of Ambition and Maturity because of a very high score of Ambition (10) and a very low score of Maturity (1) for a very important or important statement (scores 10 or 7). The score of F will be: 90 or 63.

- A high difference between the scores of Ambition and Maturity because of a high score of Ambition (7) and a very low score of Maturity (1) for a very important statement (scores 10). The score of F will be: 60.

- A high difference between the scores of Ambition and Maturity because of a high score of Ambition (score 10) and a low score of Maturity (score 1) for a less important statement (score 4). The score F would be 36.

- A moderate difference between the score of Ambition and the score of Maturity (Ambition = 10 and Maturity = 4 or Ambition= 7 or Maturity = 1) for an important statement (score 7). The score F will be: 42.

- A small difference between the scores of Ambition and Maturity (Ambition = 10 Maturity 7 or Ambition = 7 and Maturity = 4 or Ambition = 4 and Maturity = 1) with any score of importance. F will be: 30, 24, 21, 12, 3

- A high difference between the scores of Ambition and Maturity (Ambition = 10 or 7 and Maturity =1) for a not important statement (Importance= 1). F will be: 9 or 6.

F will be a zero if there is no difference between the scores of Ambition and Maturity.

A colour is defined based on these scores as an indicator so that the user can quickly understand the situation of each statement. The colours are decided based on the situations shown in Table 4-2:

Table 4-2 The colour of the statement in RiskProve based on the situation and score of F

Situation	***F* Scores**	**colour**
A large *F* when the scores of Ambition and Importance are high and the score of Matrutity is low	90, 63, 60	Red
A moderate *F* when the differnce between the scores of Ambition and Maturity is high but the score importance is low or when the difference between the scores of Ambition and Maturity is low but the score of Importance is high	42, 36	Orange
A small *F* because of a low difference between the scores of Maturity and Ambition or a high differnce between the scores of Maturity and Ambition with a very low score of Importance	30, 24, 21, 12, 9, 6, 3	Yellow
No difference between the scores of Maturity and Ambition	0	No change in the colour

The results are then analysed and presented in three levels:

A. The total maturity and ambition score per category (Figure 3-2): for each project which is equal to the average of the maturity and ambition score per category per team member (Equation 4-4 and Equation 4-5).

B. The maturity and ambition scores per aspect (Figure 3-2): for each project which is equal to the average of the maturity and ambition score per project per team member (Equation 4-2 and Equation 4-3)

C. The number of times a statement has received a specific colour by the team members.

In the second step of the research (Figure 4-1) the results are discussed in a session with the experts from each organization. In organization 1, one session was organized with the representatives from each project. This was because the projects in organization 1 are similar regarding risk management and, therefore the projects could learn from each other. In Organization 2, however, a separate session was organized with each project since risk management was not applied in the same way in each project.

During the sessions with the projects, first, the results are presented and explained (levels A and B as mentioned earlier here). Then, the results at the statement level (Level C as explained earlier here) are presented and explained. After this step, the statements that according to the most experts have a low score were selected and the experts were asked to elaborate why they think a statement needs more attention. The statement with low scores was selected based on the number of times a statement has received a specific colour. As explained earlier, the colour of each statement is defined based on the deviation from the desired level and the importance of the statement (Equation 4-6). The colours reflect the opinion of the team members regarding the urgency for improvement of a statement. For example, a statement which has received a red colour by most of the participants means that the team members think that the statement should be improved. During the session with Organization 1, one of the risk advisors has taken notes. The sessions with Organization 2 are audio recorded. This information is later used to analyse the results. A report including the results and recommendation is provided for each project. This chapter presents the results of all the investigated projects as a whole.

It should be noted that the sample in this research is intended to reflect the risk management application in the investigated organizations, hence the research does not suggest that the results are representative of the whole sector or other public organizations.

4.5 Results and analysis

The results of risk management maturity of the projects are presented based on the scores of current and ambition levels of maturity at the 'aspect' level, the 'category' level and the possible improvement at the 'statement' level. The analysis on the statements level presents the result per statement in each aspect, particularly those that are evaluated low by the experts.

Each project team may evaluate the maturity and ambition scores differently. Therefore, the ambition and maturity scores of each aspect for a project is equal to the average scores of all the project team members (which are calculated based on Equation 4-2 and Equation 4-3). The scores of maturity and ambition at the categories' level for a project is also equal to the average scores of each team member at the category level. In the final part, the improvement points per aspects are discussed. As explained in Equation 4-6 the improvement possibility is based on the differences between the scores of maturity and ambition and the score of importance of each aspect. The results at the category and aspect levels are presented per project. While at the statement level the results are presented for the whole organization (and thus not per project). The results of risk maturity of each organization is discussed first separately and then, the results of the organizations are compared.

4.5.1 Results per aspect and per category of Organization 1

Figure 4-3 presents the maturity and ambition scores of each project per aspect. On average, the aspects Culture and Personnel knowledge and Risk Assessment with a score of 7.6 are the most mature aspects. The aspect Top-management Commitment has the lowest score of maturity. The highest desire to grow belongs to the aspect Monitor & Review given the highest difference between the ambition and maturity scores (0.8). The highest maturity score belongs to the aspects Culture and Personnel knowledge of project 8 (8.6) and the highest ambition score belongs to the aspect Monitor & Review of project 4 (9.5).

	Policy & Strategy		Top-management		Culture and Personnel Knowledge		Risk Assessment		Risk Treatment		Monitor & Review	
Score / Project ID	Maturity	Ambition	Maturity	Ambition	Maturity	Ambition	Maturity	Ambition	Maturity	Ambition	Maturity	Ambition
1	6.2	7.9	6.3	7.2	6.7	7.7	6.0	7.2	6.2	7.5	6.1	7.3
2	7.6	8.0	6.6	7.0	7.5	8.5	8.3	8.7	7.5	8.1	7.8	8.4
3	5.6	7.7	6.5	7.7	6.8	8.3	7.3	8.2	6.7	8	6	8.2
4	7.5	8.6	8.3	8.9	8.2	9.1	8.2	8.5	7.6	8.9	8	9.5
5	6.4	7.6	6.8	7.8	8	7.9	7.6	8	6.8	7.9	7.3	8.3
6	8	7	6.9	6.8	7.9	8	7.8	7.7	8.4	7.9	7.2	7.5
7	7.7	6.6	6.8	7.3	7.9	7.6	7.8	6.9	7.4	7.5	7.7	7.1
8	7.5	8.1	7.7	7.6	8.6	8.9	7.9	8.4	7.3	7.7	7.6	7.6
9	6.9	8.1	6.4	8.1	6.7	8	7.5	8.6	7.9	8.8	7.1	7.9
Average	7.1	7.7	6.9	7.6	7.6	8.2	7.6	8.0	7.3	8.0	7.2	8.0

Figure 4-3 Maturity and ambition scores of each aspect per project in Organization 1

Figure 4-4 presents the results per category of each project. Project 4 has the highest maturity score in the category Organizational (8.0) while Project 3 has the lowest maturity score (6.3) in this category (Figure 4-4). Project 4 has the highest Ambition score (8.8) and project 7 has the lowest score of ambition (7.2) in the Organizational category. Project 2 and Project 4 have the highest maturity score in Application & Process category (7.9). Project 4 has the highest ambition score in the category Application & Process (9.0). Project 1 and Project 7 have respectively the lowest maturity score (6.1) and lowest ambition score (7.2) in the category Application & Process.

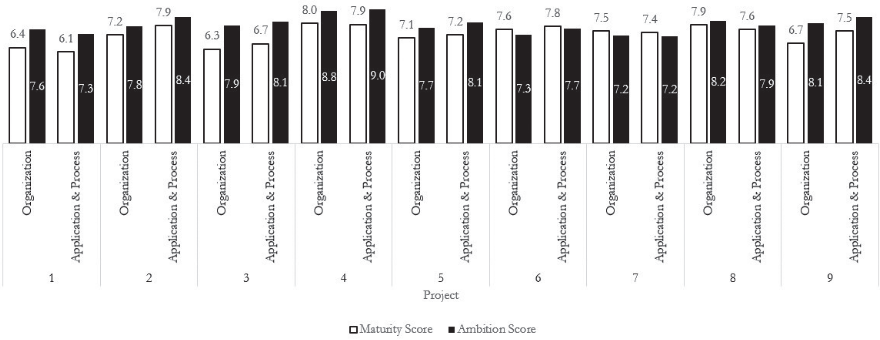


Figure 4-4 The maturity and ambition scores of Organizational and 'Application & Process' per project of Organization 1

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Figure 4-5 presents the total maturity and ambition scores of Organization 1 in the two categories of Organizational and Application & Process. Organization 1 scores almost equal in both categories and has a higher ambition to grow in the category Application & Process compared to the Organizational category.

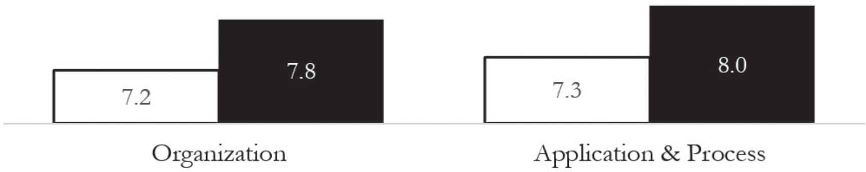

Figure 4-5 Total score of maturity and ambition of Organization 1

4.5.2 Results per statement of Organization 1

This section describes the results of risk maturity measurement at the statement level for all the projects.

Figure 4-6 presents the possible improvement per statement in the aspect Policy & Strategy. Most of the participants believe that the projects can still improve in defining the risk management objectives and the risk appetite. During the sessions with the projects, it was mentioned that the concept of risk appetite has not received attention in the projects. It was also mentioned that the vision of the project on risk appetite should be better elaborated.

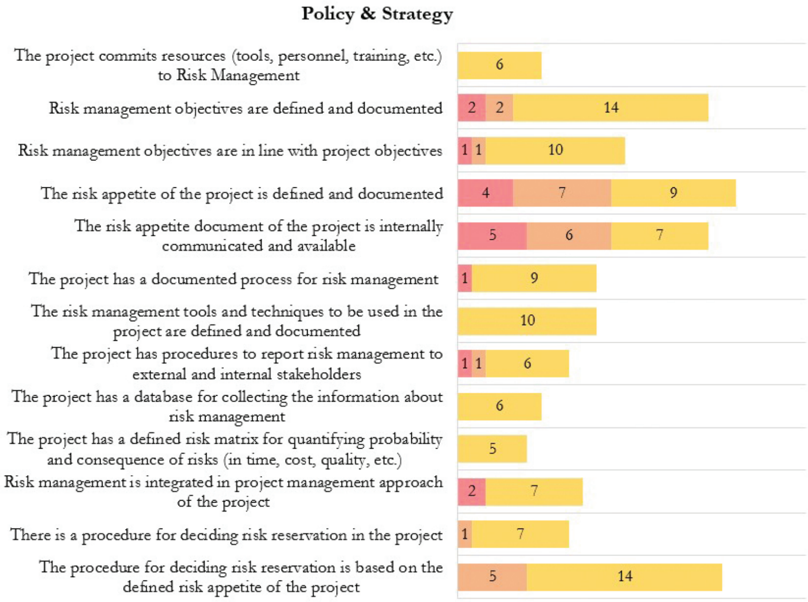

Figure 4-6 The improvement possibilities in the aspect Policy & Strategy in Organization 1

According to about half of the participants (from 42 participants), the management can still perform better in communicating the goals and strategies of risk management and making the decisions based on risk management (Figure 4-7). It should be considered that most participants have chosen a yellow colour meaning that the desired level is not much different from the current level.

Figure 4-7 The improvement possibilities in the aspect Management Commitment 1

As shown in Figure 4-8, the training of risk management needs improvement according to several participants. During the discussion, it was mentioned that several projects' members have not yet followed the risk management course. The risk advisors available at the session decided to investigate which team members have not followed the risk management course yet. In addition, it was mentioned that the new employees should, if needed, follow the risk management course as well.

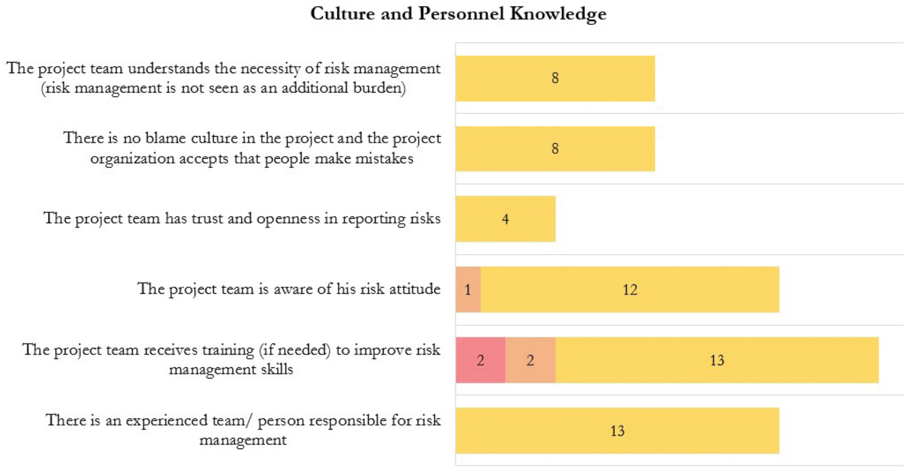

Figure 4-8 The improvement possibilities in the aspect Culture and Personnel Knowledge 1

A few statements, as shown in Figure 4-9, require attention as stated by the participants. Regarding the involvement of the stakeholders, it was mentioned that the stakeholders should be informed but participation of all the stakeholders in the risk identification is less needed.

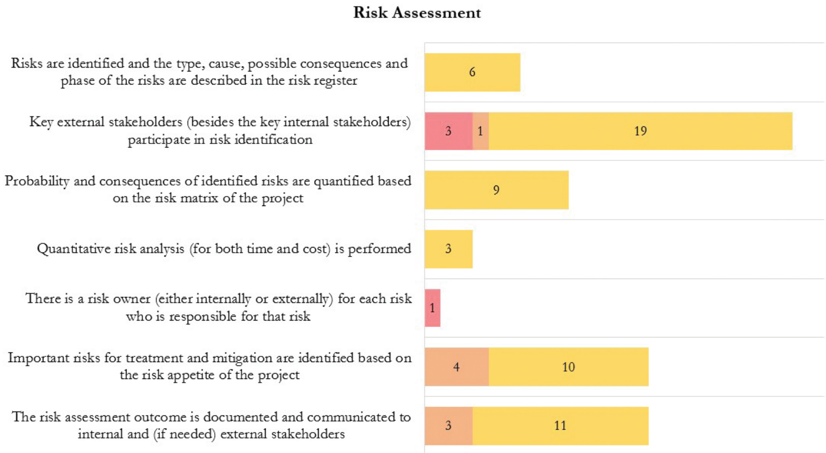

Figure 4-9 The improvement possibilities in the aspect Risk Assessment 1

Based on the participants' evaluation, secondary risk should be concisely and explicitly considered in the risk management process of the projects (Figure 4-10). Secondary risks are the risks that arise from implementation of a response strategy on a primary risk (D. Hillson & Simon, 2007). During the discussion, it was also mentioned that the time taken for applying the control measures is not always considered in the project schedule. Next to these two statements, the participants have desire to improve in several other statements as well.

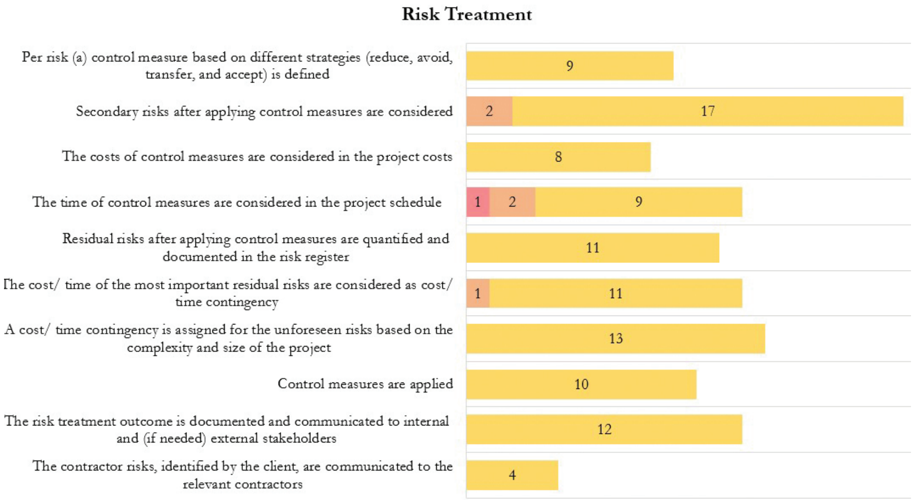

Figure 4-10 The improvement possibilities in the aspect Risk Treatment and Mitigation 1

Collecting the lessons learned and evaluating the risk management process are the possible improvements in the Monitor & Review aspect (Figure 4-11). Regarding the evaluation of risk management, the participants admitted that a better evaluation of the risk register is needed. It was discussed that the collection of the lessons learned should be facilitated by the organization. It was proposed that the risk registers are shared between the projects and the projects should evaluate the risk registers of each other. It was also suggested to use the project management meetings to share the experience of risk management. Moreover, it was stated that the lessons learned, and the evaluation of risk management can be applied before starting the new phase.

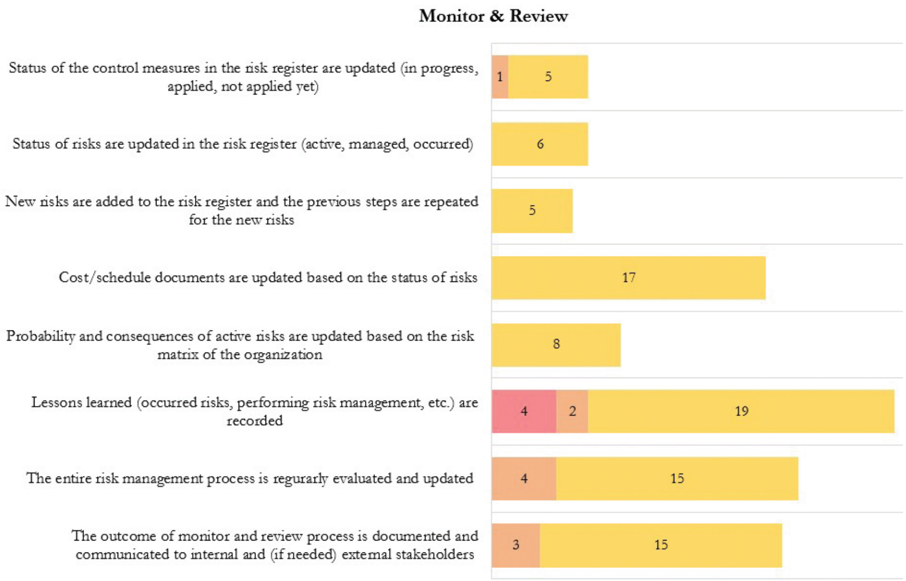

Figure 4-11 The improvement possibilities in the aspect Monitor & Review 1

4.5.3 Results per aspect and per category of Organization 2

The results of maturity and ambition scores of each project per aspect are provided in Figure 4-12. Similar to Organization 1, the aspects Culture and Personnel knowledge and Risk Assessment with the scores respectively 5.8 and 5.6 are the most mature aspects. The aspect Top-management Commitment has received the lowest score of maturity (4.8). Comparing the ambition and maturity scores of each aspect, the aspect Top-management Commitment has the highest possibility to grow (2.3), followed by the aspects Risk Treatment and Mitigation (2.2), Risk Assessment (2) and Monitor & Review (1.9).

The highest maturity score belongs to the aspects Culture and Personnel knowledge of project 5 (6.9) and the highest ambition score belongs to the aspect Risk Assessment of project 4 (8.5). Some projects such as Project 2 have a higher maturity score than the ambition score in the aspects such as Policy & Strategy and Risk Assessment. It could be that one or some participants think that for that specific project, more attention is given to some aspects than what is really needed.

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Score / Project ID	Policy & Strategy		Top-management		Culture and Personnel		Risk Assessment		Risk Treatment		Monitor & Review	
	Maturity	Ambition	Maturity	Ambition	Maturity	Ambition	Maturity	Ambition	Maturity	Ambition	Maturity	Ambition
1	4.7	7.8	4.6	8.2	5.2	7.6	4.2	8.5	4.3	8.2	4.7	7.9
2	6.6	6.4	4.5	5.2	5.6	6.3	6.7	6.6	6.3	7.1	6.6	7.2
3	5.9	6.6	4.1	6.7	5.7	7.7	6.8	7.9	4.9	7.4	4.1	7.4
4	4	7.9	3.1	7.5	5.3	8.3	4.6	8.5	4	8	3.6	7.9
5	6.7	7.1	6.2	6.7	6.9	7.7	6.8	7.3	5.6	6.9	6.4	6.6
6	4.9	7	5.2	7.5	5.9	6.6	5.2	6.6	4.8	5.6	4.9	5.3
7	5.3	7	5.6	7.8	5.9	7.7	4.9	7.7	4.3	6.2	4.6	6.1
Average	5.4	7.1	4.8	7.1	5.8	7.4	5.6	7.6	4.9	7.1	5.0	6.9

Figure 4-12 Maturity and ambition scores of each aspect per project in Organization 2

As shown in Figure 4-13, Project 5 has the highest maturity score (6.6) and Project 4 has the lowest maturity score (4.1) in the category Organization. Moreover, the highest and lowest ambition score in the category Organization belongs to Project 4 (7.9) and Project 2 (6.0) respectively. In addition, the highest maturity score in the category Application & Process is 6.6 (Project 2) and the lowest maturity score is 4.1 (Project 4). Project 1 has the highest ambition score (8.2) in the category Application & Process.

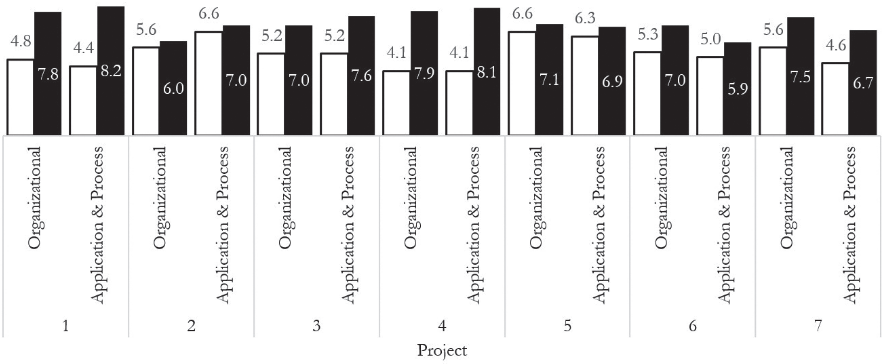

Figure 4-13 The maturity and ambition scores of 'Organization' and 'Application & Process' per project of Organization 2

The total maturity and ambition scores of the categories Organizational and Application & Process of Organization 2 is presented Figure 4-14. The organization has almost equal scores of maturity and ambition in these categories.

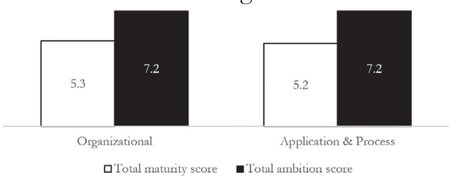

Figure 4-14 Total score of maturity and ambition of Organization

4.5.4 Results per statement of Organization 2

The same as section 4.5.2, this section presents the results per statement in each aspect for all the projects. In addition, to identify the improvement opportunities, the statements that are evaluated low by the experts are elaborated.

The results of the aspect Policy & Strategy at the statement level of Organization 2 are presented in Figure 4-15. All the statements in this aspect could be improved according to the participants. Defining and communicating the risk appetite is among the statements that needs more attention (21 out of 28 participants desire improvements for this statement). In one of the sessions, the participants mentioned that they decide based on their feeling whether a risk should be managed or it should be accepted. The need to defined a process for risk management was also mentioned in another session. Furthermore, it was mentioned that it is important that the objectives of the project and the organization are aligned. During one of the sessions, it was stated that many projects have to deal with similar risks and that some projects are struggling with a problem that might have already been solved in other projects. An Identifying these issues and trying to solve them at the portfolio level can save the teams a lot of time, costs and energy.

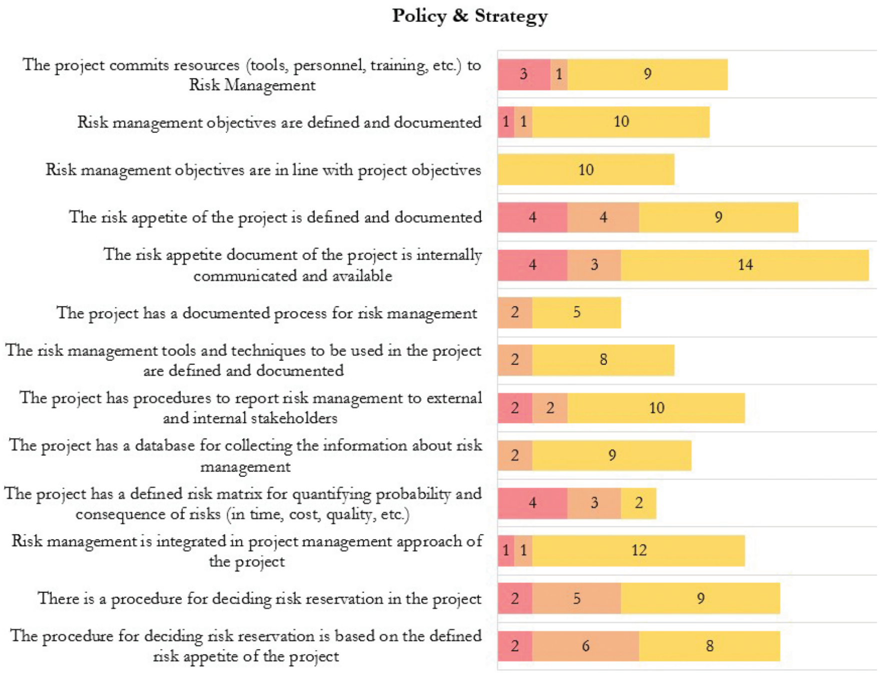

Figure 4-15 The improvement possibilities in the aspect Policy & Strategy in Organization 2

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Figure 4-16 presents the results of aspect Top-management Commitment. The participants expert more support and communication of the goals from the management (the first two statements). During one the sessions, it was stated that introducing changes for improving risk management should be both top-down and bottom-up and that there must be room within the projects for addressing risk management improvements. In one session, it was mentioned that sometimes public client is not directly involved because they wanted to try out the solution first and then involve public client if needed.

It was indicated by several projects that the management's attention to risk management is relatively low. The project team misses the involvement of public client in risk management. Some projects indicated that they expect more proactive management and more leadership from management. According to the participants, management knows that there is a need for more risk management, but it is quickly forgotten and nothing is done about it. More involvement of management does not have to be substantive. A project mentioned that they miss sometimes the internal communication with management about risks. Likewise, it was stated that if the project team knows what the risks are from the management's perspective, they could better identify and manage them. A project team mentioned that the management should explicitly define what information they need from the projects so that they can make the right decisions. This emphasizes the importance of communication between the team and the top-management.

Figure 4-16 The improvement possibilities in the aspect Management Commitment in Organization

The results of the aspect Culture and Personnel Knowledge is presented in Figure 4-17. It was mentioned during the sessions that there is no blame culture among the project members. Despite that, it was mentioned by the teams that the culture about risk management can still be improved. Lack of attention to training and coaching for risk management was also indicated by several participants. Several projects have mentioned that they have a lack of capacity. Presence of a risk manager or a risk advisor for (group of) projects could help them to improve risk management quality.

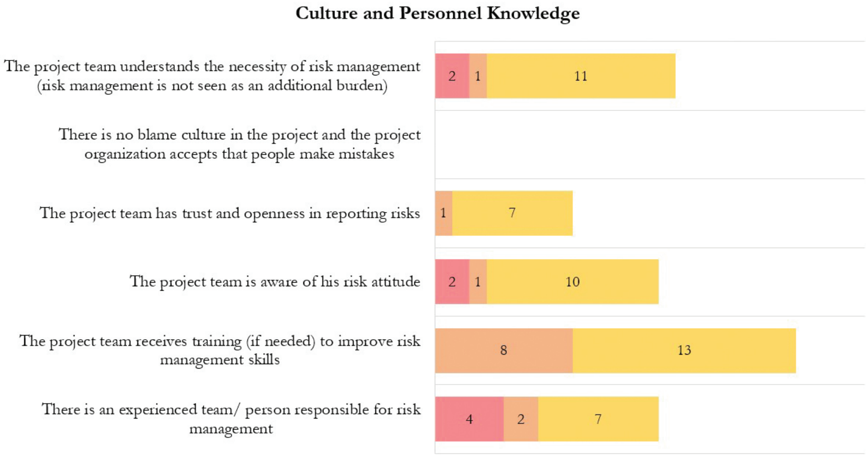

Figure 4-17 The improvement possibilities in the aspect Culture and Personnel Knowledge in Organization

Figure 4-18 reveals that the external stakeholders are not always involved in risk management sessions. One of the reasons mention during a session was that the risk sessions are mostly technical. In addition, it was mentioned that the stakeholders are not always available. Some experts mentioned that the involvement of the external stakeholders could be improved. The other statement that, according to the participants, need more attention is the documentation and communication of the risks.

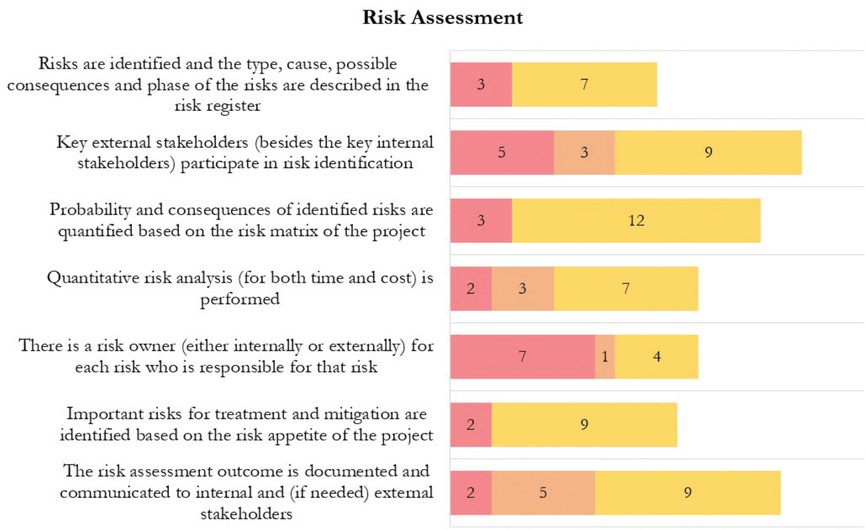

Figure 4-18 The improvement possibilities in the aspect Risk Assessment in Organization

As shown in Figure 4-19, several statements can still be improved. Integrating the duration and the costs of risks in the planning and cost estimate was mentioned in several sessions as one of the important improvement possibilities. In some sessions, it was mentioned that the risk register is stand-alone and the connection with the other project processes are not clear. Secondary risks are not considered in the projects. It was also mentioned that the contingency is decided usually based on the experience or a fixed percentage and not based on the identified risks. It was mention by a team that the control measures are not always clearly defined. In one session, it was also mentioned that due to the lack of capacity, the control measures are not always applied.

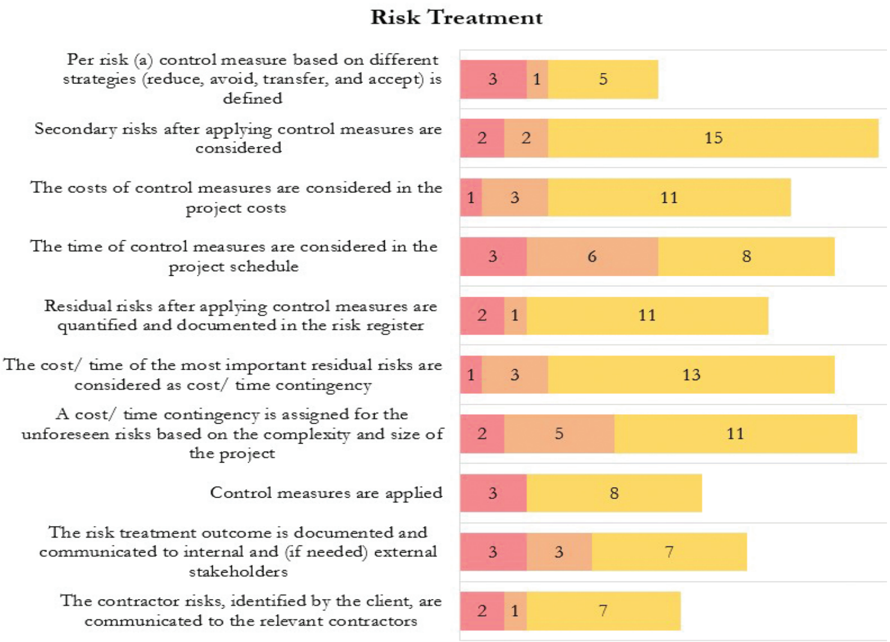

Figure 4-19 The improvement possibilities in the aspect Risk Treatment and Mitigation in Organization

The results of aspect Monitor & Review are shown in Figure 4-20. The evaluation of risk management was mentioned by several projects as one of the improvement possibilities. In most project, the status of the risks was mostly not updated by the projects. One participant stated that not evaluating risk management is just then doing an administrative work. Collecting and using the lessons learned was also among the statements which needs improvement according to most participants.

During a session, a project team seemed not very motivated to improve risk management. They explained the advantages of applying risk management are not clear for them and that they doubt whether risk management can create value.

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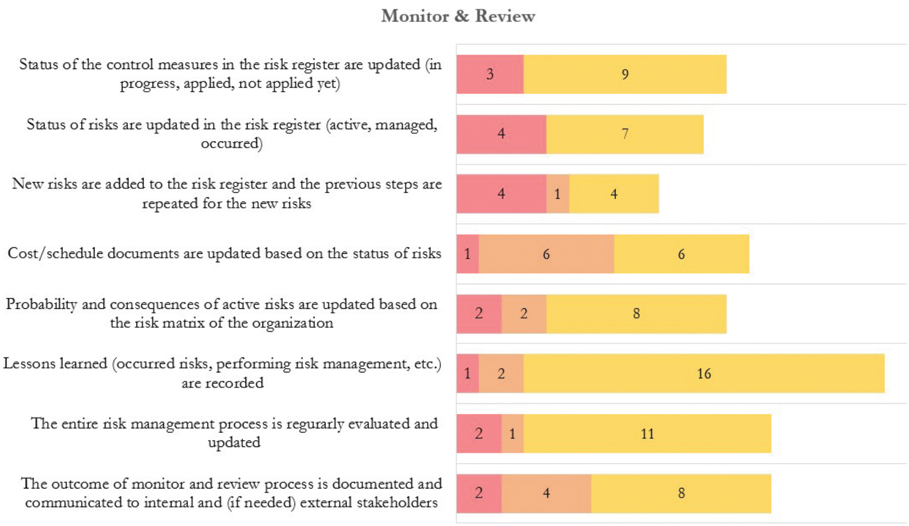

Figure 4-20 The improvement possibilities in the aspect Monitor & Review in Organization

4.6 Discussion, conclusion and recommendations

This chapter discussed the risk management maturity of projects executed by public organizations in the Netherlands. RiskProve, developed in Chapter 3, was applied in 16 projects of two public organizations. The objective of this research was to help the projects improve their risk management practices.

In this research, the risk management maturity is examined in two categories: Organization and Application & Process. These two categories consider both the essential requirements of applying risk management, (Organizational category of RiskProve) and risk management steps (Application & Process category of RiskProve). Both organizations show similar maturity and ambition results in the Organization and Application & Process categories. Comparing the results of ambition and maturity (Figure 4-5 and Figure 4-14), Organization 1 is more advanced in the risk management application. Among the studied organizations, Organization 1 shows, in general, a higher score on risk management maturity. This organization has significantly invested in risk management. In addition, the projects investigated in this organization belongs to the department of HWBP. Risk management is integrated in the projects and plays an important role in their project management approaches. As a requirement for receiving the subsidy, the projects have to perform risk management. This suggests that risk management is better established in Organization 1. In contrast, Organization 2 has either no defined risk management process or the risk management process is not actively used in their projects. In Organization 2, it was, for a large part, up to the project team to decide on how to set up risk management. This can clarify the difference between Organization 1 and Organization 2 in, for example, the aspect Policy and Strategy.

A decreasing trend can be observed in the maturity scores of the aspects Risk Assessment, Risk Treatment and Mitigation and Monitor and Review for both organizations (Figure 4-3 and Figure 4-12). This indicates that the studied projects are more advance in identifying and quantifying risks than defining and applying the control measures, evaluating the whole process and collecting the lessons learned. This is in line with the study by Bannerman (2008), where the score for risk identification (risk assessment step) is higher than the scores of managing the risk (Risk Treatment and Mitigation step) and monitoring the risk (Monitor & Review step).

Regardless of the maturity scores, both organizations see possibilities for improvements in defining the objective of risk management, evaluation of risk management process, receiving risk management training and attention to the secondary risks. Especially, collecting and using the lessons learned requires more attention according to most participant in both organizations (Figure 4-11 and Figure 4-20). It has been argued that if we 'fail to learn' from our experiences in the projects, we will 'learn to fail' (Bannerman, 2008). Moreover, both organizations have no clear policy for risk appetite. The amount of risk appetite (Policy and Strategy aspect) has a direct relation with the risk which should be treated (Risk Treatment and Mitigation aspect)). This can explain the low scores for the statements number 4, 5 and 13 in the Policy and Strategy aspect. It was observed that some of the experts had also difficulties in understanding the term 'risk appetite'. The ISO (2009, p. 10) defines risk appetite as the amount and type of risk that an organization is prepared to pursue, retain or take. In 2007, MacGillivray et al. (2007b) stated that more investment should be performed to improve risk knowledge management, education and training. It is interesting to see that at the time of writing this dissertation still the same improvement are required. Results reveal that the aspect top-management commitment has the lowest risk management maturity score for both organizations. The literature on risk management shows the importance of top-management support and involvement for the project's success (Bannerman, 2008; De Bakker, Boonstra, & Wortmann, 2010; Ehie & Madsen, 2005).

During the sessions with the projects in Organization 2, it was mentioned by some projects that they are innovative projects and are considered as proof for other projects. Therefore, there are agreements with the management that they can take more risks. It was also mentioned that risk management is different in their projects. An innovative project does not mean that risk management should not be applied in the project. It means, however, due to the novelty in the project, less risk could be identified. Regardless of the character of the project, risk management could help for delivering a successful project and better results (Chapter 2). However, due to the novelty in the project, the project could take a higher risk appetite.

For those projects where the ambition score is lower than the maturity score (Project 6 and Project 7 in Figure 4-3), one may wonder whether too much attention is paid to risk management. It would be good to investigate this further to avoid spending too much time and money on risk management in these projects.

Based on the results, the following recommendations are given to both organizations:

1. Determine the objectives of risk management in a team meeting. This ensures that everyone in the team has the same idea about risk management in the project. Ensure that the management objective for risk management is also clear to the team. Determining the risk management objective for the project helps the team and the management focus on the key risks in the project.

2. Ensure that the project members receive sufficient risk management training to increase or refresh their knowledge of risk management. Training can be provided both externally and internally. In an internal training, the project members of different projects can share their experience about risk management with each other.

3. Map the most important stakeholders for the project with the team members (for example via a stakeholder analysis and/or SWOT analysis) and determine which stakeholder should be involved and which stakeholders should be kept informed, through which channel and how often.

4. Involve the most important external stakeholders in the risk management sessions to better inform them (management of expectations) and to share the risks and responsibilities.

5. Determine and document the risk appetite of the project, in consultation with the project team. The risk appetite of the organization has a direct influence on the risk appetite of the project. Factors such as complexity of a project, political sensitivity and goal of the project influence the level of risk appetite. Based on this risk appetite, the risk matrix of the project can be drawn up and it is determined which risks are in the red area (and must, therefore, be controlled) and which risks fall in the green area (and can, therefore, be accepted). Defining the risk appetite ensures that the entire team has the same understanding about the most important risks in the project whether or not a risk should be controlled or should be accepted.

6. Sometimes the application of a control measure can cause new risks. For example, a new method of execution as a control measure for a risk might introduce new risk such as lack of expertise in the project. These risks are referred to as secondary risks. Think beforehand whether the control measures can cause new risks.

7. Take the duration and costs of control measures in the planning and cost estimate.

8. Last but not least: make sure that the lessons learned are recorded. The organization often carries out similar projects. The same risks can be relevant to multiple projects. Share the lessons learned during a session. These types of sessions can also be considered as risk management training, especially for the younger project members. Do the evaluation both at the end of each phase and at the end of a project and share the result internally (and if possible also externally). A standardized risk file is an important tool in this regard.

Specific recommendations to the second organization are:

1. Assigning a risk manager or a risk adviser to (a group of) projects who can coach and direct the team towards improving the risk management. Raz, Shenhar, and Dvir (2002) showed that when a risk manager was appointed, the impact was significant on project success.

2. More involvement and a proactive role from public client towards risk management. Involvement does not have to be in details and by participating in the sessions. It can be by, for example, showing commitment and interest to risk management and its outcome.

3. It was mentioned in a group that they have never seen the added value of risk management. It could be helpful if the team members hear the success stories of risk management in other projects. Creating a sense of urgency for risk management and passion for improvement and change could also help. Invest in the risk awareness of the organization by communicating directly and clearly the opportunities that risk management brings and the possible alternatives of not applying risk management. Define short-term milestones and plan to reach those milestones. Investigate the reasons for lack of commitment and omit them.

Part of these recommendations is validated later in Chapter 8 using three expert sessions.

4.7 References

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CHAPTER 5

Identified and Occurred Risks in Construction Projects: A Case Study of Flood Defence Projects in the Netherlands

Abstract

Learning from risks in previous projects could be a way to improve risk management and the overall success of a project. This study builds the foundation to do so by gathering actual project risks using a different approach compared to other researches. The research aims to increase the knowledge about the identified and occurred risks in construction projects. Using a case study approach, the identified risks are collected from the risk registers of 16 projects during the whole project lifecycle. The risks are categorized based on the seven categories of the RISMAN method. Occurred risks are collected by interviewing the project manager or project controller of each project. In total, 2157 risks are collected from the risk registers of projects. More risks are identified in the preparation phase than in the execution phase. In total, about 13% of identified risks have occurred, mostly in the execution phase. Most identified and occurred risks are related to the Organizational and Zoning categories. Future similar projects can use these results to get insight into the most common type of risks, the phase in which most risks are identified and have occurred and the risks that are identified and have never occurred.

Keywords: risk identification, risk categorization, project risk management, occurred risks, construction projects

5.1 Introduction

Construction projects are vulnerable to risks due to the long period of development, multi-ownership, involving substantial resources, large size, political issues and significant novelty and involvement of various public and private stakeholders (C. Chapman & Ward, 2003; Yeo & Ren, 2009; David Hillson, 2012; Hopkinson, 2012; Schwindt & Zimmermann, 2015; J. Wang & Yuan, 2016). Risks in a project can be expressed as internal or external events or circumstances, which can affect (positively or negatively) the expected outcome of the project (APM, 2012; A. Wang & Pitsis, 2019). While project risks cannot be eliminated completely (Burchett, Rao Tummala, & Leung, 1999; Taroun, 2014), project risk management can ensure that the risks have minimal negative effects on meeting the project's objectives (Zou, Zhang, & Wang, 2006; Perrenoud, Smithwick, Hurtado, & Sullivan, 2015).

Effective risk management can help to reduce, absorb, and transfer risk, and exploit potential opportunities (Liu, Flanagan, & Li, 2003; Badi & Pryke, 2016). The focus of risk management does not only lie on predicting the future, but on creating a better understanding about projects so that better decisions can be made as well (Smith, Merna, & Jobling, 2014).

Risk management helps projects achieving their objectives by escalating the probability and impact of positive events and minimizing the probability and impact of negative events (PMI, 2013; Schwindt & Zimmermann, 2015). Empirical research on project performance of major organizations across a variety of industries shows that wherever risk management is insufficiently applied, projects fail more often (Hopkinson, 2012). The cases of Panama Canal (Kendrick, 2006; Alarcon, Ashley, de Hanily, Molenaar, & Ungo, 2011), the design of the Airbus 380 (Shore, 2008), and the nuclear waste depository in the Yucca Mountain, Nevada (Swift, 2015) are a few examples of many project failures due to lacking or ineffective risk management.

5.2 Problem formulation and research objective

The risk management process contains risk identification, risk analysis, risk response, and risk monitoring and reviewing (D. Hillson & Simon, 2007; Nieto-Morote & Ruz-Vila, 2011; Yoon, Tamer, & Hastak, 2014; Perrenoud et al., 2015; T. Wang, Tang, Du, Duffield, & Wei, 2016). Risk identification forms the structure of risk management (R. J. Chapman, 1998) and is considered to be the most important phase because it has the biggest impact on the quality of the risk management process (Al-Bahar & Crandall, 1990; Bajaj, Oluwoye, & Lenard, 1997; R. J. Chapman, 1998; Jung & Han, 2017). It is important to identify risks and responses as early as possible in the project because major decisions, such as choice of alignment and selection of construction, can still be influenced in early project phases (Eskesen, Tengborg, Kampmann, & Veicherts, 2004). This can significantly affect the competitiveness, as well as profit potential of a construction company (Fidan, Dikmen, Tanyer, & Birgonul, 2011).

According to Ghaffari (2013), additional steps to the risk management process are communication, monitoring, review, and learning. Projects create a suitable environment to gain valuable experiences that can be reused in future projects (Wiewiora, Trigunarsyah, Murphy, & Liang, 2009; Pemsel, Wiewiora, Müller, Aubry, & Brown, 2014). However, learning from projects within organisations rarely happens in practice and when it does it fails to deliver the intended results (Duffield & Whitty, 2016). A reason for this within the construction sector can be the urge to deliver projects faster, with better quality and at lower cost (Egan, 1998). Learning from mistakes or potential pitfalls can help to reduce project risks because this information can prevent it from happening in future projects (Schindler & Eppler, 2003; Howard & Smith, 2016). Lessons based on completed projects are the intellectual assets of an organisation that can create value and can provide competitive advantage if used properly (Carrillo, Ruikar, & Fuller, 2013), and therefore they should be used.

As the success of a project is very dependent on the quality of risk management, and as risk identification is the most important phase of the risk management process, improving the quality of risk identification can improve the overall success of a project. A way to improve this can be by using the valuable information that lies in completed projects. This can be done by gaining insight in the risks that have been identified and the risks that have occurred throughout the project lifecycle. While it is impossible to predict all the unwanted events in a project (Schieg, 2006), it is possible to identify the common categories of risks and learn from what has or has not happened in previous projects, or know the phase in which most risks are identified or occurred.

Few researches have investigated the identified and occurred risks in real construction projects. One of this few researches is the study by Jung and Han (2017) who investigate identified and occurred risks in three moments in time from a contractor perspective. They identified risk factors from literature and, using a questionnaire, investigated risk identification, assessment and mitigation in contractor projects. Building on the current literature, the current research investigates the identified and occurred risks in the client project with a different approach. Different than Jung and Han (2017), this research investigates the risk registers of construction projects and examines the risks regarding type of risk, phase of identification and phase of occurrence. Several researchers discuss the possible categorization and ranking of risks (Miller & Lessard, 2001; Ng & Loosemore, 2007; Bentley, 2010; Famiyeh, 2015; Sanchez-Cazorla, Luque, & Dieguez, 2016; Dandage, Mantha, & Rane, 2018), however, not many researches discuss the categories of identified and occurred risks in real construction projects. This research contributes to the current risk management body of knowledge by investigating the identified as well as the occurred risks, thereby increasing the knowledge regarding these identified and occurred risks in real projects. The results of this research can help to improve the identification of future risks, as an important step in improving risk management.

Consequently, this research has the following objectives:

- To explore the category and the number of identified and occurred risks in construction projects.
- To explore the project phase in which most risks are identified and have occurred.

The research questions of this research are formulated as follows:

1. *What are the categories of identified risks in construction projects?*
2. *What are the categories of occurred risks in construction projects?*
3. *How many risks are identified in different project phases?*
4. *In which phase of construction projects do most risks occur?*

This research explores the identified risks from a client perspective of public organizations in the Netherlands. To answer the research questions, the categories of risks identified and occurred in 16 dike improvement projects are investigated.

The rest of this paper is structured as follows. The next section discusses the literature about risk categorization in projects. Next, the methodology of the data gathering and analysis is elaborated. Subsequently, the research results and analysis are presented, followed by the discussion section. Next, conclusions are drawn, limitations of the research are described, and recommendations for future researches are provided. Finally acknowledgments are listed.

5.3 Literature review on risk categorization

Risk categorization is a key part of the risk identification phase and is of great importance in an effective risk management approach (Zou et al., 2006; Sanchez-Cazorla et al., 2016). According to PMI (2008, p.280) "risk categories provide a structure that ensures a comprehensive process of systematically identifying risks to a consistent level of detail and contribute to the effectiveness and quality of the risk identification process." Construction projects can benefit from risk categorization because it expands the awareness regarding the risks involved, and therefore it is more likely that certain risks will be identified (Al-Bahar & Crandall, 1990).

5.3.1 Different methods of risk categorization

The risk management literature shows a great variety of attributes given to risk categorization. The Australia/New Zealand standard AS/NZS 4360 (AS/NZS, 2004) provides a source for risk identification and analysis. In this source, the risks are categorized as commercial and legal relationships, economic circumstances, human behaviour, natural events, political circumstances, technology and technical issues, management activities and controls, and individual activities. BSI (2000) proposes risk identification at three different levels of business, project and sub-project level. Each level corresponds to long, medium, and short-term goals and requires the participation of different people within the organization. The categorization suggested by BSI (2000) includes human factors, political/societal, environmental, legal, economic/financial, commercial, technical/operational. Ng and Loosemore (2007) categorize risks into two main groups: project risks and general risks. Project risks are the risks arising from the way a project is managed or from events in the project's environment. Examples of project risks are natural, technical, material, organizational, manpower, contractual and environmental problems. General risks are a type of risks originating from natural, political, regulatory, legal and economic events in the general macro-environment of a project. Grimsey and Lewis (2002) categorize risk in infrastructure projects in nine groups of: technical, construction, operating, revenue, financial, force majeure, regulatory/political, environmental, and project default risks.

The core of identifying risks is to examine the project in a systematic manner from as many points of view as possible to recognize the potential risks to the project (Van Well-Stam, Lindenaar, and van Kinderen (2004)). They provide a general categorization, specifically delivered for infrastructure projects in the Netherlands, containing seven categories of technical, organizational, zoning, political, financial, social, and legal. Miller and Lessard (2001) distinguish three main groups of risks: 1. Market-related risks including demand, financial and supply risks, 2. Completion risks, including technical, construction and operational risks, and 3. Institutional risks including regulatory, social acceptability and sovereign risks. Sanchez-Cazorla et al. (2016) propose nine risk categories for complex and mega projects: design, legal/political, contractual, construction, operation and maintenance, labour, customer/user/society, financial/economic and force majeure risks. Likewise, Murray, Grantham, and Damle (2011) list nine project risk categories: technological and operational, financial and economic, procurement and contractual, political, environmental, social, regulatory and legal, safety and delay risks. Bentley (2010) categorizes project risks into: strategic/commercial, economic/financial/market risks, legal and regulatory, organizational/human/management, political, environmental risks and technical/infrastructure/operational risks.

From the above categorizations two aspects are concluded: First, the similarity that different categorizations of risks share. The mentioned categorizations, despite their seeming differences, share some ground rules. All above categorizations contain the Technical, Financial, Environmental (except (Miller and Lessard (2001)), Political and Legal risks. Second, some categorizations use a higher level of detail and use multiple categories to address the same subject that is addressed in other methods as one category. For example, Grimsey and Lewis (2002) mention both 'environmental' and 'force majeure' (earth quack, war, flood, etc.) risks while Van Well-Stam et al. (2004) categorize them in one category as Zoning. Likewise, the Australia/New Zealand standard AS/NZS 4360 (AS/NZS, 2004) distinguishes between Human Behaviour, Management Activities and Controls, Individual Activities while these are endorsed under the organizational risks in, for example Van Well-Stam et al. (2004).

Despite the different terminologies and level of details implemented in different methods, it is concluded that risk can be categorized in different ways by different categorization. The following section elaborates on the risk categorization used in this research.

5.3.2 The risk categorization for this research

Risk categorization presents numerous challenges, the first of which is where to begin. Categorization systems strive not only to organize a field but also to perform it in such a way to be useful to those whom it affects (Crawford, Hobbs, & Turner, 2004). Zou et al. (2006) concluded that there are various possibilities to categorize risks and in principle, one can use them all, depending on the project, as the method must serve the purpose of the research. Therefore, the categorization of risks depends strongly on the functions and objectives of the work. The objective of risk categorization in this research is to get an insight into the common categories of risks in practice and this research benefits from reusing existing categorizations rather than 'reinventing the wheel'.

The most commonly used framework for project risk management in the Netherlands is the RISMAN method by Van Well-Stam et al. (2004). RISMAN method categorizes the risks to seven categories:

1. Technical: risks emerging due to incorrect assessment of technologies, the quantity of materials, and construction method, modifications in design and construction estimate during the execution, new technologies, and disappointing performance by contractor.

2. Organizational: risks related to lack of project's procedures, lack of clarity on client's requirement, lack of clarity about project limits and quality plan, failure to take the projects in the surrounding to consideration, lack of workforce in the organization, and late ordering of materials and incomplete or careless contract preparation.

3. Zoning: risks arising from the project location such as unexpected weather, ground and underground condition, encountering any objects in the ground, traffic and accessibility of the site, and encountering protected species.

4. Political: risks related to lack of or insufficient insight into permits and/or municipal requirements, failure to obtain the work permits (in time) or coming to an agreement with other governmental organizations.

5. Financial: risks related to bankruptcy of the contractor, client or supplier, inflation in the price of materials, salaries, lack of availability of financing at certain points, and deviation in assumed taxes

6. Social: risks occurring because of lack of communication with the inhabitants around the project area, and disturbance and damages to the third parties' property.

7. Legal: risks related to the claim from other parties, invitation to tender, purchase of required land, and error made by the contractor regarding compliance with regulatory preparations and regulations.

Table 5-1 compares the seven categories of RISMAN method with other risk categorizations mentioned in the literature. For each reference, the number of risk categories that the method uses has been presented, for example Rasool, Franck, Denys, and Halidou (2012) use eleven risk categories. Further, the results in Table 5-1 shows whether a category used by a method matches a certain RISMAN-category and if this is the case it is noted with a star (*). For example, the risk categories that Murray et al. (2011) have defined match all the RISMAN-categories, and the risk categories that Grimsey and Lewis (2002) have defined match five out of seven RISMAN-categories.

Table 5-1 Comparison between risk categories in RISMAN method and other categorizations (T = Technical; O = Organisational; Z = Zoning; P = Political; F = Financial; S = Social; L = Legal)

ID	Reference	Number of categories	RISMAN-categories						
			T	O	Z	P	F	S	L
1	(Liu, Zhao, & Yan, 2016)	21	*	*	*		*		*
2	(Tah & Carr, 2000)	20	*	*	*	*	*		*
3	(Zhi, 1995)	15	*	*	*	*	*		*
4	(Bing & Tiong, 1999)	13	*	*	*	*	*	*	*
5	(Bing, Akintoye, Edwards, & Hardcastle, 2005)	12	*	*	*	*	*		*
6	(Baghdadi & Kishk, 2015)	11	*	*	*	*	*	*	*
7	(Edwards & Bowen, 1998)	11	*	*	*	*	*		*
8	(Rasool et al., 2012)	11	*	*	*	*	*	*	*
9	(Ogunsanmi, 2016)	11	*	*	*	*	*	*	*
10	(El-Sayegh, 2008)	10	*	*	*	*	*	*	*
11	(R. J. Chapman, 1998)	10	*	*	*	*	*	*	
12	(Chan, Yeung, Yu, Wang, & Ke, 2010)	10	*	*	*	*	*	*	*
13	(Sanchez-Cazorla et al., 2016)	10	*	*	*	*	*	*	*
14	(Ng & Loosemore, 2007)	10	*	*	*	*	*	*	*
15	(Hosny, Ibrahim, & Fraig, 2018)	9	*	*	*	*	*	*	*
16	(Akintoye & MacLeod, 1997)	9	*	*	*	*	*		*
17	(Murray et al., 2011)	9	*	*	*	*	*	*	*
18	(Grimsey & Lewis, 2002)	9	*	*	*	*	*		
19	(Miller & Lessard, 2001)	9	*	*		*	*	*	
20	(Nishaant Ha, 2018)	8	*	*	*	*	*	*	*
21	(Beltrão & Carvalho, 2018)	8	*	*	*	*	*	*	*
22	(Asadi & Rao, 2018)	8	*	*	*	*	*	*	*
23	(AS/NZS, 2004)	8	*	*	*	*	*		*
24	(Mahendra, Pitroda, & Bhavsar, 2013)	7	*	*	*	*	*	*	*
25	(Choudhry, Aslam, Hinze, & Arain, 2014)	7	*	*	*	*	*	*	*
26	(Okolelova, Shibaeva, & Shalnev, 2018)	6	*	*	*	*	*	*	*
27	(Al-Bahar & Crandall, 1990)	6	*		*	*	*	*	*
28	(Bentley, 2010)	6	*	*	*	*	*		*
29	(Kuo & Lu, 2013)	5	*	*	*	*	*	*	*
30	(Han & Diekmann, 2001)	5	*	*	*	*	*	*	*
			100%	97%	97%	97%	100%	70%	90%

Table 5-1 shows that more than half of the approaches match all seven RISMAN-categories, the other approaches show less overlap, but all approaches match 5 of the seven categories. The bottom row of Table 5-1 shows a percentage per RISMAN-category, referring to the percentage of methods matching a certain risk category. For example, all the examined methods include technical risks and therefore the RISMAN-category Technical scores 100%. All methods include financial risks too, and almost all methods include organizational and zoning risks. The RISMAN-category Social has the lowest number of matches, only 21/30 (70%) methods. As shortly addressed in the previous section, some resources give more attention to the risks in a higher level of detail than the RISMAN method. For example Zhi (1995), El-Sayegh (2008), and Sanchez-Cazorla et al. (2016) include risks such as war, bribe and corruption, revolution, civil disorders. RISMAN, however, only considers risks from the direct project environment.

Based on Table 5-1 and the aforementioned arguments, it is concluded that the risk categorization of the RISMAN method roughly covers all the categories of other risk categorization literatures. Therefore, this research adopted the risk categorization of RISMAN method.

5.4 Methodology of data gathering and analysis

To have a holistic understanding of the situation (Kothari, 2004; Kumar, 2011) a case study approach is selected as research strategy (Yin, 2014). The unique strength of a case study is its ability to use different methods, such as document study and interview for data collection (Yin, 2014).

In order to explore the category of identified and occurred risks in construction projects, the research is performed in three parts: 1. Collecting the identified risks, 2. Investigating the identified risks that have occurred, and 3. Evaluation of the results. The data for the first part was collected by means of document study. The data for the second part, the occurred risks, was collected by means of interviews. In the end, the results were evaluated by interviewing three experts. Figure 5-1 presents the research design.

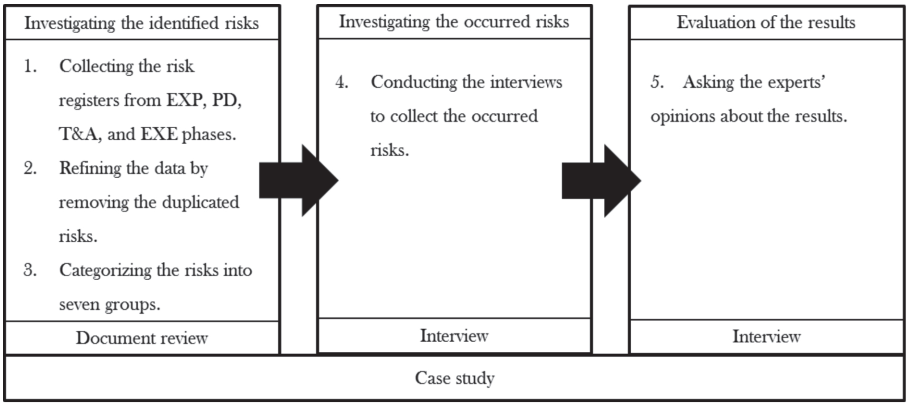

Figure 5-1 Research design (EXP stands for the Exploration phase, PD stands for Plan Development phase, T&A stands for Tender & Award phase and EXE stands for Execution phase

5.4.1 Investigating the identified risks

To examine the identified and occurred risk in construction projects, finished projects from the Flood Protection Program (known as Hoogwaterbeschermingsprogramma (HWBP)) in the Netherlands are selected as the cases. The HWBP program has the objective to improve the flood defence facilities (such as dikes, locks, pumps, etc.) in the Netherlands, which do not meet the safety norms. Each flood defence facility that does not satisfy the safety norms, will be improved in a project. The projects (cases) for this research are selected from a program of projects known as HWBP-2 as most of the projects in this program are finished.

The projects are selected based on three criteria:

1. The projects should be comparable,
2. The projects should be finished,
3. Both the risk management documents, and the project teams of these projects should be available.

Based on these criteria, 16 finished projects were selected. The selected projects are flood defence facilities (13 dike projects, one lock and two coast reinforcements). The projects are comparable since they are flood defence facilities, however, the project characteristics such as type of contract, the project location, natural environment, budget, and etc. were different.

The project team of each project is responsible to compose the risk registers during the whole project lifecycle (four phases). These four phases are:

- Exploration (EXP): In this phase, the possible alternatives and solutions are investigated. These alternatives are further elaborated, and the best alternative would be selected.
- Plan Development (PD): the selected option of the previous phase is further elaborated, and the project plan is created.
- Tender & Award (T&A): In this phase, the project follows the tendering process and is awarded to a contractor.
- Execution (EXE): the activities to realize the project are performed by the contractor.

From the above four phases, EXP, PD and T&A are the preparation phases and the EXE is the execution phase. In the first step of the research, risk registers were collected from all projects and the four aforementioned phases and recorded in an Excel document. After collecting all the identified risks of each project, it was observed that some risks are repeated in several phases of a project. Hence, the duplicated risks are removed and risks, which are mentioned in different phases of a project are considered as one risk. Also the phases in which the risks are mentioned are recorded. Next, all gathered risks are read and categorized based on the RISMAN method as explained earlier. The risks are categorized by the author. The RISMAN method provides examples of risks per category. These examples are used to categorize the risks collected from the risk registers. In some cases, a risk could not be easily assigned to a category because the risk was vaguely formulated, or it could be assigned to more than one category. In these cases, the cause or the control measure of the risk are investigated to choose the most suitable category.

5.4.2 Investigation of the occurred risks

The investigation of the occurred risks was done by conducting interviews as the occurred risks were not documented in the risk registers. The project manager or project controller of each of these projects was interviewed to discover which risks actually have occurred. Interviews were held for 14 of the total 16 projects. Project 11 had limited identified risks, so it was not included for the interviews. The project manager of project 16 was not available for an interview.

The interviews were structured interviews focussing at the identified risks in each project. During the interviews, each interviewee was provided with the list of the identified risks for the project in which he/she worked. The interviewee was asked to read the list of risks and mention which risks have occurred. For example, the interviewee read a risk and said this risk was not occurred and moved to the next risk on the list. Following this approach, the data collected was the list of occurred/not occurred risks from each project. The (possible) not identified, but occurred risks were not mentioned in the documents. At the end of each interview, the researcher asked whether there are risks that were not identified but have occurred. Most of the interviews could not remember any. During the interviews, notes were taken. The interviews were recorded to support the reporting of occurred risks.

Afterwards, the identified and occurred risks were analysed based on the categories of risk and the phases in which the risks are identified or occurred. The data was analysed in Excel. Per project, number of identified and occurred risks (per category, per phase, and in the whole project) were counted. If a risk occurred, the phase in which the risk is mentioned for the last time in the risk register is flagged as the phase in which the risk occurred.

5.4.3 Evaluation of the results by experts

As a third step in the data collection, three experts were interviewed, and their opinions were asked about the common categories of risks in these projects. The purpose of this step was to check the extent to which the experts' expectation is in line with the results from the risk registers. The experts have more than 10 years of experience and all the three experts are involved in the Flood Protection Program and have experience with flood defence projects. The questions were similar for all experts: the experts were asked to name the common categories of risks, number of identified risks, and the phase in which the most risks might occur and to elaborate on their answers. During the interview's notes were taken. Results from part 2 of the data collection were compared to the experts' responses.

5.5 Results and analysis

The research results are explained in three parts: first the results of the identified risks are presented, next the results of the occurred risks are elaborated and at last, the evaluation of the results with the experts is explained. Due to the nature of the collected data, no meaningful statistical analysis (e.g. correlation, regression, etc.) can be performed. We only descriptively explain the results of identified and occurred risks.

5.5.1 Identified risks

In total, after removing the duplications, 2157 risks are collected from risk registers of 16 projects in four phases: EXP, PD, T&A and EXE. Some examples of the identified risks in the projects for each category are:

- Technical: Sheet pile wall cannot be installed in the desired depth.
- Organisational: Delivered information to the contractor is incorrect or is not enough.
- Zoning: Unexpected objects such as explosives, pipes and cables are found in the ground during the execution.
- Political: The authorities do not agree with the plan and do not make any decisions.
- Financial: The contractor goes bankrupt.
- Social: Damage to the building around the project execution.
- Legal: Unexpectedly, a legal procedure should be started for the acquisition of the required ground.

Table 5-2 presents the total number of identified risks per project and per phase. Most of the identified risks in these projects are related to the categories Organizational (615 risks) and Zoning (449 risks), followed by Political (306 risks) and Technical (287 risks).

Table 5-2 Total number and categories of the identified risks per project

	Categories of identified risks							
Project ID	**Political**	**Zoning**	**Organizational**	**Technical**	**Social**	**Legal**	**Financial**	**Total per project**
1	10	25	22	5	7	3	2	74
2	25	33	66	34	21	19	6	204
3	5	22	22	13	5	5	4	76
4	16	57	64	21	20	15	5	198
5	22	53	49	20	14	15	9	182
6	25	38	65	18	11	15	6	178
7	13	42	57	32	9	8	8	169
8	36	24	34	22	7	18	8	149
9	10	11	12	14	5	10	5	67
10	43	26	74	4	14	31	29	221
11	5	5	4	3	4	2	2	25
12	15	8	11	6	2	14	5	61
13	16	24	16	21	11	9	6	103
14	15	47	62	28	24	13	15	204
15	4	12	8	1	2	1	1	29
16	46	22	49	45	22	26	7	217
Total per category	306	449	615	287	178	204	118	2157
Average	19.13	28.06	38.44	17.94	11.13	12.75	7.38	134.81

In some projects (such as project number 2, 10, 14, 16), in total more than 200 risks have been identified while some projects (such as project 11) have considerably less identified risks. One reason could be differences in the project characteristics. For example, a dike project in an urban area (where residents live behind the dike) will probably encounter with more risks form the environment than a dike in a natural area. These two dikes might be similar regarding, for example, the execution method but because they have different locations, the number of identified risks in one project might be higher. A second reason could be that risk identification is not performed with similar intensity in all projects.

Figure 5-2 presents the number of identified risks per phase for each project and the trend of risk identification in each project in the rightest column. Each dot on the lines corresponds with one of the project phases (first dot from left corresponds the EXP phase and so on). The red dot presents the highest number and the black dot presents the lowest number of identified risks. On average, the results show an increase in the number of identified risks per phase in the preparation phases (EXP, PD, and T&A) and less risk identification in the execution phase. Most risks, in general, are identified during T&A.

5

	Number of risks per phase				
Project ID	EXP	PD	T&A	EXE	Trend
1	36	24	43	58	
2	126	137	23	36	
3	51	52	54	66	
4	103	125	144	44	
5	32	10	105	34	
6	104	124	35	33	
7	43	85	94	50	
8	25	9	118	37	
9	20	23	32	24	
10	96	80	57	89	
11	18	18	12	14	
12	26	29	35	41	
13	26	35	26	42	
14	13	56	77	74	
15	23	23	16	8	
16	59	59	72	60	
Total per phase	801	889	943	710	
Average	50.1	55.6	58.9	44.4	

Figure 5-2 Number of identified risks per phase

As mentioned earlier, risk identification in the projects is performed in four phases. It is possible that a risk is active in more than one phase. This means that some risks are repeated during different phases, while some might happen in one of the phases, and some might expire during the project. Table 5-3 presents the number of risks in the risk register in each phase per project. Bold numbers show the number of identified risks per phase in each project and the starred numbers show the phase with the most identified risks in each project. Table 5-3Error! Reference source not found. also shows the overlap between the number of risks in each phase. For example, project number 1 has 36 risks in the risk register in the EXP phase and 23 of these risks are repeated in the PD phase as well. The information in Table 5-3, suggests how risk identification has taken place: some projects, in the early phases, have an eye for the risks in the execution phase (projects number 1, 3). So some of the risks which are identified in the earlier phases are repeated in the execution phase; while some projects (e.g. project number 2, 5, 6 and 7, 8) have less identified risks overlapping with earlier phases. Effective risk management involves that risks are identified before the project concept has been finalized (Sanchez-Cazorla et al., 2016).

Table 5-3 also shows how many risks are added in each phase to the existing risks in the risk register. For example, in project 1, it can be seen that from the 43 risks in the T&A phase, 41 risks are repeated in the EXE phase. 58 risks are in the risk register of the EXE phase meaning that 17 (=58 – 41) new risks are identified during the EXE phase. Further we see that in project 2, from 137 identified risks in the PD phase, only 5 are repeated in the T&A phase and the number of identified risks are significantly reduced. In this project either the risks are completely controlled or the project requirements (scope and design) are changed and, therefore, some of the risks are not applicable anymore. It is also possible that some incorrect risks are identified and removed later on. As another example, project 11 shows the same number of identified risks in the EXP and PD phases. This situation is the same in the T&A phase (12 risk in the T&A phase are the same with the EXP and PD phases) and only six risks are not applicable anymore. This means that in PD and T&A phases, either no risk identification was performed or no new risks were identified It is also possible that the project team had a good overview of the project's requirements and scope and, therefore, could have identified the risks of the later phases in the begin stages. In the EXE phase, the project has identified some risks.

Table 5-3 Number of identified risks per phase (showed in bold numbers) and number of risks overlapping in different phases

Project ID	Phases	EXP	PD	T&A	EXE	Project ID	Phases	EXP	PD	T&A	EXE
1	EXP	**36**	23	34	32	9	EXP	**20**	4	4	1
	PD		**24**	23	21		PD		**23**	21	3
	T&A			**43**	41		T&A			**32***	7
	EXE				**58***		EXE				24
Project ID	Phases	EXP	PD	T&A	EXE	Project ID		EXP	PD	T&A	EXE
2	EXP	**126**	124	4	1	10	EXP	**96***	13	8	10
	PD		**137***	5	2		PD		**80**	43	40
	T&A			**23**	5		T&A			**57**	34
	EXE				**36**		EXE				88
Project ID	Phases	EXP	PD	T&A	EXE	Project ID		EXP	PD	T&A	EXE
3	EXP	**51**	48	45	42	11	EXP	**18***	18	12	7
	PD		52	48	45		PD		**18***	12	7
	T&A			**54**	51		T&A			**12**	7
	EXE				**66***		EXE				14
Project ID	Phases	EXP	PD	T&A	EXE	Project ID		EXP	PD	T&A	EXE
4	EXP	**103**	99	95	2	12	EXP	**26**	18	19	17
	PD		**125**	117	3		PD		29	26	25
	T&A			**144***	5		T&A			**35**	25
	EXE				**44**		EXE				**40***
Project ID	Phases	EXP	PD	T&A	EXE	Project ID		EXP	PD	T&A	EXE
5	EXP	**32**	2	2	0	13	EXP	**26**	2	0	1
	PD		**10**	3	0		PD		**35**	26	10
	T&A			**105***	0		T&A			**26**	9
	EXE				**34**		EXE				**42***
Project ID	Phases	EXP	PD	T&A	EXE	Project ID		EXP	PD	T&A	EXE
6	EXP	**104**	102	8	1	14	EXP	**13**	10	7	1
	PD		**124***	13	1		PD		**56**	47	1
	T&A			**35**	5		T&A			**77***	13
	EXE				**33**		EXE				74

Project ID	Phases	EXP	PD	T&A	EXE	Project ID		EXP	PD	T&A	EXE
7	EXP	**43**	14	8	1	15	EXP	**23***	22	11	5
	PD		**85**	56	3		PD		**23***	11	5
	T&A			**94***	5		T&A			**16**	8
	EXE				**50**		EXE				8
Project ID	Phases	EXP	PD	T&A	EXE	Project ID		EXP	PD	T&A	EXE
8	EXP	**25**	7	25	0	16	EXP	**59**	47	39	39
	PD		**9**	9	1		PD		**59**	50	0
	T&A			**118***	6		T&A			**72***	1
	EXE				**37**		EXE				60

5.5.2 Occurred risks

The results of the occurred risk are presented in Table 5-4. Based on the interviews with the project managers or project controllers of the 14 projects, it was concluded that out of 1928 identified risks, 249 (12.91%) risks have occurred. Due to the changes in the personnel in the project teams, the interviewees did not know whether the risks occurred in a total of 105 (5.45%) identified risks. The number of these risks are mentioned under the title 'Unknown' in Table 5-4. These risks belong to the period in which the interviewees were not yet part of the project team. There are some risks that are still active (i.e. the risk related to the operation phase or the risks related to the usefulness of the executed measures in practice).

Table 5-4 Number and Percentage of occurred risks per project (project 11 and project 14 are excluded)

Project ID	Total occurred	Total identified	Percentage occurred risk	Unknown	Still active
1	3	74	4.05%	10	0
2	42	204	20.59%	1	1
3	2	76	2.63%	0	0
4	12	198	6.06%	0	0
5	19	182	10.44%	22	0
6	28	178	15.73%	21	0
7	23	169	13.61%	15	0
8	15	149	10.07%	31	0
9	17	67	25.37%	4	0
10	24	221	10.86%	0	22
12	7	61	11.48%	0	0
13	16	103	15.53%	1	0
15	3	29	10.34%	0	0
16	38	217	17.51%	0	0
Total	249	1928	12.91%	105	23

Several identified and occurred risks are about the cables and pipes in the ground. For example, the cables are not timely removed or unexpected cables and pipes are encountered during the execution. Or risks related to the contract, for example mistakes in the contract, conflicts between the contractor and client because of different interpretation of contractual points, and scope changes. Some other examples of identified and occurred risks are: noise problems for the residents and damage to the objects (cables, houses, and infrastructure). Examples of the risks that are identified, but have not occurred are: the bankruptcy of the contractor, problems in collaboration between different parties in the project (municipalities, province, etc.). Several projects have mentioned the encountering of protected species as a risk but this happened in just one project.

Table 5-5 presents the category of occurred risks per project. The categories Organizational, Zoning, and Technical are the categories with the most occurred risks. When comparing these three categories to the top three categories of identified risks (Table 5-2), we see a shift between the Political and Technical categories.

Table 5-5 Occurred risks in different category per project (project 11 and project 14 are excluded)

Project ID	Political	Zoning	Organizational	Technical	Social	Legal	Financial	Total per project
1	0	2	0	0	0	1	0	3
2	10	8	12	6	3	1	2	42
3	0	0	1	1	0	0	0	2
4	1	4	6	1	0	0	0	12
5	1	5	7	3	1	2	0	19
6	1	9	6	2	4	6	0	28
7	2	4	11	4	1	1	0	23
8	0	7	2	4	1	1	0	15
9	2	4	4	3	1	2	1	17
10	1	3	9	0	3	4	4	24
12	0	0	2	2	0	2	1	7
13	0	3	3	4	6	0	0	16
15	0	2	1	0	0	0	0	3
16	3	7	6	14	2	4	2	38
Total per category of risk	21	58	70	44	22	24	10	249

Table 5-6 presents the number of occurred risks per phase per project and the total percentage of occurred risks in each of the phases. While the number of occurred risks per phase per project is different, in total, most of the risks have occurred in the EXE phase, which is in line with the results by Thangavel and Manikandan (2015). More occurred risks in the EXE phase means that either the identified risks related to the EXE phase could not be managed or some unknown unknown risks have occurred.

Table 5-6 Number of occurred risks per phase per project and the total percentage of occurred risks per phase (project 11 and project 14 are excluded

Project ID	EXP	PD	T&A	EXE	Total per project
1	0	0	0	3	3
2	0	30	3	9	42
3	0	0	0	2	2
4	1	1	9	1	12
5	0	0	8	11	19
6	1	10	2	15	28
7	2	4	10	7	23
8	0	0	11	4	15
9	6	0	4	7	17
10	6	0	4	14	24
12	2	0	1	4	7
13	1	3	3	9	16
15	0	2	0	1	3
16	2	8	4	24	38
Total per phase	21	58	59	111	249

5.5.3 Evaluation of results

Three experts were asked to evaluate the results. The common categories of risks as well as the number of identified risks in each phase were discussed.

According to expert 1, the most common risks are related to the categories Organizational, Zoning, and Legal. Expert 2 mentioned that the top three categories are Technical, Zoning, and Legal and expert 3 mentioned that the top three are the Zoning, Organizational and Technical. All three experts confirm that the category Zoning belongs to the top categories of risks in such projects. Expert 1 mentioned, focusing on organizational risks: "if you check the reasons of most risks, it will be seen that the most of the risks are related to [a lack of or a late action from] the organizations."

Expert 1 expected that the number of identified risks in the preparation phases would be about 20 and 30-50 in the execution phase, expert 2 expected 5-10 identified risks and in the execution phase 10-15 identified risks, and expert 3 expected 30 risks in the preparation phases and 20-25 risks in the execution phase. All three experts expected less identified risks than the current research results show (Table 5-2). According to Expert 3, in practice the projects have the incentives to identify more risks.

All the three experts expected that most risks had occurred in the EXE phase, which is indeed clear from the data (Table 5-6). Expert 3 mentioned that the occurred risks in the preparation phase have more impact on time while the occurred risks in the execution phase have more impact on costs.

5.6 Discussion

The first observation is the high number of risks identified in the projects in our sample, since the experts expected considerably less identified risks. As shown in Table 5-2, the projects have on average about 135 identified risks. The examined projects are among the usual projects executed by the studied public organization and, hence, the organization is familiar with the type of projects and the method of execution. Therefore, it could be expected that the projects do not have a high risk profile, however, still the organisation identified a high number of risks. This high number of identified risks can be related to the culture in this organization. The examined organization is a public organization, which is part of the regional government. In order to overcome reputation damage and public critics, this organization has a risk averse attitude. Besides, the organization receives a full subsidy to execute the projects. By identifying more risks, a project can apply for a higher contingency reserve, providing higher certainty to finish the project within budget. Needless to say, in the end not the number of identified risks as such is important, but the identification of the relevant (top) risks. It is also possible that the three experts underestimated the number of risks because of 'optimism bias' (Flyvbjerg, 2006) and in reality the projects are riskier than expected. In the authors' view, identifying many (correct) risks in a project is not negative per se as it can increase the confidence about the project delivery. However, the authors believe that trying to manage all these risks or assigning contingency to all these identified risks is wrong and not effective. It is important that the project teams define the risk appetite and only try to manage risks that are unacceptable, so to be selective.

As shown in Table 5-2, the most identified risks belong to the Organizational and Zoning categories. The uncertainties in the preparation phases (EXP, PD and T&A) of these projects are related to set up a project team with high quality standards of knowledge and experience, project plan, the requirements of the client and other stakeholders, design, as well as selecting the type of contract, etc. Moreover, due to their characteristics the examined projects have to deal with specific uncertainties from the environment. Uncertain situations such as the possibility of encountering a protected species, utilities (cables or lines) and contamination in the underground are among the common risks in these projects. Therefore, it is logical that more Organizational and Zoning risks are identified.

Less Technical risks are identified in the studied projects compared to the categories Organizational and Zoning and there are not many differences in the number of risks identified in the category Technical (287 risks) and the category Political (306 risks) risks. The lower number of identified and occurred technical risks could be explained by two reasons. First, either the projects were not complex in terms of the technical solution or the projects were executed with proven construction methods, avoiding innovative methods. Due to familiarity with the execution methods, less technical risks were present. Second, depending on the type of the contract, the execution risks could be transferred to the contractor and, hence, another party is responsible for these risks.

Figure 5-2 shows a steady increase in the total number of identified risks up to the T&A phase and a sudden drop in the number of identified the EXE phase. Table 5-6 however, shows an increase in the occurred risks during the whole project lifecycle. All studied projects have to undergo the preparation phases (EXP, PD, and T&A). In the EXP phase, there is little information available about the project and the design and the planning of the projects are not yet defined. In the PD phase the design and scope of the project is better defined. In the PD phase the design and scope of the project is better defined. In this phase, the project has a better understanding of the type of work and accordingly, more risks can be identified. In the T&A phase, some of the risks, identified in the previous phases, have occurred or are not valid anymore. For example, the project has acquired the necessary work permits, and has performed researches for the situation of the (under)ground. At the same time more risks related to the tender and contracting can be identified. After this phase, the project is awarded to the contractor and, depending on the type of contract, some of the risks are transferred to the contractor. This explains the higher number of identified risks in the preparation phases compared to the EXE phase.

More identified risk in the preparation phases than the execution phase could be explained because the projects are client's projects. Most attention is given to the risk identification in the preparation phases and some of the risks are assigned to the contractor. After the project is awarded to the contractor, it is possible that less risk identification is performed. It is also possible that due to good risk identification in the preparation phase for the projects, less risks could be identified in the execution phase.

When a risk is identified, depending on its priority, a control measure is assigned to it to reduce its impact. The cost/time of performing a control measure should be considered in the cost estimate/schedule of the project. For example, if a research is performed to examine the situation of the underground to reduce the risk of finding an object, the expenses and time spent is added to the project estimate and to the schedule. Applying the control measure reduces the probability and/or the consequence and, as a result, the impact of a risk. The remaining risks after applying the control measure is the residual risk (PMI, 2013). In case of the risks with monetary impacts, the summation of the impact of all (important) residual risks construct the contingency reserve (Lee, Lee, Park, Kim, & Jung, 2017). If an identified risk occurs, it means that either the project has defined a wrong control measure or the defined control measure was not (timely) applied. In this case, the costs that should be paid to remedy risk are equal to the consequence of that risk and they should be paid from the contingency reserve. The Projects have usually a reserve for the unknown unknown risks and if a not identified risk occurs, the costs are paid from this reserve.

According to Table 5-6, the most risks occurred in the execution phase (111 of 249 occurred risks). The reason could be that the EXE phase involves the biggest part of the budget and most activities occur in this phase. Clearly, the most occurred risks in the EXE phase are related to the categories Zoning and Organizational. Regarding the percentage of occurred risk per project and the total percentage of occurred risks, it cannot be concluded whether this percentage is high or low. Some occurred risks might have no (considerable) impact on the project. In addition, depending on the quality of risk quantification, they might have lower/higher impact than estimated.

Earlier, some examples were given for the identified and occurred and identified and not occurred risks. Some of these risks (for example the cables and pipes in the underground) could have been avoided before starting the execution, for example, by doing research about the ground conditions. Or by timely starting the negotiations with other parties to come to an agreement regarding project related situations (for example removing or displacing the cables and pipes in the underground). In the authors' opinion, an identified and not occurred risk (for example the risk of encountering protected species) in earlier projects does not mean that the risk will not occur in future, comparable projects. It could however receive a lower probability and as a result lower priority, in a future project.

To the author knowledge and based on the observations, there is no system for collecting and sharing knowledge between the projects in the organization studied in this research. The knowledge created in the projects stays undiscovered in the documents and in most cases vanished when the project team members leave the organization. Based on our findings, the Flood Protection Program is recommended to invest more in timely evaluation of projects to investigate the improvement possibilities and to collect lessons learned. This knowledge can be used to improve, among other things, risk identification in future projects.

5.7 Conclusions

A way to improve the quality of risk identification is by using the valuable information in completed construction projects. This is possible by gaining insights about the risks that have been identified and the risks that have occurred throughout the project lifecycle. Few researches are available that discuss the number, phase, and the category of identified and occurred risks in construction projects. This research has contributed to the current risk management body of knowledge by exploring the identified and occurred risks in construction projects with a different approach. Different from the available literature, this research investigates the risk registers of construction projects and examines the risks regarding type of risk, phase of identification and phase of occurrence. In addition, the research acknowledges the risk management literature on the categorization of risks, while it contributes to the literature by investigating risk categorization in practice. The research purpose is to increase the knowledge about the identified and occurred risks in construction projects.

In this research, the category of identified and occurred risks in 16 construction projects in the Netherlands is discussed. From the risk register of these projects, 2157 risks were collected across the preparation and execution phases. On average, the projects have identified about 135 risks in their whole project lifecycle. By means of interviews with the project managers or project controllers of these projects, the occurred risks in these projects were collected. Interviews revealed that about 13% of the risks have occurred.

Answering the research questions posed, the results show that most of the identified and occurred risks are related to the Organizational and Zoning categories of risk (Table 5-2 and Table 5-5). It was shown that more risks are identified in the preparation phases of the projects, while more risks have occurred during the execution phase (Figure 5-2 and Table 5-6).

To evaluate the results, three experts were asked for their opinion about the categories of risks that were identified and occurred most in this type of projects as well as a common number of identified risks per phase. The experts expected that less risks were identified in these projects. A high number of identified risks can be explained by the risk averse culture in the organization and prickle to identify more risks. It is also possible that the experts have underestimated the number of risks due to 'optimism bias'.

Practitioners can use the results of this research to improve risk identification in their projects by giving more attention to the categories of risks that more often have occurred. The practitioners, especially in flood defence projects, should give more attention to the identified and occurred risks as mentioned in this research. In addition, they can consider a lower probability for the risks which are identified and have not occurred in earlier projects. The results show that most risks have occurred in the execution phase. The practitioners should, therefore, try to identify the execution risks already in the earlier phases and regularly apply risk management to increase the overall success of their projects.

One of the observations in this research is that occurred risks are not properly documented. A reason could be that risk registers are not evaluated and actualized in practice. A recommendation for the projects would be to better document the identified and occurred risks as well as the risks, which have occurred but were not identified. The projects should regularly evaluate and update, amongst other things, the risk register. An actualized risk register serves as a basis for further analysis and improvement of risk identification and mitigation practices.

5.8 Limitations and future research

The research has provided possibilities for future research, next to its contribution to the current literature. One limitation of this study is its focus on dike projects. The locations and the history of a dike make its design and construction unique. Many dikes in the Netherlands have centuries of history. Sometimes a building next to a dike is a monument which influences the design and execution of a dike project. A dike in the Netherlands is usually part of the direct environment of a considerable amount of residents; there are houses directly behind a dike or there are roads on the dikes. Given this uniqueness, results of our study are only applicable to flood defence projects and cannot be generalized to other type of construction projects. Some risks, however, might be similar between dike projects and other construction projects. Future research could study other construction projects and investigate the category of risks in those projects.

This research has investigated the perspective of public organizations that have the role of client. It could be interesting to investigate the perspective of contractors and check whether the categories of identified risks differ from those identified by the public organizations in their client role. In addition, similar research can be performed in other countries and the results can be compared. In this study, interviews were performed to investigate whether or not risks occurred. Why these risks occurred was out of scope and could be a future research direction. Investigating the accuracy of risk identification was also out of the scope of this research. Investigation of the accuracy of identified risk, if possible, could be an interesting future research.

This research does not investigate the financial consequences of the occurred risks. Due to the poor documentation, this information was not available. It is possible that a category with less identified risks has more financial consequences. Studying these subjects, if the required data is available, would significantly expand the available knowledge about risk management.

5.9 Acknowledgment

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CHAPTER 6

Cost Contingency and Cost Evolvement of Construction Projects in the Pre-construction Phase

Abstract[7]

The current literature discusses the methods to estimate the costs and cost contingency. Literature distinguishes 'known unknowns' and 'unknown unknowns' contingencies as well. Little is written, however, about the evolvement of total project cost estimates during the pre-construction phase of construction projects. Moreover, not many studies are investigating the 'known unknowns' and 'unknown unknowns' contingencies in real construction projects. Practice expressed the need for getting more insight into the development of the estimated costs of the projects in the pre-construction phase. This paper, therefore, discusses the estimate of the total project costs (and cost contingency) in the pre-construction phases of 29 Dutch flood defence projects using a case study approach. Altogether, the projects have experienced 11.51% increase in the estimated costs compared to the initial estimates, which is low compared to earlier studies. This increase in the cost estimates of the flood defence projects can be explained by 'technical' reasons. The investigation of 'known unknowns' and 'unknown unknowns' contingencies shows that the percentage of 'unknown unknowns' contingency has increased in the pre-construction phase while a reduction was expected. This increase suggests that the projects were not confident about their estimates and the increase can be explained by a lack of experience, organizations' culture or the phenomenon of 'pessimistic bias'. Practitioners can avoid 'pessimistic bias' behaviour by asking for opinions about their estimates and using historical project data. Further research is suggested into realized cost contingency after project execution.

Key words: Risk management, Cost contingency, Cost estimate, Construction projects, Unknown unknowns

6.1 Introduction

The literature on risk management acknowledges that projects, of all kinds and industries, are bounded with uncertainties. Uncertainty can be defined as the difficulty in predicting the final outcomes of a project in terms of time, cost, client satisfaction, and technical performance (Böhle, Heidling, & Schoper, 2016; Turner, 2016). Uncertainty, introduced by different factors, can jeopardize the objectives of projects (Hillson, 2012; Schwindt & Zimmermann, 2015). As an approach to deal with the uncertainties, projects employ a contingency to cater for unforeseen circumstances (Mak & Picken, 2000; Marco, Rafele,

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& Thaheem, 2016). This way, the projects have more confidence to finish within the allocated budget (or scheduled time). The objective of cost contingency allocation is to ensure that the budget, which is set aside for the project execution is sufficient to cover the uncertainties. Cost contingency should, therefore, be calculated properly, assigned in the budget estimation process, and controlled wisely during project execution (Baccarini, 2004; Barraza & Bueno, 2007).

A cost contingency in a project caters for 'known unknowns' and 'unknown unknowns' events. 'Unknown unknowns', in the context of projects, are unforeseeable situations within the scope of the project (PMI, 2013). 'Known unknowns', or risks, are the events which can be identified and may or may not occur in a project (Baccarini & Love, 2014).

The challenge of cost (contingency) estimation is that an estimate is a forecast to be incurred in the future and the future is uncertain (Yeo, 1990). The literature on project risk management endorses the development of numerous methods and techniques to determine the cost contingency of projects (Yeo, 1990; Mak & Picken, 2000; Barraza & Bueno, 2007; Baccarini & Love, 2014; Hammad, Abbasi, & Ryan, 2016; Marco et al., 2016). Maintaining a realistic amount of cost contingency, however, is still a mystery. Even the development of extensive cost contingency estimation methods has not improved the estimation of cost contingency in construction projects (Flyvbjerg, Holm, & Buhl, 2002; Lovallo & Kahneman, 2003; Hollmann, 2012; Homayoun Khamooshi & Cioffi, 2013; Baccarini & Love, 2014; Gharaibeh, 2014; De Marco, Rafele, & Thaheem, 2015; Marco et al., 2016).

Many construction projects fail to adequately recognize that any estimate of cost (or schedule) involves uncertainty, and that this uncertainty should be incorporated in an estimate (Reilly, McBride, Sangrey, MacDonald, & Brown, 2004). For example, an investigation in UK construction projects revealed that insufficient consideration is given to the assessment, placement and management of contingency and risk budgets (Treasury, 2010). Likewise, a review of 50 years of empirical cost estimate accuracy research by Hollmann (2012) reveals a continuous failure to effectively addressing the project cost contingency. The inaccurate cost estimations are usually a result of poor cost estimation practices, poor project management practices, and poor communication between design and construction personnel, and the stakeholders (Shane, Strong, & Gad, 2015).

Available literature regarding cost estimates addresses either the development of a method to improve the accuracy of estimates or discusses the performance of estimated contingency (i.e. comparing the estimated costs with the realized costs) (Flyvbjerg et al., 2002; Baccarini & Love, 2014). In this context, there are not many studies regarding the evolvement of the total project cost (and cost contingency) estimates in the pre-construction phase of the construction projects. This research contributes to the current body of knowledge by investigating the evolvement of the total project cost (and cost contingency) estimates in the early phases of the projects.

Risks that matter to the stability of a firm are often unidentifiable ('unknown unknowns') and simply focusing on managing the identifiable risks ('known unknowns') is inadequate (Ganegoda & Evans, 2014). While it is common for projects to assign contingencies to address the 'known unknowns' and 'unknown unknowns', there is not much insight and knowledge about the proportion of 'known unknowns' and 'unknown unknowns' contingencies in practice. This is highlighted as a second contribution: this research investigates the evolvement of 'known unknown' and 'unknown unknown' contingencies in real construction projects.

The research focusses on flood defence projects in the Netherlands performed under the flood defence program known as Hoogwaterbeschermingsprograma (HWBP). There is a need from the flood defence program to get a better insight into the estimated costs of the projects in the pre-construction phase. This research addresses this need from practice and the obtained knowledge can be applied for improving cost estimates in future projects.

To summarize, the research objective is to investigate the evolvement of the total project cost and cost contingency estimates in the pre-construction phase of construction projects. In this research, the pre-construction phase includes Exploration, Plan Development, and Tender & Award. The following research question is formulated:

How do the total project cost and cost contingency estimates evolve in the pre-construction phase of a construction project?

This paper is structured as follows. The paper starts with a review of relevant literature in the next section, followed by a description of the methods used. Next, results are presented and analysed in three parts. First, the total project cost contingency development over time in the pre-construction phase is discussed. Next, the development of the total project cost estimates in the pre-construction phase is investigated. Finally, the relation between 'known unknowns' and 'unknown unknowns' contingencies is examined. Next, in the discussion section, the results are discussed elaborating on the possible reasons for the fluctuations of cost and cost contingency estimates in the pre-construction phase and the possible consequences of these fluctuations. Subsequently, conclusions are drawn, research implications are explained, and recommendations for future research are given. Finally, acknowledgements are listed.

6.2 Literature review

A cost estimate is a quantitative assessment, based on the available information, at a given point in time, of the likely costs for resources required to complete a project. The cost estimate includes the identification and consideration of cost alternatives to initiate and complete a project (PMI, 2013). A cost estimate process generally includes five main steps: determining the estimate basis, preparing a base estimate, determining risk and setting contingency, reviewing the total estimate, and finally communicating the estimate (Anderson, Molenaar, & Schexnayder, 2007). An accurate cost estimate is crucial in deciding on whether to proceed with a project, and it serves as a baseline for project control (Yeo, 1990; Mak & Picken, 2000; Uzzafer, 2013; Baccarini & Love, 2014; Hammad et al., 2016).

The result of a cost estimate is comprised of two components: 1. The Base Cost (BC) (recognised also as known knowns), and 2. The cost contingency.

The BC is the likely risk-free cost of the project developed using historical data and cost estimating techniques. Cost contingency is, however, a provision to mitigate cost risk (PMI, 2013). According to PMI (2009), cost contingency is the amount of needed budget, above the estimated budget, to reduce the risk of overruns of project objectives to a level acceptable to the organization (PMI, 2009). Likewise, AACE (2000, p. 28) defines contingency as: "An amount of money or time (or other resources) added to the base estimated amount to (1) achieve a specific confidence level, or (2) allow for changes which, based on experience, will likely be required". Cost contingency is decided based on a list of uncertainties with their estimated financial implications to cope with the uncertainties in a project (Mak & Picken, 2000; Anderson et al., 2007; Keith Robert Molenaar, 2010; Baccarini & Love, 2014). In short: the cost contingency is allocated to handle the uncertainties in a project (Mak & Picken, 2000; Marco et al., 2016).

Literature on cost contingency distinguishes two categories of contingency: 'known unknowns' (known as contingency reserve) and 'unknown unknowns' (PMI, 2013;

Lee, Lee, Park, Kim, & Jung, 2017; Walker, Davis, & Stevenson, 2017). The 'known unknowns' contingency is determined by the risk identification step within the risk management process, focusing on the assessment of event uncertainty (Chapman & Ward, 2011; PMI, 2013). The 'known unknowns' contingency is thus dependent on the number of identified risks, with specific consideration of the post-mitigated risks rather than the pre-mitigated risks. The 'unknown unknowns' contingency is, however, intended to address the unforeseen situations within the scope of the project (PMI, 2013; Eldosouky, Ibrahim, & Mohammed, 2014). Despite its role and importance, there is no specific rule on how to determine the right amount of the 'unknown unknowns' contingency. It is often estimated just as a percentage, which is typically derived from intuition and experience (Lee et al., 2017).

Cost contingency can be determined employing deterministic and probabilistic approaches. Both approaches are applicable to discretely decide the costs and time contingencies (Purnus & Bodea, 2013; Bakhshi & Touran, 2014; Eldosouky et al., 2014; Pawan & Lorterapong, 2015), or the combination of time and cost (Purnus & Bodea, 2013). The biggest difference between the two approaches is that the deterministic approach is based on deterministic and point-estimate values, whereas the probabilistic approach is based on stochastic and range values. The former cannot mathematically incorporate uncertainty, whereas the latter can (Xenidis & Stavrakas, 2013). In the deterministic approach, simply a certain percentage of the total project costs is added to the project as the cost contingency (Shane et al., 2015). This method is criticized due to its over simplicity, and dependency on the estimator (Yeo, 1990; Mak & Picken, 2000). Probabilistic models suffer from limitations as well (e.g. unavailability of detailed quantitative information) (Panthi, Ahmed, & Ogunlana, 2009).

The available literature about cost estimation can be divided in two categories: 1. Scholars who discuss the development of the methods to improve the cost (contingency) estimates and 2. Scholars who discuss the cost performance of projects by comparing estimated costs (early in the beginning of a project) and realized costs (after the project completion) and investigating the reasons for the poor cost performance of the projects. A summary of references in each category is provided in Table 6-1.

Table 6-1 Two different categories of literature discussing cost and cost contingency estimates

ID	Description	Scholars	Scope of the research
First category	Development of new methods to improve cost and cost contingency estimates	Mak and Picken (2000), Thal Jr, Cook, and White III (2010), Lee et al. (2017), Panthi et al. (2009), Lhee, Issa, and Flood (2012), and H. Khamooshi and Cioffi (2009)	Developing quantitative methods to estimate cost contingency in pre-construction phase
		Xie, AbouRizk, and Zou (2011), and Barraza and Bueno (2007)	Developing quantitative methods to manage cost contingency throughout project execution phase
		Hammad et al. (2016), and Marco et al. (2016)	Developing methods to estimate and manage the cost contingency in both pre-construction and execution phases of a project
Second category	Investigating the cost performance in the projects	Flyvbjerg et al. (2002), C. C. Cantarelli, Molin, van Wee, and Flyvbjerg (2012), Baccarini (2004), and Hollmann (2012)	Comparing the realized and estimated costs and discussing the reasons for deviation

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Next to these two categories, there is a possible but missing third category: the evolvement of the total project cost (contingency) estimates (i.e. evolvement of Base Cost and cost contingency and the relation between 'known unknowns' and 'unknown unknowns' contingencies in the pre-construction phase of construction projects. To the knowledge of authors, few researches are reported which addresses this third category. This research contributes to this third category by investigating the evolvement of the total project cost and cost contingency in the pre-construction phase of construction projects.

6.3 Methods

To investigate the cost contingency of projects in the pre-construction phase, the research benefits from a case study approach. Yin (2014) explains that the first and most important condition for selecting a research strategy is to identify the type of research question. The research question in this research is a 'how' question, which aims to explore the cost contingency evolvement in different phases prior to the start of the execution phase. For this research question, the cost contingency needs to be traced over time. Yin (2014) states that in this situation, the case study approach is a suitable approach. The case study places more emphasis on the full analysis of a limited number of events or conditions and is, thus, an intensive exploration of the particular unit under consideration (Kothari, 2004; Yin, 2014).

The research investigates the flood defence projects (such as improvement of the dikes, locks, pumps, etc.) executed under the Flood Protection Program (known as Hoogwaterbeschermingsprogramma (HWBP)) in the Netherlands as cases. The HWBP program has a budget of about €5 billion and has the objective to improve the flood defence facilities in the Netherlands that do not meet the safety norms. The program inspects the flood defence facilities every five years. Each flood defence facility that does not satisfy the safety norms, will be improved in a project. Urgent flood defence facilities will receive priority to improve. Each batch of the projects is governed under a program of projects. The Flood Protection Program is responsible for approving the subsidy required for the execution of these projects. The regional public organizations, known as waterboards, responsible for the flood defence facilities, have to submit their estimated budgets to the program. The program provides the waterboards with the required funding after approval of the estimates. The projects (cases) for this research are selected from a program of projects known as HWBP-2 as most of the projects in this program are finished.

This study focuses on the cost estimates made by the waterboards in the pre-construction phase. Each project goes through each of the phases of Exploration, Plan Development, and Tender & Award. A short explanation of these phases is given below:

- Exploration (EXP): In this phase, the possible alternatives and solutions are investigated. These alternatives are further elaborated and the best alternative would be selected.
- Plan Development (PD): the selected alternative of the previous phase is further elaborated and the project plan and design are created.
- Tender & Award (T&A): In this phase, the project follows the tendering process and is awarded to a contractor.

The EXP is the first official phase in which the project organisations submit the first cost estimate of the projects. In each of the above mentioned phases, projects provide an estimate of project costs containing both Base Cost (BC) and the required cost contingency for the whole project execution. Going through the phases, the design and scope and consequently the cost estimate might change. By finishing the T&A phase the cost estimation is finalized. After this phase, the contract is awarded and the contractor starts the execution of the project.

The total budget of a project in each phase is a summation of the costs of work packages: Construction (i.e. the costs of project execution by the contractor who wins the project through tendering), Engineering (i.e. costs of consultancy and design), Real Estate (i.e. cost of ground expropriation), Other costs and the cost contingency. The summation of the Construction, Engineering, Real Estate and Other Costs composes the project BC.

The projects in this study determine the cost contingency based on similar methods as mentioned by Yeo (1990) and Shane et al. (2015). This research acknowledges that there are different methods to calculate the cost contingency of projects (e.g. using probability distribution of estimated costs). In our research, the method for calculating cost contingency is determined by the projects that were examined. Earlier in this paper, it was explained that the 'known unknowns' contingency addresses the identifiable risks and 'unknown unknowns' contingency addresses the uncertainties which cannot be identified upfront (Böhle et al., 2016). In the examined projects, the 'known unknown' contingency is determined based on the most important identified risks from the risk analysis step. The risks are quantified and the summation of risks' impact (probability*consequence) forms the 'known unknowns' contingency. The 'unknown unknowns' contingency, is determined on a percentage of BC depending on the risk profile of each project (to cater for unforeseen events and the ambiguities and the variability in the estimated amounts. The percentages that the projects in this research typically use to account for 'unknown unknowns' are between 5%-10% of the BC. Note that these percentages are defined by the projects, based on their experience. The authors do not justify these percentages and neither indicate that these percentages should be generalized to other projects. The authors just explain the percentages used by the projects. The summation of the 'known unknowns' and the 'unknown unknowns' contingencies is the total cost contingency of the projects. Project Total Cost (TC) is the summation of the BC and the cost contingency. These explanations are clarified by an example from a real project shown in Table 6-2. The Base Cost (BC) (= € 14,367,184.74) is calculated based on the summation of the costs of the work packages Construction, Engineering, and Other costs (the project in this example has no costs for the work package Real Estate). The amount of 'unknown unknowns' contingency (= € 718,359.24) is 5% of the BC and the total cost contingency is equal to the summation of 'known unknowns' and 'unknown unknowns' contingencies (= € 2,314,609.24). Equations 1 through 3 explain how each part of the cost contingency in the examined projects is calculated.

Table 6-2 Example of the cost estimate composition of a project

Different work packages	**Explanation**	**Amount**
Construction costs		€ 12,066,206.95
Real Estate costs		€ 0
Engineering costs		€ 1,603,164.00
Other costs		€ 697,813.80
Base Costs	The summation of above cost components	€ 14,367,184.74
'Known unknowns' contingency	The summation of the impact of the most important risks	€ 1,596,250.00
'Unknown unknowns' contingency	5% of Base Costs	€ 718,359.24
Total cost contingency	The summation of 'known unknowns' contingency and 'unknown unknowns' contingency	€ 2,314,609.24

$$Known\ unknown\ contingency = \sum_{i=1}^{n}(Probability_i \times Consequence_i) \quad (1)$$

Equation 6-1 Formula for known unknowns contingency where n represents the number of risks

$$Unknown\ unknowns\ contingency = x\% \times Base\ Cost \quad (2)$$

Equation 6-2 Formula for the unknown unknowns contingency, x is a number between 5-10

$$Cost\ Contingency = Known\ unknown\ contingency + \ Unknown\ unknowns\ contingency \quad (3)$$

Equation 6-3 Calculating the total Cost Contingency

To examine the cost contingency in practice, construction projects from different waterboards were selected. These projects were selected based on the following criteria:

- The project has passed the pre-construction phase (so the project is either in the execution phase or the execution is already finished).
- The cost estimation document(s) in at least one of the pre-construction phase is available.

Based on these criteria, out of 79 HWBP-2 projects, 29 recent projects from 10 waterboards were considered suitable for the study and all were included. From these 29 projects, 22 are dike reinforcement projects, two are dune reinforcement projects, and five are coast reinforcement projects. Table 6-9 in Appendix B provides the total costs of the projects in T&A phase. In the T&A phase, the estimated project execution costs range between 0.6 and 140 million euro. All these projects had their start and finish between 2011 and 2016. For the 29 projects, the cost estimation documents from the three phases were collected. For each phase, different numbers of cost estimate documents were found:

- In the EXP phase, 28 out of 29 projects have an appropriate cost document
- In the PD phase, 26 out of 29 projects have an appropriate cost document
- In the T&A phase, 29 out of 29 projects have an appropriate cost document

The amount of the total cost contingency, ‘known unknowns’, and ‘unknown unknowns’ contingencies (as explained in Equation 6-1, Equation 6-2, Equation 6-3) were calculated for each project in each specific phase. Next, the results are checked by an expert. The purpose of this step was to check the accuracy of the method and results. The expert has more than 10 years of experience and works at HWBP, the overarching program. This expert is responsible for drawing periodic financial reports and is familiar with the working methods and financing strategy of the projects.

The collected data were quantitatively analysed and compared in order to understand the evolvement of the total project cost contingency in the pre-construction phase. The significance of the results in each part is statistically tested. Based on the analysis, possible reasons for the evolvement of the cost contingency in the pre-construction phase are given. These reasons are also explained from a more theoretical point of view in the Discussion section of this article. The authors’ knowledge and experience with the HWBP projects helped explaining the possible reasons for the changes in the estimate.

6.4 Results and analysis

In this section, the development of estimates over time is discussed. First, the changes in the estimates are elaborated. The quantitative analysis of cost contingency, BC and percentage of cost contingency in three phases of EXP, PD, and T&A are discussed. Next, the cost evolvement of the projects in the pre-construction phase is explained. Finally, the relation between ‘known unknowns’ and ‘unknown unknowns’ contingencies of the projects is investigated.

6.4.1 *Changes in the* estimates *over time*

Table 6-3 shows that the mean and the Standard Deviation (SD) for cost contingency, BC, and the percentage of cost contingency have reduced over time. Comparing the cost contingency in the EXP and T&A phase shows indeed a reduction in the uncertainty of the projects as the projects progressed (p=0.001, independent sample t-test). The changes in the estimated cost contingency and BC of the projects are provided in Figure 6-14 in Appendix B.

Table 6-3 Descriptive statistics of cost contingency (in M€), BC (in M€), and calculated percentage of cost contingency per project phase (28 projects in EXP phase, 26 projects in PD phase, and 29 projects in T&A phase)

	Cost contingency			**BC**			**% cost contingency**		
Measure	EXP	PD	T&A	EXP	PD	T&A	EXP	PD	T&A
Mean (M)	6.69	5.57	5.08	32.45	32.34	30.62	20.28%	17.67%	14.93%
Standard Deviation	7.89	6.54	6	40.70	35.81	36.56	6.71	5.69	4.61
Number of projects	28	26	29	28	26	29	28	26	29

As shown in Table 6-3, the largest uncertainty, as expected, is in the EXP phase. In the EXP phase, the scope of the work is based on the requirements and wishes without any clear design. In this phase, different alternatives and solutions are provided. Eventually one alternative is selected in this phase, which will be further developed in the next phases. Hence, cost estimation at each successive stage progresses toward a smaller number of options, since more detailed designs, more accuracy of quantities and better information about unit prices are available (Flyvbjerg et al., 2002). This generally leads to reduction of the uncertainty and a lower cost contingency. Another reason for the reduction in the cost contingency could be that some risks, identified in the early phases, did not occur or are not applicable anymore. For example, in later project phases, a project has acquired the necessary work permits, and has performed research for the (under)ground conditions.

The histogram of estimated cost contingency (percentages) for each phase is presented in Figure 6-1, Figure 6-2 and Figure 6-3. As shown in the histograms, the percentage of cost contingency is shifted over time to the left confirming the reduction of the uncertainties in the projects.

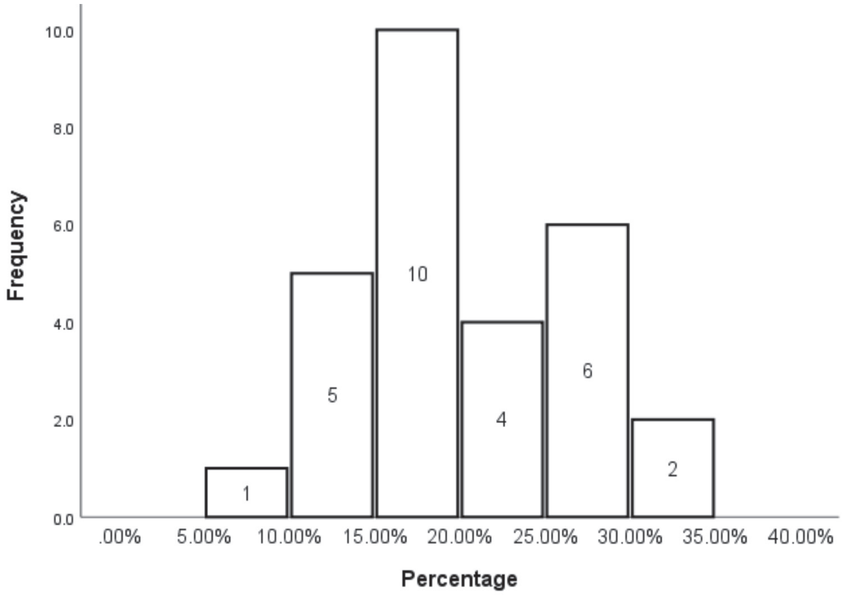


Figure 6-1 Histogram of cost contingency of the projects in the Exploration (EXP) phase (N=28)

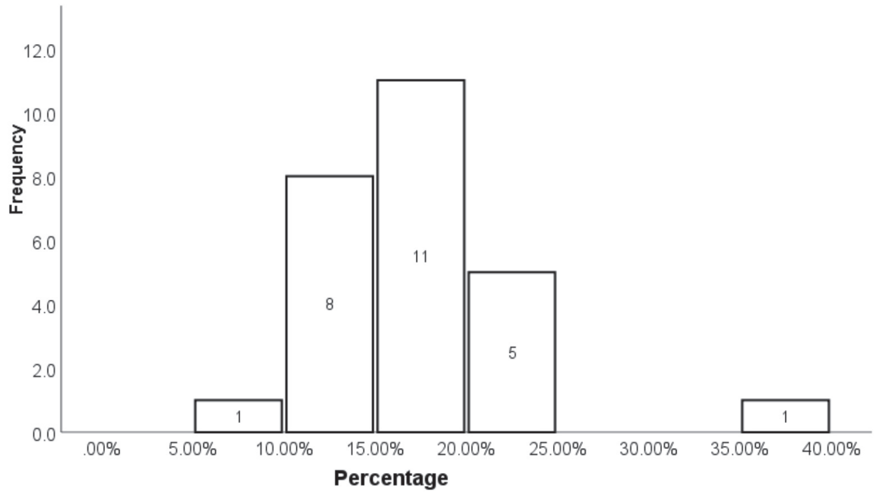


Figure 6-2 Histogram of cost contingency of the projects in the Plan Development (PD) phase (N=26)

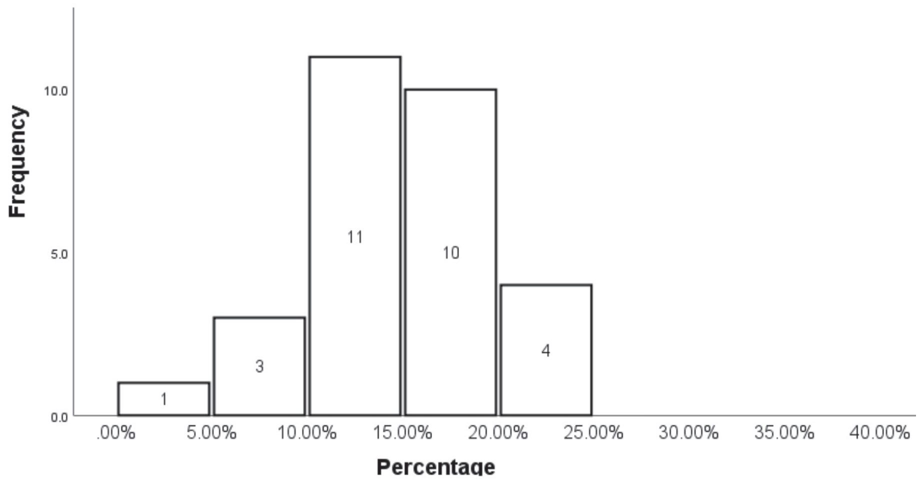


Figure 6-3 Histogram of cost contingency of the projects in the Tender & Award (T&A) phase (N=29)

Further, three distributions are fitted to the histogram of the percentage of cost contingency in each phase to check which distribution better reflects the empirical data. The cumulative frequency of the empirical data is compared to the cumulative distribution function (CDF) of the theoretical distribution to accept the best distribution. Probability paper, as explained by Ang and Tang (2007), to check which distribution best fits the empirical data.

To construct a probability paper a transformed probability scale should be used in such a way to obtain a linear graph between the cumulative probabilities of the underlying distribution and the values of the random variable (Ang & Tang, 2007). Using the procedure explained by Ang and Tang (2007), three distributions were selected: beta, lognormal, and gamma distribution. Figure 6-4 to Figure 6-6 show the Probability Density Function (PDF) for the percentage of cost contingency in each phase.

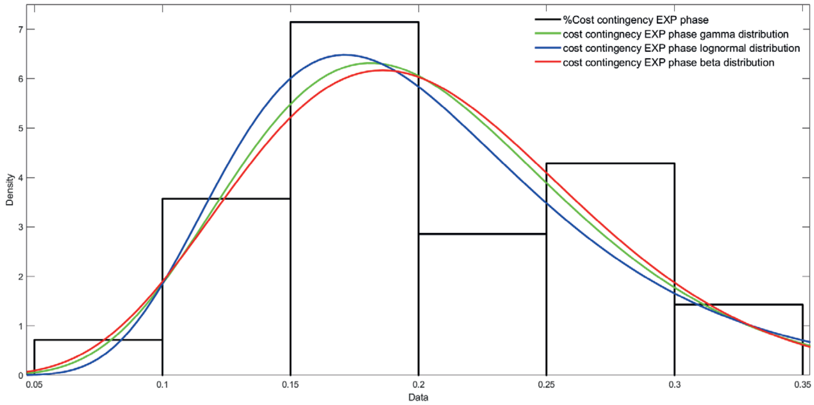


Figure 6-4 Histogram and PDF fitting distributions for the percentage of cost contingency in EXP phase

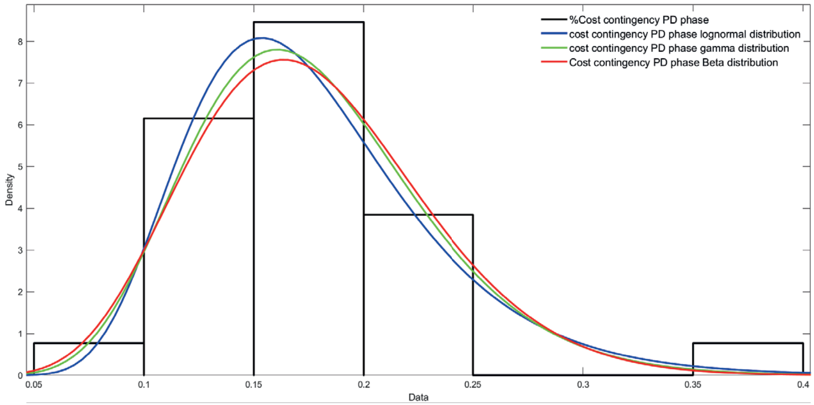


Figure 6-5 Histogram and PDF fitting distributions for the percentage of cost contingency in PD phase

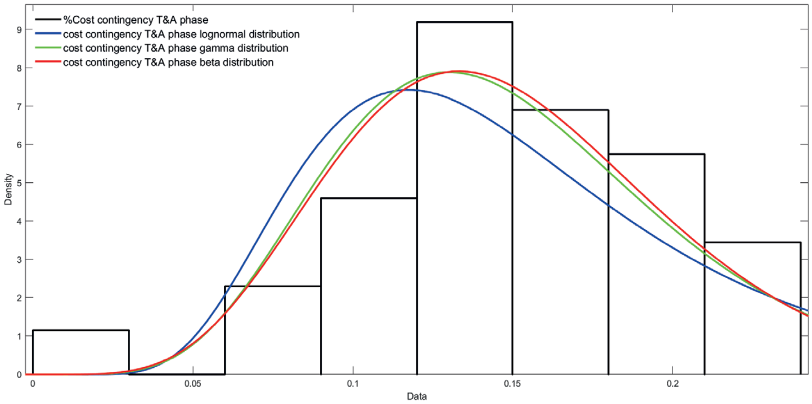


Figure 6-6 Histogram and PDF fitting distributions for the percentage of cost contingency in T&A phase

6

The goodness-of-fit for each of the distribution models are checked by performing a Chi-square test. The Chi-square goodness-of-fit checks the observed frequency of k variables with the corresponding theoretical frequencies calculated from the assumed theoretical distribution model (Ang & Tang, 2007). Table 6-4 presents the results of the Chi-square goodness-of-fit for the percentage of the cost contingency in the three phases (where x_f^2 = chi-square, f is the degrees-of-freedom and $C_{1-\alpha,f}$ is the critical value of the Chi-square as explained in (Ang & Tang, 2007). As shown in Table 6-4, the lognormal distribution best fits the percentage of cost contingency in the three phases. Table 6-5 presents the parameters of all the distribution per phase. Figure 6-7 presents the changes in the lognormal distribution in the three phases of EXP, PD, and T&A, confirming a reduction in the percentages of cost contingency as the project progresses.

Table 6-4 Chi-square goodness-of fit test for the percentages of cost contingency in the EXP, PD and T&A phases

Distribution	**EXP phase**			**PD phase**			**T&A phase**		
	Chi-square x_f^2	f=k-1	$C_{1-\alpha,f}$(α=0.05)	Chi-square x_f^2	f=k-1	$C_{1-\alpha,f}$(α=0.05)	Chi-square x_f^2	f=k-1	$C_{1-\alpha,f}$(α=0.05)
Gamma	5.72	5	11.07	13.35	6	12.59	2.03	4	9.48
Lognormal	6.46	5	11.07	10.03	6	12.59	0.86	4	9.48
Beta	6.44	5	11.07	15.79	6	12.59	2.31	4	9.48

Table 6-5 Distribution parameters derived from the Gamma, Lognormal, and Beta distributions per phase

Distribution	Gamma		Lognormal		Beta	
Parameters	a	β	μ	σ	a	β
EXP phase	9.39	0.02	-1.65	0.34	7.53	29.58
PD phase	11.04	0.02	-1.78	0.31	8.88	41.32
T&A phase	7.79	0.02	-1.96	0.42	6.95	39.75

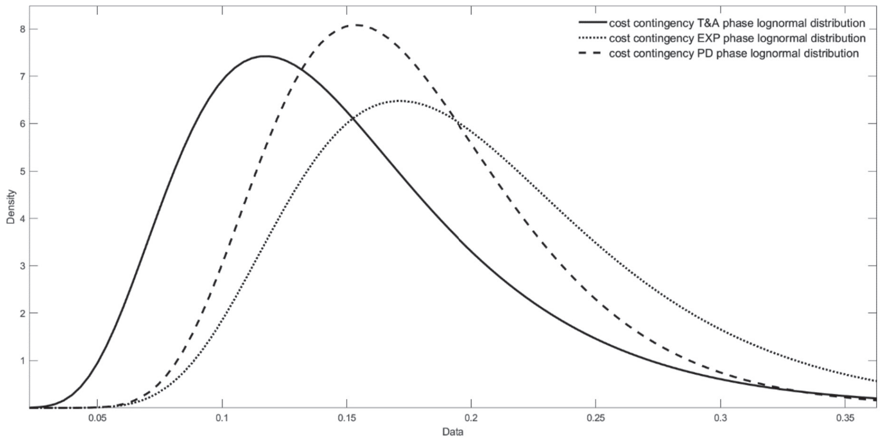
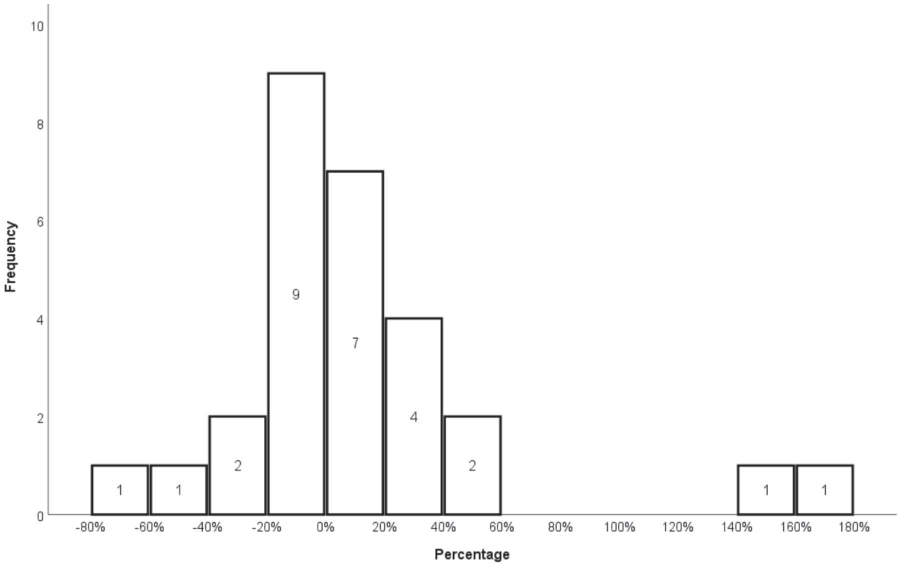


Figure 6-7 Changes in the distribution in the three phases

6.4.2 Cost evolvement in the preparation phase

Cost evolvement of the projects in the preparation phase was calculated by comparing the Total Costs (TC) in two moments: EXP and T&A. Data from 28 projects were used, as data was required for both EXP and T&A. The delta of the cost estimates (Total Cost estimate at T&A phase – Total Cost estimate at EXP phase) in these two phases is used to calculate the amount of cost evolvement. Figure 6-8 and Figure 6-9 present the distribution of percentage and the amount of cost evolvement respectively. An accurate estimate means that the delta is zero or around zero.

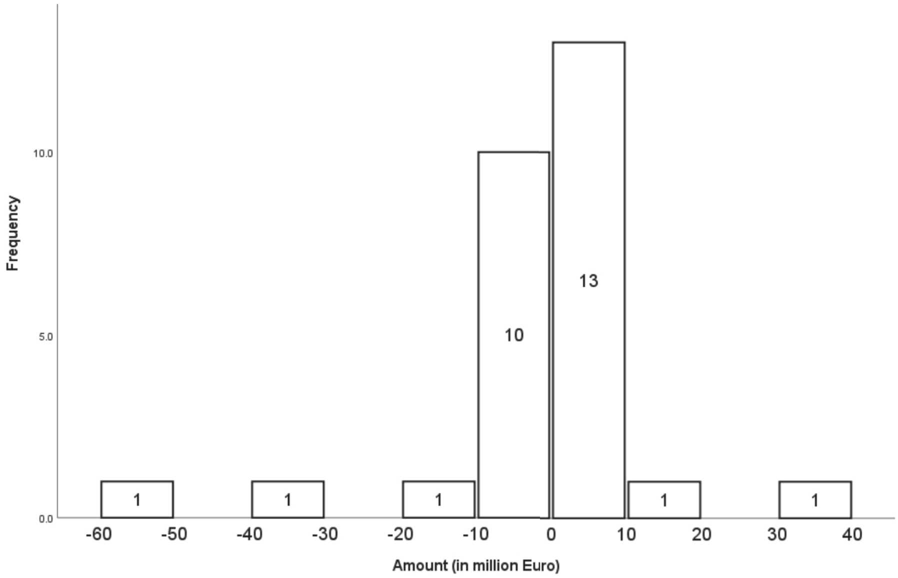
The histogram in Figure 6-8 shows that 13 out of 28 projects experienced a decrease in the costs (cost underrun) in the pre-construction phase. Two projects show no differences in the estimates. For the projects with an increase in the estimated costs, the average cost estimate increase is about 45.52% (SD= 55.14). For the projects with a cost estimate decrease, the average percentage is -20.73% (SD=20.91). The magnitude of the percentage of cost estimate increase in the pre-construction phase (45.52%) is higher than of the cost estimate decrease in the pre-construction phase (20.73%) ($p= 0.001$, independent samples t-test).



	Statistical analysis of percentage of cost estimate increase	Statistical analysis of percentage of cost estimate decrease	Number of projects without changes in the estimates	Overall results
Mean	45.5%	-20.73%	-	11.51%
Median	26.44%	-13.41%	-	0.13%
Standard Deviation	55.14	20.91	-	51.12
Minimum	2.1%	-65%	-	-64.86%
Maximum	169.4%	-1.8%	-	169.42%
Count	13	13	2	28

Figure 6-8 Distribution of percentage of cost estimate increase and cost estimate decrease in the preparation phases of Dutch flood defence projects (N=28)

Figure 6-9 shows the amounts rather than the percentage. About half of the projects have experienced cost underrun in the pre-construction phase (13 projects). Projects with a cost estimate increase mostly have an increase of up to 10 million Euro (13 projects), which is small compared to the total amount of estimated cost in the T&A phase (see Table 6-9 in Appendix B). As shown in Figure 6-9, looking at only projects with a cost estimate increase, the average cost estimate increase is 6.76 M€ (SD=9.87). The average of cost estimate decrease for the projects with a cost estimate decrease is -11. 6 M€ (SD=15.28). The magnitude of the amount of cost estimate increase is higher than cost estimate decrease in the pre-construction phase (p=0 001, independent samples t-test).



	Statistical analysis of amount of cost estimate increase	**Statistical analysis of amount of cost estima-te decrease**	**Number of projects without changes in the estimates**	**Overall results**
Mean	6.76	-11.60	-	-2.25
Standard Deviation	9.87	15.28	-	14.85
Minimum	0.03	-52.80	-	-52.8
Maximum	37.10	-0.13	-	37.10
Sum	87.87	-150.86	-	-62.99
Number of projects	13	13	2	28

Figure 6-9 Distribution of amount of cost estimate increase and cost estimate decrease (in million euro) in the pre-construction phase the of Dutch flood defence projects (N=28)

The descriptive statistics of cost evolvement in the pre-construction phase for all projects are presented in Table 6-6.

Table 6-6 Descriptive statistics of the amount of cost evolvement in the pre-construction phase for all projects

	Statistical analysis of amount of cost estimate increase (in M€)	**Statistical analysis of %cost estimate increase**
Mean	-2.25	11.51%
Standard Deviation	14.85	51.12
Minimum	-52.8	-64.86%
Maximum	37.10	169.42%
Number of projects	28	28

The percentage of cost estimate increase in the pre-construction phases is %11.51 (SD= 51.12) and the amount of cost estimate increase is -2.25 M€ (SD=14.85).

The research by C. C. Cantarelli et al. (2012) about the cost overrun in the pre-construction phase of transport infrastructure projects in the Netherlands reveals that projects become more expensive in the planning phase (at least in the case of the Netherlands), and once the construction phase has started cost overruns are less common. Please consider that the results of C. C. Cantarelli et al. (2012) (in the pre-construction phases) and the results of this research are in fact referring to cost evolution in the pre-construction phase, not cost overrun as such. Table 6-6 compares the cost evolution in the pre-construction phase of flood defence projects (this study) and transport infrastructure projects by C. C. Cantarelli et al. (2012). The amount of cost estimate increase in the pre-construction phase of transport infrastructure projects is 19.7%, which is higher than the cost estimate increase in flood defence projects (11.5%). The percentage of cost estimate increase for the projects with a cost estimate increase, however, is higher in flood defence projects compared to transport infrastructure projects (45.5% for flood defence projects against 30.8% for the transport projects). There is less cost estimate increase in flood defence projects but if there is, it has a higher magnitude. The percentage of cost estimate decrease for the projects with a cost estimate decrease is higher in flood defence projects (18%) than in transport infrastructure projects (6.5%). In both studies, the overall (average) results show a cost estimate increase.

Table 6-7 Comparing the cost overrun in flood defence projects with transport infrastructure projects in the pre-construction phase

	Flood defence projects (this research)	**Transport infrastructure projects by Cantarelli et al. (2012)**
% cost estimate decrease for the projects with a cost underrun	18%	6.5%
% cost estimate increase for the projects with a cost overrun	45.5%	30.8%
Total cost estimate increase (%)	11.5%	19.7%

6.4.3 Relation between 'known unknowns' and 'unknown unknowns' contingency

The proportion of 'known unknowns' and 'unknown unknowns' contingencies are further investigated based on the explanation provided in Equation 6-1 and Equation 6-2. Table 6-8 presents the descriptive statistic of the 'known unknowns' and 'unknown unknowns' contingencies in three phases. In all phases, the percentage of the 'unknown unknowns' contingency is higher than the percentage of the 'known unknowns' contingency.

Table 6-8 Comparing 'known unknowns' and 'unknown unknowns' contingencies in different phases

	EXP phase		**PD phase**		**T&A phase**	
	Known unknowns	Unknown unknowns	Known unknowns	Unknown unknowns	Known unknowns	Unknown unknowns
Mean	18.61%	81.39%	30.54%	69.46%	27.52%	72.48%
Standard Deviation	18.63	18.63	23.38 %	23.38	23.42	23.42
Minimum	0%	36.88%	0%	7.89%	0%	0%
Maximum	63.12%	100%	92.11%	100%	100%	100%
Number of projects in dataset	28	28	26	26	29	29

Keith R Molenaar (2005) explains that the amount of 'known unknowns' and 'unknown unknowns' contingencies should decrease during the course of a project (Figure 6-10).

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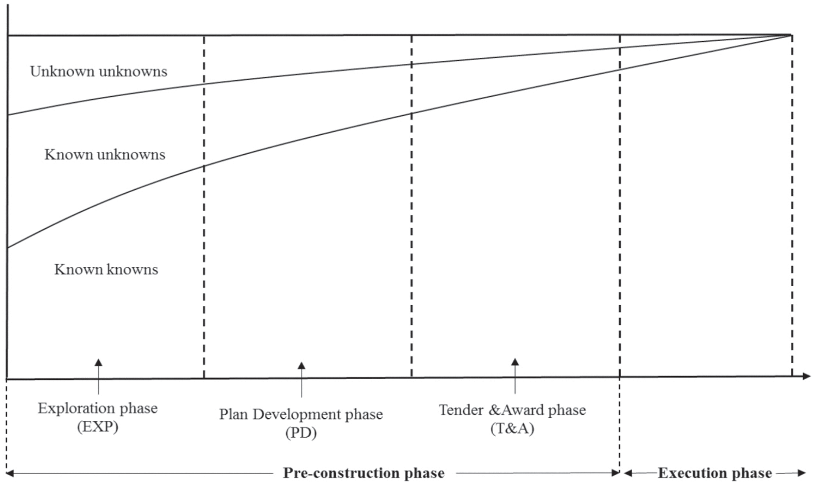

Figure 6-10 The relation between known knowns, known unknowns, and unknown unknowns during the project lifecycle (adapted from (Keith R Molenaar, 2005))

The reduction in estimated cost is a result of better defining cost variables and eliminating uncertainty as cost factors are finally incorporated into the project plan. By further developing a project, the design and scope become clear (causing less ambiguity uncertainty), the cost variables are better defined (causing less inherent uncertainty) and some risks are not applicable anymore. As a result, both 'known unknowns' and 'unknown unknowns' contingencies reduce (Figure 6-10). The results of this research, however, do not fully confirm this. As shown in Table 6-6, the mean value of the 'unknown unknowns' contingency shows an increase in the T&A phase comparing to the EXP phase (p=0.047, independent sample t-test).

Figure 6-11, Figure 6-12 and Figure 6-13 show the distribution of the percentage of 'unknown unknowns' contingency in EXP phase, PD phase, and T&A phase respectively. The histograms show a skewness to the right of the figures, meaning that most of the projects faced higher 'unknown unknowns' contingency than 'known unknowns' (i.e. a project with 80% 'unknown unknowns' contingency means that it has only 20% 'known unknowns' contingency) (Figure 6-11, Figure 6-12 and Figure 6-13). Even in the T&A phase (Figure 6-13) where a decrease in the 'unknown unknowns' contingency was expected, some projects had large contingency to address 'unknown unknowns'. Overall, it is concluded that the projects in this research seem to be conservative in their estimates.

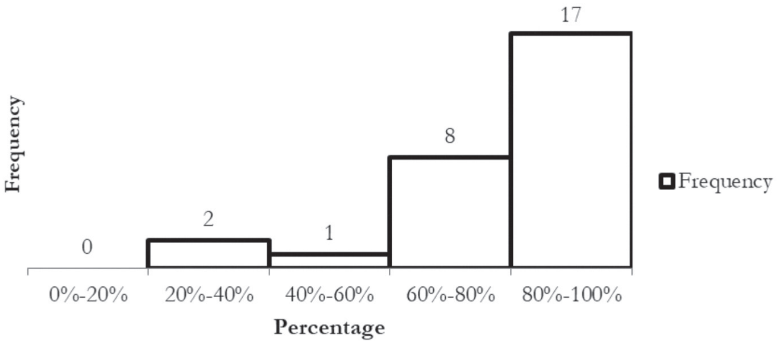

Figure 6-11 Distribution of 'unknown unknowns' contingency in the EXP phase (28 projects)

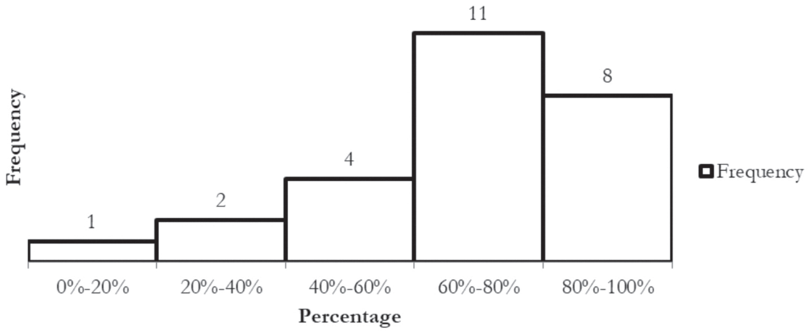

Figure 6-12 Distribution of 'unknown unknowns' contingency in the PD phase (26 projects)

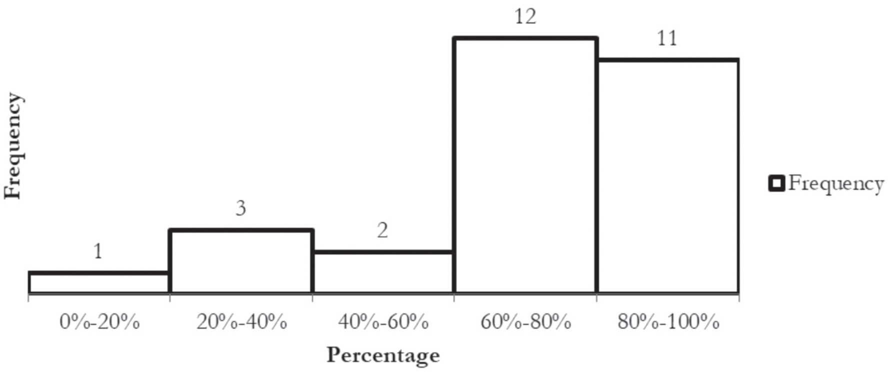

Figure 6-13 Distribution of 'unknown unknowns' contingency in the T&A phase (29 projects)

6.5 Discussion

The research investigates the cost evolvement of the Dutch flood protection projects in the pre-construction phase. The examined projects experienced on average 11.51% cost estimate increase in the pre-construction phase (Table 6-5) which is less than a similar study on the Dutch transport infrastructure projects (19.7%, C. C. Cantarelli et al. (2012)). Although the main reasons for the overruns cannot be concluded, several aspects might play a role.

Lovallo and Kahneman (2003) mention, among others, 'anchoring' and 'adjusting' as reasons for cost increase in projects. 'Anchoring' means that the estimator makes initial estimates and 'adjusts' his/her assessment to reach those estimates (Baccarini & Love, 2014; Lovallo & Kahneman, 2003). From the data in this research, it cannot be concluded whether any 'adjusting' and 'anchoring' has occurred in the cost (contingency) estimates. If it was the case, it would be expected that the cost (contingency) estimates in the T&A phase to be the same or close to the cost (contingency) estimate in the EXP phase. However, the results (see Table 6-3) show that the cost contingency is reduced for most projects.

Another reason for poor cost performance mentioned in the literature is 'optimism bias' and 'strategic misrepresentation' (Flyvbjerg et al., 2002; Flyvbjerg, Bruzelius, & Rothengatter, 2003; Chantal C Cantarelli, Flyvbjerg, van Wee, & Molin, 2010). 'Optimism bias' means that promoters and forecasters are overly optimistic about project outcomes in the preparation phases (Flyvbjerg et al., 2002), and 'strategic misrepresentation' refers to deliberate misrepresentation of project costs and risks for other gains such as political and economic gains (Flyvbjerg, 2006). Due to the nature of the projects in our study, however, it is difficult to relate the cost increase in the preparation phase to these two phenomena. All the projects in this study are flood defence projects, which have failed the safety tests according to the norms, and therefore, they should be improved. All these projects, no matter what, will receive the required funding. As any budget left after the project execution should be given back to the Flood Protection Program, there are a no incentives for the projects to apply 'optimism bias' or 'strategic misrepresentation', i.e. proposing lower costs than actually expected. Therefore, in contrast to C. C. Cantarelli et al. (2012) who conclude that the cost increase in the Dutch transport projects can be explained by psychological and political-economic explanations, this study rejects these aspects as reasons of cost increase in the pre-construction phase of flood defence projects.

The cost estimate increase in projects in this research could be related to 'technical' reasons such as imperfect forecasting techniques, inadequate data, and lack of experience, as also mentioned by Flyvbjerg et al. (2003) and Flyvbjerg et al. (2002). When the examined projects started, they were relatively new for the responsible waterboards and they had limited experience with cost estimation of this type of projects. Mistakes caused by lack of historical data or lack of experience were unavoidable. It is expected, however, that such errors reduce as the waterboards perform similar projects and gain more experience with this kind of projects. Another possible reason for the cost increase in the preparation phase can be simply the result of more detailed design and more clear scope as the project progress towards the execution phase. In the pre-construction phase, the scope is still not fixed meaning that a project can change the design alternative, execution techniques or materials. Consequently, the costs might deviate from the initial estimate. Therefore, an increase in cost estimates could be expected and acceptable.

Next to the investigation of the cost evolvement, the research shows that the projects have a tendency for a high 'unknown unknowns' contingency (Figure 6-11, Figure 6-12, and Figure 6-13). One reason for the increase of the 'unknown unknowns' contingency, from EXP phase to T&A phase (Table 6-6), could be the lack of certainty in the estimates. This increase in the 'unknown unknowns' contingency is what the authors would call 'pessimistic bias'. This reveals that the projects were pessimistic; not confident in their estimates and despite the reduction in the total cost contingency (Table 6-3), the 'unknown unknowns' contingency has increased. For the studied projects, a shortcoming in the budget means bureaucratic and administrating work to get the extra funding. To avoid these hassles, the project might have increased the 'unknown unknowns' contingency upfront. It is generally observed that the estimator's assessment of range estimates tends to be conservatively biased for the upper-bound value assigned (Yeo, 1990). Mak and Picken (2000) mention that estimators usually tend to include an inflated buffer in the contingency estimate.

Organizations' culture may have played a role in increasing the 'unknown unknowns' contingency as well. The examined organizations are public. In order to overcome reputation damage and public critics, their attitude is risk avoidant. Estimating a higher cost contingency gives them more certainty to finish the project within the assigned budget. The 'unknown unknowns' contingency is calculated simply based on a percentage of BC. In the T&A phase, the design and scope are almost fixed and the changes in the BC and the 'known unknowns' contingency is less possible. Therefore, to achieve a higher cost contingency, it would be easier for the projects to adjust the 'unknown unknowns' contingency. This way the projects have more confidence in their estimations. One possible pitfall of increasing the 'unknown unknowns' contingency is that this amount becomes exaggerated, meaning that the projects have extra reservations. If there are fewer needs on the cost contingency budgets could be seriously underspent. This remaining budget could have been used in other projects, but, as the budget was already reserved, 'gold plating' could also happen, leading to unnecessary expenditures.

6.6 Conclusion and implication for practice

This research investigated cost contingency and cost evolvement of construction projects in the pre-construction phase. It is concluded that the examined projects have mostly experienced an increase in the estimated costs in the pre-construction phase. The results shows that the projects were conservative in their estimates.

The research has contributed to the available literature in three ways. Firstly, until now, few studies were reported on the evolvement of the total project cost estimate in the pre-construction phase. Our research contributes to closing this gap. Secondly, the concept of 'known unknowns' and 'unknown unknowns' is a rather undiscovered and vague one in current literature and there is no example, to the knowledge of the authors, of the investigation of this concept in construction project practice. This research has contributed to the current body of knowledge by investigating the 'known unknowns' and 'unknown unknowns' contingencies and explaining the proportion of these contingencies compared to the total cost contingency of projects. Thirdly, while some researchers conclude that 'optimism bias' is one of the reasons of cost increase in projects, this research shows that a lack of confidence in the estimates or 'pessimism bias' is another possible reason for cost increase. This third contribution has also practical implications. The practitioners could consider the results of this study to avoid 'pessimism bias' behaviour and, as a result, improve their cost estimating practices. Being aware of 'pessimism bias' behaviour, the organizations can define strategies to minimize this phenomenon in their cost estimate practices. One possible strategy to avoid 'pessimism bias' is to ask for a second opinion on the estimates (external view). The projects can ask for opinions on their estimates by experts in similar projects, which would be very helpful in the case of HWBP. Another possible implication of the research is to use the data to better estimate the costs of future projects. The results show that the lognormal distribution fits well to the percentages of cost contingency in Table 6-4.

This distribution can be used to improve the estimate of the percentage of cost contingency in future projects. Using the historical data to estimate the project costs (known as 'outside view' (Kahneman & Tversky, 1977; Lovallo & Kahneman, 2003) provides a check on the estimate by comparing the estimate with available historical data.

In total, cost documents of 29 flood defence projects in the pre-construction phase are studied. The results in the first part show that the mean value and the standard deviation of cost contingency percentage have reduced from the EXP phase to T&A phase. This confirms that the risk profile of the projects in the pre-construction phase has decreased. The results in the second part of the analysis revealed on average 11.51% increase in the total estimated costs of the projects in the pre-construction phase. This amount is smaller than the cost estimate increase in the pre-construction phase of the Dutch transport infrastructure projects (19.7%). The literature on cost estimation mentions that cost increase is a result of one or more of the following factors: 'adjusting', 'anchoring', 'optimism biases', and 'strategic misrepresentation'. Due to the financing method of the examined projects in this research, it could not be concluded that these factors have played a role in the cost estimate increase in the preparation phases of the projects. Technical reasons such as imperfect forecasting techniques, inadequate data, and lack of experience seem more logical reasons in this case.

Comparing the 'known unknowns' and the 'unknown unknowns' contingencies revealed that the projects in our research showed a tendency to a higher 'unknown unknowns' contingency when the project progresses. This would give the projects more confidence to finish within the budget. A higher 'unknown unknowns' contingency can be a result of 'pessimistic bias' where the projects are not confident with their estimates. In addition, it can be due to a lack of experience with the type of projects, to avoid the bureaucratic and administrative work to obtain an extra subsidy or to overcome reputation damage and public criticism. Overestimating the risks and reserving extra budget, more than really needed, however, is ineffective use of public money.

6.7 Research limitation

The projects studied in this research make a border between the 'known unknowns' and 'unknown unknowns' contingencies and this border was used in the research in the data gathering process. A clear border between the 'known unknowns' and 'unknown unknowns' events, however, might theoretically be impossible.

6.8 Recommendation for future research

This research has studied the cost contingency evolvement of Dutch flood defence projects. A possible area for future research could be investigating the cost contingency in the pre-construction phase of other types of projects in the Netherlands. It is also suggested that the same research is performed in other countries. This way insight can be obtained in the cost contingency evolvement before the start of project execution in different countries.

Possible reasons for changes in the cost contingencies were theoretically explored in this research. These reasons, however, were not investigated in-depth in the projects. This could be part of subsequent investigations.

As a next step, the current research could be expanded to later project phases (construction) and compare the estimated cost contingency and the actual cost contingency after execution.

The research showed that the lognormal distribution is a good fit for the percentage of cost contingency in the examined projects. Future research could investigate whether using this distribution can help making more accurate estimates of cost contingency (development).

6.9 Data availability

Some or all data, models, or code used during the study were provided by a third party. Direct requests for these materials may be made to the provider as indicated in the Acknowledgements.

6.10 Acknowledgment

The authors would like to thank Hoogwaterbeschermingsprogramma (HWBP) program for funding this research and providing the project documents used in this research.

6.11 Appendix B

Table 6-9 shows the total estimated cost of 29 projects in the Tender & Award (T&A) phase.

Table 6-9 Total project costs at the T&A phase

Project ID	Total cost estimate at T&A phase (in M€)
1	23.31
2	140.17
3	8.89
4	6.95
5	51.29
6	2.37
7	24.66
8	56.45
9	2.97
10	13.96
11	49.78
12	23.83
13	50.63
14	3.73
15	39.89
16	29.27
17	124.13
18	0.60
19	5.38
20	38.73
21	4.13
22	10.40
23	8.81
24	1.89
25	126.06
26	123.01
27	60.82
28	0.74
29	2.66
Total	1,0351.51

Figure 6-14 shows the development of cost contingency in the three phases. Each dot on the lines represents a phase in which the left dot is EXP phase, the middle dot is PD, and the right dot is T&A. The red dot indicates the highest amount in each trend.

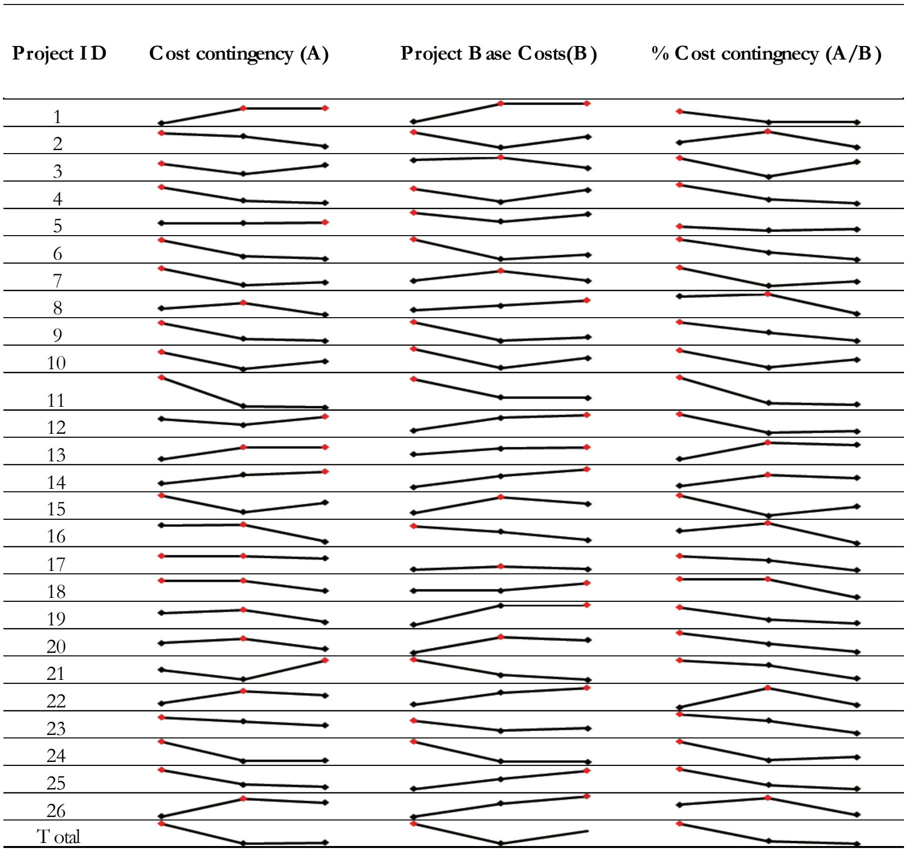

Figure 6-14 Trends of Base Cost, cost contingency, and percentage of cost contingency

6.12 References

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CHAPTER 7

Cost Performance and Cost Contingency during Project Execution: Comparing Client and Contractor Perspectives

Abstract[8]

Current literature shows that poor cost performance in projects has become a routine. Research on cost performance has mostly focused on one of the involved parties: either the client or the contractor. Not many researches discuss the cost contingency performance of projects. This research discusses the cost performance cost contingency of projects in the execution phase from the perspective of a client as well as a contractor. Using a case study approach, 95 projects are investigated: 44 client projects and 51 contractor projects. The results show that depending on the perspective, projects can have cost overruns or cost underruns. Comparing the total realized and estimated costs, projects experienced on average about 16% underrun from a client perspective. From a contractor perspective, projects experienced on average up to 2% overrun. The estimated cost contingency in the client's projects was on average 2.64% more than the required cost contingency. The estimated cost contingency in the contractor's projects was on average 5.41% less than the required cost contingency. These differences are explained by 'pessimism bias' and Technical reasons at the client's side. At the contractor side, 'optimism bias', Technical and Political reasons play a role, resulting in opportunistic behaviour. The findings help practitioners to enhance their cost estimates by avoiding both 'pessimistic bias' and 'optimism bias' behaviour, for example by using historical data from earlier projects. Further investigation into the influence of market conditions on cost estimates is suggested.

Key Words: Construction projects, Contingency reserve, Cost estimate, Cost performance, Risk management

7.1 Introduction

Costs are one of the basic elements of the iron triangle of project management, and a crucial element in funding decisions of projects. It is also one of the most basic parameters for measuring project success. An accurate cost estimate is an important element in the cost control of a project. A cost estimate is a quantitative assessment, based on the available information, at a given point in time and of the likely costs for resources required to complete a project (PMI, 2013). To obtain an accurate cost

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estimate, comprehensive information, expanded knowledge, considerable expertise, and continuous improvement are required (Hatamleh, Hiyassat, Sweis, & Sweis, 2018). Accuracy in a cost estimate can be defined as an indication of the degree to which the final cost outcome of a project may vary from the estimated cost of the project (Ogilvie, Brown Jr, Biery, & Barshop, 2012).

In construction projects, the accuracy of cost estimates is fundamental to achieve project success (Olawale & Sun, 2015) for both clients and contractors. Contractors in the construction industry bid usually in a competitive bidding setting where they estimate a total bid price based on the available project information (Shane, Strong, & Gad, 2015). The challenge is that a contractor needs to develop a cost estimate, which is low enough to allow the contractor to become the lowest bidder, but high enough to guarantee a decent level of profit (D. Y. D. D. Y. Kim, 2008). For the client, the situation is different; the client needs to come with a reasonable estimate to keep the investors or the taxpayers satisfied. An accurate cost estimate is crucial for the client to assess the viability of a project and to determine whether to proceed with the project (Yeo, 1990; Mak & Picken, 2000; Uzzafer, 2013; Baccarini & Love, 2014; Hammad, Abbasi, & Ryan, 2016).

Construction projects, however, are affected by numerous uncertainties due to the, for example, long period of development, involving substantial resources and political issues (Mustafa & Al-Bahar, 1991; Chapman & Ward, 2003; Yeo & Ren, 2009; Hillson, 2012; Hopkinson, 2012; Schwindt & Zimmermann, 2015). Hence, there is a high chance that an estimate does not turn out as planned and the project ends up with cost overruns (Nicholas & Steyn, 2017). One of the ways to deal with the uncertainties and avoid cost overruns in projects is to employ cost contingency (Yeo, 1990; Mak & Picken, 2000; Lhee, Issa, & Flood, 2012; Marco, Rafele, & Thaheem, 2016).

Cost contingency is the amount of money needed to address the uncertainties in a project to reduce the risk of cost overruns to an acceptable level (PMI, 2009, 2013). Cost contingency increases the chance of project success by increasing the confidence that the budget for the project execution is sufficient to cover the uncertainties (Yeo, 1990; Mak & Picken, 2000; Baccarini, 2004; Uzzafer, 2013; Baccarini & Love, 2014; Hammad et al., 2016). The amount of cost contingency should be proportionate to the level of uncertainty that the project is subjected to; the higher the uncertainty, the bigger the cost contingency amount. The contingency is then added to the raw estimates (known as Base Costs) to form the cost baseline.

For the contractor, allocation of low amounts of contingency to a project with a high amount of uncertainties may result in significant losses while a high amount of contingency may decrease the chances of winning the contract (Sonmez, Ergin, & Birgonul, 2007; D. Y. D. D. Y. Kim, 2008; Hammad et al., 2016). For the client, over-allocation of the cost contingency results in misuse of public money and under-allocation might increase the chance of project failure.

Current literature on cost estimates acknowledges the development of methods and techniques to estimate project costs and cost contingency (Mak & Picken, 2000; Barraza & Bueno, 2007; Baccarini & Love, 2014; Hammad et al., 2016; Marco et al., 2016; B.-C. Kim & Pinto, 2019). Even this development has not improved the cost estimate practices and projects still suffer from cost overrun (Pinheiro Catalão, Oliveira Cruz, & Miranda Sarmento, 2019). Despite the consensus on the importance of cost contingency, many projects fail to address the uncertainties in their cost estimates (Reilly, McBride, Sangrey, MacDonald, & Brown, 2004), and, as a result, end up with cost overruns (Bruzelius, Flyvbjerg, & Rothengatter, 2002; Baloi & Price, 2003; Lovallo & Kahneman, 2003; Hollmann, 2012; Khamooshi & Cioffi, 2013; Gharaibeh, 2014; Brunes, 2015; Marco et al., 2016). Cost overruns, especially in most large and complex projects, are considered more the rule than an exception (Flyvbjerg, Holm, & Buhl, 2002; Baloi & Price, 2003). Inaccurate estimation of the costs is named as one of the most frequently identified causes of project overrun (Olawale & Sun, 2015).

7.2 Literature review

The importance of cost overrun in projects is a reason for many scholars to study the magnitude of cost overrun in projects. Yap, Chow, and Shavarebi (2019) identify 23 most important problems in construction industry. Their results show that cost overrun is one of the most mentioned problems of the construction industry in literature and one of the five most critical problems in the Malaysian construction industry. Cost performance can be different per project phase. For example, Cantarelli, Molin, van Wee, and Flyvbjerg (2012) show that Dutch transport projects experience mostly cost overrun in the pre-construction phase while projects experience cost underrun in the execution phase. This trend is, however, different per country and Cavalieri, Cristaudo, and Guccio (2019) show that Italian transport infrastructure projects have mostly cost overrun in the execution phase. The magnitude of cost overrun can also be different depending on whether it is carried out by the local or central government (Pinheiro Catalão et al., 2019).

Many scholars have studied the reasons for cost overrun. Among recent studies, research by Li, Yin, Chong, and Shi (2018) shows that cost overruns in projects are related to the level of trust between stakeholders. The shortage of skilled workers in North America has been identified as another factor with significant influence on cost overrun of projects (Karimi, Taylor, Dadi, Goodrum, & Srinivasan, 2018). Organizational behaviours such as the incentives or the reporting environment have a significant effect on the ability to create accurate cost estimates (Grau, Back, & Mejia-Aguilar, 2017).

In general, the literature on causes of cost overruns in projects can be divided into two main categories. The first category is the work by scholars who identify the factors that contribute to cost overruns (Memon, Rahman, & Azis, 2011; Abdul Rahman, Memon, Karim, & Tarmizi, 2013; Rahman, Memon, Aziz, & Abdullah, 2013; Akram, Ali, Memon, & Khahro, 2017). For example, Rahman et al. (2013), identified 35 factors contributing to the cost overrun in projects. These factors are called endogenous, focusing on project characteristics (Catalão, Cruz, & Sarmento, 2019). The second category which focuses on the more exogenous motives (Catalão et al., 2019), consists of the work of scholars who elaborate, on a more abstract level, on reasons for cost overrun. This category of cost overrun reasons is vastly elaborated by scholars such as Flyvbjerg, Cantareli and Molin. The first category has some weaknesses as the factors are not mutually exclusive; some factors are covered in other factors as well (Brunes, 2015). The second category has received criticisms such as not considering scope changes or overstating the physiological reasons (Love & Ahiaga-Dagbui, 2018). Pinheiro Catalão et al. (2019) and Catalão et al. (2019) mention that the current literature has mostly focused on the endogenous project characteristics and exogenous characteristics are not widely discussed. Building upon the most recent literature, this research focuses on the second category to explain cost overruns in projects, benefitting from the work of Flyvbjerg and his colleagues. They classify the reasons for cost overrun in four groups: Technical, Economic, Psychological and Political (Flyvbjerg et al., 2002; Flyvbjerg, Bruzelius, & Rothengatter, 2003; Lovallo & Kahneman, 2003; Cantarelli, Flyvbjerg, van Wee, & Molin, 2010). The explanation for each category is as follows:

- Technical reasons include ‘forecasting errors’ expressed in technical terms; such as imperfect forecasting techniques, inadequate data and lack of experience.
- Economic reasons involve issues of either economic (self) interest or public interest. Project promoters deliberately underestimate costs in order to make projects look more attractive and thereby increase the chance of being selected.

- Psychological reasons comprise the concepts of planning fallacy and ‘optimism bias’. Planning fallacy means the tendency to underestimate the time needed to complete certain tasks and ‘optimism bias’ is the systematic tendency to be over-optimistic by overestimating benefits and underestimating costs.
- Political reasons include ‘strategic misrepresentation’ through the deliberate and strategic underestimation of costs when forecasting the outcomes of projects.

Flyvbjerg et al. (2002) concluded that the inaccuracy of early cost estimates is not a matter of incomplete information and inherent difficulties in an accurate estimate because if this were the case, inaccuracies could be expected to be random, or close to random. They conclude that the two main explanations for the inaccuracy in the cost forecasting for infrastructure projects are ‘optimism bias’ and ‘strategic misrepresentation’ (Kahnernan & Tversky, 1977; Flyvbjerg et al., 2002; Lovallo & Kahneman, 2003; Flyvbjerg, 2006; Liu & Napier, 2010). Flyvbjerg and his colleagues state that errors in estimates, resulting from uncertainties, are systematic biases that would improve over time because the errors and their sources are recognized and addressed, better methods are developed, and more experience is gained in cost estimating. In contrast, ‘optimism bias’ (explained by psychological reasons) and ‘strategic misrepresentation’ (explained by political reasons) are non-systematic and, therefore, likely to continue (Flyvbjerg, 2006).

7.2.1 Problem formulation and research objectives

Those scholars who investigate the magnitude of cost overrun in the construction projects (Pinheiro Catalão et al., 2019), focus merely on one of the main project parties; either client or contractor. However, there is an indisputable difference between the client and contractor perspectives in terms of financial success of a project; a financially successful project for the client can mean a loss for the contractor. Therefore, it is essential to address both perspectives. While most of the current literature deliberates on the accuracy of cost estimate, in general, studies in the accuracy of cost contingency are scarce.

The research objective of this study is to investigate the differences between the cost and cost contingency performance of client and contractor projects in the execution phase. The research also explains the reasons for cost deviation in the examined projects based on reasons gathered in literature.

The research question is formulated as follows:

What are the differences between the cost performance and cost contingency performance of client's and contractor's projects in the execution phase of construction projects?

This research answers the main research question by:

1. Investigating the cost performance by comparing the estimated and actual costs of construction projects of a client and a contractor in the execution phase.

2. Investigating the accuracy of cost contingency by comparing the estimated and required cost contingency of construction projects of a client and a contractor in the execution phase.

The remaining part of this paper is structured as follows. In the next section the research methodology of this paper is described. Then, results and analysis are presented followed by the Discussion section. Next, conclusions are drawn and recommendations are given for future research. Finally, acknowledgments are listed.

7.3 Methods

The research question has an exploratory characteristic. To answer the research question, the estimated and realized costs (contingency) of the projects should be followed back in time. Yin (2014) mentions that a case study strategy is preferable when the study is exploratory and has to deal with information to be traced over time. Therefore, this research follows a case study approach to investigate the cost and cost contingency performance of projects in the execution phase of construction projects. The case study places emphasis on the full analysis of a number of events or conditions and is, thus, an intensive exploration of the particular unit under consideration (Kothari, 2004; Yin, 2014).

One client and one contractor, who were available to participate in this research, are selected as the cases. From each of these cases, several projects are selected and the cost data, obtained from the archives of these parties are investigated. To make the results from the two perspectives comparable, similar criteria are used to select the projects. In addition, an identical approach is followed to calculate the cost performance of the projects.

Scholars such as Flyvbjerg et al. (2002), Cantarelli, van Wee, Molin, and Flyvbjerg (2012), Flyvbjerg et al. (2003), Hollmann (2012), and Cantarelli, Flyvbjerg, and Buhl (2012), compare the estimated and realized costs in two moments of time:

1. The cost estimate at the Time of formal Decision to build (ToD), and

2. The realized costs at the year of completion.

The ToD is the first official estimate of project costs. The ToD is, however, not always the best moment to choose since cost estimates become more accurate in the course of time, and the cost estimate at the ToD is far from final (Flyvbjerg et al., 2002).

The objective of this research is to investigate the cost performance in the execution phase. Therefore, in this study, in contrast with the aforementioned researches, the final estimate before the start of the execution phase is compared with the realized costs after the project realization and the cost estimate at the ToD is neglected. By investigating the cost performance in the execution phase, the results of the contractor and client could be compared. This would not have been possible if the cost estimate at the ToD would be considered as the contractor is not usually involved at ToD. Figure 7-1 compares the approach in this research with the approach of the other researches.

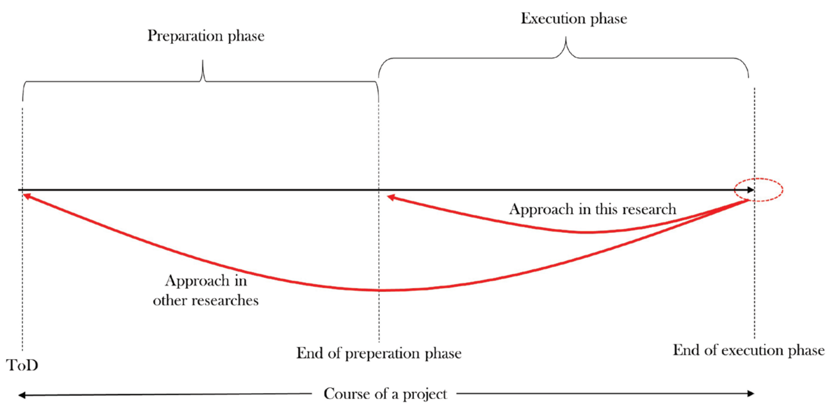


Figure 7-1 Comparing the scope of this research with other research efforts in the course of a project

To ensure the consistency of data collection, one team was responsible for collecting the data from the cases. The data collection of each party is explained next.

7.3.1 Data collection of the client's projects

The data from the client part is collected from the archive of the Flood Protection Program (known as Hoogwaterbeschermingsprogramma (HWBP)) in the Netherlands. The program is part of the Ministry of Infrastructure and Water Management (in Dutch: Ministerie van Infrastructuur en Waterstaat) and is responsible to improve all the flood protection facilities (such as dikes, locks, pumps, etc.) in the Netherlands, which do not meet the safety norms. The flood defence facilities in the Netherlands are examined every five years and each flood defence facility that does not meet the safety norms will be improved in a project. Each batch of the projects is governed under a program of projects. The Flood Protection Program is responsible for approving the subsidy required for the execution of these projects. The regional public organizations, known as waterboards, responsible for the flood defence facilities, have to submit their estimated budgets to the program. The submitted estimate is reviewed and tested several times by the Flood Protection Program in the preparation phase and the program provides the waterboards with the required funding, by giving the approval of the final estimates. After this step, the project is awarded to a contractor. After project completion, the realized costs of the project are calculated. In case of realized project costs being less than the estimated costs, the waterboards pay the remaining budget back to the Flood Protection Program. In case of actual project costs being more than the estimated project costs, the Flood Protection Program pays the extra costs to the waterboard.

The projects for this research are selected from a program of projects known as HWBP-2; most of the projects in this program are finished.

To select the projects for this research, two criteria are used:

1. The projects should be finished.
2. The final cost estimate documents at the beginning of execution and the cost estimate documents showing the realized costs of the project after the project completion (Figure 7-1) are available.

Based on these criteria, 44 projects from 11 waterboards are selected. All these projects are flood protection facilities and most of the projects are dike reinforcements.

7.3.2 Data collection of the contractor's projects

The contractor data is collected from the archive of a contractor in the Netherlands which was available to collaborate in the research. To select the contractor's projects, the same criteria as for the client are used.

Based on these criteria, 51 projects are selected. All projects are construction projects with different modalities (i.e. bridge, road, flood defence, building). From the selected projects, the last version of financial cost control reports is gathered and analysed both at the end of the preparation phase (moment of tender) and after the project completion.

7.3.3 Calculating the cost and cost contingency performance of the projects

From the cost documents of the client (44 projects) and the contractor (51 projects) at the end of preparation phase, three types of costs are collected:

1. Estimated Base Cost: is equal to the summation of the estimated work packages of Construction, Engineering, Real Estate and Other costs, without the estimated cost contingency, before the start of the project execution. Real estate costs are the costs to buy the ground (or the building) that is the property of a third party which is located in (part of) the project location and should be bought for project execution. Real estate costs are the responsibility of the client and are, therefore, only collected from the client's projects.

2. Estimated cost contingency: the estimated amount of cost contingency to cover the uncertainties during the project execution.

3. Total estimated costs: the summation of the estimated Base Cost (point 1) and the estimated cost contingency (point 2). This amount is the approved budget for the project execution (in case of the client) or the contract amount (in case of the contractor).

From the cost documents of the client and the contractor at the end of the execution phase, this information is collected:

- Total Realized costs: the total realized costs at the year of project completion.

The cost performance, expressed in percentage, is calculated as shown in Equation 7-1.

$$\%\ Cost\ performance = \frac{(Total\ realized\ costs - Total\ estimated\ costs)}{Total\ estimated\ costs}$$

Equation 7-1 calculating the cost performance (%)

In both cases of client and contractor, the total realized costs are given in the documents as the summation of realized costs of different work packages (Construction, Engineering, Real Estate and Other) but the required cost contingency is not given separately. The amount of required cost contingency is covered in each work package. In other words, the required cost contingency of the projects cannot be extracted directly. To compare the estimated and the required cost contingency, this information is still needed:

- Required Base Cost: the actual costs of different work packages (without cost contingency) that the project ideally needed.
- Required cost contingency: The amount of cost contingency that was actually required to address the negative risks.

These costs are calculated by another approach.

As explained, the total estimated costs (point 3 aforementioned) are equal to the summation of the work packages and the cost contingency. To calculate the required cost contingency, the estimated costs of each work package at the end of the preparation phase is subtracted from the realised costs of the same work package at the end of project execution. The result of this subtraction is a delta (Δ). Figure 7-2 presents the comparison of each work package in two moments. Please consider that the Real Estate costs are only collected for the client projects.

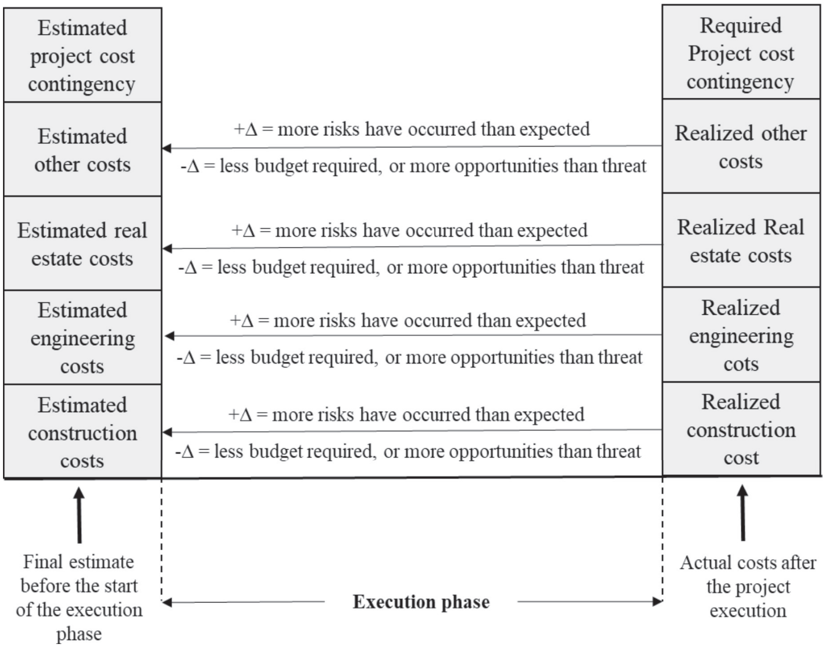


Figure 7-2 Comparing the realized and estimated costs

A positive delta (+Δ) means that the realized costs of the work package were more than the estimated costs. This deviation from the estimated costs is either because of the uncertainties that could not be identified beforehand or they are identified and not managed appropriately. For example, a +Δ for the construction work package can be due to one or all of the below reasons:

- An unexpected event that occurred (unknown unknowns) or
- The inherent variability in the price or amount is not addressed properly (e.g. the uncertainty in the amount of soil need is either not addressed in the estimated or it is addressed less than actually needed), or
- There is a risk that could have been identified beforehand but it is either not identified or identified but not mitigated (an unmanaged known unknown) (e.g. mistakes in the drawing).

In case of a negative delta (-Δ), the estimated costs are more than the realized costs for that work package. Therefore, there was less budget required than estimated, or there were more opportunities than threats (e.g. the contractor has a lower bid or an innovative method is used that cuts the amount of materials). It should be noted that in Figure 7-2, there is no arrow between the required and estimated cost contingency implying that these two amounts cannot be compared directly.

This approach is further elaborated by examples from two real projects; see Table 7-1 and Table 7-2.

In project 1, most of the realized costs (except the Real estate costs) are less than the estimated costs and the project is finished with a cost underrun. The extra costs for the Real estate work package are the only costs the project had to pay for the uncertainties and for the rest of the work packages, the opportunities were higher than threats. Therefore, the total required cost contingency to address the negative risks is equal to the +Δ of the Real estate costs which is € 7,895.

If we would want to consider the -Δ in the calculations, the amount of the required cost contingency would be negative. Negative cost contingency is implying that the project opportunities (positive risks) are more than the threats (negative risks). While a negative cost contingency is possible in theory, it is not common in the cost contingency estimates of the projects in practice. In practice, most projects focus only on the negative risks. Therefore, the authors purposefully focus on the cost contingency that the project needed to cover the negative risks (threats).

Table 7-1 First example of calculating the required cost contingency to address the negative risks

Project 1			
Work packages	Estimated costs (A)	Realized costs (B)	Difference (B-A)
Engineering costs	€ 2,612,600	€ 728,938	€ -1,883,662
Construction costs	€ 26,864,213	€ 20,749,876	€ -6,114,337
Other costs	€ 366,300	€ 114,358	€ -251,942
Real Estate	€ 0	€ 7,895	€ 7,895
Cost contingency	€ 2,392,905	Not available	Not available
Total	€ 32,236,018	€ 21,601,067	€ -10,634,951
Required cost contingency to cover the threats= +Δ Real estate = € 7.895			

In project 2 (Table 7-2), the realized Engineering costs are less than estimated so it has a -Δ. This can be either due to grasping the opportunities or mistakes in the estimate.

The realized Construction costs, Real estate cost and Other costs are higher than the estimated costs so they have +Δ. The project has finished with a cost overrun equal to € 6,369,041. The required cost contingency to address the negative risks is equal to the summation of the +Δs of the work packages Construction, Other costs and Real Estate costs (Table 7-2) which is € 10,905,528. The -Δ of the Engineering work package has contributed to a lower cost overrun at the end, but this amount is not considered to calculate the required contingency to cover the negative risks in the project.

Table 7-2 Second example of calculating the required cost contingency to address the negative risks

Project 2			
	Estimated costs (A)	Realized costs (B)	Difference (B-A)
Engineering costs	€ 1,968,643	€ 304,587	€ -1,664,057
Construction costs	€ 17,896,762	€ 28,755,558	€ 10,858,795
Other costs	0	€ 43,347	€ 43,347
Real Estate	0	€ 3,386	€ 3,386
Cost contingency	€ 2,872,430	Not available	Not available
Total	€ 22,737,837	€ 29,106,878	€ 6,369,041
Required cost contingency to cover the threats= (+Δ construction) + (+Δ Other costs) + (+Δ Real estate)= € 10,905,528			

The abovementioned arguments are summarized in Equation 7-2. The required cost contingency is, therefore, equal to the summation of positive deltas.

$$Required\ cost\ contingency = \sum_{i=1}^{p} \Delta_i^+$$

Equation 7-2 Required cost contingency where P is the number of work packages with a +Δ

To calculate the required Base Cost (point 5), the costs that were actually needed for each work package are considered. The minimum amount of the estimated and realized costs for each work package is equal to the required costs of that work package because that is the amount that the project actually needed to realize that work package. For example, in the case of project 1 (Table 7-1), in the Engineering work package, the realized costs is the amount that the project actually required for that work package (i.e. the minimum amount between the estimated and realized costs for that work package). In case of project 1, the required Base Cost is, therefore, equal to summation of realized costs of the work package Engineering (€ 728,938), the realized costs of the work package

Construction (€ 20,749,876), the realized costs of the work package Other costs (€ 114,358), and the work package Real estate (€ 0). The required Base Cost is calculated as shown in Equation 7-3.

$$Required\ Base\ Cost\ = \sum_{i=1}^{p} Min(Estimated\ work\ package_i\ , Realized\ work\ package_i)$$

Equation 7-3 Required Base Cost

Percentage of required cost contingency is calculated as

$$\%\ Required\ cost\ contingency = \frac{Required\ cost\ contingency}{Required\ Base\ Cost} \times 100$$

Equation 7-4 Percentage of required cost contingency

Due to the nature of the collected data, no meaningful complex analysis (e.g. correlation, regression, etc.) can be performed. Therefore, the collected data for both the client and contractor are analysed, applying descriptive statistics such as mean, SD, and histograms. In Discussion section, the possible reasons for the deviation between the estimated and realized costs are explained from a theoretical point of view. Investigating the reasons for cost overruns is not the objective of this research and falls, therefore, out of the scope of the research.

7.4 Results and analysis

The results of the research are presented in two parts: the client and contractor. First, the results of the client are presented. The results in each part are divided into investigation of cost performance and cost contingency performance.

7.4.1 Investigating the client's projects

7.4.1.1 Cost performance in the projects of the client

Figure 7-3 presents the cost performance of the client's project. The cost performance is calculated by subtracting the total estimated costs from the total realized costs (cost performance = total realized costs – total estimated costs). The positive amounts mean that the project has a cost overrun while a negative amount means that the project has cost underrun. As shown in Figure 7-3, most of the projects have cost underrun. As shown with a line on the figure, for most of the projects with cost underrun, the amount of cost underrun is between zero and 5 M€. The maximum amount of cost underrun is 18.82 M€ (project 29). The total estimated costs of 44 projects are € 1,130.52 billion (average of estimated costs is 25.7 M€) and the total realized costs are € 1,027.81 billion (average of actual costs is 23.4 M€). This means that the projects have in total € 102.71 M€ (9.09%) cost underrun. Only nine projects (project 9, 10, 13, 14, 17, 22, 32, 38, 39 as shaded in the graph) out of 44 (20.45%) have experienced cost overrun and the total amount of cost overrun for these nine projects is 12.95 M€ (1.15% of the total estimated cost). Except project number 10 (with 4.53 M€ cost overrun) and project number 17 (with 6.41 M€ cost overrun), the amount of cost overrun for the rest of the projects is negligible.

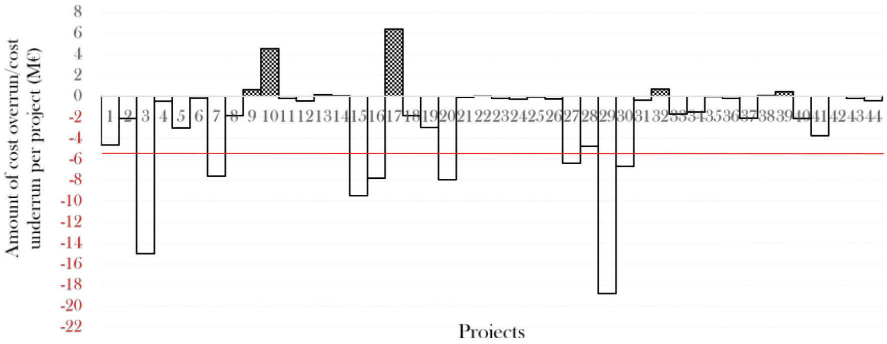


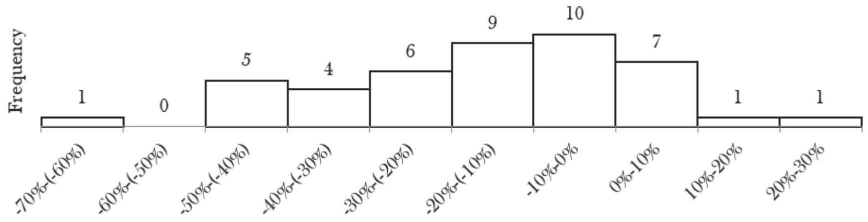
Figure 7-3 Cost performance of the client's projects

Table 7-3 presents descriptive statistics of the projects with either cost underrun or cost overrun. The average cost overrun in the projects with cost overrun is 6.05% and the average of cost underrun in the projects with cost underrun is -21.58%.

Table 7-3 Descriptive statistic of amount (in million euro) of cost overrun and underrun in client's project

	Cost underrun (M€)	Cost overrun (M€)	Cost underrun (%)	Cost overrun (%)
Mean	-3.3	1.44	-21.58	6.05
Standard Deviation	4.40	2.35	16.37	9.09
Sum	-115.66	12.95	-	-
Count	35	9	35	9

Figure 7-4 presents the distribution and statistical analysis of the percentage of cost performance of the client's projects. The histogram shows a larger spread in the negative side confirming that the projects have more cost underrun than cost overrun. In total, the mean percentage of cost performance of projects is -15.93%. From the projects with cost underrun (35 projects), the projects have mostly cost underrun up to 50% with most of the projects having a cost underrun up to 30% (25 projects). From the projects with cost overrun (9 projects), the percentage of cost overrun for most of the projects is up to 10% (7 projects).



Mean	-15.93%
Standard Deviation	18.82
Minimum	-65.94%
Maximum	28.18%
Count	44

Figure 7-4 Distribution and statistical analysis of percentage of cost performance of the client's projects (N=44)

7.4.1.2 Investigating the estimated and required cost contingency in the client's projects

Only 30 projects from 44 projects have enough data to estimate the required cost contingency according to the procedure shown in Figure 7-5. The estimated cost contingency was extracted directly from the documents. The percentage and the amount of the required cost contingency of these 30 projects are calculated based on Equation 7-2 and Equation 7-4. Figure 7-5 compares the amount of required cost contingency (A), estimated cost contingency (B) and the differences between required and estimated cost contingency (A - B). Except eight projects (the projects number 6, 9, 10, 13, 14, 17, 21, and 22) the rest of the projects have higher cost contingency estimated than required. The projects number 10 and 17 are the projects with the largest differences between estimated and required cost contingency (4.53 M€ and 8.03 M€ respectively). The total amount of estimated cost contingency is 83.20 M€ while the required cost contingency is 51.18 M€. This difference is about 32 M€ (38%).

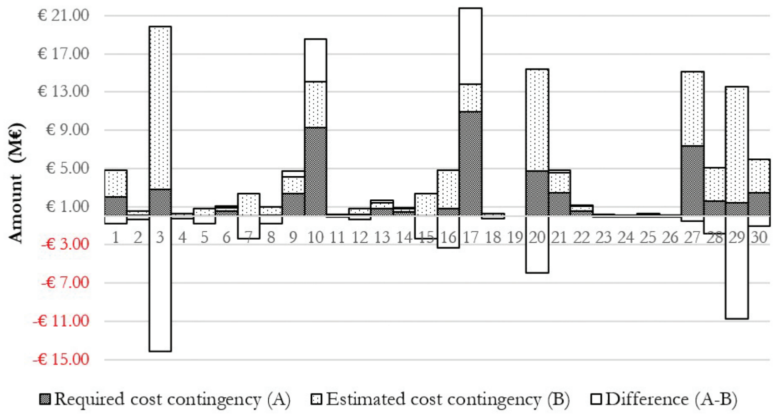


Figure 7-5 Comparing the required and estimated cost contingency of the client's project (N=30)

The histogram presented in Figure 7-6 compares the percentage of estimated and required cost contingency in 30 projects. The required cost contingency is more shifted to the left with 12 projects having a required cost contingency up to 5%, confirming that the required cost contingency is less than the estimated cost contingency.

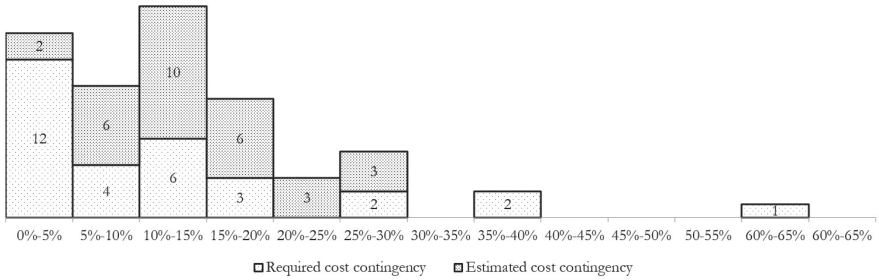


Figure 7-6 Comparing the percentage of estimated and required cost contingency of the client's projects (N=30)

The statistical analysis of the estimated and required cost contingency is provided in Table 7-4. The mean of the estimated cost contingency is 2.7 M€ while the mean of the required cost contingency is 1.7 M€ meaning that on average the projects have one million euro extra cost contingency. The average of estimated cost contingency is 14.21% and the average of the required cost contingency is 11.57% (on average 2.64% extra reservation).

Table 7-4 Statistical analysis of estimated and required cost contingency in M€ (N=30)

	Estimated cost contingency (M€)	**Required cost contingency (M€)**	**Estimated cost contingency (%)**	**Required cost contingency (%)**
Mean	2.77	1.71	14.21	11.57
Standard Deviation	4.09	2.82	7.38	14.19
Minimum	0.00	0.00	0	0
Maximum	17.03	10.91	29.65	59.90
Sum	83.02	51.18	-	-

The results show that the client's projects have higher estimated costs than required and most of the projects are realized below the estimated budget. Less required cost contingency than estimated cost contingency confirms that the projects were less risky and uncertain than expected or that the opportunities in these projects were underestimated. The following section investigates the cost performance of the contractor's projects.

7.4.2 Investigating the contractor's projects

This section investigates the results of contractor's projects. Similar to the presentation of the results of the client, this section is divided in two parts of cost performance and cost contingency performance.

7.4.2.1 Cost performance in the projects of the contractor

7

Figure 7-7 shows the cost performance of the contractor's projects. Again, the cost performance is calculated by subtracting the estimated budget from the realized budget (cost performance = total realized costs – total estimated costs). From 51 project, 26 projects (50.98%) have experience cost overrun (shown by shaded bars on the graph). The red line on the graph shows that only two projects have experienced cost overrun more than 3 M€ (project 2 and project 5). The maximum amount of cost overrun is 7.29 M€ (project 2) and the maximum amount of cost underrun is 3.52 M€ (project 3). The total estimated costs of 51 projects are € 711.75 M€ and the total realized costs are € 719.84 M€. This means that the projects have in total € 8.1 M€ (1.28%) cost overrun.

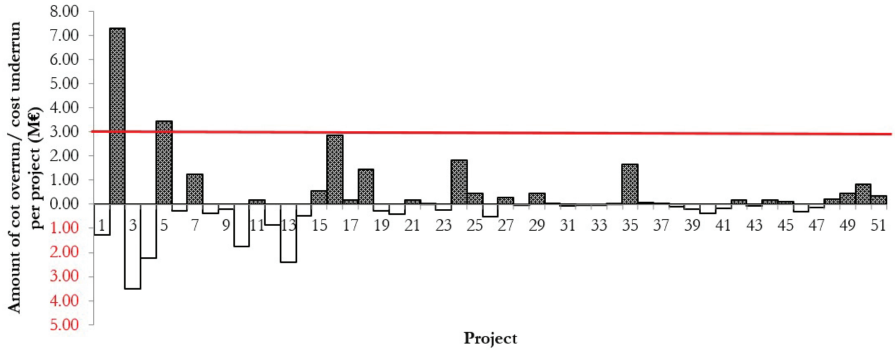


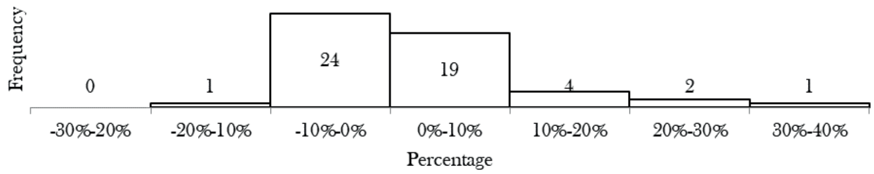
Figure 7-7 Cost performance of the contractor projects

Table 7-5 shows the descriptive statistics of the projects with either cost underrun or overrun. The average percentage of cost overrun in the projects with cost overrun is 7.78% and the average of cost underrun in the projects with a cost underrun is -4.10%. On average the amount of cost overrun of the projects with cost overrun is less than 1 M€.

Table 7-5 Descriptive statistic of amount (in million euro) of cost overrun and underrun in contractor projects

	Cost underrun (M€)	Cost overrun (M€)	Cost underrun (%)	Cost overrun (%)
Mean	-0.65	0.94	-4.10	7.78
Standard Deviation	0.9	1.57	3.2	7.8
Sum	-16.28	24.38	-	-
Count	25	26	25	26

The distribution and statistical analysis of the percentage of cost performance of contractor's projects are shown in Figure 7-8. In total, the average of cost overrun is 1.96% (SD=8.4) which is low.



Mean	1.96%
Standard Deviation	8.45
Minimum	-12.72%
Maximum	34.37%
Count	51

Figure 7-8 Descriptive analysis of percentage of cost performance of the contractor's project

7.4.2.2 Investigating the estimated and actual cost contingency in the projects of contractor

Similar to the client's projects, the amount and the percentage of the required cost contingency of the contractor's projects are calculated based on Equation 7-2 and Equation 7-4. Figure 7-9 compares three amounts of required cost contingency (A), estimated cost contingency (B), and the difference between the required and estimated cost contingency (A-B). From 51, only five projects (project 3, 8, 10, 13, and 23) have an estimated cost contingency more than the required cost contingency, and for the rest, the estimated cost contingency was not sufficient.

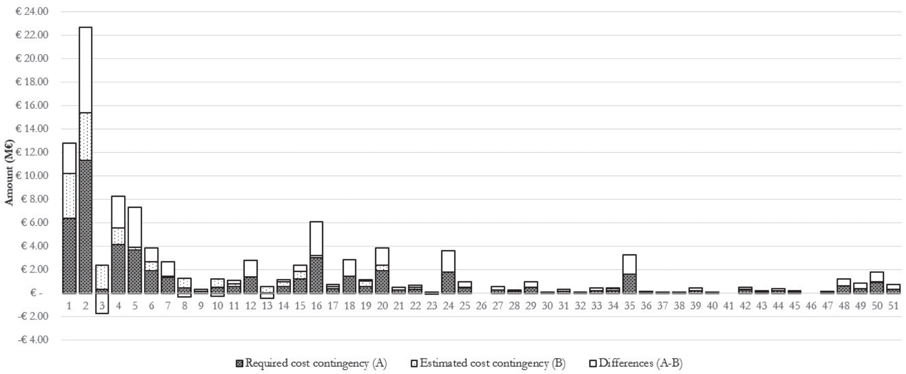


Figure 7-9 Comparing the required and estimated cost contingency of the contractor's project (N=51)

7

The histogram presented in Figure 7-10 compares the percentage of estimated and required cost contingency in 51 contractor's projects. The percentage of required cost contingency is more skewed to the right meaning that the projects have required more cost contingency than what was estimated. The estimated cost contingency of most projects (44 out of 51 projects) is less than 5%.

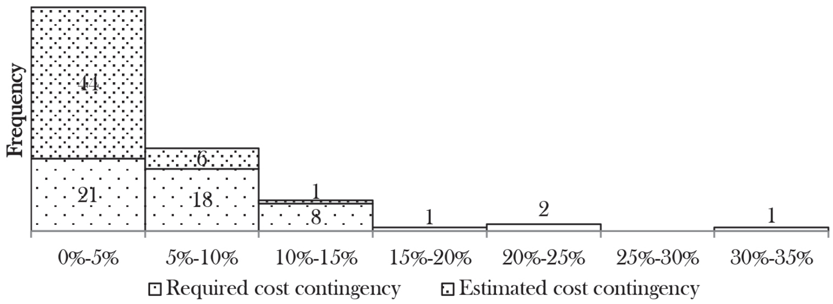


Figure 7-10 Comparing the percentage of estimated and required cost contingency of the contractor's projects (N=51)

Table 7-6 presents the statistical analysis of the amount and percentage of estimated and required cost contingency. The average of estimated cost contingency is 1.65% and the average of the required cost contingency is 7.06%. On average, the projects have 5.41% less estimated cost contingency than the required cost contingency.

Table 7-6 Statistical analysis of estimated and required cost contingency in M€ (N=51)

	Estimated cost contingency (M€)	**Requires cost contingency (M€)**	**Estimated cost contingency (%)**	**Requires cost contingency (%)**
Mean	0.35	1.01	1.65	7.06
Standard Deviation	0.82	1.91	2.4	6.85
Minimum	0	0	0	0
Maximum	4.05	11.33	10.57	34.37
Sum	17.96	51.47	-	-

Different from the clients' projects, the contractors' project have mostly underestimated the costs and cost contingency, confirming that the projects were either more risky and uncertain than expected or that the opportunities in these projects were overestimated.

7.4.3 Comparing the results of the client's and the contractor's projects

The results show that the contractor's projects have experienced more cost overrun than the client's projects. While the client's projects have on average -15.93% cost underrun (Figure 7-4), the contractor's projects have 1.96% cost overrun (Figure 7-8). Comparing the results of the contractor in Table 7-5 with the results of the client in Table 7-3, the contractor shows a larger percentage of cost overrun than the client's projects.

The amount and percentage of cost contingency show exactly opposite results for the client and contractor. While only eight projects of the client had less estimated cost contingency than required (Figure 7-5), the results of the contractor show that only five projects have had sufficient cost contingency (Figure 7-9). In total, the client's projects have 2.64% extra reservation (Table 7-4) while oppositely, the contractor's projects have suffered in average 5.41% as lack of contingency. More interestingly, the results in Figure 7-9 show that some contractor projects (for example project 18 and 24) have no estimated cost contingency. In general, it seems that the contractor was more optimistic in the estimates and has overestimated the opportunities while the client was more pessimistic or careful, with a tendency for overestimating the costs and underestimating the opportunities.

7.4.4 Comparing the results of the client's projects with a similar study

In this section, the results of this research are compared with the study by C. C. Cantarelli, E. J. E. Molin, et al. (2012). Their study looks at the cost performance in the Dutch transport infrastructure projects. This study is selected for the comparison since it looks, among others, at cost overrun in the execution phase. Moreover, their study is performed in the Netherlands with a relatively comparable database (37 projects in the execution phase). From the research by C. C. Cantarelli, E. J. E. Molin, et al. (2012), it can be concluded that the research is performed in client projects, although it is not mentioned explicitly, RWS is acknowledged which is a public organization and has the role of the client in the Netherlands. Hence, the comparison is performed with the results of the client projects in this research. Table 7-7 shows the results of this comparison.

Table 7-7 Comparing the cost performance in this study with Dutch transport infrastructure project

	Flood defence projects (client in this research)	**Study by C. C. Cantarelli, E. J. E. Molin, et al. (2012)**
mean	-15.93%	-4.5%
Standard deviation	18.82	14.4
range	-65.94% to 28.18%	-35.4% to 22.8%
Count	44	37
% of projects with cost underrun	79.5%	62%

In both studies, the projects show cost underrun in the execution phase. From 37 Dutch transport infrastructure projects, only 38% have a cost overrun and 62% have a cost underrun while 79.5% of the projects in this research have cost underrun and only 20.5% of the projects have cost overrun (9 projects out of 44 as shown in Table 7-3). Both studies confirm that public projects in the Netherlands have more cost underrun than overrun in the execution phase. The amount of cost underrun, however, is even larger in flood defence projects in the Netherlands (this research). Note that differences between the results can be related to sample size, type of project and year of execution as the current study was performed more recently.

7.5 Discussion

The research has investigated the cost performance and cost contingency of 44 client's projects and 51 projects of a contractor in the execution phase. Flyvbjerg et al. (2002) conclude that the error of underestimating costs is significantly more common and much larger than the error of overestimating costs. However, this study shows that depending on the role (client or contractor) this can be different. While the client has overestimated the costs, the contractor has underestimated the costs. The results show that the client and contractor face contradictory cost performance in the execution phase. While the client's projects have mostly experienced cost underrun (Table 7-3 and Figure 7-4), the contractor's projects have experienced cost overrun (Table 7-5 and Figure 7-8). In addition, the client's projects have more cost contingency estimated than actually was required. In contrast, only a few of the contractor's projects have had enough cost contingency estimated. It seems that while the client had extra budget reserved, the contractor faced a lack of budget.

The approach to examine the cost performance is different in this research compared to the research by scholars such as C. C. Cantarelli, E. J. E. Molin, et al. (2012). In their studies, the cost estimate at the Time of formal Decision to build (ToD) is compared with the actual cost and it is concluded that the projects, in general, have cost overrun. In this research, however, the final moment before the start of the execution is compared with the actual cost. Comparing the results of this study with the study by C. C. Cantarelli, E. J. E. Molin, et al. (2012), it can be concluded that cost underrun in the execution phase is not uncommon, at least in the case of the Netherlands (see Table 7-7).

Results of the contractor's projects show that the amount of cost overrun is less than 2% which is very low. This result is in contrast with other studies that show that the projects have in general high cost overruns (for example C. C. Cantarelli, E. J. E. Molin, et al. (2012) mention that the magnitude of cost overrun in projects is between 5% to 86%). A reason for this difference, next to the differences in the selected moments to compare with the realized costs, could be differences in the type of projects. While authors such as Siemiatycki (2009) and C. C. Cantarelli, E. J. E. Molin, et al. (2012) report the cost performance of transportation projects only, the contractor's projects in this research include a broader variety of projects. Another reason could be differences between the client and contractor perspectives. Strangely enough, the researches on cost overrun do not usually specify the perspective (client or contractor). Since these researches use usually the ToD moment, it can be concluded that they investigate the client's perspective. This research shows that cost performance can be different for client and contractor projects.

Despite all differences between this research and the other researches, this research and research by other scholars show that the cost estimates are not accurate and as a result, either cost overrun or underrun in the projects are unavoidable. The authors now discuss some possible reasons of the cost overrun and underrun in the examined projects based on literature findings.

As mentioned earlier, Flyvbjerg et al identify four main reasons for cost overrun: Technical, Economic, Psychological, and Political reasons. For the contractor in this research, Technical, Psychological, and Political reasons seem more convincing as the reasons for cost overrun. Due to the role of contractors, Economic reasons are less applicable (i.e. a contractor could not make the project more attractive to get the funding). The cost overrun in the contractor's projects can be as a result of mistakes in the estimates (Technical reasons). The costs might be underestimated due to the Psychological reasons because the contractor was overoptimistic or due to the Political reasons to just win the contract. The fact that some projects have no or very little estimated cost contingency (Figure 7-9 and Figure 7-10) confirms the presence of either 'optimism bias' (Psychological reasons) or intentionally changing the estimates (Political reasons). The study by Jung and Han (2017) demonstrated that risk opportunistic behaviour in bid preparation by the contractor is not uncommon. The market conditions can lead to intentionally changing the estimates. The market condition and number of contractors signing up for the tender can (negatively) affect the contractors' cost estimates. Liu and Napier (2010) mention that the contractor's tender prices are often a product of not only the estimating department but also managers' objectives; managers may reduce prices in an 'ad-hoc manner' to unrealistic levels in an attempt to win the job (Political reasons). The average estimated cost contingency is low (as shown in Table 7-6). It is possible that the contractor has cut contingency costs with the hope to win the contract and then secure the profit margins by claiming extra work.

In general, the contractor's results show a low cost overrun (Figure 7-8). This small deviation can also be because of inefficient use of materials. Brunes (2015) mentions that when discussing cost functions, it is typically assumed that the firms are efficient and do not use more inputs than necessary, but in reality, waste might occur and explain cost overruns.

While most literature sources elaborate on the reasons for cost overrun in projects, reports on the reasons for cost underrun in projects are limited. Ahsan and Gunawan (2010) are one of the limited research efforts that discusses the subject of cost underrun in projects in developing countries and mention that International Development (ID) projects have 14.5% cost underrun. Ahsan and Gunawan (2010) explain that the depreciation of currency, lower price for procurement of goods and contracts and competitive bidding, scope cut, and tax and interest changes are the reasons for cost underrun in ID projects.

Assuming a stable economy in the Netherlands, depreciation of the currency and interest changes could not contribute to the cost underrun of the client's projects. In addition, the projects have not suffered from scope change since the waterboards have to execute the projects based on the agreed scope and subsidy. However, competitive bidding can be one of the reasons for the cost underrun in the client's projects (Table 7-3 and Figure 7-3). While the market condition and competitive bidding could be a reason for cost overrun in the contractor projects, it could be at the same time a reason for the cost underruns in the client's project. The client's projects could have benefited from the low bidding of the contractors. In this case, market conditions could have positively influenced the client's projects.

From the four reasons mentioned by Flyvbjerg, Economic and Political reasons do not contribute to the reasons for cost underrun in the client's projects (Table 7-3 and Figure 7-3). The client's projects in this study are public projects, which have failed the flood safety test, and therefore they should be improved. All these projects will receive the subsidy and any budget left after the project execution will be returned to the Flood Protection Program. Hence, Economic and Political reasons (trying to make the project interesting or estimating lower costs to get the funding) are not applicable in this case. The Technical (errors in the calculations and lack of competency) and Psychological reasons could, however, have contributed to the cost underrun in the client's projects.

When the examined projects started, they were relatively new for the waterboards responsible for the projects and they had limited experience in estimating the costs for these projects. Hence, mistakes in the estimates due to imperfect forecasting techniques, inadequate data, and lack of experience (Technical reasons) could have occurred. Regarding the Psychological reasons, Flyvbjerg et al. (2002) use the term 'optimism bias'. However, an 'optimism bias' can lead to cost overrun in the projects. In the case of this research, we would call this situation 'pessimistic bias' where the projects are pessimistic and conservative about the estimates and tend to increase the costs to cover any unexpected uncertainties. Mak and Picken (2000) mention that when it is extremely difficult to ask for a budget top-up in case of an underestimate, there is a tendency to overestimate. A shortcoming in the budget for the waterboards means more bureaucratic and administrating work to get the extra funding. To avoid these hassles, the projects might have come with higher estimates. The waterboards are public organizations. In order to overcome reputation damages and public critics, this organization strives to avoid uncertainties. Providing a higher cost estimate (for both cost contingency and the total costs) gives them more certainty to finish the project within budget. Mak and Picken (2000) mention that an over-exaggerated contingency is not uncommon in many public project estimates. People tend to be conservative in forecasting project returns and to be speculative in estimating project costs, which leads to differences in personal risk perceptions (D. Y. D. D. Y. Kim, 2008).

7

In the case of the contractor, underestimating the cost can lead to loss of profit margin. In the worst situation, it can lead to contractor failure and bankruptcy. In the case of the client, an overestimate of the budget leads to misallocation of resources as more than sufficient funds are locked up in the projects. In the case that there is no need for the contingency funds, budgets can be seriously underspent. One possible peril here is that the extra budget is overspent to reach the estimated budget. This concept is explained as "Money Allocated Is Money Spent" (MAIMS). In this behaviour, once a budget has been allocated to a project, it will tend to be spent up entirely (Kujawski, Alvaro, & Edwards, 2004; Abran, 2015).

One way to increase the accuracy of the estimates is to use the historical data from the previous projects (Lovallo & Kahneman, 2003; Flyvbjerg, Skamris Holm, & Buhl, 2005; Flyvbjerg, 2006; Liu & Napier, 2010). The study by Mak and Picken (2000) shows that the estimators mention the lack of historical data as a reason for poor estimates. Use of historical data from previous projects reduces the inaccuracy of estimate through 'optimism bias' (Kahnernan & Tversky, 1977) and 'pessimism bias'. This is because the projects do not rely only on the results of the 'inside view'; an 'outside view' is also incorporated in the results. The 'inside view' looks to the inside of the project, thus a project specific view. The 'outside view' means that estimates are based on reference projects or other types of historical data, or the perspective of the experts outside the project, thus a non-project specific view. When both forecasting methods are applied with equal intelligence and skill, the outside view is much more likely to produce a realistic estimate (Lovallo & Kahneman, 2003; Liu & Napier, 2010).

7.6 Conclusion and recommendations

The research contributes to the current body of knowledge in two ways. First, the research investigates cost performance from the perspectives of both client and contractor. Second, the research investigates the cost contingency performance of client's projects and contractor's projects, a rather underexposed area in the current literature. The results help practitioners to be aware of the possible behaviours such as 'optimism bias' and 'pessimistic bias', which can result in cost overrun or underrun in projects. They can avoid these behaviours by using historical data from earlier projects to improve cost estimates in their projects.

With respect to answering the research question, 44 client's projects and 51 projects of a contractor are investigated in the execution phase. The results of the client projects and the contractor projects show opposite situations confirming that the different perspectives of contractor and client should be considered while investigating the cost performance of projects. The results show that the client's projects have mostly experienced cost underrun (79.55% of projects) with the magnitude of cost underrun being about -15.93%. In contrast, the contractor's projects have suffered more from a cost overrun (50.98% of the projects) up to 2% in overall amount. In total, the client's projects have ended up with 102.71 M€ unspent budget while the contractor's projects faced in total € 8.1 M€ lack of budget. Comparing the client's projects in this research with an earlier research on the Dutch transport projects, both studies confirm that the public projects in the Netherlands have more cost underrun than overrun in the execution phase. The number and percentage of cost underrun in our study, however, higher than reported for Dutch transport projects.

Regarding the cost contingency, the results endorse that the client's projects had in average one million euro extra cost contingency reserved (14.21% estimated cost contingency versus 11.57% required cost contingency). Contrariwise, most of the contractor's projects had a lack of cost contingency (1.65% estimated cost contingency versus 7.06% required cost contingency).

The cost underrun in the client's projects could be due to Technical reasons such as lack of historical data, mistakes in the estimates or lack of experience, and Psychological reasons such as 'pessimistic bias' or overestimating the costs. The cost overrun in the contractor's projects can be explained by Technical, Psychological, and Political reasons. 'Optimism bias' and underestimating the costs with the hope to win the contract are respectively Psychological and Political reasons for the cost overrun in the contractor's projects. The small cost overrun of the contractor's project can also be simply due to the inefficient use of resources.

Using the historical data from previous projects and maintaining an 'outside view' next to an 'inside view' can contribute to improving project cost estimates.

7.6.1 Recommendation for the practice

Firstly, it is recommended that historical data of finished projects is collected in both the client organisation and at the contractor and used to estimate the costs of new projects.

This study shows that while most of the client's projects have cost underrun, the contractor has mostly cost overrun. In order to reach a more predictable estimate, closer collaboration between client and contractor in early project phases is recommended. More accurate estimates provide the potential of a win-win situation and a successful project for both parties.

7.6.2 Limitation and future research

This research has investigated the cost performance of client's projects and contractor's projects. The research, however, could not investigate the cost performance of the client and the contractor in the same projects. This can be a possible area for future research.

Other researches show that the magnitude of cost performance differs in different countries. It is, therefore suggested to perform similar research in other countries and compare the results.

This research has investigated the estimated and realized costs in two moments: 1. End of preparation phase, and 2. End of the execution phase (Figure 7-1). It is suggested that future research considers the moment of ToD as well and compares the costs in three moments as shown in Figure 7-1.

The possible influence of market conditions on the cost estimate of the projects is addressed in this research. It is suggested that future researches more deeply investigate the role of market conditions in the cost estimate of projects.

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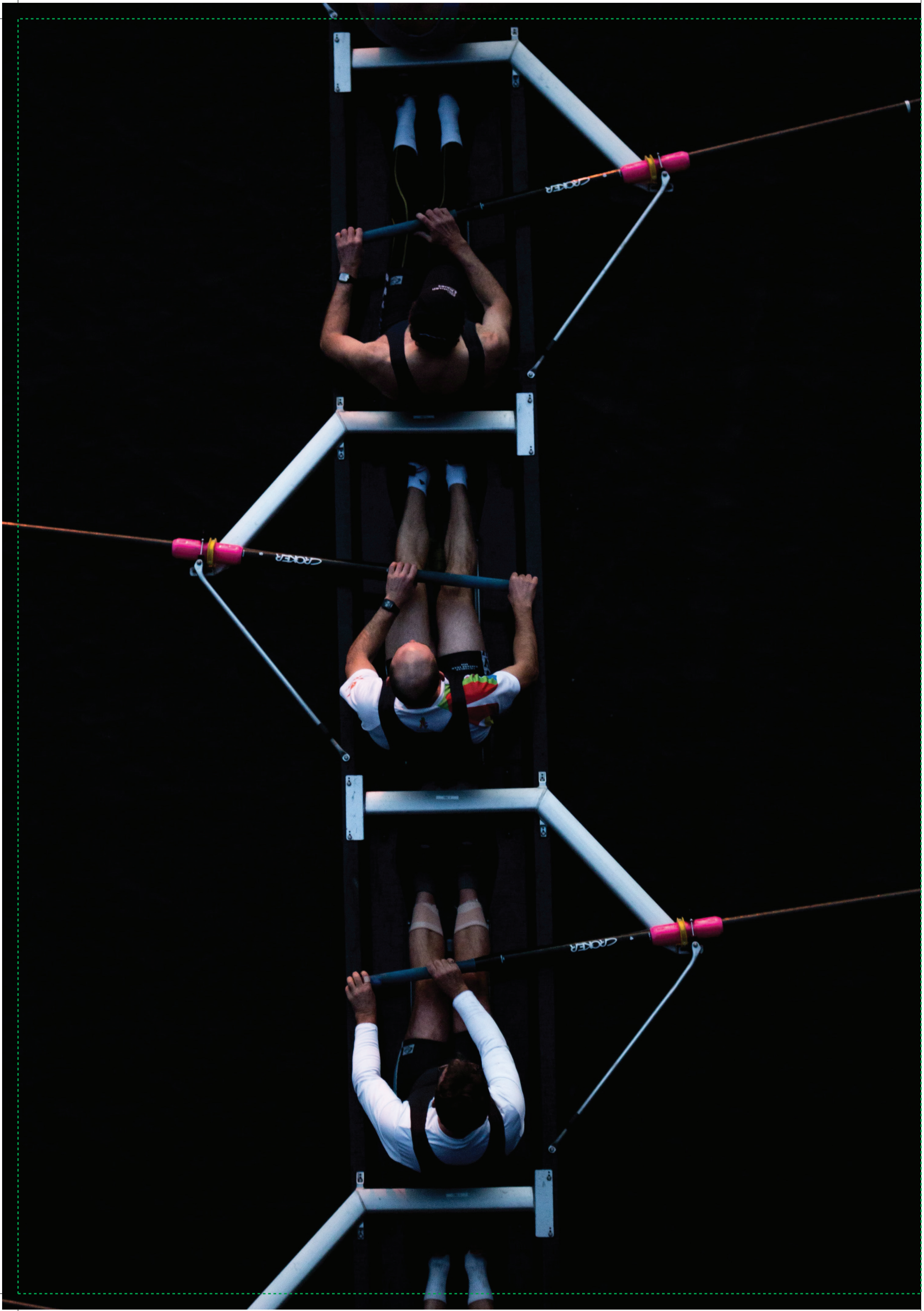
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CHAPTER 8

Pulling together: Recommendations to Improve Risk Management Practices in HWBP Projects

Abstract

Based on the results of the previous chapters, a list of 20 recommendations is drawn to improve the risk management application in HWBP projects. The feasibility of these recommendations is tested by three expert sessions: one session with project controllers from the waterboards, one session with experts from the PD-HWBP who are involved in risk management, and one session with experts who have strategic and directorate roles in HWBP. Before performing the expert sessions, the clarity of the recommendations was evaluated by a general group of practitioners. During the expert sessions, the experts were asked to, first, score the importance and feasibility of each recommendation. Next, the recommendations were discussed by the experts in each group. Based on the results, the recommendations are assigned to one category out of four categories: 'important-feasible', 'important-not feasible', 'not important-feasible', and 'not important-not feasible'. Most of the recommendations are assigned to the category important-feasible. It was observed that both the experts from the waterboards and the PD-HWBP see opportunities for improving risk management. It seems, however, that the waterboards have some resistance against the recommendations that might question their autonomy or any one-side decision-making that would influence their working approaches. It is important, therefore, that the PD-HWBP and the waterboards define their objectives regarding risk management and define the role and responsibility of each party towards these objectives. This would be the first and the most crucial step if risk management practices in the HWBP project are to be improved.

Improving the risk management practices of HWBP is the responsibility of both the waterboards and the PD-HWBP. Five milestones have been defined and each recommendation is assigned to either the waterboards or the PD-HWBP. These milestones and the role and responsibility of the PD-HWBP and the waterboards are presented in a Risk Management Map (RM-Map).

8.1 Introduction

Based on the results from the previous chapters, several recommendations are drawn to improve the risk management implementation in HWBP projects. This chapter presents the validation of the recommendations. The recommendations are drawn based on the results of three research phases as explained in Chapter 1. The first set of recommendations is drawn based on the risk management maturity of investigated projects (Chapter 4). This set of recommendations aims to improve risk management application in projects. The second set of recommendations is based on the investigation of identified and occurred risks in the HWBP-2 projects (Chapter 5). The third set of the recommendations is based on the investigation of costs and cost contingency of the project (Chapters 6 and 7). Table 8-1 presents the list of recommendations used for the expert sessions. The practicability of the recommendations is tested in three sessions with the experts from the PD-HWBP and the waterboards. Before performing the expert sessions, a generic set of recommendations is evaluated in a session by practitioners from different organizations. This step was performed to check the clarity of the recommendations. This generic list of recommendations is provided in Appendix C.

Table 8-1 The list of the recommendation for the expert sessions

ID	Recommendations based on the results of maturity measurement (Chapter 4)	ID	Recommendations based on the investigation of the risk registers (Chapter 5)	ID	Recommendations based on the investigation of cost contingency of the projects (Chapters 6 and 7)
1	Apply RiskProve regularly in projects to improve risk management.	9	A standard risk register template to be used by all waterboards that makes sure that all projects are delivering similar and comparable data.	14	Report the actual cost at the end of the project so that the expenses are transparent.
2	Define the risk appetite of the project with your team.	10	A clear formulation of the risks, causes and consequences in order that the control measures can also be clearly defined.	15	Return to funding the projects based on the post-calculation.
3	Define the objective and the procedure of risk management in the project with your team.	11	Document the occurred risks (identified and not identified).	16	Reduce the ranges for the percentage of risk reservation per phase based on this research to increase the incentives for efficiency.
4	Make sure that public client is involved in risk management.	12	Document the cost of control measures and the actual cost of occurred risks.	17	Project risks with low probability and high consequences should be managed at program level.
5	Assign a risk manager or a risk advisor to (a group) projects.	13	Evaluate the control measures to see whether the control measures were really useful.	18	Work closely with market parties in the preparation phase to get a more realistic assessment of the risks.
6	Make an open and safe culture to share and discuss risks.			19	Include only the costs of the top 10 risks (after applying the control measures) to the cost estimate.
7	Evaluate risk management regularly to collect the lessons learned in the projects and find the improvement areas.			20	Regularly collect and use the data (for example risk register, financial documents) of the finished projects and share with the waterboards for better identification of the risks or estimation of the costs.
8	Share the experiences and lessons of risk management in and between the waterboards.				

The recommendations 2 through 7 in the column 'Recommendations based on the results of maturity measurement (Chapter 4)' in Table 8-1 are directly drawn from Chapter 4. Recommendation 1 is added to the list as the experts experienced applying RiskProve positive for improving risk management. Recommendation 8 is added to the list to encourage sharing the experiences of applying risk management and learning between the waterboards.

The recommendations in the column 'Recommendations based on the investigation of the risk registers (Chapter 5)' in Table 8-1 are drawn based on the observations and the investigations of the project risk registers. Each waterboard is using her risk register format which makes the comparison and learning difficult (rec_9). In some cases, identified risk had a wrong formulation; it was not clear what was the actual risk (rec_10). The occurred risks were usually not recorded (rec_11) and consequently the cost of the occurred risk (rec_12). It was not clear whether the control measures are applied and if they were useful (rec_13).

The recommendations in the column 'Recommendations based on the investigation of cost contingency of the projects (Chapters 6 and 7)' in Table 8-1 are based on the observations and investigations of the cost estimate documents of the projects. HWBP projects do not report the actual costs of the projects since the current regulation of HWBP is based on pre-calculation of the costs. With the current approach for financing, the actual costs were unknown (at least for PD-HWBP) and as a result, no evaluation of the costs can happen. Rec_ 14 and Rec_15 are to address these issues. The results in Chapter 7 showed that the HWBP-2 projects have reserved extra contingency. Rec_16 suggests to reduce the ranges of percentages of cost contingency (Table 1-1). The other suggestion was that risks with low probability and high consequence are financed at program level, to avoid extra reservation at project level (Rec_17). Rec_19 is given also in the same direction to avoid unnecessary extra cost contingency in projects. Rec_18 is drawn from Chapter 7 in which the result shows that the contractor's projects have estimated cost contingency lower than required (overoptimistic behaviour) while the HWBP-2 projects have estimated the cost contingency higher than required (overpessimistic behaviour). For a more successful project, more collaboration between client and contractor is recommended. Results of applying RiskProve revealed that the project can improve regarding collecting and using lessons learned of the risk management application. It was also observed that HWBP does not have any explicit process for collecting and sharing the lessons learned. Rec_20 is, therefore, drawn to increase the learning capabilities of HWBP projects.

8.2 Method

To validate the recommendations, it was important that while the experts discussed their opinions about the recommendations, they could be triggered by one another and build upon each other's viewpoints. In such situation, a focus group session is suitable. A focus group is a qualitative research approach in which attitudes, opinions or perceptions towards an issue are investigated by a group of experts (Langford & McDonagh, 2003). The purpose of conducting the expert sessions is:

To evaluate the feasibility and importance of the recommendations by experts from both the PD-HWBP and the waterboards and to understand the possible obstacles to apply the recommendations in practice.

To assure that the opinions of both the PD-HWBP and the waterboards are considered, the experts from both parties were included in the expert sessions. To ensure that the experts from both PD-HWBP and the waterboards have enough time to speak their minds, separate sessions were held with each party. In this way, any possible confrontation of the opinions between the experts from PD-HWBP and waterboards could be avoided. The experts from PD-HWBP relevant for the expert sessions have two types of roles: Operational and Strategic. The experts at the operational level are involved with risk management on daily basis. The experts at the strategic level have the strategic and directorate roles, use the inputs from risk management, and decide the objective and strategy of risk management. Therefore, separate sessions are organized with the experts at strategic and operational levels. To summarize, three separate expert sessions were organized with experts from three different groups:

1. Group 1 (WB) includes the experts from the waterboards who are directly involved in the projects. The experts in this group have the role of project controller (in Dutch: manager projectbeheersing).

2. Group 2 (PD-operational) includes the project controllers and risk managers who work at the PD-HWBP.

3. Group 3 (PD-strategic) are selected from the experts at a strategic level in the PD-HWBP who define the objectives of HWBP and have a directorate and strategic roles.

From these three groups, WB and PD-operational are substantively involved in risk management.

The experts were contacted via email. In the email, only the purpose of the session was mentioned, and no further information was provided. For WB, eight experts from different waterboards were invited; five experts showed up in the meeting. For PD-operational, six experts were invited; five experts participated in the session. For PD-strategic, seven experts were invited; six joined the session.

A list of 20 recommendations (Table 8-1) was printed and provided to the experts in a special format: columns were provided on the list for evaluation of the importance and feasibility of the recommendations. The experts were asked to evaluate the importance and feasibility of each recommendation choosing a score between 1, 2, 3, and 4. A scale of four was chosen so that no middle number could be chosen and that the experts were forced to make a decision as explained by Garland (1991) and Matell and Jacoby (1972). The definitions of the scores are given in Table 8-2.

Table 8-2 The definitions for the scores of importance and feasibility

Definition score of Importance	Definition score of Feasibility
1= Not important	1= Not feasible
2= Less important	2= Hardly feasible
3= Important	3= Mostly feasible
4= Very important	4= Totally feasible

The experts were also asked to write their reasons for choosing the score of Feasibility of a recommendation in a given column on the list. Importance scores were only used to prioritize the outcomes. Using the Importance scores, the recommendations that are important and feasible and the recommendations that are feasible but are less important could be distinguished.

Each session started with a presentation of the researcher. At the beginning of the presentation, the objective and goal of the session were sketched. After the presentation, the printed lists of the recommendations were distributed to the experts and the approach was explained. The experts were asked to evaluate the importance and feasibility of the recommendations individually. Next, they were asked to elaborate on the feasibility score per recommendation, on a specified column provided on the list of recommendations. After this step, each recommendation was plenary discussed. After each session, the filled forms were collected.

Each session took about one and half hour. In each session, next to the researcher, an assistant was present. During the sessions, both the researcher and the assistant took notes. The sessions with PD-operational and PD-strategic were also audio recorded. The filled forms, notes and audio recordings were used in the analysis of the results.

8.3 The results of the expert sessions

To analyse the results, the average scores of importance and feasibility for each recommendation in each expert session are calculated and compared. Based on the scores of importance and feasibility, four different situations are possible for each recommendation. These four situations are explained below and are presented in Table 8-3.

1. Less important and less feasible: no action from the waterboards or/and PD-HWBP is required to implement the recommendation.

2. Less important but feasible: the waterboards or/and PD-HWBP can assign a low priority for implementing the recommendation.

3. Important but less feasible: the waterboards or/and PD-HWBP should work on the practicability of the recommendation.

4. Important and feasible: the PD-HWBP or/and the waterboards should take immediate actions to apply the recommendation.

Table 8-3 Four possible situations for each recommendation

	Less feasible	**Feasible**
Less important	No action needed	Define the priority
Important	Work on the applicability	Take immediate action

Each recommendation is assigned to one of the four categories in Table 8-3. The category of the recommendations is decided in the first place based on the discussion and opinions of the experts during the sessions. The average scores of importance and feasibility are used as an indicator to decide the category of the recommendation. The average scores equal and less than two are considered as less important/feasible while the average scores greater than two are considered as important/feasible. Depending on the nature of the recommendations, they are assigned, as a responsibility to either the PD-HWBP or the waterboards or both the PD-HWBP and the waterboards.

8.3.1 Recommendations based on risk management maturity of the projects

Figure 8-1 presents the average scores of importance and feasibility in each expert session for the first set of the recommendations. Each recommendation is separately discussed.

ID	Recommendations based on risk management maturity of the projects	Score Importance WB (N=5, scale 4)	Score Importance PD-operational (N=6, scale 4)	Score Importance PD-strategic (N=6, scale 4)	Score Feasibility WB (N=5, scale 4)	Score Feasibility PD-operational (N=6, scale 4)	Score Feasibility PD-strategic (N=6, scale 4)
1	Apply RiskProve regularly in projects to improve risk management.	2.8	3.0	3.5	3.3	3.2	3.3
2	Define the risk appetite of the project with your team.	3.7	2.6	3.3	3.3	3.0	3.2
3	Define the objective and the procedure of risk management in the project with your team.	2.5	4.0	3.8	2.5	4.0	3.8
4	Make sure that the line management is involved in risk management.	2.8	2.8	3.2	2.8	3.0	3.3
5	Assigning a risk manager or a risk advisor to (a group) projects.	3.2	3.7	4.0	3.2	4.0	3.8
6	Make an open and safe culture to share and discuss the risk.	3.6	3.8	3.7	2.8	2.7	3.5
7	Evaluate risk management regularly to collect the lessons learned in the projects and find the improvement areas.	3.2	3.7	3.3	3.0	3.3	3.7
8	Share the experiences and lessons of risk management in and between the waterboards.	3.6	3.8	3.3	2.8	2.5	3.2

Figure 8-1 The average scores of importance and feasibility per group of experts for the first set of recommendations

1. Apply RiskProve regularly in projects to improve risk management.

The experts in all groups find this recommendation important and feasible (Figure 8-1). An expert in WB, which is familiar with RiskProve said: "[apply RiskProve] in each project phase." Likewise, another expert from WB mentioned: "apply [RiskProve] from HWBP [level] in waterboards [level]." One expert from PD-operational suggested that: "apply [RiskProve] once at the beginning of the project and once in later phases." Some experts from PD-strategic have left the scores of importance and feasibility blank, which means that they had no idea about the model.

This recommendation fits the category 'important and feasible'. To increase the learning purposes between the waterboards, the PD-HWBP can be made responsible to facilitate the application of RiskProve in waterboards. One person at the PD-HWBP can be responsible for periodic performing risk management maturity measurement at HWBP projects, identifying the possible improvement areas and reporting to both the PD-HWBP and the waterboards.

2. Define the risk appetite of the project with your team.

WB has given a higher score for importance and feasibility of this recommendation (Figure 8-1) than the other groups. A person in WB said: "I miss the role of the board of the waterboard [in this recommendation]." One expert in PD-operational mentioned: "… the risk appetite should be defined in organization level." Experts from PD-operational and PD-strategic gave also similar comments. Based on the comments, it is decided to change the recommendation, as the role of the board of a waterboard was not considered in the recommendation. This recommendation is changed to:

The board of the waterboard and the project team should define the risk appetite and translate the organization risk appetite to project risk appetite.

This recommendation fits the category 'important and feasible'. The board of each waterboard with the project team should define how much risk they want to take; which risks should be managed, and which risks should be accepted. Defining the risk appetite of the organization has a direct influence on the risk management approaches in projects (HM Treasury, 2004).

3. Define the objective and the procedure of risk management in the project with your team.

The experts in PD-operational and PD-strategic think that the recommendation is both important and feasible (Figure 8-1). One expert from WB mentioned: "it should be defined by the organization and should be applied by the projects." According to this expert, a project cannot define the objective itself, the objectives should be defined from a higher level. Another expert in WB has the same opinion. This comment was not mentioned by the experts from other groups suggesting that WB has a better understanding of the actual situation in the waterboards. Based on the comments, this recommendation is changed to:

The board of the waterboard and the project team should define the objectives and the procedures of risk management in the projects.

This recommendation fits the category 'important and feasible' and similar to rec_2, it is the responsibility of the board of waterboard and the project team to apply it.

4. Make sure that public client[9] is involved in risk management.

The experts in PD-strategic give a higher importance and feasibility to this recommendation (Figure 8-1) than the other groups. The experts in WB have different opinions about the importance and feasibility of this recommendation, which can be due the different situations in each waterboard. From PD-strategic, it was stated by an expert: "commitment, guidance, knowledge, and understanding from the public client is essential." An expert in the PD-operational mentioned: "informing the public client can perfectly be done but giving the public client an active role in risk management is difficult." An expert in WB said: "risk management is not just the responsibility of the IPM team and it is important that the board and the public client are involved." For some experts, it was not clear what is meant by 'is involved'. By 'being involved', it is not meant that the public client is per se physically present in the risk management sessions. It is meant, however, that the public client supports, shows interest and is committed to risk management. The literature on risk management emphasizes the importance of management support and involvement to success of risk management (Ehie & Madsen, 2005; Bannerman, 2008; De Bakker, Boonstra, & Wortmann, 2010).The recommendation is, therefore, adjusted to:

Make sure that public client is informed about risk management and shows commitment and interest.

This recommendation fits the category: 'important and feasible' and is seen as the responsibility of each waterboard.

8

5. Assign a risk manager or a risk advisor to (a group of) projects.

All three groups think that this recommendation is important and feasible (Figure 8-1). An expert in WB mentioned: "[it helps in] support and improvement of risk management."

This recommendation fits the category 'important and feasible'. Each waterboard should assign a risk manager or an adviser to a group of the projects.

6. Make an open and safe culture to share and discuss risks.

All three teams give a high score of importance to this recommendation, however, the feasibility has received a low score (Figure 8-1). An expert in PD-operational: "it is important but maybe not applicable.

9 In Dutch: Ambtelijke opdrachtgever

It needs culture change that we have little experience with it." Similarly, an expert in WB mentioned: "cultural aspects are usually obstinate."

Another expert in WB mentioned that the recommendation is ambiguous. This recommendation intends to create and increase an open culture to share risks with public client. The literature on risk management explains the importance of an open and safe culture to share the risks (Loosemore, Raftery, Reilly, & Higgon, 2006; Zou, 2010; Hopkinson, 2012). This recommendation is, therefore, adjusted into:

Make an open and safe culture to share and discuss risks with public client.

This recommendation fits in the category 'important but less feasible' because it needs more effort than simply improving risk management. This recommendation depends highly on applying rec_2, rec_3 and rec_4. Commitment and interest of the public client helps creating an open and safe culture to discuss risks with them.

7. Evaluate risk management regularly to collect lessons learned in projects and find improvement areas.

All three groups admit the importance and feasibility of this recommendation (Figure 8-1). An expert in WB indicated: "it is easily feasible, the issue of the day cause that it is applied limitedly." An expert in PD-strategic made a similar statement: "[evaluation] is the first thing that is removed from the tasks." Another expert from the same group stated that it should be performed per phase. An expert in PD-operational discussed that it is applicable, but it cannot be regularly since it takes too much time. Another expert from the same group suggested doing the evaluation once per half year.

This recommendation fits the category 'important and feasible' and it is the responsibility of each water board to apply it.

8. Share the experiences and lessons of risk management in and between the waterboards.

All three groups think that the recommendation is important but not feasible without obstacles (Figure 8-1). Two experts from PD-operational confirmed that sharing the experiences and lessons is important for the alliance between the PD-HWBP and the waterboards. They indicated that: "facilitation from the PD-HWBP is needed" and "time and priority are the challenges." The experts from WB mentioned: "it costs time, but it is a good idea" and another expert said: "the community of dike workers (In Dutch: 'Dijkwerkers') can be used here." Similar comments were given by the expert from the same group.

This recommendation fits the category "important and feasible". It is crucial that the PD-HWBP facilitates collecting and sharing the knowledge between the waterboards.

8.3.2 Recommendations based on the investigation of project risk registers

Figure 8-2 presents the average score of importance and feasibility for each group for the second set of recommendations.

ID	Recommendations based on the investigation of risk registers of the projects	Score Importance WB (N=5, scale 4)	Score Importance PD-operational (N=6, scale 4)	Score Importance PD-strategic (N=6, scale 4)	Score Feasibility WB (N=5, scale 4)	Score Feasibility PD-operational (N=6, scale 4)	Score Feasibility PD-strategic (N=6, scale 4)
9	A standard risk register template to be used by all waterboards that makes sure that all projects are delivering similar and comparable data.	2.0	3.3	3.3	2.8	2.8	3.0
10	A clear formulation of the risks, causes, and consequences. A correct formulation of the risks makes sure that the control measures are also clearly defined.	3.0	3.7	2.8	3.2	3.5	2.8
11	Document the occurred risks (identified and not identified).	3.2	3.5	3.8	3.0	3.5	3.5
12	Document the cost of control measures and the actual cost of occurred risks.	3.3	3.3	3.3	2.8	2.5	3.0
13	Evaluate the control measures to see whether the control measures were really useful.	3.0	2.7	3.0	2.2	2.5	3.2

Figure 8-2 The average scores of importance and feasibility per group of experts for the second set of recommendations

9. A standard risk register template to be used by all waterboards that makes sure that all projects are delivering similar and comparable data.

This recommendation received the lowest importance score by WB (the experts from the waterboards). PD-strategic considers this recommendation important but not easily applicable (Figure 8-2). Conflict of opinions about this recommendation were observed during the session with WB. Two experts who support this recommendation mentioned: [a standard risk register] can be easily made available." Other experts in the same group had opposite opinions. It was said: "waterboards are totally responsible for the project risks in HWBP and, therefore, waterboards should decide [to have a uniform risk register template or not]." Likewise, it was stated: "the goal is not to do comparable [methods] but to realize a project." Another expert said: "then each waterboard would say that their approach is the best and choosing one approach is almost impossible." It was, nevertheless, admitted that a shared risk register template could be very valuable.

The experts from PD-operational, who have to analyse the risk registers of the waterboard, consider this recommendation as important. An expert said: "the more parties involved, the more difficult it is to compare." But they realize that this is challenging at the same time: "each waterboard and assigned risk manager will follow her own preference." Two experts mentioned that agreements should be made from the perspective of the alliance between the PD-HWBP and the waterboards about a standard template. This was also mentioned by an expert in PD-strategic. Conscious about the possible resistance from the waterboards for a uniform risk register template, two experts from the PD-strategic mentioned: "we [the PD-HWBP and the waterboards] can create the uniform risk register together." Other experts confirmed this comment.

This recommendation fits to the category "important and feasible" and both the waterboards and the PD-HWBP are responsible for its implication.

10. A clear formulation of the risks, causes and consequences in order to clearly define the control measures.

The experts in all three groups give high importance to the recommendation, however, the experts from WB and PD-operational, who are actively involved in risk management, give higher scores of importance and feasibility to this recommendation (Figure 8-2). Two experts from PD-operational mentioned: "it is important and feasible. Nobody can be against it."

The recommendation fits the category of 'important and feasible' and it is the responsibility of each waterboard.

11. Document the occurred risks (identified and not identified).

The experts in all the three groups consider the recommendation important and feasible (Figure 8-2). Two experts in WB mentioned that they document the occurred risks in their projects. As mentioned by an expert in PD-operational: "it is important for learning. Make an overview of the occurred risks and discuss it at the end." Most experts in PD-strategic have mentioned that this is very essential.

This recommendation fits the category 'important and feasible' and is the responsibility of each waterboard.

12. Document the cost of control measures and the actual cost of occurred risks.

The experts agree about the importance of the recommendation but the feasibility of the recommendation seems challenging (Figure 8-2). An expert in WB mentioned: "it is very difficult in practice." Similar statements are given by the experts in PD-operational: "it is difficult to estimate the cost of the control measures." The experts in PD-strategic expressed different opinions: one thinks it is applicable while the other thinks that is challenging. One expert in PD-strategic mentioned: "the cost of the occurred risks is important and I can understand that they should be collected but the costs of the control measures cannot easily be distinguished and collected."

The purpose of this recommendation is to document the costs of occurred risks and the cost of the control measures. According to the experts, it is possible to document the costs of the occurred risk but documenting the costs of the control measures is challenging.

With this recommendation, it is not meant to estimate and document the expenses for the delays as such (like the extra cost for the rented equipment because of a delay due to not timely receiving the permissions). The author can imagine that estimating the costs of the control measures of the risks that have consequences on time could be difficult. According to the SSK method (CROW, 2010), the costs of the control measures should be added to project costs. In the preparation phase, the approximate costs of control measures could be, with a bit of effort, documented. For example, if there is a risk about an explosive in the underground and the control measure is to perform research about the underground situation, the costs of the research can be easily recorded. It is, therefore, expected that the cost of control measures in the preparation phase, at least for the control measures such as the aforementioned example, are recorded.

This recommendation is, therefore, split in to two recommendations:

12a. Document the actual cost of occurred risks.

12b. Document the cost of control measures.

Recommendation 12a fits the category 'important and feasible'. The recommendation 12b goes deeper, than other recommendations, into the risk management work methods and needs more effort to be applied, compared to the other recommendations. Therefore, this recommendation fits the category 'important, but less feasible'.

13. Evaluate the control measures to see whether they were useful.

The experts in PD-strategic (Figure 8-2) have given relatively higher scores of importance and feasibility to this recommendation comparing to the scores of WB and PD-operational. It was mentioned by an expert in WB that the project team is assigned immediately to another project and there is no time for evaluation. Two experts in WB mentioned that it is important to evaluate the control measures, though. An expert said: "if a risk occurs then either the project has not done his job correctly or a wrong control measure was selected." The experts in WB and PD-operational expressed doubts about the feasibility of the recommendation in practice. An expert in PD-operational mentioned: "except the standard risks, the impact of the control measures on the risks can hardly be estimated." Some experts in PD-operational mentioned that the recommendation is feasible, but they do not think that it contributes that much to improving risk management.

PD-strategic was more positive about the feasibility of this recommendation. It was said that we can learn from the control measures for the other project and another said the evaluation can be done by the supervisor team. Some experts in PD-strategic mentioned that this recommendation goes too much in details.

Based on the comments, the author thinks that evaluating the control measures for all risks would not be feasible in practice. Especially because if a risk has not occurred, it would be difficult to distinguish whether it was because of the taken control measure or other factors. Additionally, the control measure for some risks could be different per phase. Based on these arguments and the comments from the experts, this recommendation fits the category "less important and less feasible".

8.3.3 Recommendations based on the investigation of costs of the projects

The third set of recommendations and the average scores of importance and feasibility per group are presented in Figure 8-3.

ID	Recommendations based on the investigation of costs of the projects	Score Importance WB (N=5, scale 4)	Score Importance PD-operational (N=6, scale 4)	Score Importance PD-strategic (N=6, scale 4)	Score Feasibility WB (N=5, scale 4)	Score Feasibility PD-operational (N=6, scale 4)	Score Feasibility PD-strategic (N=6, scale 4)
14	Report the actual cost at the end of the project so that the expenses are transparent.	2.4	3.8	4.0	2.6	3.4	3.5
15	Return to funding the projects based on the post-calculation.	1.5	3.5	3.0	2.0	3.0	2.3
16	Reduce the ranges for the percentage of risk reservation per phase based on this research to increase the incentives for efficiency.	2.0	2.2	2.8	2.4	3.2	2.3
17	Project risks with low probability and great consequences should be managed at program level.	3.0	3.0	3.6	1.8	2.3	2.3
18	Work closely with market parties in the preparation phase to get a more realistic assessment of the risks.	2.0	3.2	3.0	2.0	2.3	2.7
19	Only include the costs of the top 10 risks (after applying the control measures) to the cost estimate.	2.3	2.2	2.0	2.3	3.2	3.0
20	Regularly collect and use the data (for example risk register, financial documents) of the finished projects and share with the waterboards for better identification of the risks or estimation of the costs.	3.0	3.3	3.4	2.8	3.0	3.6

Figure 8-3 The average scores of importance and feasibility per group of experts for the third set of recommendations

14. Report the actual cost at the end of the project so that the expenses are transparent.

This recommendation shows a high difference in the scores between the experts in WB and the other groups regarding the importance and feasibility (Figure 8-3). An expert WB said: "it is easily applicable but there are [currently] arrangements in the regulation [of HWBP] that say the waterboards do not need to report the actual costs." Another expert in the same group who did not agree with this recommendation said: "the project team has no interest to evaluate the project because the project is finished … the objective of HWBP is [to realize a project] 'sober and adequate' (in Dutch: 'sober en doelmatig'). So, the waterboards do not need to do it [evaluation] because it is not the objective of HWBP." One expert in WB, who supported the recommendation, said: "I do not know why some waterboards do not like to share…we should learn from each other and this is one way." Another expert in WB, who did not agree with the recommendation, emphasized on the autonomy of the waterboards on choosing how the risk management should be done: "... The PD-HWBP wants more insight in the risk documents of the waterboards but I am wondering where is the responsibility of the waterboards about their own risk documentations, as organizations with autonomy, and how do you want to make a collective decision from the perspective of the alliance?"

An expert in PD-operational, who was positive about the recommendation, said: "you need to change the regulation of HWBP for this recommendation … with the current regulation we have no insight in the costs." And another expert in PD-operational said: "it is not easily feasible because it does not fit in the work method of the projects and conflict of interest can hinder applying this recommendation."

It was mentioned by the experts in PD-strategic that the recommendation is important from the transparency principle and from the perspective of the alliance between the waterboards and the PD-HWBP. Another expert said: "transparency is important, and it does not mean that it will have consequences. It just belongs to the PDCA (Plan-Do-Check-Act) process."

The author thinks that this recommendation is one of the most important recommendations of this research. If actual costs are not recorded, no evaluation of the projects in the future will be possible. It is, therefore, important that the actual costs of the projects are recorded at the end of each phase and after the project realization.

This recommendation fits the category 'important and feasible', despite the resistance expressed by some experts. The PD-HWBP and the waterboards should discuss this subject from the alliance perspective. Modifications in the current regulation of HWBP are required, if this recommendation is to be applied.

15. Return to funding the projects based on post-calculation.

Differences in the opinions of the experts in the three groups could be observed in this recommendation as well (Figure 8-3). One expert in WB said: "it is still soon to decide whether the pre-calculation (lump sum) method is not working. The PD-HWBP should facilitate by collecting data, and after some years evaluate the current system. Then it can be said whether we should go back to the post-calculation (reimbursable) method." It was also mentioned that: "Pre-calculation method is a good incentive for the projects to do risk management … the other projects in the waterboards learn from HWBP projects … if we go back to the post-calculation method nobody does risk management and it has negative impacts on category 1 and 2 of the recommendations."

The experts in PD-operational think that it should happen: "it will happen … I would give a score of 10 if I could." The experts mentioned that the projects want to identify many risks to get a higher budget in the current situation of pre-calculation. It was also mentioned that the regulation of HWBP should be modified to apply this recommendation.

One expert in PD-strategic, who gave a low score for the importance and applicability of the recommendation, said: "pre-calculation was a conscious choice based on the recommendations of Taskforce Ten Heuvelhof." It was said that the pre-calculation method was decided to give the projects an incentive for better risk management but, at the same time, it has become a reason for the projects to reserve more money than what they actually might need. From the scores and the observations, it could be seen that the opinions of the experts in PD-strategic are closer to the opinion of the experts in WB about this recommendation. It suggests that PD-HWBP is aware of the waterboards' interests.

The project expenses should be transparent and traceable. This can be achieved by either fulfilling rec_14 or rec_15. The author believes that if rec_14 is applied, rec_15 is less needed. Rec_15 is, therefore, assigned to the category "less important but feasible".

16. Reduce the ranges for the percentage of risk reservation per phase.

The experts have diverse opinions about the importance and feasibility of this recommendation (Figure 8-3). According to an expert in WB: "The defined ranges are not used anymore. Each project decides which range should be used and the ranges [in the regulation] are no longer consulted in the projects."

A person in PD-operational said: "you should only use the range for cost contingency to examine the estimates during the review and test process. If you mention all the ranges for risk reservation, the projects know how much they can get". The expert meant that the projects can negatively use the ranges for cost contingency and apply for the maximum percentage. Another expert in PD-operational said: "I am wondering if it (reducing the ranges) has any effect." One expert in PD-strategic has mentioned: "the range is useful when there is a discussion between the project and PD-HWBP about the amount of cost contingency." It was stated by an expert in PD-strategic: "it is firstly important that we [the PD-HWBP and the waterboards] decide clearly about bearing the responsibilities, the risks and risk reservation, then you can talk about the ranges for risk reservation." Another said: "the ranges of risk reservation should not be the point of discussion; other things should be discussed first."

The ranges in the regulation of HWBP give the percentages of cost contingency per phase based on the budget of the whole project (see Table 1-1 in Chapter 1). In practice, the projects must calculate the cost contingency per phase (before the start of that phase) based on the budget of that phase. Therefore, it seems that the current ranges have no use in practice and can be removed from the regulation of HWBP. This recommendation fits, therefore, to the category "less important but feasible". If the ranges must remain in the regulation of HWBP, they should be adjusted for the estimated risk reservation per phase.

17. Project risks with low probability and high consequences should be managed at program level.

All three groups admit the importance of this recommendation, but they doubt whether it is easily feasible (Figure 8-3). The word 'managed' was ambiguous for the experts in WB. The experts suggested that 'managed' should be replaced with 'financed' as the PD-HWBP cannot manage the projects' risks. An expert said: "only a waterboard can take and apply the control measures but financial consequences can be collective." Another said: "who decides then which risks have a low probability but high consequence?" There was also an expert who thinks the recommendation is very important and easily applicable: "good to show solidarity in this together."

An expert in PD-operational said: "it is a good recommendation, but the regulation should be changed." Another was against this recommendation and said: "I do not think it is important … it is dependent on the quality of the risk registers. It can be a way for the waterboards to shift the risks to the program level." Not everyone agrees with this statement though. It was an agreement about this recommendation between the experts in PD-strategic. It was mentioned by an expert in PD-strategic: "it can be a possibility to reduce the estimated costs of the projects." Another expert stated: "yes, it is logical. Then it should be a reserve at program level, and it should be very clear what will/will not be financed." The author asked: how is 'small' defined and how do you want to make sure that it does not become a reason to shift the risks towards the PD-HWBP. One expert answered: "it is about the risks that the waterboards cannot manage. Risks such as changes in the laws or something that is very expensive for a project. Thus unforeseen-unforeseen." An expert said that you should define clearly what falls under this type of risks.

To solve the ambiguity mentioned by WB, the recommendation is changed to:

Project risks with low probability and high consequences should be financed at program level.

This recommendation fits the category 'important and feasible'. A team from both the PD-HWBP and the waterboards should define the risks that fall in this category. This can be later added in the regulation of HWBP. Applying the recommendation is the responsibility of PD-HWBP.

18. Work closely with market parties in the preparation phase to get a more realistic assessment of the risks.

There were some ambiguities regarding the word 'market parties' in WB. It was explained by the researcher that with 'market parties' is meant 'contractor' in this recommendation. The experts in WB, who are in contact with the contractors, did not perceive the recommendation high regarding the importance and feasibility. Some experts in WB said that the contractors do not have much to add in the preparation phases.

Experts in PD-operational have different ideas. Some think that involving the contractor in the preparation phase has not much added value and some think that they can have added value about the risks in the execution phase. Three experts in PD-strategic have not given any score, meaning that they have no opinion about it. One expert in PD-strategic said: "it is not important and not applicable because it is related to the revenue model of the contractor." Another said: "it is essential for the realization phase … this is actually part of carefully preparing the project." The argument of this expert changed the opinions of the other experts. One said: "if I listen now, I think it is feasible. I had before [this argument] doubts about it." Another completed: "this is challenging because you have to decide to what extent you will involve a party and how? But it is good to join the strengths and to see what the risks are and who can better manage them."

The recommendation is changed to:

Work closely with the contractor in the preparation phase to get a more realistic assessment of the risks in the execution phase.

This recommendation goes beyond the arrangements between the waterboards and the PD-HWBP, and it requires arrangements with the other parties as well. Results from Chapter 7 show that more collaboration between the client and contractor in the front-end could increase the accuracy of the cost estimates for both parties.

However, applying this recommendation needs investigating the cooperation between public and private parties, beyond risk management. Compared to other recommendations, this recommendation has less priority for improving risk management and, therefore, it is assigned to the category "less important but feasible". It is, however, considered a recommendation for future research (see Chapter 9).

19. Include only the costs of the top 10 risks (after applying the control measures) to the cost estimate.

All three groups think that this recommendation is not so important. The experts in PD-operational and PD-strategic have given a higher score of feasibility than the experts in WB (Figure 8-3). One expert in PD-strategic, who supported the recommendation said: "it helps to create focus because you cannot manage a lot of risks." Another expert in PD-strategic said: "the effect is not measurable and it will cause that the top 10 risks are estimated bigger." An expert in PD-operational indicated: "the top 10 risks are not necessarily the top risks with effect on cost." This was a true comment. If the top 10 risks have an impact only on time, based on this recommendation, no risk reservation for the known unknowns should be included in the cost estimates. Based on the comment, the recommendation is improved by changing it to:

Focus on top 10 risks and take only the top 10 risks with effect on cost in the cost estimate.

Based on the author's observations, some projects take all the identified risks in their cost estimate. The purpose of this recommendation was to prevent the projects from having a reserve for all their risks. Based on the comments, it is understood that in practice focusing on just the top 10 risks might not always be possible. It is important, though, that projects understand that not all the risks should be managed, and some risks can be accepted. If the risk appetite (rec_3) of the projects is defined, this recommendation will be less needed. Based on these arguments, this recommendation is included in rec_3 and is not considered as a separate recommendation.

20. Regularly collect and use the data (for example risk register, financial documents) of finished projects and share amongst waterboards for better identification of the risks or estimation of the costs.

All three groups think that the recommendation is important, but each group has different opinions about the feasibility of the recommendation. One expert in PD-operational mentioned: "if we would like to do this, then we need a team of five people that works full time on collecting the information from 21 waterboards. The results could be very valuable though." Another expert thinks the recommendation is feasible and PD-HWBP and waterboards should jointly apply the recommendation.

This recommendation fits the category 'important and feasible'. The PD-HWBP should ensure that this recommendation is applied. Rec_9, rec_11 and rec_14 are, however, the prerequisites of this recommendation meaning that without the collaboration of the waterboards, this recommendation will not be feasible.

8.4 Discussion

In the previous section, each recommendation is assigned to a category based on the feasibility and importance. Table 8-4 provides an overview of the recommendation in each category. Most of the recommendations fall in the category 'important and feasible'.

Table 8-5 provides a summary of the important recommendations.

Table 8-4 An overview of the recommendations in each category

	Less feasible	Feasible
Less important	13	15, 16, 18, 19
Important	6, 12b	1, 2, 3, 4, 5, 7, 8, 9, 10, 11, 12a 14, 17, 20

Table 8-5 A summarized version of the important recommendations

Recommendation
Rec_1. Regular application of RiskProve
Rec_2. Define risk appetite of project
Rec_3. Define the risk management objectives
Rec_4. Involve public client in risk management
Rec_5. Assign a risk manager to (group of) projects
Rec_6. Create an open and safe culture to share risks
Rec_7. Evaluate risk management and collect lessons learned
Rec_8. Collect and share the experiences of applying risk management
Rec_9. Use a standard risk register for all the waterboards
Rec_10. Increase the quality of risk registers
Rec_11. Document the occurred risks
Rec_12a. Document the costs of occurred risks
Rec_12b. Document the costs of control measures
Rec_14. Collect and report the estimated and realized cost
Rec_17. Finance the low probability and high consequence risks by the PD-HWBP
Rec_20. Collect and use the data to improve risk identification and costs estimation

During the sessions it was observed that the waterboards and the PD-HWBP share ideas about risk management. The PD-HWBP and the waterboards agree that risk management practices can still be improved in the projects. It seems, however, that the waterboards have some resistance against the recommendations that might question their autonomy or anyone-side decision-making that would influence their working approaches. This was concluded based on the discussions about, for example, rec_ 9 or rec_14.

From the comments by PD-strategic, it was concluded that the PD-HWBP is aware of these possible different opinions. As mentioned by some participants in PD-strategic, agreements and arrangements should be made between the PD-HWBP and the waterboards regarding risk management approaches of the project. Reaching a common ground and having a common understanding about risk management approaches is the first step to apply the recommendations and improve risk management in projects.

First, objectives need to be defined by both parties about why and what changes in risk management approaches of HWBP projects are required. The objectives can be, for example, availability of data from HWBP project for evaluation of the program or accessibility of data for cross-project analysis for learning purposes. When such objectives are clear for both the PD-HWBP and the waterboards, it can be decided whether implementing a recommendation contributes to the desired results. The concerns of both parties should be explicitly discussed and both parties should make concessions for better collaboration and "best for program". Second, based on the defined objective, the approaches for risk management in HWBP and the role and responsibilities of each party in risk management should be defined. These roles and responsibilities might fall under the current responsibilities of each party or might introduce new responsibilities for each party. This leads to a general recommendation that precedes the other recommendations:

The PD-HWBP and the waterboards should make arrangements about the objectives and the role and responsibilities of each party towards risk management approaches of HWBP.

One outcome of this arrangement is an improved regulation for HWBP, which reflects the objectives and responsibility of each party regarding, for example, sharing the data, and managing 'low probability and high consequences' risks. The current regulation, as mentioned by several experts, hinders the potential application of some recommendations. The improvements should facilitate the application of the recommendations.

Another outcome of the arrangement between the waterboards and the PD-HWBP should be a standard risk register template (rec_9) for the projects. To respect the autonomy of the waterboards and to create more solidarity, both parties should collaborate to develop this. A committee from both parties, for example, can be responsible for this task. A standard risk register format also contributes to more efficient data collection and evaluation of risk management in projects (rec_20).

The improved regulation should address, among other things, two concerns. First, the responsibility of the waterboards to document and report the realized costs for the evaluation and learning purposes to the PD-HWBP (rec_14). For the learning incentives of the waterboards and since the pre-calculation system is recommended based on the Taskforce Ten Heuvelhof, the PD-HWBP should still examine the usefulness of the pre-calculation method. The prerequisite is, however, that the rec_14 is applied. Based on the information collected after applying rec_14, the PD-HWBP and the waterboards should evaluate whether the pre-calculation system was successful and whether going back to the post-calculation system (reimbursable) is required. The information collected here should be analysed and shared by the PD-HWBP with the waterboards (rec_20) to improve the risk identification and cost estimation practices of the project in HWBP. Second, it should mention that the project risks with low probability and high consequences are the responsibility of the PD-HWBP (rec_17). A clear definition of the risks that fall in this category should be given in the improved regulation of HWBP to avoid any unnecessary discussions.

Based on the arrangement between the waterboards and the PD-HWBP, the risk management objectives (rec_3) and the amount of risk appetite of the projects (rec_2) should be defined by the board of each waterboard and each project team. These recommendations could be included as a new or updated policy of risk management for each waterboard. Implementing rec_2 and rec_3 will assure that the objectives defined on a higher level between the waterboards and the PD-HWBP are translated to the project level. The new policy is proposed to the projects in each waterboard through public client (rec_ 4). This will make sure the board and public client are involved in risk management, and that the arrangements made at the higher level are fulfilled at the project level.

Assigning a risk manager(s) to a group of projects (rec_5) (for example in the department of HWBP in each waterboard) can ensure professional implementation of risk management. This way, the quality of risk registers can be improved (rec_10), occurred risks can be documented (rec_11), the risk management process is evaluated (rec_7) and the costs of the occurred risks are documented (rec_12). Having a risk manager does not mean that risk management implementation is only the responsibility of the risk manager. The project team is responsible for risk management as well. Training and a stricter review and test process from the PD-HWBP could possibly contribute to improving the quality of the risk registers (rec_10). Assigning a risk manager to the projects of the waterboards also shows the commitment of the board and the public client towards risk management. This would also contribute to some extent to a more open and safe culture to share the risks with the higher levels of the organization (rec_6). When the project team realizes that the higher level of the organization is committed to risk management, they would probably feel more comfortable communicating the risks with them.

The maturity of risk management can be measured by RiskProve and the improvement areas can be identified (rec_1). Applying RiskProve provides a check on the application of risk management and contributes to improving the quality of risk management in projects (thus rec_2, rec_3, rec_4, rec_5, rec_6, rec_7, rec_10, rec_11 and rec_12). To facilitate comparing projects and increase the learning abilities from projects, the PD-HWBP should be responsible for the measurement of risk management maturity. It is important that the application of rec_1 is facilitated by, for example, including it in the improved regulation of HWBP. The PD-HWBP should collect and share the lessons learned of risk management (rec_8). Applying rec_1 by the PD-HWBP contributes to collect and share the lessons learned of risk management between the waterboards (rec_8). The PD-HWBP should be responsible to collect, analyse and share the information such as identified and occurred risks and the estimated and realized risk reservation per phase (rec_20). For both rec_8 and rec_20, a person or a small group can be responsible to collect the data from different projects and make sure that it is shared between the waterboards. Part of this recommendation is already applied through communities such as 'Dijkwerkersdag' (a community of the experts working from different organizations in water projects). However, a more structured community focused specifically on risk management is recommended to be established by the waterboards.

The database made in this research (Chapter 4) should be kept updated by new information collected from HWBP projects. The information about the estimated and realized risk reservation of the project should be recorded and reported to the PD-HWBP (rec_14) and should be shared with the waterboard (rec_20). This information should be used and consulted to improve risk identification and cost estimation. Without applying rec_9, rec_11 and rec_14, application of rec _20 would not be possible. The Risk Management Map (RM-Map) to improve risk management practices in HWBP projects is presented in Figure 8-4. Only the important recommendations (Table 8-4) are included in this figure, the less important ones are neglected.

The steps to improve risk management should be taken by both the PD-HWBP and the waterboards, while each party has its own responsibilities. The Risk Management Map (RM-Map) contains five milestones:

1. Defining the strategy of RM by the PD-HWBP and the waterboards
2. Creating the conditions to apply recommendations
3. Translating the defined strategy to objectives at waterboards and showing commitment
4. Improving the RM application in projects
5. Support, facilitate, and share the knowledge

From these five milestones, milestones one and two are the responsibility of both the waterboards and the PD-HWBP, milestones three and four are the responsibility of the waterboards, and milestone five is the responsibility of the PD-HWBP. The infinity form of the RM-Map emphasises the continuous process of evaluating and improving.

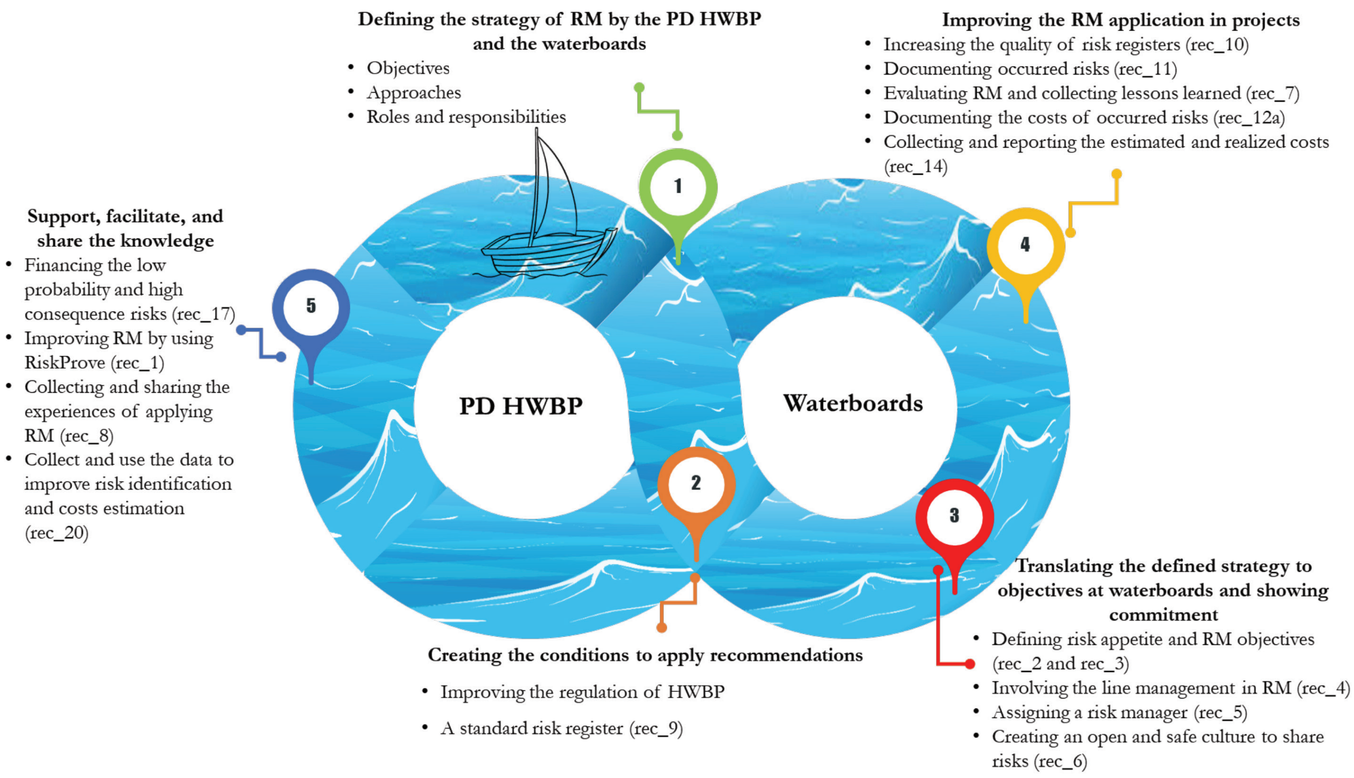

Figure 8-4 The RM-Map to improve risk management practices in HWBP projects

8.5 Conclusion

In this chapter, the recommendations to improve risk management in the HWBP projects, drawn upon the results of the previous chapters, are presented and evaluated by the experts from both the PD-HWBP and the waterboards. The purpose was to understand how the experts perceive the importance and the feasibility of the recommendations and to find out the possible obstacles that might hinder the application of the recommendations. Based on the results of the expert sessions, most of the recommendations are perceived as important and feasible. The experts do agree on the importance of general recommendations such as rec_10. However, it seems that there is some resistance regarding the recommendations that ask for more standardization from the waterboards (e.g. rec_9 and rec_14). It is, therefore, important that the waterboards and the PD-HWBP have the same understanding about why applying these recommendations is important. The parties should define together the objectives, approaches and their roles and responsibilities toward risk management. This is the first essential step in the application of the recommendations and improving risk management in HWBP projects. The second step is modifying the current regulation of the HWBP. The current regulation does not allow, for example, to share the realized costs with the PD-HWBP (rec_14) or that risks with low probability and high consequence are financed by the PD-HWBP. Taking these steps, the application of the recommendations from this research (Figure 8-4), would be facilitated. Evaluation is needed to check whether the planned actions are actually applied and whether risk management practices of HWBP are on the right track.

8.6 Appendix C

Before performing the expert sessions, part of the recommendations (Table 8-6) are evaluated by a generic group of experts familiar with risk management. The purpose of this step was to understand how the experts in the field perceived the recommendations. Also, the clarity and understandability of the recommendations could be checked. The initial list of the recommendations and the corresponding chapters are presented in Table 8-6.

Table 8-6 The main list of the recommendations

ID	Recommendations based on the results of maturity measurement (Chapter 4)	ID	Recommendations based on the investigation of the risk registers (Chapter 5)	**ID**	**Recommendations based on the investigation of cost contingency of the projects (Capter 6 and Chapter 7)**
1	Apply RiskProve regularly in projects to improve risk management.	9	A standard risk register template to be used by all waterboards that makes sure that all projects are delivering similar and comparable data.	15	Report the actual cost at the end of the project so that the expenses are transparent.
2	Define the risk appetite of the project with your team.	10	A clear formulation of the risks, causes and consequences in order that the control measures can also be clearly defined.	16	Return to funding the projects based on the post-calculation.
3	Define the objective and the procedure of risk management in the project with your team.	11	Document the occurred risks (identified and not identified).	17	Reduce the ranges for the percentage of risk reservation per phase based on this research to increase the incentives for efficiency.
4	Make sure that public client is involved in risk management.	12	Document the cost of control measures and the actual cost of occurred risks.	18	Project risks with low probability and high consequences should be managed at program level.
5	Assigning a risk manager or a risk advisor to (a group) projects.	13	Evaluate the control measures to see whether the control measures were really useful.	19	Work closely with market parties in the preparation phase to get a more realistic assessment of the risks.
6	Make an open and safe culture to share and discuss the risk.	14	Do not make a long list of the risks but focus on managing the top risks.	20	Regularly collect and use the data (for example risk register, financial documents) of the finished projects and share with the waterboards for better identification of the risks or estimation of the costs.
7	Evaluate risk management regularly to collect the lessons learned in the projects and find the improvement areas.				
8	Share the experiences and lessons of risk management in and between the waterboards.				

Some of the recommendations in Table 8-6 are generalized in order to make them applicable beyond HWBP projects. For example, Rec_15 in Table 8-6 is divided to two recommendations of 12 and 15 in Table 8-7. In addition, rec _9, rec _16, rec _17 and rec _18 that are specific to HWBP projects are removed. The list of recommendations (for the evaluation session) and the relation between modified and the main recommendations are presented in Table 8-7. Similar to Table 8-6, the recommendations are structured based on the three phases of the research.

Table 8-7 The generic list of recommendations for evaluation by experts

Recommendations based on the results of chapter 2	**Corresponding with the recommendation in Table 8-6**
1. Make sure that public client is involved in risk management.	4
2. Assign a risk manager or a risk advisor to (a group) projects.	5
3. Make an open and safe culture to share and discuss risks.	6
4. Define the risk appetite of the project with your team.	2
5. Define the objective and the procedure of risk management in the project with your team.	3
6. Collect and share the lessons of risk management.	7* and 8*
Recommendations based on the results of chapter 4	**Corresponding with the recommendation in Table 8-6**
7. A clear formulation of the risks, causes and consequences in order that the control measures can also be clearly defined.	10
8. Do not make a long list of the risks but focus on managing the top risks.	14
9. Document the occurred risks (identified and not identified).	11
10. Document the cost of control measures and the actual cost of occurred risks.	12
11. Evaluate the control measures to see whether the control measures were really useful.	13
Recommendations based on the results of chapters 5 and 6	**Corresponding with the recommendation in Table 8-6**
12. Evaluate the estimated and actual costs at the end of project (phase).	15*
13. Collect and use the realized and estimated costs of the finished projects to estimate the costs of the new projects.	20*
14. Work closely with market parties in the preparation phase to get a more realistic assessment of the risks.	19
15. Make the use of risk reservation transparent.	15*

8

8.6.1 The setup of the evaluation session

The recommendations are evaluated during the Dijkwerkersdag of 2019. The author had the chance to give a workshop about the results of this doctorate research. The participants in the workshop were from both contractor and client organizations. Some of the participants are/were involved in HWBP projects while some were new to HWBP and its working method.

The whole session took about three quarters. First, a 15 minutes presentation was given about the results of this research and subsequently, the recommendations were shown. At the beginning of the presentation, the agenda and the objective of the workshop was explicitly stressed. The evaluation of the recommendations was performed using Mentimeter which is an online voting platform. Using their cell phones and a specific code, the participants could have accessed the recommendations. The participants were asked to evaluate the importance of each recommendation in their projects based on a scale of four where 1 is less important and 4 is important. A scale of four was intentionally chosen so that the participant could not choose the middle score. After the evaluation of each set of recommendations, there was a plenary discussion about the recommendation with the lowest score.

8.6.2 The results of the evaluation session

Table 8-8 presents the score of importance for the first group of recommendations. It also shows which scores are mostly selected by the experts. In total, 37 individuals have participated in this evaluation. Most of the participants perceive the recommendations important for their projects and there was no comment about the clarity of the recommendations. Rec_3 has received the highest score and rec_1 and rec_4 have received the lowest score. Regarding rec_1, it was said that public client is not really involved in risk management in some organization and it is also difficult to make public client involved. For rec_6, it was mentioned that collecting and sharing lessons learned is important for the next projects, but it is less important for the current project. It was also mentioned that there is less time for evaluation of projects afterwards. This group of recommendations is used in the expert sessions.

Table 8-8 Results of the Mentimeter for the first set of the recommendations

Recommendation	**Average**	**Scores where 1 is less important and 4 is important**			
		1	**2**	**3**	**4**
1. Make sure that public client is involved in risk management.	3.2	1	6	14	16
2. Assign a risk manager or a risk advisor to (a group) projects.	3.5	1	1	14	21
3. Make an open and safe culture to share and discuss risks.	3.7	1	0	7	29
4. Define the risk appetite of the project with your team.	3.2	2	7	10	18
5. Define the objective and the procedure of risk management in the project with your team.	3.4	1	4	12	20
6. Collect and share the lessons of risk management.	3.5	2	2	10	23

The results of the evaluation of the second group of recommendations are presented in Table 8-9. A number of 34 individuals have participated in this voting. Again, most of the participants have perceived the recommendation important for their projects. Rec_8 has received the lowest score. The experts said that the quantification of the risk changes from time to time and focusing just on the top risk loses the focus on the other risks. It was also mentioned that the number of identified risks is not important and even identifying more risks gives more certainty. It was, furthermore, discussed that not all the identified risks should be used in the estimation of the risk reservation. Based on these comments, the recommendation is changed to:

Include only the costs of the top 10 risks (after applying the control measures) to the cost estimate.

Since this modified recommendation is about the cost estimate now, it is assigned to the third category of the recommendations (Table 8-1). Except for rec_8, there was no comment for the rest of the recommendations, and they are used in the expert sessions.

Table 8-9 Results of the Mentimeter for the second set of the recommendations

Recommendation	Average	Scores where 1 is less important and 4 is important			
		1	**2**	**3**	**4**
7. A clear formulation of the risks, causes and consequences in order that the control measures can also be clearly defined.	3.6	0	3	8	23
8. Do not make a long list of the risks but focus on managing the top risks.	2.9	5	5	11	13
9. Document the occurred risks (identified and not identified).	3.4	1	6	7	20
10. Document the cost of control measures and the actual cost of occurred risks.	3.4	0	5	10	19
11. Evaluate the control measures to see whether the control measures were really useful.	3.4	0	5	11	18

The results of evaluation of the final set of the recommendations are presented in Table 8-10. Most of the 30 participants in this set of voting consider the recommendation important. Rec_14 has received the lowest score. It was said that the client is reluctant to consult with a contractor. There were no other comments about the recommendations. These recommendations are also further used in the expert sessions.

Table 8-10 Results of the Mentimeter for the third set of the recommendations

Recommendation ID	Average	Score where 1 is less important and 4 is important			
		1	2	3	4
12. Evaluate the estimated and actual costs at the end of project (phase).	3.6	1	1	6	22
13. Collect and use the realized and estimated costs of the finished projects to estimate the costs of the new projects.	3.1	5	1	11	13
14. Work closely with market parties in the preparation phase to get a more realistic assessment of the risks.	3.0	3	7	8	12
15. Make the use of risk reservation transparent.	3.4	1	2	12	15

The final list of the recommendations for the expert sessions are provided in Table 8-1. Rec_14 in Table 8-6 is replace with rec_19 in Table 8-1.

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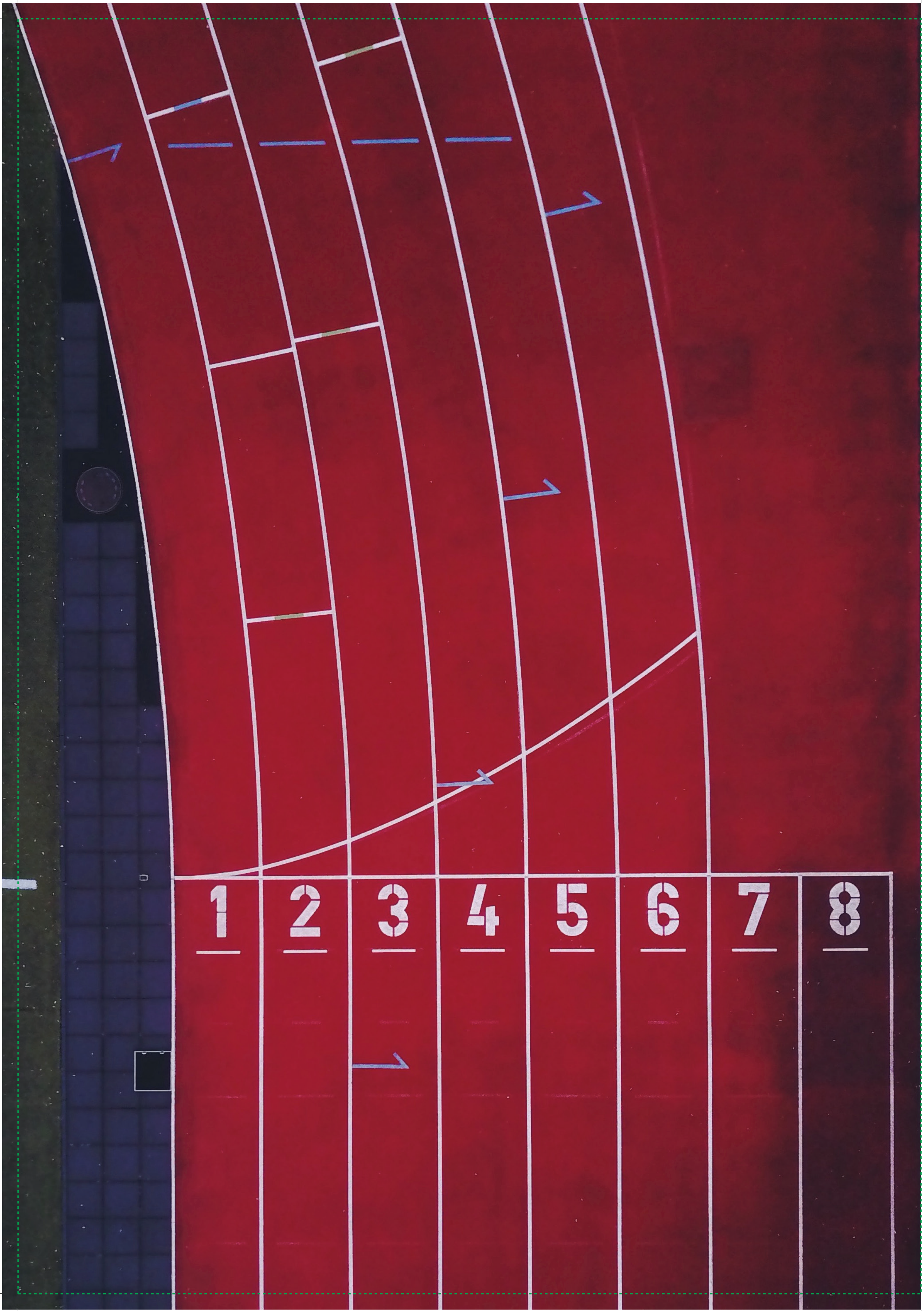
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CHAPTER 9

Closure

9.1 Introduction

This chapter presents the conclusion and the scientific contribution of this doctoral research. The chapter is structured as follows: first, in the Discussion section, the validity of the research is discussed, followed by explaining the scientific contribution and research limitations. Next, in the Conclusion section, the sub-questions and the main research question, sketched in Chapter 1, are answered. Afterwards, the research limitations are described and, next, research recommendations are provided.

9.2 Discussion

9.2.1 Validity of the research

Quality of research can be measured by two factors of validity and reliability which convince the readers that research has a value (Guba & Lincoln, 1994). Reliability refers to the extent that repeating a measurement by a test or scale under the same condition gives the same results (Tashakkori & Teddlie, 1998; Kumar, 2011).

The concept of validity can be discussed from three different perspectives: internal validity, external validity and measurement validity.

Tashakkori and Teddlie (1998), define the internal validity as the causal relationship between variables or events. Internal validity refers to the extent to which the causal relationships between two factors, are indeed caused by the factors studied. Internal validity is of less concern in this dissertation as no relationship between different factors are studied in this research. Internal validity can be a concern in Chapter 2 wherein the link between risk management and project success is studied. To check this link, literature is consulted and based on different researches, it is shown that risk management does have influence on project success.

External validity refers to whether the apparent causal conclusions resulting from an experiment can be generalized beyond the experimental context (Tashakkori & Teddlie, 1998; Pruzan, 2016). Regarding the external validity of the research, different HWBP-2 projects from different waterboards (7 waterboards in Chapter 5, 11 waterboards in Chapter 6, 13 waterboards in Chapter 7, depending on availability of data) were investigated. The flood defence projects performed by the waterboards are comparable regarding project characteristics such as method of execution, location, and size. By considering projects from different waterboards, it was ensured that the results are generalizable to the other water defence projects.

Measurement validity is the degree to which an instrument/experiment measures what it is supposed to measure (Tashakkori & Teddlie, 1998; Kothari, 2004; Pruzan, 2016). From the different methods of measurement validity, the content validity and construct validity (Tashakkori & Teddlie, 1998; Kothari, 2004) are applicable in this research.

Content validity means that a group of experts evaluate the extent to which items on a test measure the intended objective (Tashakkori & Teddlie, 1998). The content validity was applicable to the development of RiskProve (Chapter 3). The content validity was considered in the two expert sessions, organized to validate the model. The experts were asked to evaluate the statements in the model and check whether the statements contribute to measuring the risk maturity of the projects. During the application of RiskProve in projects, if the experts had reasonable comments about the statements, these comments were also applied. Application of RiskProve in practice (Chapter 4) and the results of the expert sessions assure the content validity of the research. Using RiskProve by more than 30 projects in practice confirms that the model addresses the needs of the practitioners regarding measuring and improving risk management in projects.

Construct validity checks whether the test measures the construct (Tashakkori & Teddlie, 1998). To ensure the construct validity, two experts from the PD-HWBP checked results of the analysis of the cost documents of the projects in Chapter 6 and Chapter 7. To ensure the construct validity in Chapter 5, the taken interviews are recorded and the interview reports were sent to the interviewees for review and approval.

To ensure the reliability of the data collection, the cases in Chapters 5, Chapter 6, and Chapter 7 are investigated following strict protocols. The entire studied documents (risk registers, cost estimate documents, etc.) are printed and kept. The information from the interviews and the expert sessions are stored. Specific attention was given to the reliability of data analysis. All the analyses and results are stored in defined Excel-documents and each analysis is performed several times. Where needed, notes are left on each studied document.

As explained in Chapter 1, each research question follows an appropriate research method. The research started with qualitative methods (constructivism approach) in Chapter 3 to develop RiskProve, while its application in projects (Chapter 4) was a combination of qualitative and quantitative methods (mixed method). Identified and occurred risks and the cost performance of projects (Chapter 5, Chapter 6, and Chapter 7) were more quantitatively discussed (positivism approach). At last, the recommendations to practice are discussed with qualitative methods. The overall research method was mixed-method and both qualitative and quantitative methodologies are performed to increase the validity of the research as the mixed-method maximise the strengths and minimizes the weaknesses of these methodologies in single research (Tashakkori & Teddlie, 1998; Johnson & Onwuegbuzie, 2004).

9.2.2 Scientific contribution

Research has contributed to the Risk Management Maturity (RMM) body of knowledge in different ways. As mentioned by Wendler (2012) most publications dealing with the development of maturity models are empirical studies while theoretical reflective publications are scarce. Wendler also explains the relation between conceptual and design-oriented maturity model development and mentions there is still a gap in evaluating and validating maturity models. This research has contributed to the RMM literature by developing a risk maturity model based on sound theoretical foundations, validated by experts from practice.

A way to improve the quality of risk identification is investigating completed projects and examining the risks that have been identified and the risks that have occurred throughout a project. The available literature on risk management addresses different categorizations of risks (Miller & Lessard, 2001; Ng & Loosemore, 2007; Bentley, 2010; Sanchez-Cazorla, Luque, & Dieguez, 2016). No research could be found that investigated the identified and occurred risks or the number and phase of identified or occurred risks in real construction projects, which was a gap addressed in the current research.

This research has made some contributions to the current cost contingency body of knowledge by investigation of cost and cost contingency of the projects in the preparation as well as the execution phase. Regarding the investigation of the costs and cost contingency in the preparation phase, few articles discuss the evolvement of cost contingency in projects. The ratio of 'known unknowns' and 'unknown unknowns' contingencies in the real projects was not investigated, according to our literature research. Regarding cost performance in the execution phase, the results show that clients and contractors have different cost performances. Despite the common belief that projects in general face cost overrun (Flyvbjerg, Holm, & Buhl, 2002; Flyvbjerg, Bruzelius, & Rothengatter, 2003; Lovallo & Kahneman, 2003; Chantal C Cantarelli, Flyvbjerg, van Wee, & Molin, 2010), this study shows that this depends on whose perspective is considered, client or contractor. This research shows that cost underrun in the execution phase is not uncommon, which is in line with study by C. C. Cantarelli, Molin, van Wee, and Flyvbjerg (2012). This research reveals that for the studied projects, next to the 'optimism bias' as one of the reasons of cost overrun in projects, lack of confidence in the estimates or 'pessimism bias' is a possible reason for cost underrun.

9.2.3 Limitations

As occurred risks were not documented properly, occurred risks in the research were collected by means of interviews. Due to the large number of identified risks in some projects, most time of the interviews was assigned to investigating the occurred risks that were identified in the projects. Investigation of the risks that are not identified but had occurred has received less attention.

The research has discussed the number of identified and occurred risks based on the categories of RISMAN without taking into account the (potential) impact of a risk. It is possible that a category of risk that has less identified risks has more impact on the performance of the project, but it could not be investigated due to a lack of data.

In Chapter 6 and Chapter 7, possible reasons for the deviation between the estimated and realized cost and cost contingencies were discussed from a theoretical point of view. These reasons, however, were not tested in the projects. It is possible that not all reasons are applicable to specific HWBP-2 projects. This research has investigated the cost performance of the client's and contractor's projects (Chapter 7). The research has not, however, investigated the cost performance of the client and the contractor in exactly the same projects. The other limitation of the research is that it does not investigate time uncertainty in projects.

9.3 Conclusion

9.3.1 Answers to the sub-questions

1. How can the risk management maturity of construction projects be measured?

Current literature confirms that there is a link between risk management and project success (Chapter 2). A moderate risk management application has positive effects on the project outcomes (Zwikael & Ahn, 2011). Risk management improves decision-making, increases stakeholder satisfaction and delivery according to requirements (Oehmen, Olechowski, Kenley, & Ben-Daya, 2014) (De Bakker, 2009) (Raz, Shenhar, & Dvir, 2002). Literature on risk management also confirms a link between the maturity of risk management and success of a project (Yeo & Ren, 2009). Maturity in terms of risk management means the evolution towards full development and application of the risk management process in a project or an organization. A risk maturity model (RMM) helps organizations to identify the weak and strong areas of risk management and plan for improvement.

Research by Wendler (2012) shows an increase in the number of maturity models. Those maturity models, however, are not empirically validated and they are based on the experience of their authors, not on a theoretical background (Wendler, 2012; Tarhan, Turetken, & Reijers, 2016). By investigation of 13 RMMs (Chapter 3), more deficiencies of current RMMs are revealed. For example, some models (such as Alarm (2009)) define fixed conditions for each level and relate the risk maturity of projects to these defined conditions. Projects are, however, unique and the same condition might not be applicable in all projects. The level of risk management maturity can be different per project and a high level is not necessary for all projects (Westerveld, 2003).

To address the deficiencies in current RMMs, a new model is developed in this doctoral research, named as RiskProve (Figure 9-1). Despite other RMMs, RiskProve is based on a sound theoretical background. Using Qualitative Content Analysis (QCA), the important steps of risk management application are collected from 30 risk management guidelines such as RISMAN, COSO and PMBOK. These steps are then converted to the statements for RiskProve. RiskProve was validated using two focus group sessions. RiskProve has received attention by organizations from practice: RiskProve is chosen by the risk management pool of Rijkswaterstaat as the risk management maturity tool for the organizations. During the doctorate research, RiskProve has been applied in several p

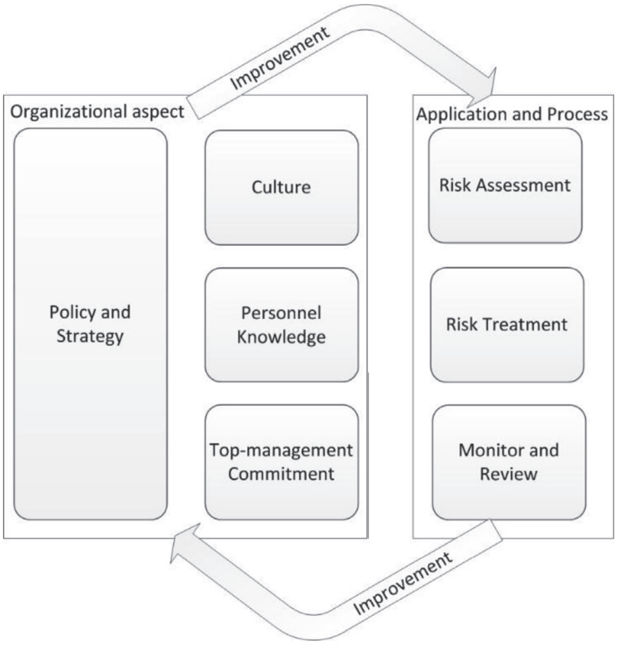

Figure 9-1 The RiskProve framework

2. What are the improvement areas of risk management in projects of public organizations?

The results of the application of RiskProve are described in Chapter 4 in which the risk management maturity of 16 projects in two public organizations is assessed. The results confirm that risk management has found a place in the project management of these organizations. However, the risk management application itself can still be improved. The results show that 'Culture and Personnel Knowledge' of risk management has the highest score of maturity among the projects while, 'Top-management Commitment' has received the lowest maturity score. The results show that the projects' members expect more involvement, support, and encouragement regarding risk management from the top-management. The projects, in general, score higher in 'Risk Assessment' than in 'Risk Treatment' and 'Monitor & Review'. This indicates that the project members give more attention to risk assessment activities such as organizing risk management sessions and identifying and quantifying the risks. While 'Risk Treatment' and 'Monitor & Review' activities receive less attention in the course of a project. This observation is in line with the study by Bannerman (2008). Training of risk management was another possible improvement in risk management of the investigated public organizations. Lack of capacity to apply risk management was mentioned by several project members as well. In this case, assigning a risk manager to (a group of) projects could be helpful. The investigated organizations see possibilities to improve in better defining the objective of risk management, defining the risk appetite, and evaluating and collecting the lessons learned. Collecting and using the lessons learned are among the activities that need more attention in the investigated organizations (Figure 4-11 and Figure 4-20). Based on the results in Chapter 4, recommendations are drawn for HWBP (see 4.6), which will be discussed when answering sub-question 6.

3. What can be learned from the risk identification of the HWBP-2 projects?

In Chapter 5, the results of the investigation of the risk registers of 16 projects are presented. More than 2000 risks are collected from the whole life-cycle of these projects. The risks are categorized based on the seven categories of RISMAN method: Organizational, Political, Financial, Zoning, Legal, Social, and Technical. On average, 135 risks are identified in an examined project. By means of interviews with the project managers or project controllers of these projects, the occurred risks in these projects were collected.

The results reveal that risks related to the categories Organizational (e.g. mistakes in the contract, lack of capacity) and Zoning, e.g. finding objects in the (under)ground are among the most identified and occurred categories of risks in projects. The interviews revealed that in total, about 13% of identified risks have occurred. It cannot be concluded whether this percentage is high or low. Some occurred risks might have no (considerable) impact on the project. In addition, depending on the quality of risk quantification, they might have lower/higher impact than estimated. The results show that more risks are identified before the start of the execution while more risks have occurred during the project execution. The results also show that risks related to, for example, cables and pipes in the (under)ground are among the most identified and occurred risks. A risk such as bankruptcy of contractor is among the identified and not occurred risks. The knowledge gained from the identified and occurred/not occurred risks of previous projects can be used to better identify the risks in future projects. The practitioners, especially in flood defence projects, should give more attention to the identified and occurred risks in this research. They can consider a lower probability for the risks which are identified and have not occurred in earlier projects. The results show that more risks have occurred in the execution phase. The practitioners should, therefore, try to identify the execution risks already in earlier project phases. This way, the practitioners can increase the chance of the project success. Unfortunately, the investigations of the financial consequences of occurred risks were not possible since this information was not available. Investigation of the financial consequences of the risks requires a change in capturing project data. The recommendations drawn based on the results of this chapter are further validated in Chapter 8, which will be discussed when answering sub-question 6.

4. What can be learned from the cost contingency of the HWBP-2 projects in the preparation phase?

In Chapter 6, the cost evolvement of projects in the preparation phases is investigated. The chapter also investigates the evolvement of the 'known unknowns' and 'unknown unknowns' contingencies in real construction projects. In total, cost documents of 29 HWBP-2 projects in the pre-construction phases are studied. The cost and cost contingency estimations in three phases of Exploration (EXP), Plan Development (PD), and Tender & Award (T&A) are investigated and their evolvements are discussed. It was concluded that the risk profile of the projects are reduced from the EXP phase to the T&A phase (as it was expected) but, at the same time, the projects have experienced, in general, an increase in the estimated costs in the preparation phase. The results revealed that the average of the percentage of cost overrun is 11.51% which is smaller compared to the cost overrun in the Dutch transport infrastructure projects (19.7%). The cost increase in the preparation phase of the construction projects is also explained in other studies such as by Welde and Odeck (2017). This increase in the cost estimates of the flood defence projects can be explained by 'technical' reasons. The 'technical' reasons such as mistakes due to the lack of historical data, or lack of experience seem to be more reasonable in this case. It should, however, be noted that cost increase in the preparation phase could be the result of more detailed design and more clear scope, and hence acceptable.

Results show a reduction in the cost contingency, as the projects progress in time, confirming a reduction in the uncertainties of the projects. Despite that, it was observed that the 'unknown unknowns' contingency has increased (Table 6-6). This suggests that the projects are conservative and not confident about their estimates. This is what we call a 'pessimism bias' in the estimates. Reasons such as lack of experience, trying to avoid the bureaucratic and administrative works to obtain an extra subsidy, or to overcome reputation damage and public criticism could have played a role here. Maintaining a more ‘outside view’ rather than an ‘inside view’ and using historical data from previous projects could improve the cost estimate practice. The recommendations drawn based on the results of this chapter are further validated in Chapter 8, which will be discussed when answering sub-question 6.

5. **What can be learned from the estimated and realized cost and cost contingency of the HWBP-2 projects in the execution phase?**

Chapter 7 discusses the cost and cost contingency performance of projects in the execution phase, comparing the perspectives of the client and contractor. In total, 95 projects are investigated as the cases in this chapter: 44 client projects and 51 contractor projects. While other researches do not usually specify the perspectives of client and contractor, our results showed differences between the cost performance of the client and contractor projects. Comparing the estimated and realized costs of the client’s projects (HWBP-2) in the execution phase revealed that, on average, the projects have faced 16% cost underrun. In contrast, the results of the contractor show that on average, the projects have faced 2% cost overrun. Investigating the estimated and realized cost contingency of the projects, it was observed that the HWBP-2 projects have in average 2.64% more than required cost contingency while the contractor projects have on average 5.41% shortage in cost contingency. In general, the contractor was more optimistic in the estimates and has overestimated the opportunities while in the HWBP-2 projects, estimates were more pessimistic with a tendency for overestimating the costs and underestimating the opportunities. The earlier study in the cost estimation of the Dutch transport infrastructure projects also confirms that cost underrun in the execution phase of the project, at least in the case of the Netherlands, is not uncommon.

The cost overrun of the contractor’s projects can be explained ‘technical’ reasons (lack of historical data or mistakes in the estimates or inefficient use of materials) and market condition. The market condition, especially during the crisis, and the number of contractors signing up for tender could have been a reason for the low cost contingency of the contractors. The market condition could be at the same time a reason for the cost underruns in the client’s project. The client’s projects could have been benefited from the low bidding of the contractors. ‘Technical’ reasons and ‘pessimistic bias’ could be again here the reasons of cost underrun in the client’s project. In the case of the client, it is possible that the extra budget blocked is overspent based on the concept of “Money Allocated Is Money Spent”.

The results of this phase led to a list of recommendations for improving the cost estimation of projects. The recommendations drawn based on the results of this chapter are further validated in Chapter 8, which will be discussed when answering sub-question 6.

6. How can the application of risk management in HWBP projects be improved based on the observed results in HWBP-2 projects?

Based on the results of the previous chapters, a list of 20 recommendations is drawn. The feasibility of these recommendations was tested during three experts' sessions: a session with experts from the waterboards, a session with experts from the PD-HWBP who are involved in risk management, and another session with experts from the PD-HWBP who have strategic and directorate roles.

It was observed that experts from the waterboards and the PD-HWBP both see opportunities for improving risk management in HWBP projects. However, it seems that the waterboards have objections against one-side decision-makings that might question their autonomy or their working approaches. It is important, therefore, that the PD-HWBP and the waterboards jointly define the objectives and the role and responsibility of each party towards risk management approaches in HWBP. This would be the first and the most crucial step if risk management practices in HWBP projects are to be improved.

In the second step, the conditions for applying the recommendations should be created by both parties. Improving the current regulation of the HWBP would be needed, as mentioned by several experts as well, if the recommendations are to be applied. Moreover, a standard template for a risk register, developed jointly by the PD-HWBP and the waterboards, is required.

Taken the first and the second step, the PD-HWBP and the waterboards are responsible for applying part of the recommendations. The waterboards are responsible for translating the defined objectives to the objectives at the organization and project level. They should, in addition, invest in improving risk management in projects. The PD-HWBP has to keep the current role as facilitator and at the same time, collect data and share knowledge created in the projects. Based on these steps, a watermap is defined with five milestones, including roles and responsibilities of the PD-HWBP and the waterboards (Figure 8-4).

9.3.2 Answer to the main research questions

After answering the research sub-questions, the main research question can be answered:

What are the lessons learned of applying risk management in HWBP-2 projects and how can these lessons be used to improve the risk management application in HWBP projects?

Different lessons can be learned from risk management in HWBP-2 projects. Regarding the risk management maturity of the projects, it can be concluded that the projects are more mature in risk assessment while risk treatment and review of projects still need attention. Project teams should distinguish between 'risk management application' and 'managing risk'. By 'risk management application' only following the risk management steps is meant identifying and quantifying risks and assigning control measures to the risks. By 'managing risks', however, it is meant reaching a common understanding by the project team that (negative) risks can endanger the project objectives and therefore should be proactively identified, communicated and managed. Project teams must realize that 'managing risks' is about taking actions to manage the risks and just filling a risk register is never enough. Identifying and quantifying risks are important steps to obtain an insight into the risks, but they are not enough to manage the risks. Risk management should not be seen as an extra activity but as regular and routine activity of each role. In an ideal situation, there should be no need for a risk manager. Project members should identify, record, communicate and manage the risks themselves. Project members should give special attention to applying the control measures and evaluating the usefulness of them. Evaluating and reviewing the projects and collecting the lessons learned of the projects can improve risk management in HWBP projects. Evaluating and reviewing means that projects should be examined to collect information such as (including but not limited to): number of identified and occurred risks, type of risks, phase of risks, how risks are evolved during the project and whether 'risks are managed'. This information can be used in future projects as also mentioned by Welde and Odeck (2017). Periodic measurement of risk management maturity, using RiskProve, can check whether the HWBP projects are on the right path.

Regarding the identified and occurred risks in HWBP-2 (Chapter 5), also lessons can be learned. Firstly, most identified and occurred risks are related to the categories Organizational and Zoning. These two risk categories should receive extra attention in HWBP projects. An important lesson learned is that the projects should better document the occurred risks. The costs of the occurred risks should be recorded as well. The database of risks made in this research can be used in HWBP projects to check the completeness of their risk registers. The practitioners can also learn from the control measures taken in other projects

Regarding the cost and cost contingency estimate of the projects (Chapter 6 and Chapter 7), an important lesson is that such information should regularly be collected and evaluated. Cost performance of the projects (comparing the realized and estimated costs) should be performed and the reasons for deviation should be investigated. The consequences for overestimating the budget due to 'pessimistic bias' behaviour should be communicated to the projects and the importance of efficiently using public money should be emphasized. It is important that the estimated and realized costs of the finished projects are collected and made available to the projects. Future HWBP projects should strengthen their estimates using historical data from the past.

An important observation from investigating the HWBP-2 projects is that it was enormously difficult to collect the information. It took the author a long time to find the data of the projects. One of the eye-opening conclusions was that for about one-third of the projects no trace of the risk registers or cost estimation documents could be found. Additionally, the information in some phases was missing for many projects. Let us remember that these projects are not from the last century but from the past few years. Collecting the occurred risks and the amount of actual cost contingency was also difficult. To collect the occurred risk, some project members must be interviewed as there was no other way to collect this data.

Fortunately, HWBP projects follow a better regime for collecting information, although, this is not enough. Currently, HWBP collects the information up to the beginning of the realization phase and the information from the realization phase is not collected. The information of the realization phase is only available (if properly collected) at a single waterboard. This makes the process of evaluating the projects, learning and sharing the knowledge gained from the projects very difficult. The other issue is that there is no insight in the realized costs of projects because in the current regulation of HWBP, the waterboards do not need to report the realized costs. In this respect, HWBP-2 has more information available than HWBP, because HWBP-2 was based on post-calculation method and all realized cost had to be reported. The author flags a risk in this situation:

Because the correct information is not collected, there would be insufficient information to evaluate future HWBP projects.

If a situation like the one in 2010 (that the parliament of the Netherlands has asked for the evaluation of HWBP-2) would occur again, there will not be enough information for evaluating the projects. It is suggested that the directors of HWBP and the board of the waterboards are to be prepared for this risk. Recommendation 20 is focused on this risk:

Recommendation 20: Regularly collect and use the data (for example risk register, financial documents) of the finished projects and share with the waterboards for better identification of the risks or estimation of the costs.

Regardless of the strategy of HWBP for financing the project (reimbursable or lump sum) the information should be collected properly, evaluated and shared regularly among the waterboards). The author believes that the current approach of HWBP for financing the projects is better than the approaches in HWBP-2 (see section 1.3.4). The pre-financing approach in HWBP is a good incentive for the waterboards to think in advance about the risks and, hence, better define their estimates. Going back to post-calculation would be a step-back for the waterboards. Pre-financing, however, does not mean that the project should not report their realized costs. In the regulation of the HWBP is mentioned that: after finishing each phase, there will be no recalculation of the costs10. This part must be removed from the regulation of the projects. For learning purposes and transparency of the realized costs, projects should report their costs in any case.

One of the initial questions in this doctorate research was about the percentage of risk reservation (cost contingency) of the projects. As explained in Chapter 8, the percentage of risk reservation in HWBP-2 projects is based on the total cost of the projects while the percentages of risk reservation in HWBP projects are based on the project costs in each phase. As a result, the percentage (or the range) of risk reservation cannot be concluded based on this research. The author thinks that the current ranges of risk reservation in the regulation of HWBP (Table1 -1) can be removed as they are based on the total project costs and not on the costs of each project phase. If these ranges are to be kept, it should be mentioned that the ranges are indicative. The projects have usually the tendency to choose for the maximum percentage with the argument that it is mentioned in the regulation. This leads to long discussions with the PD-HWBP for accepting the subsidy. The projects should come with arguments why a percentage is needed for a project and the best way would be to use historical data from past projects.

10 Werkwijze bij het vaststellen van subsidiabele en niet subsidiabele kosten, behorend bij de Regeling subsidies hoogwaterbescherming 2014 (versie 2017), pagina 6: Na afronding van de fase vindt geen verrekening op basis van nacalculatie plaats. Deze werkwijze beperkt de administratieve lasten en houdt tevens een prikkel tot doelmatigheid in.

Attention should be given to 'use' of the collected information from projects and just 'collecting' the information is not enough. At HWBP, there is currently no process to collect and use the lessons learned of projects. In the past years, the TU Delft has taken important steps to help projects collecting and using their lessons learned. HWBP is a continuous program and investing in collecting and using the lessons learned can significantly help HWBP.

9.4 Research recommendations

The relationship between risk management and project success has been studied in Chapter 2. The investigated articles discuss mostly the role of risk management in Information Technology (IT) project success. No articles could be found related to this topic in, for example, the construction industry. This research gap can be addressed in a research in which the contribution of risk management to the success of construction projects is explored.

One ambition to develop RiskProve was to make a generic risk maturity model that can address the needs of projects in the construction industry. Use of RiskProve in current projects shows that the model is applicable in the case of the Netherlands. However, yet it cannot be said that it addresses the needs of practitioners in the construction industry all over the world. Therefore, expanding the research to cover an international scope could be considered as a possible future research direction.

RiskProve was initially developed for construction projects. Recent research by Guo (2018) in improving the risk management practices in the manufacturing industry revealed the potential of RiskProve application in other industries. Future research could investigate the applicability of RiskProve in other industries and examine which steps should still be taken to make it a generic model for risk management.

As explained under section 9.2.3 Limitation, the 'not identified and occurred risks' and the financial consequence of the risks are not investigated. Studying these subjects, if the required data is available, would be an interesting topic for future research. This would significantly expand the available knowledge about risk management and financial consequence of risks. This research has mainly focused on the cost contingency of the projects and the time contingency was out of scope of research. Future research could investigate time contingency in projects.

This research has tried to address the importance of soft factors of risk management in Chapter 2. However, the nature of the research questions and investigated data in Chapter 5, Chapter 6 and Chapter 7 shows less focus on soft factors of risk management. The research by Hertogh, Baker, Staal-Ong, and Westerveld (2008) showed that the Large Infrastructure Projects (LIPs) are better in hard aspects rather than in soft aspects. Several recommendations, drawn in this research (Chapter 8), focus on soft factors of risk management, and the link between hard and soft factors. For example, sharing the risk management data, as a hard factor, needs a culture of openness and trust, as underlying soft factors. Future research could investigate the role of soft factors in improving risk management in the (HWBP) projects.

RiskProve was applied in two public organizations (Chapter 4). A possibility for future research could be to investigate the application of RiskProve at more organizations. Investigating risk management maturity in contractors' projects is another possible future research direction. It would be interesting to investigate the risk maturity of projects over time. Finally, comparing perspectives on risk management maturity of projects based on the roles of the participants is suggested for further research.

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Cover photo by Marvin Ronsdorf.

About the author

Erfan Hoseini was born on 22 September 1987, in Kermanshah, Iran. He obtained his bachelor's degree in Industrial Engineering in 2011 at Tabriz University in Tabriz, Iran with the bachelor thesis title: 'Risk Management of Dikes Using System Dynamic Approach'. After his Bachelor study, Erfan started his carrier as project planner in construction projects of Iran. To pursue his ambition in project management and gain international experience, Erfan moved to Norway. In June 2013, he obtained his Master of Science in Project Management from Norwegian University of Science and Technology (NTNU). He then moved to the Netherlands to pursue his PhD in the filed of risk management under the supervision of Prof.Dr.ir. Marcel Hertogh. His PhD dissertation entitled "Learning from our projects; Evaluating and Improving Risk Management of the Flood Protection Program"

Resulted in research publications in different scientific journals and conferences' proceedings. He has presented her research in different national and international conferences. During his PhD, he had a close collaboration with Rijkswaterstaat and several Waterboards. He has supervised more than 20 master students and has collaborated with several companies during his PhD. He gave presentation during several events such as Risk & Resilience Festival 2018, Risk & Resilience Festival 2019, and Dijkwerkersdag 2019.

Since November 2019, he is working as a risk manager in BAM Infraconsult where he pursues his passion in project and risk management.

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List of Publications

1. Zidane, Y. J., Johansen, A., Andersen, B., & Hoseini, E. (2015). Time-thieves and bottlenecks in the Norwegian construction projects. Procedia Economics and Finance, 21, 486-493.

2. Hoseini, E., Hertogh, M., & Bosch-Rekveldt, M. (2019). Developing a generic risk maturity model (GRMM) for evaluating risk management in construction projects. Journal of Risk Research, 1-20.

3. Hoseini, E., Bosch-Rekveldt, M., & Hertogh, M. (2018). Risk management maturity of construction projects in the Netherlands. In Proceeding of the 34th Annual ARCOM Conference, ARCOM 2018 (pp. 657-666).

4. Hoseini, E., Bosch-Rekveldt, M., & Hertogh, M. (2020). Cost Contingency and Cost Evolvement of Construction Projects in the Preconstruction Phase. Journal of Construction Engineering and Management, 146(6), 05020006.

5. Hoseini, E., van Veen, P., Bosch-Rekveldt, M., & Hertogh, M. (2020). Cost Performance and Cost Contingency during Project Execution: Comparing Client and Contractor Perspectives. Journal of Management in Engineering, 36(4), 05020006.

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