Dealing with project reserves

Insights into the project circumstances that influence the estimation and expenditure of project reserves in Dutch road-widening projects

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Preface

Project reserves of infrastructure projects are examined from a theoretical and practical perspective, including both estimation and actual expenditure. This topic is located on the area of risk management and cost management within general project management. This report is the result of my graduation internship at AT Osborne in order to complete the masters of Construction Management and Engineering at Delft University of Technology.

Early in March, I set foot at the office of AT Osborne in Baarn for the first time as graduation intern. From that moment on, I consider all cooperation and supervision of the employees of AT Osborne as a huge opportunity to discover the practical perspective on all subjects within the discipline of construction management. Many thanks go to all the colleagues who assisted me throughout the process and give me a unique insight into their projects. In particular, thanks to Frank Jacobsen and Jeroen Versteegen for your guidance during my internship. Your constructive criticism and advice foster me for improvement on my work and retain focus on the initial research goals. Also special thanks to project team members from Rijkswaterstaat for their cooperation towards the project cases. It was great opportunity to get practical knowledge on leading infrastructure projects in The Netherlands.

In addition, I want to thank my supervisors from the TU Delft: Marcel Hertogh, Pieter van Gelder and Jos Vrancken. Thank you all for your valuable comments, scientific view and interesting discussions about the topics related to this research.

With this thesis, an end has come to the nice and valuable period at AT Osborne and to great student days in Delft. On to the next stage!

Baarn, 28 November 2013

Tom Kremers
Summary

Infrastructure projects face uncertainties on their way to reach their project objectives in terms of budget, scope and time schedule. Primary goal of project reserves is to prevent negative influences of these uncertainties on the project objectives, where this research has a focus on the objective to stay within budget. A low estimation of the project reserves makes the project more competitive in comparison with other investment opportunities, but also increases the probability of costs overrun. According to these conditions for choosing a lower or higher amount of project reserves, there should be – in theory – an optimal amount of project reserves for each infrastructure project to achieve maximum economic value.

So, the decision on the amount of project reserves is very important for the project’s feasibility and competitiveness. Research defines two main problems relating to this decision. Firstly, estimation methods for the amount of reserves tend to be very subjective. Secondly, there is no clear insight into the expenditure of established project reserves in current practice. According to these problems, the research objective is to provide a more conscious and substantiated guideline for the decision on the amount of project reserves in infrastructure projects in The Netherlands, by providing insights into the project circumstances that result in expenditure of the project reserves.

Three successive studies are conducted to explore and analyse data related to project reserves: the cost experts survey, three case studies and the project survey of 17 road-widening projects. Research includes both qualitative (interviews and reports) and quantitative data (risk and financial files). The focus on road-widening projects is chosen because of its relevance to the increasing shortage of free space in The Netherlands as well as the program ‘Spoedaanpak Wegverbredingen’¹, where most of the projects are nearly finished.

Estimation of project reserves

Research shows that there is a full focus on the risk file, when estimating project reserves. This is true for both the contingency reserve (covering the identified and quantified risks) and management reserve (covering unknown uncertainties and creates management flexibility). The contingency reserve is directly quantified by the initial identified risks and the management reserve indirectly by a percentage of the quantified risks. In the case studies – on average – 55% of the reserves are substantiated with the initial risk file during the tender phase. This ratio between both parts of the reserves was not identical over the case studies, although these were all road-widening projects in the same phase. Different project

¹ Spoedaanpak Wegverbredingen program covers 30 bottlenecks in the Dutch road network that are selected for accelerated improvement.
circumstances and a different quality of the risk analysis are the only explanations found for this difference and considered as invalid. Different project circumstances indicate different project uncertainties, which should already be covered by the risk file and a difference in the quality of the risk analysis is observed as remarkable when dealing with these very expensive infrastructure projects financed with public resources.

**Expenditure of project reserves**

The analysis on the contractual and scope modifications in the case studies results in an overview of the characteristics of expenses from the project reserves. The occurred risk events that eventually result in use of the project reserves are categorized by their underlying cause, project factor and complexity. Additionally, the events are checked on a possible link to the initial risk file and potential exogenous influences. In total 196 events in the three case studies have been assessed.

Research shows four main causes for expenditure of project reserves: legal failure of project decisions, changing functional requirements, political pressure and a lack of knowledge of the initial assets. Legal failure of project decisions is observed as incidental, but it did have huge consequences for that particular case. The latter three are present in every case and thereby appointed as structural causes. According to the results of both the case studies and the project survey, research indicates a strong cause-effect relation between knowledge of the initial assets and actual use of the project reserves.

Reflection on the initial risk file gives insights into the predictability of occurred risk events during the project. Research illustrates that – on average – 25% of the actual occurred risks could be linked to an initial identified risk. Related to the corresponding costs 44% of the costs are initially identified in some way. The analysis in the three cases shows that the initial risk file could substantiate no more than 35% of the total project reserves.

According to the project management triangle of budget, time and scope, extra costs by exogenous influences should result in extra budget. So in theory, these external influences should not affect project reserves. Analysis demonstrates that 27% of the occurred events are caused by exogenous influences. Mostly small expenditures are caused by these influences. Apparently, small consequences of occurred risks result in ignorance of the project management triangle rule, but the total exogenous influence is substantial: 16% of the corresponding costs of all occurred risks are designated as exogenous.

**Six disturbing mechanisms**

There are six mechanisms observed in the case studies that disturb the search for an optimum amount of project reserves during estimation or hinders the project overview and manageability. The first four mechanisms affect the optimal estimation of the project reserves and are partly related to the inaccuracy of estimations described by Flyvbjerg (2002). Parkinson’s law is also observed during the realization phase, so the last three mechanisms are present when the project reserves are used and disturb the manageability during project execution.
1. **Subjective judgment**: quantification of project reserves includes many opportunities of subjective judgement and shows a wide spread of estimations from cost experts with little consistency. Decisions on the amount of reserves remain very dependent on the person who is invited to make these decisions.

2. **Optimism bias**: assessment on the predictive value of the initial risk files seems to be significantly lower than assumed for the determination of the management reserve in the case studies.

3. **Tender result**: this delta between reserved budget and the actual price for the contract is identified as exogenous in case of a negative result, while a positive result is mostly awarded to the project.

4. **Parkinson’s law**: project costs tend to extend towards the budget available, which is seen during the estimation and expenditure of the project reserves.

5. **Exogenous influences**: as mentioned, the exogenous influences on expenditure of project reserves are substantial. Additionally, there is no consistency among the cost experts about the involvement of exogenous influences in estimations.

6. **Strategic administration**: organizational overhead costs are assigned to individual projects because of strategic motivations. The latter is a form of exogenous influence on the project organization and eventually does not cause additional costs, but it does decrease the ability to manage the project costs.

**Preferred management of project reserves**

Improvement of the manageability of individual infrastructure projects is desirable according to project management success. Increasing the probability for project management success starts with elimination or minimization of the negative effects of the disturbing mechanisms. In this way, the conditions are created to use strive for optimal use of project reserves. Several recommendations are proposed to improve the manageability of the reserves.

- **Set the project organization as reference for the definition of exogenous**. For improvement of the manageability, it is recommended to set the project organization itself as reference and handle influences from for example Rijkswaterstaat as exogenous. Eventually, Rijkswaterstaat does not manage the project, the project organization does.

- **Respect the project management triangle** of budget, time and scope defined by the public client to keep exogenous influences out of individual projects. Monitoring of occurred exogenous influences also gives insights to the influences of strategic administration.

- **Do not call a negative tender result exogenous**. Technically, there is no change of scope and the consequences are manageable through tender conditions.

- **Make use of the positive effect of Parkinson’s law** when assigning budgets. Previous research (Kamma, Geetha, & Neela, 2013) found a significant increase of efficiency by a decreased availability of resources in combination with frequent monitoring.
• **Manage the reserves as an external project entry.** Creation of strict financial boundaries results in direct insights into the causes for extra costs.

• **Retain the distinction between contingency and management reserve during realization.** Links between the initial risk file and the occurred risks give insight into the condition of the reserves and into the available resources for active handling of risks (treat, transfer or terminate). Based on the case studies, this research suggests that 44% on the project reserves need to be substantiated by risks during the tender phase.

• **Record expenditure data within standard framework for continuous analysis.** Make use of predefined categories to record underlying causes, complexities, predictability, exogenous influences and consequences of occurred risks. This gives direct opportunities to react to or prevent future extra expenses. In other words, avoidable costs could be avoided.

• **Make use of correlations between project circumstances to increase the use of historical project data and minimize subjective judgments and optimism bias in the important decision on the amount of project reserves.** This recommendation is further explained in the next paragraph.

**Preferred method of estimation for project reserves**

Decisions on the project budgets are very important to eventually maximize economic benefit, where this research illustrates that the initial risk file is not sufficient to use as decision-making tool for the amount of project reserves. An alternative estimation method for project reserves is simulated on the basis of 17 road-widening projects. This research shows significant correlations between project circumstances and the actual spent amount of project reserves.

So, a preferred estimation of future amounts of project reserves is based on the project circumstances and the corresponding expenditure data of previous projects. The storage of expenditure data can be used as reference data to decrease the subjectivity and possible strategic behaviour along the important decision on the amount of project reserves. Increasing the number of projects in the reference database results in an applicable estimation model for infrastructure project, which is purely based on objective historical references.

Overall, insights are provided into the estimation and expenditure of the project reserves in order to improve the project manageability. More conscious handling towards the reserves and storage of expenditure data gives instant knowledge about causes of extra costs and these stored data should be used to substantiate the estimation of future project reserves.
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The conducted research is introduced by a brief elaboration on the context, the corresponding problems within current practice and the used research methodology. The context briefly illustrates the current practice in the disciplines involved in order to formulate the problem definition. Research methodology is covered in paragraph 1.3. The main research structure is explained, followed by the three defined parts of the research: cost experts survey, three case studies and a project survey. The methodology of all parts is explained and is linked towards the structure of this report, which is clarified at the end of this chapter.
Subject of the research are the project reserves of infrastructure projects in The Netherlands, with the focus on road-widening projects. This topic is clearly related to risk management and cost estimation within general project management in the civil engineering sector.

Civil infrastructure increases the mobility and stimulates the economy of the region. This economic effect is the reason for governments to invest in infrastructure of rail, road and water. Most of these constructions are sponsored by tax money and seen as communal assets. Civil infrastructure projects are becoming larger and larger in order to search for a zero-friction society. These projects become so large that government budgets can be affected for years when projects fail. And some of them did fail in the past (Flyvbjerg, Bruzelius, & Rothengatter, 2003).

These large infrastructure projects need to be built and managed as efficient as possible. This is the moment for project management to come forward: the integral approach to manage all different aspects of a project. Unfortunately, project management is defined as self-evidently correct (Williams, 2006). Project failure is described as a consequence of a failure to follow the procedures according to project management. On the other hand, projects are generally defined as unique products or services, so every project requires a different approach or strategy (Project Management Institute, 2008).

Infrastructure projects struggle with huge cost overruns (Flyvbjerg et al., 2002), which is seen as project failure. This is where project reserves are introduced. Primary goal of the project reserves is to deal with uncertainty within the projects, without directly affecting the project budget, scope or time schedule. Risk management tries to deal with the project uncertainties with measures to treat, transfer, terminate or tolerate the project risks. Risks are identified and quantified in order to assess possible measures to react on these so-called known unknowns. There are also uncertainties that are not known nor identified: unknown unknowns. These risks could not be mitigated by definition. This uncertainty is a huge challenge for the discipline of cost estimation. Insight into project costs is very important in all phases of the project to secure the project’s financial feasibility.

Basically, the project reserves could be divided into two parts: the contingency reserve and the management reserve (see Figure 1). The contingency reserve generally covers the expected value of the identified risks: the known unknowns. Goal of the management reserve is to absorb occurred unknown unknowns. Chapman and Ward (2007) stated that the management reserve has to be planned to an ‘as needed’ basis, to avoid unnecessary planning costs and to obtain an amount of flexibility of the project.
There tend to be multiple aspects or factors involved that play a role in the game of determining the optimum amount of project reserves. It will be clear that the decision on the amount of project reserves is an important project decision, when it comes to project flexibility and efficiency.

1.2 Problem analysis

In an optimal situation there is no project reserves are needed; the project scope is fully known at the beginning of the project; risks are all known and eliminated from the beginning and all projects are executed within time and budget. This utopic scenario is unrealistic because of the continuous presence of uncertainty during the full project lifetime.

An unlimited amount of reserves will be the solution to prevent projects for cost overrun. Only, resources are limited, even governmental resources. So scarcity is involved when projects are selected for execution. Economic benefit of the selected projects needs to be maximized. Also, a project will be less competitive – towards other projects – when a higher contingency reserve is assigned (Turner, 2007). So a low estimation of the reserves increases the probability of project execution, but also increases the risk of cost overrun. In addition, large amounts of resources could make projects less efficient and do not stimulate the optimization of processes. This is mainly illustrated by Parkinson’s law: 'the demand upon a resource tends to expand to match the supply of the resource’ (Gutierrez & Kouvelis, 1991). So in theory, there should be an optimal amount of project reserves for each infrastructure project. This implies the problem: how to reach this optimum in practice?

In order to come one step closer to this theoretical optimum, four problems are defined, which are elaborated briefly towards the problem definition in the next paragraph. These problems also address the practical and scientific relevance of the research.
Subjective judgment

Project reserves are hard to determine, because of the uncertainty involved in large infrastructure projects. In general, the most common method is to establish the amount of projects reserves as a percentage of the total cost estimation and based on intuition, past experience and historical data (Baccarini, 2006), where only historical data could be seen as objective. A closer look on both defined parts of the reserves results in a mainly subjective substantiation of the project reserves.

Subjective influences in the cost estimation in these large infrastructure projects could result in a democratic deficit where democratic decisions are based on project information that is presented more optimistic than in reality. Estimation of costs should be done rationally, but often it is about power. This side of estimation is underexplored (Flyvbjerg, Skamris Holm, & Buhl, 2005).

Expenditure of the project reserves

Past experience and historical data are mentioned as an important basis for cost estimation by Baccarini (2006). Mainly this statement refers to the use of assumptions made in the past and still used. This implies the question: what is the current quality of the applied principles and assumptions for the estimation of the reserves?

The strict distinction between the different reserves tends to blur during the project, so the question is whether the specific reservations are really used for their original purpose. When the goal of the management reserve is to finance unknown unknowns and it also finances the consequences of known unknowns, this reserve is more like a tool to camouflage bad risk management. Verification of the use of the project reserves should give insights into the current practice.

Project circumstance involved

Oberlender and Trost (2001) appoint multiple factors that influence the accuracy of cost estimation within the estimation procedure. This accuracy of the direct costs estimations is also influenced by the circumstances during the project realization, which is not fully covered by previous research. Infrastructure projects are executed mainly in situ, where eventually project circumstances and environment determine the amount of uncertainty involved. So, in current practice, there is a lack of knowledge of the project circumstances and factors that influence expenditure of the reserves.

Missing data for probabilistic cost estimation

One of the current standards for cost estimation in The Netherlands is the SSK, ‘Standaardsystematiek voor Kostenramingen’ (English: Standard methodology for cost
estimation) (CROW, 2010). This method also makes a distinction between a contingency reserve and management reserve. A probabilistic approach shows a normal distribution of the possible project costs, with the mean based on direct costs, indirect costs and the contingency reserve, see Figure 2.

The mean of the management reserve is not included in this distribution, but is determined as a probability to execute the project within budget, for instance a probability of 90% to be within budget. Exclusion of the mean of the (inevitably) unforeseen project costs results in an invalid conclusion to have a 90% probability to be within budget and is seen as an invalid substantiation for the management reserve. Mean and variance of the management reserve need to be inserted to require a valid conclusion about the probability of budget exceedance.

The problems stated are summarized in Box 1.

1. Subjectivity in the determination of the reserves
2. Even after project completion, there is no knowledge of the expenditure of the project reserves and the satisfaction to the initial goal
3. Lack of knowledge about the project circumstances that have influence on the expenditure of project reserves
4. Missing data for probabilistic cost estimation of the management reserve

Box 1: Problems definitions
1.2.1 Research objective

The research objective that covers the problems stated above is presented in Box 2.

The research objective is to provide a more conscious and substantiated guideline for the amount of project reserves in road-widening projects in The Netherlands, by providing insights into the project circumstances that result in expenditure of the project reserves.

Box 2: Research objective

In other words, the goal of this research is to provide more insight into the project reserves in order to strive for an unambiguous substantiation in the Dutch infrastructure projects. This research makes the underlying factors clear and scales them in order to substantiate the reasoning process for the reserve estimation.

1.2.2 Research questions

The research questions formulated need to provide an adequate solution for the research objective stated above (Verschuren & Doorewaard, 2010). Firstly, a conceptual model is developed in order to schematize the estimation and the actual expenditure of the project reserves. Figure 3 illustrates the visualization of this model.

The research questions are formulated with respect to the conceptual model, where there is a clear difference made between the estimation and expenditure of the project reserves. The framework connects the estimation and expenditure of the project reserves by looking at the underlying factors. The codes in the black circles correspond to the assigned research questions in the research.
The main research question is supported by three sub questions, which all are defined below. All these questions are descriptive, which is consistent with the research objective to provide insights into the project circumstances that result in expenditure of the project reserves.

**Main research question**

**MQ**

What project circumstances should be included by the project organization for a conscious and substantiated decision on the amount of project reserves in Dutch road-widening projects?

**Sub research questions**

**SQ1**

What is the current practice within project organizations in estimating project reserves in road-widening projects?

**SQ2**

What kinds of events lead to the expenditure of project reserves and what are the underlying causes?

**SQ3**

What are the differences and similarities between estimations in current practice and the actual expenditure of project reserves?
1.3 Research methodology

The conceptual model needs data to execute the analyses and eventually achieve the research objective. In order to do so, three successive research parts are defined to obtain the data required: cost experts survey, three case studies and project survey for regression analysis.

The specific objectives and methodologies of these studies are discussed in this paragraph, but first the general research strategy is given.

1.3.1 Research strategy

There are several kinds of data collection used during the research: surveys, interviews and project data files. Interviews and project data files will be the most likely sources of information from the cases. Interviews allow a pretty flexible research design (Verschuren & Doorewaard, 2010), where surveys need to be fully prepared from the first day on. A sequential method is used to adjust the following studies with the obtained insights and knowledge.

Research structure

The global research framework is defined in order to structure the research. This framework is illustrated in Figure 4 and is a visualization of the steps involved to meet the objective stated. Research is divided into four specific phases: preparation, analysis, validation and conclusion. The cost experts survey, case studies and project survey are included in the framework.

Preparation consists of the establishment of literature study and practical preparation for the research like the acquisition of project data. This literature study focuses on the topics of risk management, cost management, project organization, decision-making process, project complexities and estimation methods. These are elaborated in chapter 2 and are considered as scientific framework for this research.
Qualitative or quantitative

This research is qualitative oriented on the factors that affect the estimation and expenditure of the project reserves. Interviews in general produce mainly qualitative data through explanations and descriptions. These qualitative observations of the project data files are underpinned with the corresponding costs in order to obtain weighted ratios of effects. Project members within the project survey are asked to scale the established qualitative factors in order to quantify the results. This quantification is needed for statistical analysis.

Empirical research or desk research

This is an empirical research with interviews and data collection within case studies. Data is based on individual knowledge from interviewees and observations from the researcher. Project data files will generate more desk research on the initial projects reserves and its final expenditure.

1.3.2 Research units

Selection of the cases can provide a strategic sample of research units (Verschuren & Doorewaard, 2010). Research units should be selected from a wide range of possible infrastructure projects, which could be pretty different from one project to another. Research focuses on road-widening projects, because of its continuous relevance due to the increasing need for mobility and the population growth in combination with a chronic lack of space in the Netherlands. This relevancy resulted in 2003 in the ‘Spoedaanpak’, described in the law ‘Spoedwet Wegverbredingen’ (Ministerie van Infrastructuur en Milieu, 2003). Main
purpose is to accelerate modifications for the current bottlenecks in the main road infrastructure. These measures result in an acceleration of 2 years for the main procedures before construction. Most of the projects executed on the occasion of this law are nearly finished at the moment of writing, which is essential for the research when analysing expenditure of the project reserves. Experiences of events that caused expenditure of the reserves are fresh in memory in that case.

Eventually, three projects are selected for the case study. For confidential reasons, these project are referred to as project A, B and C. The general case descriptions are provided in appendix C.

1.3.3 Cost experts survey

According to the problem analysis expert judgment is very important towards the estimation of the project reserves. Main input for this expert judgment is intuition. This intuition could be based on historical experiences, but is still considered as very subjective. Substantiation of an expert judgment is very hard, because the reasoning process is not visible. Goal of this part of the research is to obtain insights into the reasoning process of cost experts to the estimated project reserves. In other words, answers are searched for the question marks in Figure 5.

![Figure 5: Reasoning process is invisible](image)

The used method is the submission of a questionnaire towards all cost experts of Rijkswaterstaat. The respondents are forced to use a deterministic method in order to figure out the consistency among the cost experts within one organization. Baccarini (2005) concludes that 77% of the project teams use this deterministic method for the project reserves.
Analysis of the obtained data includes distribution analysis of the submitted. Conclusions on this survey will provide answers and insights referring to sub research question 1 (see page 77).

1.3.4 Case studies

The three cases studies are the main source of information for this research and results in the collection of the primary knowledge on the project reserves. The case studies mainly consist of a theoretical approach in order to compare estimation and expenditure of the project reserves. The approach is defined as theoretical, because in practice there is not clear whether or not expenses are financed by the project reserves. The experiment is structured as shown in Figure 6 in order to obtain comparable data of each case and remain within research scope.

![Conceptual model for the case studies](image)

Figure 6: Conceptual model for the case studies

Project circumstances are reduced from the occurred risks during the project and described by the project complexities and the project factors, where the latter is defined as cause of the cause. More on project complexities in paragraph 2.1. The numbers in the model correspond with the following four case questions relevant towards the described theoretical approach.
Case questions

CQ1  What are the underlying causes for occurred risks?

CQ2  To what extent could they initially predict risk events in the project?

CQ3  To what extent have exogenous events impact on the actual expenditure of project reserves?

CQ4  What could be concluded considering the factors that are involved in the actual expenditure of the project reserves?

As visual in the conceptual model, the following data is needed from in the projects in order to answer the case questions.

- Initial risk file
- Occurred risks
- Project scope

This method requires and assumes a proper project administration. In case of administration defects, the databases have to be modified by hand and checked by the team members in order to obtain the dataset needed.

Interviews are conducted in addition to this required project information to obtain practical knowledge of the processes and factors behind the project reserves. As Mintzberg (1979) mentioned: “We uncover all kinds of relationships in our hard data, but it is only through the use of this ‘soft’ data that we are able to ‘explain’ them”. This qualitative data is obtained from interviews with the project manager involved, Project control manager and risk manager.

The case studies result in the primary knowledge, which refers to knowledge about the factors that affect the project reserves during the realization phase and globally elaborate about the relations between those factors. Findings are discussed with the literature in mind. Conclusions on the case studies contribute in successfully find the answers on research question 2 and 3. This knowledge also functions as starting point for the project survey.
1.3.5 Project survey

The main objective of this survey is to project the gained insight from the case studies on multiple road-widening projects of Rijkswaterstaat. This objective could be divided into two sub objectives. (1) Firstly, insights from the case studies are tested on a wider range of projects to increase the scientific value of these insights and in addition, (2) relations between project circumstances and the actual spent project reserves are tested statistically.

Eventually, the project circumstances is structured in three categories: project facts, judgment factors and external factors. Project facts describe the project on the basis of facts. The judgment factors include scalable factors, which cover the main causes for the expenditure of the project reserves from the project case studies. Project properties are also linked to external factors to investigate the influence of this data. Eventually, a reference database is collected with specific properties and circumstances of the road-widening projects.

The obtained data will be analysed by several tests to discover significant relations between the defined project factors and the final used project reserve. Correlation analysis and linear multiple regression analysis are the main tools for the analysis.

1.3.6 Verification and validation

Validation is crucial for the above-described kind of statistical models and for the overall applicability of the research results. Firstly, the project case studies are verified internally by comparing the collected project data with the explanations and clarifications from the interviews. Output of the qualitative data from these case studies is validated externally by the project survey. Both results should be in line with each other to accept these results as valid.

The statistical model is validated according to an x-fold cross-validation method (Moore, 2007), where the dataset is split up into x sections. The model is calculated x-times, where each time one of the sections is functions as validation data. Eventually, a 8-fold cross-validation is chosen to reduce the loss of calculation data and therewith significance of the model.

Overall results and recommendations are assessed on its validity by an expert meeting on 15th November 2013. Subjects and slides of this meeting are presented in appendix E.
1.3.7 Research delineation

Assumptions are needed to make the research workable. The delineation and the choices made are discussed in the next chapter. The general research delineation is listed below and refers to corresponding page within the theoretical perspective.

- Events are categorized within five types of complexities: technical, social, financial, legal and organizational (page 18)
- Influences of the time complexity is examined separately (page 19)
- The estimation of the project reserves is seen as a one-time event; possible continuous estimation of the reserves is excluded in order to focus on the quality of one single estimate of the reserves
- The moment just before tender is set as benchmark for the estimates, because of the importance of this milestone (page 23)
- The research is focussed on the project reserves in terms of money; possible reserves on time and quality management are left behind, because these follow other mechanisms and are calculated in other way
- The perspective from the internal project organization is set to focus on project management success (page 20), in this way portfolio of projects are included in the analysis
- There is no difference made between types of project contracts (page 28)
- There is a focus on risks, not on opportunities (page 25)

The development of the project reserves over time is interesting, but not crucial in this research. Estimators make their estimate at one moment in time in order to propose an amount of reserves for the rest of the project independent of the moment of possible expenditure. This research checks the accuracy of this estimate and its substantiation by analysing the events from that moment on till project closure. For this research is chosen for the project estimation during the tender phase, because of the importance of the estimate for this milestone.
1.4 Report overview

The structure of the report is straightforward with the three main parts: introduction, analysis and conclusions.

This report provides answers to the research questions stated in paragraph 1.2.2. Table 1 gives an overview of where these answers could be found.

<table>
<thead>
<tr>
<th>Research question</th>
<th>Answers found in</th>
</tr>
</thead>
<tbody>
<tr>
<td>MQ What project circumstances should be included by the project organization for a conscious and substantiated decision on the amount of project reserves in Dutch road-widening projects?</td>
<td>Chapter 4, 6 and 7</td>
</tr>
<tr>
<td>SQ1 What is the current practice within the project organization in estimating project reserves in road-widening projects?</td>
<td>Chapter 3</td>
</tr>
<tr>
<td>SQ2 What kinds of events lead to the expenditure of project reserves and what are the underlying causes?</td>
<td>Chapter 4</td>
</tr>
<tr>
<td>SQ3 What are the differences and similarities between estimations in current practice and the actual expenditure of project reserves?</td>
<td>Chapter 5</td>
</tr>
</tbody>
</table>
This chapter provides an exploration of the relevant literature on the research topic. A scientific framework is created to cover current scientific knowledge in the relevant areas of knowledge. The chapter starts with a broad view on infrastructure projects in order to zoom in on several topics involved.
2.1 Infrastructure projects and their complexities

Construction of civil infrastructure is of all times and has become more and more complex. The construction industry has great difficulties to cope with this increasing complexity (Baccarini, 1996), which puts pressure on project management. Success of project management is measured against the performance on cost, time and quality of the project (Cooke-Davies, 2002), also called the project management triangle. Changing one of the aspects, should results in adaption of the others, which makes them correlated. In this way of thinking, Cooke-Davies gives another definition for overall project success, which is measured against the overall objectives of the project. The disciplines involved, relevant to this research, are part of project management and its tools to manage a project, which is the reason to focus on project management success instead of overall project success.

Project complexities

The western part of The Netherlands is a highly populated area with lack of space for new infrastructure. These circumstances contribute to the increasing project complexity nowadays. There are a lot of definitions within literature for project complexity in the construction industry, where most definitions refer to interrelations and interdependency between project components in a system (Edmonds, 1999; Hertogh & Westerveld, 2010; Vidal & Marle, 2008). Project complexity is the property of a project, which makes it difficult to understand, foresee and keep under control its overall behaviour, even when given reasonably complete information about the project system (Vidal & Marle, 2008). Complex projects, like infrastructure projects, can only be fully understandable with reasonably complete knowledge. This is more like a utopia, because it is impossible to have this reasonably complete knowledge or information about a project, which is unique by definition. Baccarini (1996) defines the term project complexity as 'consisting of many varied interrelated parts' and can be operationalized in terms of differentiation and interdependency. In addition to this definition, Baccarini elaborates on the technical and organizational aspects of complexity, where integration by coordination, communication and control is the key to success.

The interdependency of components is a central topic in project complexity literature, which results in a clear distinction between detail and dynamic complexity as two perspectives on complexity (Hertogh & Westerveld, 2010). Detail complexity is defined as the distinct number of components or parts that make up a system and dynamic complexity refer to the unpredictability of a system’s response to a given set of inputs, driven in part by the interconnectedness of the many parts that make up the system (Bozarth, Warsing, Flynn, & Flynn, 2009).
Side note is that the assessment of complexity is considered as subjective, because a situation could be seen as complex by one person, but simple by another (Hertogh & Westerveld, 2010). Hertogh and Westerveld define 6 types of complexity within large infrastructure projects: technical, social, financial, legal, organizational and time. The six categories are defined briefly in order to apply these complexities to the causes of possible reserve expenditure.

*Technical complexity* is related to technical difficulties, uncertainties and unproven technology in the projects. Unproven technology is related to innovation within new projects. A dilemma arises whether or not to implement innovation into the project. Because of the large-scale effects of most infrastructure projects, innovation could provide opportunities for production efficiency that could have an effect on the financial benefits. On the other hand, usage of innovative technologies attracts more risk towards the project. When ‘proven’ technologies tend to fail, solutions are already present and ready to prevent failure. These reactive solutions are not present when dealing with unproven innovative technologies, which increase the probability of extra project costs.

*Social complexity:* infrastructure projects have an extreme impact on the social environment, which takes place in multiple arenas. Multiple interests and goals are influencing the decision-making. A project organization has a lot of external interaction with stakeholders with these different interests. All social perceptions and influences are included into this category, which also includes political aspects.

*Financial complexity:* large infrastructure projects tend to be expensive and need to create value for money. Estimation of costs and benefits is hard to calculate and requires a lot of assumptions to come to a conclusion. Additionally, these costs and benefits are not equally distributed within a society, which illustrates a relation to social complexity. Compensation for burden or nuisance is applied to level out costs and benefits.

*Legal complexity* is related to the extensive legislation and rules, which are changing over time and space and could be conflicting as well. These laws are needed for the processes for partial planning and so on, but all people involved need space to operate. Complexity could also arise in legal matters, when rules are absent or diffuse. In that case the stakeholder network is of major importance to avoid trouble. Most of the agreements with the stakeholders are recorded into contracts, which result in an enormous amount of contracts for consultants, contractors and suppliers.

*Organizational complexity:* the complete network of stakeholders within infrastructure projects can be very large and has to be handled by the project organization (external processes). Also the project organization itself contains many processes that could interfere mutually (internal processes).

*Time complexity:* Construction of infrastructure projects is very time-consuming and can take decades. There are a lot of developments during this long time frame because of its dynamic environment. This category of complexity includes all disturbances towards project success as a result of non-linear implementation processes during the construction. This category is
related to all other complexities, because time makes others even more complex. Therefore, time complexity is handled separately in the research.

Figure 8: Illustration of the complexities in infrastructure projects (Hertogh & Westerveld, 2010)

Figure 9 shows the results of the research done by Hertogh and Westerveld. The values illustrated are the average of the interviews and events in their study. They showed that social, organizational and technical complexities are most presented in infrastructure projects. Social complexity is dominant, because changes in technical, organizational, financial or legal matter cause social complexity as well.

Figure 9: Relevance of complexities towards infrastructure projects (Hertogh & Westerveld, 2010)

### 2.2 Project organization

The government is the main sponsor and client for the construction and maintenance of public infrastructure, where the Ministry of Infrastructure and Environment is responsible.
The minister also have a lot of influence in the decision-making as the main sponsor, which is discussed in chapter 2.3. Rijkswaterstaat, as the executive body, is responsible for the state of the road infrastructure.

The defined problem could be approached from different perspectives. The perception of the project organization is set in the research, because they are responsible for the project management to succeed the infrastructure projects. Project management success is mainly applicable for this project team. One specific project organization is part of the complete organizational model of the Ministry of Infrastructure and Environment and Rijkswaterstaat, which is illustrated briefly in Figure 10.

As shown in Figure 10, the project organization is part of a huge network of divisions linked to the organizational complexity. Road-widening projects are mainly part of the division of large projects and maintenance (Dutch: Grote projecten en onderhoud - GPO), which have numerous projects in its portfolio. This organizational structure is introduced very recently in April 2013 (Rijkswaterstaat, 2013).

The different levels in the organizational chart have different responsibilities. There is a difference between the programs and the projects. The project organization that is only responsible for success of just one project in contrast to the program manager who is responsible for the overall success of all projects in the portfolio. The program manager is exposed to scarcity of its resources and has to divide the available resources carefully to maximize economic benefit. This phenomenon of scarcity is not directly applicable for the project-role of the project organization.

Project organizations within Rijkswaterstaat are defined towards the Integrated Project Management (IPM) model (Heeren, 2010), which defines five main roles: project manager,
project control manager, environmental manager, technical manager and contract manager. Definitions and the Dutch translations are provided in Table 2.

Table 2: Definitions (Heeren, 2010) and Dutch translations of the five IPM-roles

<table>
<thead>
<tr>
<th>English</th>
<th>Dutch</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project manager</td>
<td>Project manager</td>
<td>Primarily responsible for the achievement of project success</td>
</tr>
<tr>
<td>Project control manager</td>
<td>Manager projectbeheersing</td>
<td>Responsible for the insight into the state of affairs in the field of quality, money, time and scope at any time in the project</td>
</tr>
<tr>
<td>Environmental manager</td>
<td>Omgevingsmanager</td>
<td>Responsible for the social embedding of the project and functions as intermedium between the project and its environment</td>
</tr>
<tr>
<td>Technical manager</td>
<td>Technisch manager</td>
<td>Responsible for the technical content of the project</td>
</tr>
<tr>
<td>Contract manager</td>
<td>Contractmanager</td>
<td>Responsible for the process-based management of determining the purchasing needs, the preparation of the procurement plan, contract preparation, tendering and contract management</td>
</tr>
</tbody>
</table>

The role of project manager is to have an overview of the state of affairs and is seen as a central figure in the project organization, which is illustrated in Figure 11. The roles of, for example, risk manager and cost estimator are not directly mentioned (Rijkswaterstaat, 2012) in the IPM-model, because these are considered as supporting and advising roles for the project organization and are part of the project control team. Notwithstanding this fact, there is a lot attention for both disciplines, because of direct influence on the project costs.

Knowledge of the organization of the public client is needed for analysis on the occurred risks, especially for the definition of the exogenous influences and the handling of the
corresponding costs. Insights into the internal project team are mentioned to understand the internal processes within the project organization as part of the organizational complexity.

2.3 Decision-making process

The decision-making process is crucial for the budget decision on infrastructure projects and indirectly for the amount of project reserves. Also the timing of the decisions is important when discussing the establishment of the project reserves. This paragraph briefly elaborates on topics like budget decisions and the Tracéwet.

In order to increase the quality and quantity of the Dutch infrastructural network, the Ministry of Infrastructure and Environment develops a multiannual plan, in Dutch called the ‘Meerjarenprogramma Infrastructuur, Ruimte en Transport’ (MIRT). The selected infrastructure projects should provide maximum economic benefit for The Netherlands based on economic analysis. The plan includes the assigned budget for each project.

The decision-making process for infrastructure projects is described in the Tracéwet, which is comparable with the English Record of Decision (ROD). This law includes all procedures for the implementation of new infrastructure projects or widening of existing infrastructure. Because of the major impact of the construction of infrastructure on the surrounding environment, participation of stakeholders is included. Modification of existing infrastructure requires the shortened procedure, which includes two possibilities for participation of stakeholders.

The total process of the Tracéwet includes several budget decisions made by the ministry. The three most important budget decisions are elaborated in Table 3.

<table>
<thead>
<tr>
<th>Phase of the Tracéwet</th>
<th>Budget decision</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decision to start</td>
<td>Budget decision for exploration</td>
<td>Initial budget to start exploration of alternatives. No reservation is made for the realization yet.</td>
</tr>
<tr>
<td>Preferential decision</td>
<td>Budget decision for realization</td>
<td>First budget decision estimation based on early cost estimate</td>
</tr>
<tr>
<td>Project decision</td>
<td>Implementation order</td>
<td>Definitive budget decision based on elaboration of project plans</td>
</tr>
</tbody>
</table>

Table 3: Budget decisions in relation to the phases of the Tracéwet (Rijkens, 2013)
The phases for project establishment are illustrated in Figure 12, including the spatial planning, budget decisions and contractual decisions. The latter mainly consists of two points in time: contract award to the constructor to execute the work and the moment of delivery.

![Diagram of project phases and decisions](image)

**Figure 12:** Illustration of the project establishment according to the Tracéwet including spatial planning, budget decisions and contractual decisions (Rijkens, 2013)

There are two main fields of research defined in the figure above: estimation and expenditure of the project reserves. The project budget is finally defined in the project decision, which also includes the final decision on the project reserves included. Within the research, this point in time is seen as the ultimate determination of the reserves (point A). From that point on, expenditure of the project reserves could occur.

### 2.4 Risk management

Uncertainty is a problem for every project and every stakeholder in the civil engineering, from client to contractor. All projects have to deal with it, so it has to be part of overall project management in the form of risk management. In a more broad sense it is called uncertainty management, which applies the covering of threats (negative effect) as well as opportunities (positive effect) within the projects. Versteegen and Rijkens (2007) define uncertainty as starting point which eventually could result is losses or gains for the project (see Figure 13).
Biggest difference between risks and opportunities is that a risk threatens the project goals, while taking opportunities cause enrichment of those goals. In this way, occurred risks are more visible. The influence of risks is considered as more influential on the expenditure of the project reserves, which results in a focus on risks within this research.

Risk management is part of the pre-project planning to obtain knowledge about the future work. The degree in which pre-project planning is executed is crucial for the final results of a construction project (Gibson Jr, Wang, Cho, & Pappas, 2006), which confirms the importance of risk management. Through formal preproject-planning effort, risk is reduced, cost performance can increase by as much as 20%, and schedule performance by as much as 40% (Hamilton & Gibson Jr, 1996).

Three kinds of uncertainty

Focussing on uncertainty results in the definition of three kinds of uncertainty: decision uncertainty, knowledge uncertainty and future uncertainty (CROW, 2010). These categories of uncertainty have a clear difference and identified risks and occurred events could be identified to one of these uncertainties.

Decision uncertainty covers the uncertainty concerning the decisions of the sponsor. Within the scope of a project, there is space for multiple solutions to reach the project goal and all those solutions have different consequences, in time or costs. This type of uncertainty is mainly presented in the early project stage, when most of the decisions still need to be made.

Knowledge uncertainty is the result of a lack of knowledge of the situation or system. Estimations need to be made to come to a proper project design and here is uncertainty involved. There is always uncertainty involved when dealing with estimations. Backwards, any statement about uncertainty is by definition estimation. Conclusion is that estimations and uncertainty are directly linked.
Future uncertainty is reflecting on uncertainties linked to possible future events. Future events could have negative (threats) or positive (opportunities) influence on the project success and are mainly within the project scope. This type of uncertainty is main category that is applicable when it is not decision or knowledge uncertainty.

**Probability**

Another starting point for this discipline is probability, where Frank H. Knight defined three types of probability: risk, statistical and uncertainty (Norman & Shimer, 1994), which also implies a clear difference between risk and uncertainty. Risk is defined as objective probability, where parameters are known and uncertainty as subjective probability, where parameters are not known. In the latter case, these parameters need to be estimated without any references. Statistical probability is a combination, where parameters could be estimated based on historical data. The defined problem in this research (see paragraph 1.2) is seen as a statistical probability in Knight’s theory, where prior observations could increase the accuracy estimation of the project reserves.

Perspective on risk and its probability is dependent on the applicable conditions, referring to Bayes’ theorem. The notation of this conditional probability is P(A|B), to be read “probability of A given B”, where B is the condition given. In the case the project reserves could be formulated by the following probability.

\[ P(R|C_1 \cap C_2 \cap C_3 \cap \ldots \cap C_n) \]

R = cost overrun
Ci = all project conditions

In addition, possible events could also be correlated. Correlation analysis gives insights into the risk profile through the relations between separated risks. This analysis is excluded in this research to focus on the project factor and the events that affect the project reserves instead of the relation between those events.

**Risk properties**

In order to deal risks, they need to be quantified. Risks are described as probability of occurrence and the corresponding impact. This impact is mostly described in terms of money and calculated with the following equation. These two products are the main characteristics of identified risks in the risk register.

\[ Risk = probability \times impact \]
Occurred risks have characteristics that are of interest for this research. Two basic separations are made.

- Endogenous or exogenous
- Known unknown or unknown unknown

Risk could come from inside (endogenous) or outside (exogenous) the project scope. Decision uncertainty is mostly exogenous, because this external decision could result in consequences for the project scope. This research is about the expenditure of the project reserves, so when exogenous risks have affect on the project reserves, these events are included in the analysis. When extra budget is provided without a change of scope, this is seen as a direct complement on the project reserves.

There could be discussions about whether or not an event is endogenous or exogenous. A lot of exogenous events come from the client, who was originally also the main decision-maker in case of the project requirements. These changes of requirements are seen as an exogenous event within project organization, although endogenous to the project client. Project management success is focused on the project management triangle: cost, time and scope of the project itself. For that reason, additional requirements from the project client are seen as exogenous for this research.

The second separation is already elaborated in the introduction chapter. This research defines this property of event on the fact whether or not a risk is identified during the risk analysis. In other words, known unknowns are included in the initial risk file.

**Black swan risks**

Black Swan risks are a special category of risks. Taleb (2007) defines a Black Swan as an event that lies outside the regular expectations and carries an extreme impact. Typically for human beings is the tendency to make these events explainable and predictable after occurrence. These events could have an enormous impact on the costs, time and quality of the project. Some of these risks have probability of occurrence that is so small that accurate risk estimates cannot be based on empirical observation (Slovic, Fischhoff, & Lichtenstein, 1982). Question arises about whether or not to include these types of risks when considering the amount of project reserves.

**Risk perception**

Perception on a specific risk is dependent on a lot of factors (Sjöberg, 2000) and most on the perspective. A penalty in a football game is seen as a threat for the defensive team and an opportunity for the offensive team (Versteegen & Rijkens, 2007). The RISMAN-method describes seven categories to assess risks in the construction sector (Kennisnetwerk Risicomanagement RISNET, 1996). The following categories are defined: technical,
organizational, social, political/administrative, financial/economical, legal and spatial. These are clearly related to the defined complexities, which increases the validity of the complexity-framework used. Main difference between the two frameworks is the category time, which is not mentioned within the RISMAN categories.

In theory, the project organization should be able to increase its project knowledge during the preparation phase. In practice, paradoxically, this increase of project knowledge is more likely to result in an increase of uncertainty rather than a decrease (Versteegen & Rijkens, 2007). Probably, this increase of project knowledge also increases the knowledge of the amount of sources of uncertainty during the project. This is could be linked to human optimism about his own capabilities, the theory of the optimism bias in estimation. This is further discussed in the next paragraph.

Risk allocation

Consequences of occurred risks need to be carried by one of the contract parties. In other words, risks are allocated to one or multiple stakeholders involved. Each risk should be allocated to the party which is in power to handle the risk (Bing, Akintoye, Edwards, & Hardcastle, 2005). Risk allocation is described into contracts, which clearly linked to the legal complexity of infrastructure projects.

Choice of contract does mainly affect the organizational structure and payment structure. This allocation is also related to the endogenous or exogenous risks, where the public client carries most of the exogenous influences. In that case, the difference in contract types is considered as irrelevant towards the research topic, because cost estimation and risk allocation of exogenous influences are independent from the contract type.

2.5 Cost estimation

Estimation of project costs is the basis for any project decision, although there is a clear difference between the budget decision and the cost estimation during the project. The budget decision by the project sponsor, described in chapter 2.3, is a clear top-down approach for project costing. Cost planning is possible in three ways (Maylor, 2010), as showed in the equations below.

\[ 1. \text{budget} = \text{costs} + \text{reserve} \]
\[ 2. \text{costs} = \text{budget} - \text{reserve} \]
\[ 3. \text{reserve} = \text{budget} - \text{costs} \]
Although all equations are mathematical the same, these equations do have a very different meaning when looking at the dependency of the terms. The first is considered as target costing, where the sponsor fixes budget. Application of the third equation would mean that the reserve is not estimated, but is derived from the terms budget and costs. This would mean that the amount of project reserves involves not any consideration at all, which results in none substantiated choice by definition.

So, future project costs are one of the main parameters for project assessment, but these costs are subject to uncertainty as well. They need to be estimated. Maylor (2010) describes several estimating techniques that could be used to estimate the full project costs. These are briefly elaborated in Table 4.

<table>
<thead>
<tr>
<th>Estimation techniques</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parametric estimating</td>
<td>Breakdown into units that could be estimated and multiplied by the cost per unit</td>
</tr>
<tr>
<td>As ... but ...s</td>
<td>Estimation based on previous experiences with several adjustments to come the a valid approximation</td>
</tr>
<tr>
<td>Forecasts</td>
<td>The best guess, this could include margins</td>
</tr>
<tr>
<td>Synthetic estimation</td>
<td>In case of repetitive work in a project, work measurements is used to analyse the scale of effort that is needed</td>
</tr>
<tr>
<td>Use of learning curve effects</td>
<td>In case of repetitive work in a project, improvement of the craftsman’s skills could lead to a decrease of time and money needed to prefer a task.</td>
</tr>
<tr>
<td>Wishful thinking</td>
<td>Not as much a technique, but more a cause of estimate adjustment. Maylor listed four causes: optimism bias, politics, improper use of estimates, failure to be systematic about planning.</td>
</tr>
</tbody>
</table>

Most of the direct and indirect project costs are estimated on the basis of parametric estimating, because unit quantity and unit costs are easy to approximate. This is not the case for estimation of the project reserves, where most of the time a percentage of the total cost estimation functions as an estimate. The assessment of this percentage is mainly based on expert judgment, here considered as a black box method with input (project information) and an output (percentage for project reserves). The reasoning process within this black box is invisible, which results in an estimate that is hard to substantiate.

Next to the percentage method, there are several other estimation models for estimation the needed amount of project reserves. An overview is provided by Baccarini (2006). This research focuses on the method called factor rating, which is also carried out by Oberlender and Trost (2001). They conclude that the factors that affect estimations for the construction in the process technology and recommend further research for infrastructure projects.
Reserve estimation based on a percentage of the total project cost is an example of a deterministic approach, where Figure 2 in chapter 1.2 is an example of a probabilistic approach. This latter approach is based on the probability of a certain outcome with given margins for its elements. One of the problems with this probabilistic approach is discussed in the problem analysis (chapter 1.2).

As mentioned before, the SSK-method (Dutch: ‘standaardsystematiek voor kostenramingen’) is the most used cost estimation method in The Netherlands. It describes some steps for estimation of costs and is applicable for all construction projects. The SSK-method globally divides the project costs in direct costs (cost of materials), indirect costs (costs of labour) and the project reserves. An extra addition on the method is the lifetime costs to make it compatible with the project lifecycle approach.

One of the alternative method for estimation or correction on estimations is reference class forecasting (Kahneman & Tversky, 1977), which is based on theories of planning and decision-making under uncertainty (Flyvbjerg, 2008). Kahneman and Tversky argued that inaccuracies by optimism bias and strategic misrepresentation in estimation are mostly assessed from an ‘inside view’, focusing on the internal processes and uncertainties. Instead, an ‘outside view’ is preferred by focussing on results of previous, similar projects using their distributional information. Within the method, this distributional information is separated in multiple reference classes.

Underestimation of project costs including its reserves results in cost overrun, which refers to a cost increase and budget overrun at the same time. Cost overruns in infrastructure projects are pretty common (Flyvbjerg et al., 2003), which causes a lot of negative publicity. That is a reason for extensive research on the cause for this cost overrun, which tend to the inaccuracy of estimations (Flyvbjerg et al., 2003; Trost & Oberlender, 2003). Results of this inaccuracy are diverse. Accurate cost estimations of these projects are very important for these kinds of projects for adequate decision-making on the economic and financial benefits (Oberlender & Trost, 2001). Oberlender and Trost also stated that inaccurate early estimates could lead to lost opportunities and lower returns. Underestimated costs and overvalued revenues affect the cost-benefit analysis (Flyvbjerg et al., 2003).

Flyvbjerg (2002) did his research on 258 European megaprojects and concluded that there are three aspects that cause inaccuracy of estimations: technical, political and psychological. The technical aspects of inaccuracy are related to the technical details of a project. Technical feasibility of the project needs to be secured for the start of the construction. The psychological aspects cover a lot of psychological mechanisms that influence the personal perspective on uncertainty and affect the accuracy of estimations on this uncertainty. Examples are the optimism bias, Parkinson’s law, Hofstadter’s law and Pygmalion effect. These phenomena are explained briefly in Table 5.
<table>
<thead>
<tr>
<th>Phenomenon</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimism bias</td>
<td>Optimism bias is inconsistent with the independence of decision weights and payoffs found in models of choice under risk and uncertainty, such as expected utility theory, subjective expected utility, and prospect theory (Bracha &amp; Brown, 2012)</td>
</tr>
<tr>
<td>Parkinson’s law</td>
<td>The demand upon a resource tends to expand to match the supply of the resource (Gutierrez &amp; Kouvelis, 1991)</td>
</tr>
<tr>
<td>Hofstadter’s law</td>
<td>It always takes longer than you expect, even when you take into account Hofstadter’s Law (Hofstadter, 1985)</td>
</tr>
<tr>
<td>Pygmalion effect</td>
<td>The greater the expectation placed upon people, the better they perform (Rosenthal &amp; Jacobson, 1968)</td>
</tr>
</tbody>
</table>

The political – economical aspect refers to the influence of decision-makers on the cost estimations of projects. When the reserves of infrastructure projects are kept low to convince the decision-maker, who is assigned democratically in case of a public project sponsor. Decision-makers base their decisions on manipulated unsubstantiated project data, which causes a democratic deficit: decisions are based on manipulated information, which makes these decisions non-democratic (Flyvbjerg, 2007). Flyvbjerg prescribes some solutions for these problems on estimations, which are mainly focused on accountability. Estimators that involve strategic behaviour should be punished by a code of ethics (Flyvbjerg et al., 2003; Flyvbjerg et al., 2005).
In the upcoming pages, there is a focus on the estimation of the project reserves in practice. The following research question is related to this chapter, where observations and analysis are discussed to provide an answer.

**SQ1**

*What is the current practice within project organizations in estimating project reserves in road-widening projects?*

There are mainly three topics included in the analysis: (1) expert judgment as basis for estimation, (2) estimating reserves in the cases and (3) observed inaccuracy mechanisms of estimations. Insights into these topics provide knowledge to give an underpinned answer to the question stated.
3.1 Expert judgment as basis for estimation

This paragraph elaborates on the analysis of the survey among the cost experts of Rijkswaterstaat. The methodology of the research is introduced in chapter 1.3.3. Several factors are elaborated to create insights into the reasoning process of the cost experts of Rijkswaterstaat. The input request towards the cost experts resulted in a response rate of 58% (32 out of 55).

A first inventory of important project circumstances was the input for the survey. The initial list of factors that could affect the project reserves is derived from previous research (Oberlender & Trost, 2001) and categorized towards the complexities within infrastructure projects (Hertogh & Westerveld, 2010).

Analysis

The analysis is done in two parts: estimated reserve and distribution of judgments. Eventual gathered insights are shown in the end of the paragraph.

Estimated reserve

Independent variable is the estimation of the needed project reserves for the fictive case description. Cost experts gave their estimation as a percentage on top of the total project cost. The case description was very briefly formulated and straightforward without any risk information. In this way, cost experts were forced to use intuition on this case. The survey shows that the reserve estimates by the experts range from 5% till 50% on top of the total project costs for the given case (see Figure 14).

The diagram of the estimated project reserves in the figure below tends to be lognormal distributed, due to a longer tail on the right. The corresponding mean and standard deviation is respectively 18.91% and 9.81%. The median of the dataset is located to the left of the mean, which results in a positive skewness of the distribution. The cumulative function indicates a smooth S-curve, which illustrates the relation between a specific estimated percentage and the share of cost experts till class of estimates.

The observed range of judgments arise doubts about the consistency of expert judgments. Experts have different considerations to come to their judgment. In this way, subjectivity in the estimation of the reserves is clearly visible.
Distribution of judgments

In total 23 factors were presented to the cost experts with the question to scale the factors on its influence on the amount of project reserves estimated. The final distribution of the expert judgments per factor is visible in Figure 15 on page 36. The boxplots illustrate the 25th, 50th and 75th percentile; so narrow green boxes represent a closer match of judgments from the cost experts. In that case, there is more agreement upon this factor. Some of the factors do directly show a trend towards one side.

There is not always a clear trend visible, which could have two causes: (1) there is no consistent opinion on those factors or (2) the presented definition of the factor is not clear. This is mainly the case by the factors social support of the project (#12 in Figure 15) and stability of the scope (#7 in Figure 15). The spread of expert judgements could undermine the importance of these particular factors.

There is clear difference visible in the applicability of exogenous factors, like uncertainty around law and regulations (#13 in Figure 15). Also social factors tend to be exogenous and score relatively low like political support for the project (#21 in Figure 15). Still, the scores of these factors are not minimal, which implies that these factors are taken into account in some way. Some of the cost experts refer in their comments to a fixed project scope with a corresponding estimate of budget, where exogenous factors are excluded. This raises the question about whether or not project organization must take exogenous influences into account. Paragraph 4.3 continues on this topic.

Figure 14: Distribution and its properties of the estimated project reserves by cost experts (n=32)
Figure 15: Expert judgments of project factors on the degree of applicability towards estimation of the project reserves

**Judgment scale:**

1. Project factor is **never** in my consideration according to the amount of project reserves
2. Project factor is **sometimes** in my consideration according to the amount of project reserves
3. Project factor is **often** in my consideration according to the amount of project reserves
4. Project factor is **always** in my consideration according to the amount of project reserves

**Judgment scale:**

1. Project factor is **never** in my consideration according to the amount of project reserves
5. Project factor is **always** in my consideration according to the amount of project reserves

---

36
All factors were initially categorized with the definitions of the complexities in mind. Figure 16 is generated on the basis of the average score of the factors per complexity. Especially technical and time factors are taken into account. This could be explained by the fact that these factors are relatively easy to quantify. Previous research on the complexities concludes social complexity as very important within infrastructure projects (Hertogh & Westerveld, 2010), a complexity which tends to be relatively underexposed by cost experts, like shown in the figure below.

Complexities observed in the estimation of reserves

![Complexities observed in the estimation of reserves](image)

Figure 16: Distribution of the judgment according to the defined complexities

*Insights into expert judgment*

Main conclusion of this cost experts survey is that there is no clear consistency among the cost experts about the involvement of exogenous influences and hard-to-quantify factors, like social and organizational. In addition, the submitted expert judgments are not completely consistent towards the same case, resulting in a lot of subjectivity according to the estimation of the reserves. This does not mean that intuition of an expert is not valuable, but apparently multiple perspectives and standards are used in order to give the forecast.

Goal of the survey was to generate insights into the reasoning process of the cost estimators. Figure 17 illustrates the most important factors that were included in the consideration of the cost experts towards the project reserves, where the factors are scaled to their importance.

Some appointed factors need more specification in further research. Both *direct surrounding of the project* and *unique elements in the project* have huge influence in the experts' opinion, but these descriptions are very broad. These factors are approached more closely in the project case studies. Insights into the expert judgment are taken into account during the project case studies, which are presented in the next paragraph.
3.2 Estimation of the reserves in the case studies

Besides the expert judgments of cost expert, it is also interesting to get insights into the current practice within actual road-widening projects when it comes to estimation of the project reserves. These insights are collected from the three case studies, where a brief project description is given in appendix C. This paragraph elaborates on the assumptions and principles used by the projects to estimate their project reserves. The analysis is based on interpretation of project data and interview with the corresponding project team members. Firstly, the general findings are discussed, followed by a focus on the contingency reserve and the management reserve.

Perspectives on project reserves

All the interviews started with a relevant question towards this topic: what is the goal of the project reserves? There are different goals identified based on different perspectives, whereby the global distinction is made between the following three perspectives (source: interview project control manager of project C):

- Project management perspective
- Program management perspective
- Political perspective
Firstly, the project management perspective is the most applicable one for the internal project organization. As mentioned before, the project organization strives for project management success, so the goal of the project reserves is to remain within the planned project management triangle of budget, time and scope with possibility of risks in mind (Maylor, 2010). The reserves introduce some more flexibility in the project (source: interview project manager of project C). Part of this purpose is that it is not desirable to ask for more project budget every time a risk occurred (source: interview project control manager of project C). Keywords in the goals of the reserves are flexibility and efficiency.

Secondly, the program perspective on the goal of the project reserves emerges in the combination of multiple projects. Programs like the ‘Spoed aanpak’ have a separate reserve to achieve its goals. Influences from the program on the individual projects are financed by this reserve in case the project reserves are exhausted. This perspective is focussed on program success and does not always take the project management triangle into account. Examples are given in the next chapter.

Lastly, the political perspective is based on the financial stability of decision-making and also linked towards the financial and economical analysis of the business cases. Decision-making takes time and in the meantime the projects parameters should not be changed, which could be realized by adding reserves. An optimum ratio between direct project costs and the reserves does not have priority.

**Observed estimation methods**

Globally, it is said that estimations of the project reserves are based on historical data (Baccarini, 2006), but no historical data or direct reference is found during the case studies. These historical data seems to be ‘soft’ knowledge: opinions and experiences about previous projects. Nobody was able to show ‘hard’ historical data in order to substantiate his or her decision about the amount of reserves.

Besides this observation, in total four different methods for the estimation of the project reserves are observed during the case studies.

1. Project reserves according to the actual risk file, where 40-60% of the project reserves need to be substantiated with the risk file
2. Project reserves according to the direct project costs, where the reserves need to be about 10-20% of the direct project costs
3. Project reserves according to the biggest risk that needs to be covered
4. Project reserves according to the anticipated amendments

The ratios of method 1 and 2 are extracted from risk traffic light model for DBFM contracts (Dutch: Risicostoplichten model DBFM), which is based on the expert opinions from cost experts within Rijkswaterstaat. This model covers the assumptions that are generally made
to derive initial project reserves of DBFM contracts. This model functions as control model for the risk distribution between constructor and public client, where there is a clear division between the realization phase and the exploitation phase. This clear division makes the model also applicable for design and construct contracts. The model does not include different project circumstances, so the ratios functions as a general guideline.

The first method is mostly applied in the projects studied, which creates a huge focus on the risk file. The following paragraph continues on this topic.

3.2.1 Contingency reserve

As stated, the contingency reserve is dependent on the identified risks. This paragraph focuses on the initial identified risks in the case studies and the complexities involved.

Analysis on the initial risk files

It will be clear that the identified risks at the budget decision are crucial. The risk files at the moment of tender from the case studies are analysed to gain insights into this main basis for the determination of the project reserves. Starting point for the analysis is the allocation the initial identified risks.

Allocation of risk

All identified risks in the initial risk file are allocated to one of the stakeholders, for example: project organisation, Rijkswaterstaat and Ministry of Infrastructure and Environment and the main contractor. This research has a focus on the project organization, so influences from Rijkswaterstaat and the Ministry are seen as exogenous. It is interesting to compare the ratios between exogenous and endogenous initial identified risks for each project case in order to distinguish the focus on possible exogenous impacts. It is concluded that, on average, 63% of the initial identified risks are allocated to the project organization and are determined as endogenous risks.
Table 6: Ratio of the risk value that is allocated to the project organization

<table>
<thead>
<tr>
<th>Project</th>
<th>Total number of identified risks</th>
<th>Allocated to the project organization</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project A</td>
<td>44</td>
<td>31</td>
<td>70%</td>
</tr>
<tr>
<td>Project B*</td>
<td>82</td>
<td>56</td>
<td>68%</td>
</tr>
<tr>
<td>Project C**</td>
<td>53</td>
<td>27</td>
<td>51%</td>
</tr>
<tr>
<td>Average</td>
<td>60</td>
<td>38</td>
<td>63%</td>
</tr>
</tbody>
</table>

* Risks for DBFM exploitation phase excluded / ** Risks for plan procedure excluded

Complexities involved

Every risk in the initial risk file of the case studies is assessed and assigned to one of the defined complexities. This gives a clear overview of the kind of risk identified during the tender phase of each project. The results of are presented in Table 7. As mentioned, project B is a DBFM contract, which includes the exploitation of the road for the given amount of years. This addition to the contract also attracts different kind of risks. To make an adequate comparison, these typical DBFM risks are excluded from analysis.

Table 7: Overview of the characteristics of the initial identified risk allocated to the project organization

<table>
<thead>
<tr>
<th>Complexities</th>
<th>Project A</th>
<th></th>
<th></th>
<th>Project B</th>
<th></th>
<th></th>
<th>Project C</th>
<th></th>
<th></th>
<th>Average</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>#</td>
<td>Ratio</td>
<td>#</td>
<td>Ratio</td>
<td>#</td>
<td>Ratio</td>
<td>#</td>
<td>Ratio</td>
<td>#</td>
<td>Ratio</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Technical</td>
<td>12</td>
<td>36%</td>
<td>11</td>
<td>1%</td>
<td>10</td>
<td>43%</td>
<td>11</td>
<td>27%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Social</td>
<td>1</td>
<td>1%</td>
<td>15</td>
<td>13%</td>
<td>4</td>
<td>0%</td>
<td>7</td>
<td>5%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Legal</td>
<td>13</td>
<td>52%</td>
<td>13</td>
<td>50%</td>
<td>4</td>
<td>11%</td>
<td>10</td>
<td>38%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Organizational</td>
<td>1</td>
<td>3%</td>
<td>14</td>
<td>7%</td>
<td>9</td>
<td>46%</td>
<td>8</td>
<td>19%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Financial</td>
<td>4</td>
<td>8%</td>
<td>3</td>
<td>29%</td>
<td>0</td>
<td>0%</td>
<td>2</td>
<td>12%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>31</td>
<td>100%</td>
<td>56</td>
<td>100%</td>
<td>27</td>
<td>100%</td>
<td>38</td>
<td>100%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Comparison between the table above and the results of the cost experts survey is hard to make, because of the exclusion of the time factor in the case studies. Still, the experts are mostly focussed on technical aspects, where legal difficulties are mainly appointed as irrelevant. Analysis on the initial risk files suggests far more legal complexity based on procedures and the possibility of legal failure of project decisions.

As basis for the project reserves, these identified risks try to predict future difficulties during the project. The distribution of complexities assigned for every case is seen as a prediction for the underlying project circumstances during realization, which is also illustrated in the conceptual model on page 7. It is clear that every project have a quite different distribution of complexities involved. Main complexities towards the estimation of reserves in the cases are technical and legal.
Notable risks

Of course there are risk descriptions behind the figures in Table 7. Some risks are briefly described per case to give a better impression of the underlying risks.

The risk file of project A is mainly focussing on legal and technical aspects of the project. Main cause for the huge ratio of legal risks is uncertainty about the interpretation of norms and regulations. In some risks, the contractor is mentioned as the party that has to deal with these regulations, but apparently the project organization takes responsibility. Also the possibility of the cancellation of the route decision (Dutch: Tracébesluit) is identified including huge estimated consequences, but within the database this did not result in an extra risk reservation. Eventually, the route decision is destructed after all, which will be discussed in chapter 4.1.

The majority of the identified risks in project B also have legal aspects, mainly concerning a possible lack of quality of the contract in the tender phase. Investigations during the plan procedure are conducted to secure that the functional requirements are matching the local regulations. Failure of this match is seen as a big risk. This is a contract related risk, but similar risks are found in the other risk files, so this is not seen a typical DBFM risk. Another interest risk with a substantial reservation is ‘insufficient interest of the market during tender’. This risk is closely related to tender result (Dutch: aanbestedingsresultaat), which is described in paragraph 3.3.1.

Project C is different with a risk focus on organizational risks. The project is located nearby other projects, which could affect the possibilities for lane closure in certain period and cause a lack of freedom in the planning of the contractor. This is a typical organizational risk that refers to the internal process within the large organization as Rijkswaterstaat. The second largest risk is technical and is referring to a lack of knowledge about the current state of the infrastructure, which is after all considered as one of the main causes for extra project costs. Paragraph 4.1 elaborates on this.

Remarkable are the exogenous risks concerning possible negative tender results. Negative results are identified as exogenous in the initial risk files, so the public client (Rijkswaterstaat or the Ministry) has to pay the bill. Positive tender results are awarded as an addition towards the project budget and in that case seen as endogenous. Paragraph 3.3.1 continues on this subject.

3.2.2 Management reserve

The goal of the management reserve is to cover unknown unknowns. Unexpected events could make or break a project and need to be covered by this reserve. Eventually, ‘that what
I do not know, eventually will determine my project success’ (source: interview project manager of project C).

As mentioned, the most common principle to estimation this reserve is to create a dependency on the identified risks and its corresponding value. The derivation follows from the chosen ratio between the known unknowns and the unknown unknowns in the project. There are different ratios found within the studied projects (see Table 8), which requires an explanation. According to the project manager of project A, this ratio is dependent on the quality of the risk management at that specific moment in time. When there has been a lot of attention on risk management, more knowledge is obtained about the possible circumstances and events. This substantiation is clearly linked to expert judgment on the risk quality. Note that all ratios are assessed during tender phase. Apparently, difference in the quality of risk analysis in very expensive infrastructure projects is accepted.

Table 8: Assumed ratios between the contingency reserve and management reserve in the projects during tender phase

<table>
<thead>
<tr>
<th></th>
<th>Project A</th>
<th>Project B</th>
<th>Project C</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contingency reserve</td>
<td>70%</td>
<td>45%</td>
<td>50%</td>
<td>55%</td>
</tr>
<tr>
<td>Management reserve</td>
<td>30%</td>
<td>55%</td>
<td>50%</td>
<td>45%</td>
</tr>
</tbody>
</table>

The assumed ratio between both reserves, suggests the amount of uncertainty that is known by the project organization. In case of project A, the assumption is made that 70% of the future events is identified in the risk file during the tender phase, which is confirmed by the project manager. This is seen as the qualitative approach to substantiate the management reserve. In addition to this assumption, the data could also be interpreted from a quantitative perspective. This ratio could also be chosen to come to the desired total amount of reserves in a quantitative way. Both approaches need to be considered to be fully aware of the decision made about the reserves. Paragraph 5.1 continues on these qualitative and quantitative approaches of the assumptions used.

In some of the studied project progress reports, this reserve was used as a closing entry to balance the budget with the estimation of future direct costs. These progress reports are not related to the reserve budget estimation, but still important for proper project management during the project realization. There is no indication of possible future budget deficit, when using the management reserve as closing entry.

Properties of management reserves

The absence of the statistical properties of the management reserve in the Dutch estimation standard is indicated in the problem analysis in paragraph 1.2. The project survey offered the opportunity to collect data of actual needed management reserves of multiple infrastructure projects. Through the confidentiality of these data, the results are only visible in the confidential appendix G.
3.3 Inaccuracy mechanisms of estimations

The introduction of the problem analysis describes the search for an optimal amount of project reserves to maximize economical value. This is theory, because in practice there several mechanisms observed that disturb this search. Paragraph 2.5 already mentioned the three explanations for inaccuracy of estimation, appointed by Flyvbjerg (2002): technical political-economical and psychological. Research observations are discussed according to those three categories.

3.3.1 Technical aspects

Technical aspects of inaccuracy are related to the methods used to come to the estimate. Flyvbjerg (2002) stated that forecasting accuracy has not improved over time. There is one main technical aspect seen during the estimation of the reserves in the case studies, namely the tender result.

The tender result after contract award hinders the search for maximization of economic value; see timespan Y in Figure 18. The implementation order sets the final project budget. Important part of the budget is the contract price for construction, which is only known when the contract is awarded. In practice, the estimation of the tender tends to be on the safe side, which mainly results in a positive tender result (Rijkens, 2013). This results basically in an addition to the project reserves. Result: a theoretical optimum amount of project reserves is calculated during before tender and already adjusted after contract award, while the project scope remains the same.

There some side notes to make according to this aspect. A positive tender result could be caused by mistranslation of the project master plan into the contract (source: interview project manager of project A). In that case, extra modifications towards the contract are required resulting in extra costs. Some people can argue that the benefits by a positive tender result need to be reserved for these possible mistakes in the functional requirements. But again, project scope did not change, while extra project budget is available.
3.3.2 Political-economical aspects

Flyvbjerg explains the political-economical aspect of inaccuracy by terms of interests and power in a political and economical way (Flyvbjerg et al., 2002). He points out that forecasts are intentionally biased to serve the interests of project promoters in getting projects started: strategic behaviour. This intentionally influencing project estimates is not observed in the case studied. Logically, biasing forecasts could only be present in the very early stage of the project, before the point of no return. The focus of this research was not on this early stage, which could explain the absence of the political-economical explanation for inaccurate estimations.

3.3.3 Psychological aspects

There are mainly one psychological aspects observed that are influencing the estimation of the project reserves, namely Parkinson’s law. This law implies that project costs tend to extend towards the budget available. It is seen as part of the procedure to determine the project costs, time and scope. For explanation is referred to timespan X in Figure 18. There are two budget decisions to determine the project budget: budget decision for realization and implementation order (Dutch: uitvoeringsbesluit). The first decision tends to be based on
a conservatively high estimate for the complete execution of the project. During the phase of plan development, more project information is gathered to estimate the project costs more accurate. When the actual project costs tend to be lower than the initial assigned budget, the surpluses are spent on several aspects to improve the total project quality, scope or time schedule. A negative difference is avoided by retrench of the design till it fits within the initial assigned budget. In this way, both decisions contain the same estimate with an upgraded or downgraded scope, so the business case of the best economic alternative is already adjusted before project execution.

Additionally, the phenomenon optimism bias is expected in the assumption for estimating the project reserves. Flyvbjerg (2002) refers to an inaccuracy of estimations because of an optimistic view on the costs estimated. Paragraph 4.2 elaborates on this suspicion through assessment of the initial assumptions.

### 3.4 Conclusions on current practice of estimation

Current practice regards to the estimation of the project reserves raises a lot of questions, which resulted in the following research question that requires an answer.

**SQ1** What is the current practice within project organizations in estimating project reserves in road-widening projects?

Analysis on this topic focuses on the underlying principles and assumptions for the estimation of project reserves, where a full focus is observed on the initial risk file. The decisions on the amount of contingency reserve and management reserves are both based on the initial identified risks. The contingency reserve is directly linked to the quantification of the identified risks and a percentage is picked to distinguish the management reserve. Through this approach the initial risk file is not only a tool for risk handling, but it is also a decision-making tool for important project decisions like the decision on the amount of reserves.

Different percentages are used along the case studies for the estimation of the management reserve, which is explained by a difference in project circumstances and a different quality of risk analysis. These explanations are identified as invalid, because different project circumstances indicate different project uncertainties, which should already be covered by
the risk file and a difference in the quality of the risk analysis is observed as remarkable when dealing with these very expensive infrastructure projects financed with public resources.

The following four mechanisms are observed that disturb the accuracy of reserves estimations: subjective judgment, tender result, Parkinson’s law and optimism bias. Through these mechanisms, it is very hard for cost estimators to conclude about a proper economical amount of reserves.

The involvement of subjective judgment around the project reserves is clearly visible in the conducted survey among cost experts and in the interviews within the case studies. Although it is said that historical data is used for estimation, nobody is able to show this historical data on which decisions for the amount of reserves are based. This historical data seem to be ‘soft’ historical knowledge: opinions and experiences about previous projects. Overall perspective from the project members is that the project reserves could be calculated theoretically, but finally the feeling of project members should be good. This results in main three possibilities for subjective judgment on the estimation of project reserves: (1) determination of the amount of identified risks; (2) quantification of the risks’ probability of occurrence and possible impact; and (3) the used ratio between the contingency reserve and the management reserve. The consistency of expert judgments is tested during the cost experts survey, where the opinions tend to be pretty different by a given a specific project case.

Secondly, the delta between the reserved contract budget minus the actual contract price is defined as the tender result. This delta results in a positive or negative impact on the project budget without any change in the project scope. Additionally, there is inconsistency about how to handle the tender results: exogenous or endogenous. Paragraph 4.3 continues on this topic.

Thirdly, Parkinson’s law is observed during the plan development phase of projects. The project costs tend to extend to the available budget, where the scope is adjusted to match the available budget. Theoretically speaking, economical value of individual projects changes after project selection through this mechanism, which makes it impossible to find the best economic alternative during project selection.

Lastly, optimism bias is expected based on estimation theories. The used assumptions are judged as optimistic, so the used assumptions are assessed on the presence of this mechanism. Paragraph 4.2 elaborates on this assessment in the case studies.

In short, the current practice towards the estimation of project reserves includes subjective instruments. Estimations by experts are very dependent on the person who is invited to do so. This conclusion confirms the problem statement in paragraph 1.2. Only, expert judgment seems to be an accepted instrument to rely on in practice, even as the quality of the risk files. Performance of these instruments is discussed in the next chapter.
As mentioned in the introduction, this research is focussed on the tender phase and the corresponding budget decision at that time. This is a theoretical budget decision, which is explained in paragraph 2.3. In this chapter the research investigates the quality of the assumptions made in the estimation process within the case studies. In total, there are 196 occurred risks assessed that influenced the use of project reserves in the three case studies. Insights are obtained in order to answer the following research question.

SQ2

*What kinds of events lead to the expenditure of project reserves and what are the underlying causes?*

This question basically consists of two parts: the kind of events that result in expenditure and the underlying causes of the occurred risks. The research distinguished four main event properties to identify the kind of events that cause expenditure of the project reserves: costs
of consequences; main underlying cause; initial identified or unidentified and exogenous or endogenous. The chapter contains four analyses and is mainly based on the conceptual framework for the case studies in Figure 6 on page 11. The upcoming four paragraphs are referring to a part of this framework and the corresponding case question. Finally, the global answer to the research question is given in paragraph 0.

First observation from the analysis is the fact that not all descriptions of the events contain enough information for an adequate judgment. Sometimes, underlying causes and influences are hard to find. Events with insufficient information are left out of the research. It is remarkable that these causes for extra project costs are not described to the very detail.

### 4.1 Main causes of expenditure

The first analysis is focused on the most important causes that eventually affected the project reserves in the three case studies. Each and every occurred risk does have an underlying cause, an origin. All events in the database are analysed on its possible cause. Quite similar causes were categorized to distinguish the main causes in the project and give an answer to the following case question.

**CQ1**

*What are the underlying causes for occurred risks?*

Analysis on the causes of the events studied generated several insights. Firstly, the main causes for each project are presented to give an impression of the influences on the project cases, after which a more focused elaboration is presented towards the structural and incidental causes of expenditure of the project reserves.

The Table 9 contains the top 5 causes for each project. The column quantity refers to the amount of events affected by this causes in that particular case and the last column refers to the corresponding share weighted by actual costs of the cause. The causes are elaborated according to their structural or incidental character.
Table 9: Main causes of expenditure of the project reserves in the project case studies

<table>
<thead>
<tr>
<th>Project</th>
<th>#</th>
<th>Causes</th>
<th>Quantity</th>
<th>Share</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1</td>
<td>Legal failure of project decisions</td>
<td>4</td>
<td>66%</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Political pressure</td>
<td>9</td>
<td>8%</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Instability of processes and policies of organizations involved</td>
<td>4</td>
<td>4%</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Lack of clarity about financial responsibility</td>
<td>1</td>
<td>3%</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Unclear or changing functional requirements</td>
<td>3</td>
<td>2%</td>
</tr>
<tr>
<td>B</td>
<td>1</td>
<td>Unclear or changing functional requirements</td>
<td>9</td>
<td>33%</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Lack of knowledge of the initial assets</td>
<td>5</td>
<td>18%</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Technical uncertainty</td>
<td>5</td>
<td>17%</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Legal failure of project decisions</td>
<td>1</td>
<td>6%</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Political pressure</td>
<td>1</td>
<td>6%</td>
</tr>
<tr>
<td>C</td>
<td>1</td>
<td>Technical uncertainty</td>
<td>7</td>
<td>30%</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Lack of knowledge of the initial assets</td>
<td>16</td>
<td>26%</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Unclear or changing functional requirements</td>
<td>8</td>
<td>20%</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Political pressure</td>
<td>1</td>
<td>10%</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Unclear project scope</td>
<td>4</td>
<td>5%</td>
</tr>
</tbody>
</table>

Structural causes

There are three main structural causes for expenditure found in the case studies: political pressure, unclear or changing functional requirements and a lack of knowledge of the initial assets.

Firstly, the political pressure is seen in all the case studies. It is mainly visible in the time component in the projects, causes a time-focused project. Project members indicate that this time pressure is desirable, because it speeds up the process (source: interview project manager of project C). So, political time pressure reduces political resistance in the processes, which is seen as a huge advantage for the projects, but also results in extra project costs. This cause is seen as structural because of the presence in all case studies, but note that the program ‘Spoedaanpak’ influences all projects, which could also be seen as incidental. This program could explain the presence of this cause for expenditure.

Additionally, unclear or changing functional requirements are mentioned twice in Table 9. Apparently, the public client does not exactly know what he (or she) wants at the moment of tender. This is concluded from the fact that unclear or changing functional requirements are one of the top causes in expenditure. Globally 14% of the expenditure is caused by this confusion on their wishes. Project B was mainly struggling with differences in the implementation and development agreements (Dutch: uitvoeringsovereenkomsten en uitwerkingsovereenkomsten). Development agreements refer to the individual agreements between the project organization and, for example, municipalities and the implementation agreements between the project organization and the constructor (source: interview risk
manager of project B). These arrangements need to be consistent to prevent a delta between the local agreements and the functional requirements in the contract. In case of Project C, the plan procedure was timed parallel to the construction of the road, which allowed the project organization to be quite flexible on the determination of the functional requirements of additional structures to the road. So, this corresponding contractual structure caused more flexibility towards the functional requirements.

Finally, the lack of knowledge of the initial assets is notable. This is also one of the reasons for the large share of technical complexity in the expenditure of the project reserves. Proper knowledge about the current state of the project environment seems to be crucial to prevent additional project costs. The overestimated state of maintenance and unexpected presence of objects, cables and pipelines are some of the main causes for the contractor to request modifications to the contract.

Because of the structural character of these three main causes in these case studies, there is a hypothetical cause-effect relation towards the used project reserves. Chapter 6 continues on this possible relation.

Incidental causes

The main incidental causes are directly visible form the complexities in Table 10. Project A shows a huge peak in legal complexity in project, where project C has peak on technical complexity.

The main cause within project A is clearly the cancellation of the route decision, in other words the legal failure of project decisions. This event was partly identified in the initial risk file, but the consequences were a factor 56 higher than the corresponding risk reservation made initially. According to the project manager, the cause of the cancellation was social dissatisfaction with the implementation plans and not a major lack of support for the overall project. Primarily a mediocre legal assessment was conducted given the law and the project (source: interview project manager of project A).

<table>
<thead>
<tr>
<th>Complexities</th>
<th>Project A</th>
<th>Project B</th>
<th>Project C</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical</td>
<td>39 7%</td>
<td>12 37%</td>
<td>38 59%</td>
<td>30 34%</td>
</tr>
<tr>
<td>Social</td>
<td>23 10%</td>
<td>12 13%</td>
<td>7 27%</td>
<td>14 17%</td>
</tr>
<tr>
<td>Legal</td>
<td>13 73%</td>
<td>15 23%</td>
<td>2 4%</td>
<td>10 33%</td>
</tr>
<tr>
<td>Organizational</td>
<td>15 4%</td>
<td>7 27%</td>
<td>7 7%</td>
<td>10 13%</td>
</tr>
<tr>
<td>Financial</td>
<td>3 6%</td>
<td>2 0%</td>
<td>1 3%</td>
<td>2 3%</td>
</tr>
<tr>
<td>Total</td>
<td>93 100%</td>
<td>48 100%</td>
<td>55 100%</td>
<td>65 100%</td>
</tr>
</tbody>
</table>
Project C has a large amount of technical complexity involved, as seen in the figure above. Still, the project manager underpins that these projects are not technically complex: “it is just asphalt, concrete and some additional structures” (source: interview project manager of project C). As indicated in Table 9, 7 events result from the cause technical uncertainty. The major event is related to the technical dependency of different components in the design. Changes in the design principles result in modifications and additional costs. Another event is due to management measures to prevent a technical risk from happening.

Eventually, the following complexities are observed in the occurred risks during the case studies:

![Complexities observed in the expenditure of reserves](image)

**Figure 19: Complexities observed in the three case studies according to the average expenditure of the project reserves**

**Observed additional difficulties**

Parkinson’s law is also observed during the realization phase of infrastructure projects. This phenomenon is applicable for both budget and time. Firstly, interviewees point the success on project time schedule as a result of political pressure. In case of the ‘Spoedaanpak’ this political pressure during the case studies was focussed on time. This results in a relief of pressure on the project costs according to the project management triangle. Secondly, experts confirm that projects could be more generous when there is financial space within the project budget. Fewer budgets could held project managers a little but sharper in the meantime (source: interview project manager of project A).

Also a more political disturbing mechanism is seen in the case studies: strategic administration. Due to strategic motivations, general organizational costs are assigned to the project organization. This is a form of exogenous influence by the overarching organization and in the end does not generate additional costs. Costs are shifted from one administration to another. But from the perspective of the project organization, this strategic behaviour is still a cause of expenditure of available project reserves and it does decrease the ability to manage the project costs.
4.2 Predictability of additional project costs

As discussed in paragraph 3.2, the quality of the estimation of the project reserves is mainly dependent on the quality on the initial risk file. The occurred risks that resulted in expenditure of the project reserves are reflected on the initial risk file during analysis of the case studies. The results of this reflection are discussed in order to conclude about the project’s ability to identify oncoming risk events according to this initial risk file. This will give an answer to the following case question.

CQ2 To what extent could they initially predict risk events in the project?

In other words, what is the predictive value of the initial risk file? This paragraph explains the results of this analysis, where two methods are used: frequency-based and cost-based assessment. Both result in a ratio of the total expenditure of the reserves.

The first method is frequency-based and includes the ratio of initial identified events in relation with the total number of events. This method is related to the absolute counting of initial identified events, independent with its corresponding costs.

\[ \text{Frequency – based ratio} = \frac{\text{numbers of foreseen events}}{\text{total number of events}} \]

The second method is cost based and includes the corresponding costs of the event.

\[ \text{Cost – based percentage} = \frac{\sum \text{costs of foreseen events}}{\sum \text{costs of all events}} \]

Figure 20 illustrates the outcomes from the analysis by visualising the results of the two methods used.
The results from both methods are pretty different in every case studied, where it is remarkable that the cost-based ratio is quite larger. This implies that overall the more expensive expenditures of the project reserves (occurred risks with large consequence) are identified in the initial risk file. So, a project organization is able to predict more than the average calculated frequency-based ratio of 25%, when taking the corresponding costs into account.

Notable is the relative large difference between the ratios of project A. This could be explained by the huge impact of the cancellation of the route decision, which was partly foreseen initially. The cost-based ratio (72%) of project A is considered as an outlier, because no risk reservation was made according to the possible risk of the cancellation of the route decision. The average value of the cost-based ratio is therefor set on 44%. In general, because of the assumption described in the note, the real predictive value of the initial risk file is determined as much less than this average 44%.

It is concluded that the predictive value of the initial risk file is within a range from 25% till 44% of the expenditures on occurred risks in these case studies. In case of equal weights, it is concluded that the qualitative predictive power of an initial risk file is about 35%. In other words, about 35% of the upcoming events could be identified during the tender phase, on average.
4.3 Endogenous and exogenous events

All conducted interviews stated that none of the projects do included possible exogenous influences in their project budget. All of them refer to the project management triangle of project costs, time and scope. This assumption of no exogenous influence is analysed in order to find an answer to the following case question.

CQ3 To what extent have exogenous events impact on the actual expenditure of project reserves?

Sources of the underlying causes that result in actual expenditure of project reserves can be defined as exogenous or endogenous. The definition for exogenous influence is set in paragraph 1.3.7 with the perspective of project organization in mind. The analysis is similar to the one in the previous paragraph. The same kinds of ratios are used corresponding to the following formulas.

\[
\text{Frequency-based ratio} = \frac{\text{numbers of exogenous events}}{\text{total number of events}}
\]

\[
\text{Cost-based ratio} = \frac{\sum \text{costs of exogenous events}}{\sum \text{costs of all events}}
\]

The results are illustrated in Figure 21. To give insights into the exogenous influence and several examples are given.

In this analysis, the average frequency-based ratio is larger than the cost based ratio, which is in contrast with the previous analysis on the predictive value of the initial risk file. This implies that relatively many small expenses have exogenous influences. In that case, it is possible that these small breaches of the project management triangle rule are neglected by the project organisation.

One of the more recent examples is the VAT (Dutch: BTW) increase from 19% to 21%. Based on a project budget of hundreds of millions, this could cause a cost increase of several millions. This increase is caused by political decision-making and certainly not manageable for the project organizations of infrastructure projects.
Chapter 4 - Expenditure of project reserves

Figure 21: Obtained ranges of exogenous influence on the expenditure in the case studies

Another typical example is the decision of Rijkswaterstaat to apply an administrative ploy to reduce its own operating costs. This is accomplished by adding external advisories on the project accounts instead of the corporate balance sheet. Again, extra project costs are generated by external decisions outside of the scope of influence of the project organization.

Globally, the main cause of extra costs through exogenous influences is the fact that the public client does not always respect the project management triangle of costs, time and scope. Unexpected costs – that are not related to the initial project scope – still could be allocated on the project organization’s budget, because of sufficient amounts of available project reserves. Attitude of the public client in this issue is like: first project’s reserves, than the program’s reserves. If the allocation of exogenous costs to the project organization results in cost overrun, this project organization will contact the public client for extra budget and in that case the public client indirectly pays the exogenous influence. The message towards the projects is more or less: it is exogenous, but make it possible within the same budget (source: interview project manager of project C). This reasoning makes sense when it prevents lots of paperwork, but it does not consider the manageability of the project. These exogenous influences contaminate the project data, which is used for monitoring the project’s performances.

In short, it is clear that exogenous influences should not affect any expenditure of the project reserves when following the project management triangle rule. Analysis on the case studies suggests that – on average – 16% of the total reserve expenses are caused by exogenous influences. This is in contrast with the assumed theory.
4.4 Underlying factors that cause expenditure

Particular circumstances and preconditions – here defined as project factors – are defined in order to explain the causes of expenditure of the project reserves. This paragraph concludes on the following case question.

CQ4 What could be concluded considering the factors that are involved in the actual expenditure of the project reserves?

Main purpose is to establish the main factors that did cause extra project costs in the case studies. The main causes of expenditure are taken as starting point for this analysis. These factors are input for the project survey described in 1.3.5, which requires scalable factors.

Every main cause within the case studies is evaluated towards the circumstances that could have influenced the impact of the cause. Also the underlying complexities are determined to give an overview on the complexities in the oncoming analysis. The translation from causes to underlying factors results in a list of factors that did have a direct or indirect involvement in the expenditure of the project reserves in the case studies, where Table 11 contains the results. In total, 14 project factors are distinguished from this analysis.

For example, more proper project preparation and less social resistance towards the project could have decreased the probability of legal failure of project decisions. Further, more knowledge of the initial assets, less technical challenges, smaller project size and shorter project duration in the project could have decreased the technical uncertainty.
### Table 11: Underlying factors that could have influence on the impact of the main causes of expenditure

<table>
<thead>
<tr>
<th>Main causes</th>
<th>Underlying factors</th>
<th>Complexities involved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Legal failure of project decisions</td>
<td>→ Project preparation</td>
<td>→ Legal complexity</td>
</tr>
<tr>
<td></td>
<td>→ Social resistance towards the project</td>
<td>→ Social complexity</td>
</tr>
<tr>
<td></td>
<td>→ Stability of the initial project scope</td>
<td>→ Social complexity</td>
</tr>
<tr>
<td>Political pressure</td>
<td>→ Social resistance towards the project</td>
<td>→ Social complexity</td>
</tr>
<tr>
<td></td>
<td>→ Financial space within governmental budget</td>
<td>→ Financial complexity</td>
</tr>
<tr>
<td></td>
<td>→ Population density</td>
<td>→ Social complexity</td>
</tr>
<tr>
<td>Instability of processes and policies of organizations involved</td>
<td>→ Government efficiency</td>
<td>→ Organizational complexity</td>
</tr>
<tr>
<td></td>
<td>→ Political stability</td>
<td>→ Social complexity</td>
</tr>
<tr>
<td>Lack of clarity about financial responsibility</td>
<td>→ Cooperation of executing parties involved</td>
<td>→ Organizational complexity</td>
</tr>
<tr>
<td></td>
<td>→ Financial space within governmental budget</td>
<td>→ Financial complexity</td>
</tr>
<tr>
<td></td>
<td>→ Order book of constructor</td>
<td>→ Financial complexity</td>
</tr>
<tr>
<td>Unclear or changing functional requirements</td>
<td>→ Quality of initial functional requirements</td>
<td>→ Technical complexity</td>
</tr>
<tr>
<td></td>
<td>→ Project preparation</td>
<td>→ Organizational complexity</td>
</tr>
<tr>
<td></td>
<td>→ Stability of the initial project scope</td>
<td>→ Social complexity</td>
</tr>
<tr>
<td>Lack of knowledge of the initial assets</td>
<td>→ Knowledge of the initial assets</td>
<td>→ Technical complexity</td>
</tr>
<tr>
<td>Technical uncertainty</td>
<td>→ Technical challenges in the project</td>
<td>→ Technical complexity</td>
</tr>
<tr>
<td></td>
<td>→ Knowledge of the initial assets</td>
<td>→ Technical complexity</td>
</tr>
<tr>
<td></td>
<td>→ Project size</td>
<td>→ Overall</td>
</tr>
<tr>
<td></td>
<td>→ Project duration</td>
<td>→ Overall</td>
</tr>
<tr>
<td>Unclear project scope</td>
<td>→ Project preparation</td>
<td>→ Organizational complexity</td>
</tr>
<tr>
<td></td>
<td>→ Stability of the initial project scope</td>
<td>→ Social complexity</td>
</tr>
</tbody>
</table>
4.5 Conclusions on the expenditure

The following research question is applicable to the discussed field of expenditure of the project reserves and is answered by a summary of the analyses and observations in this chapter.

SQ2

What kinds of events lead to the expenditure of project reserves and what are the underlying causes?

Answer to this question is given by elaboration on the found underlying complexities, causes, and project factors. Additionally, the predictive power of the initial risk file and presence of exogenous risks are assessed.

Assessment on the underlying complexities of the 196 risk events studied results in the following distribution of complexities during the case studies: technical (34%), legal (33%), social (17%), organizational (13%) and financial (3%). So technical and legal complexities played a major role during these three road-widening projects, which is mainly explained by the large involvement of these complexities on the main causes of expenditure.

Analysis on the causes of the occurred risks results in a list of main causes, where a distinction is made between structural and incidental causes. Unclear or changing functional requirements, lack of knowledge of the initial assets and political pressure are observed as the top 3 main structural causes for expenditure of project reserves. Main incidental cause is legal failure of project decisions. Project factors are defined as causes of causes and are therefor derived from the main causes of expenditure. In total, 14 project factors are distinguished as input for the project survey.

Chapter 3 concludes that the full focus on the risk file when estimating project reserves. The corresponding quality of the decisions made through risk analysis is assessed. Based on two methods, research concludes that the initial risk file is able to identify no more than 35% of the reserve expenses during the realization phase. On average, the case studies assumed to be able to identify about 55% of the expenditure of the project reserves (see Table 8), which implies and confirms the presence of optimism bias in the principles used for estimation of the project reserves.

There are three mechanisms observed that disturb cost management during the realization phase and make it hard to define an optimum value for the project reserves. Distinction is made between exogenous influences, Parkinson’s law and strategic administration.

Firstly, exogenous influences are observed in the assessed risks events, which caused expenditure of the project reserves. On average, 16% of the reserves are spent on
exogenous risk events, in contrast with the project management triangle that assumes no exogenous influences at all.

Secondly, Parkinson’s law is also present during the realization phase in spending project reserves. Experts emphasize that this is only the case according to negotiations for extra (consulting) services or in dealing with exogenous impacts. The mechanism is not recognized in the negotiations with the main contractor (source: expert meeting).

Thirdly, strategic administration by the public client is observed. Costs of organizational overhead are assigned to individual projects in some of the case studies, because of strategic motivations. The latter is a form of exogenous influence on the project organization and eventually does not cause additional costs, but it does decrease the ability to manage the project costs.

Summarizing, it is concluded that risk analysis should be a tool to manage possible threats during the project, but the predictive value is considered as too low for decision-making. Purpose of risk analysis should be to eventually avoid possible risks and the corresponding costs. The project factors that eventually cause the expenditure of reserves are designated and further assessed in chapter 6.
According to the conceptual model on page 7, both the input for the estimation and the output of expenditure could be categorized by the defined complexities. Several comparisons are made within the research involved in order to give an explicit answer to the following research question.

What are the differences and similarities between estimations in current practice and the actual expenditure of project reserves?

Insights are gathered by an internal and external comparison of the research data. The internal analysis includes the comparison of obtained data within the research: the estimation and expenditure in the case studies. The input and output complexities are compared in order to find relations and explanations. External analysis involves the comparison with data outside of this research.
5.1 Internal comparison

The internal comparison focuses on the complexities in the individual cases, followed by an overview of the average distribution of complexities. This comparison is done in a qualitative and quantitative way to give a complete overview.

Qualitative comparison is done on the basis of the underlying complexities involved for estimation (initial risk files) and expenditure (occurred risks). The quality of the initial estimation is derived from the overlap between those figures by the sum of the minimum ratio per complexity. A large overlap is seen as a good estimation of future project complexities in qualitative way. It does not consider the fitness of the quantitative estimation of the reserves.

The quantitative comparison is based on the theoretical designated project reserves – according to the rules in Table 8 on page 43 – and the theoretical expenditure according to the obtained data. This results in a ratio between those two.

Project A

The distribution of the complexities in project A is indicated in Figure 22. The legal complexity dominates in both the estimation and the expenditure of the project reserves. Apparently, the legal difficulties were foreseen initially. Remarkable is the huge ratio of technical complexity in the estimation, which is caused by the presence of technical uncertainty in the design and not because of innovative techniques and other difficulties. Although the complexities were estimated pretty well (overlap is 69%), the quantitative comparison reveals that the expenditure of the project reserves is a factor 3,4 more than the appointed reserves. This does not directly mean a cost overrun for the project, because of the involvement of more mechanisms like a positive tender result (see 3.3.1). Still, the project reserves as defined in this research were not sufficient to cover the occurred risk events in this project.

![Figure 22: Distribution of the complexities due to project reserves estimation and expenditure of project A](image-url)
Project B

Initially there was a huge focus on the legal complexities in project B. Eventually, the technical uncertainties and lack of knowledge of the initial assets turned to be the major source of expenditure. This technical complexity was seriously underestimated. There was one risk related to the assets, but without a corresponding reservation. Financial complexity was included in the initial consideration, but this resulted in an overestimation of the financial consequences on the project. The contract type of DBFM could explain this overestimation, but it can be concluded that the use of this contract type did not cause more financial complexity during the realization phase of this project. The qualitative overlap is 44% for this project.

Focus on the quantitative comparison shows that only half of the initial reserves are used.

![Figure 23: Distribution of the complexities due to project reserves estimation and expenditure of project B](image)

Project C

As mentioned in paragraph 4.1, project C did expect a lot of organizational difficulties because of interfaces with surrounding projects of Rijkswaterstaat. According to these interfaces the freedom of planning for the constructor was limited. Ratio of expenditure shows that the consequences of these risks are mitigated. One explanation is overestimation, but a good effort of the project team to mitigate these risks is more plausible. The technical complexity seems to be dominant according to the use of the project reserves, which is in contrast with the information obtained from interviews: ‘Infrastructure in The Netherlands complex? It is just asphalt, concrete and some structures. Nothing technical complex.’ (source: interview project manager of project C)

Eventually, the social complexity seems to be underestimated, because none of the risks indicated social difficulties. This was mainly the result of extra requirements from local government, without any addition of extra budget.
The overlap of the qualitative estimation on the occurred risks is 54% and the actual quantitative use of the project reserves is about twice as initial appointed.

Overall

The following figure represents the average distribution on the complexities by looking at the three case studies. The estimation and expenditure are remarkable closer than the individual cases, which could be confirmed by the overlap of 81%. It is obvious that these average values generate a closer match, because extreme events are faded out.

There are three notable observations in the graph above. There is a peak on the legal complexity and on the technical complexity, both mostly driven by two of the three projects and in that case not seen as purely incidental. Lastly, there seems to be a structural underestimation of the social complexities in the projects.

As mentioned in chapter 3, the total amount of reserves is eventually determined by a ratio of the initial risk file. In the previous quantitative comparisons is clearly visible that two of the three projects actually needed more reserves than estimated. So the question arises:
which ratio should be chosen to cover all extra expenses in the project? The answer for the individual projects and average value is visible in Table 12.

Table 12: Assumed and theoretical needed ratios between the contingency reserve and management reserve in the case studies

<table>
<thead>
<tr>
<th></th>
<th>Project A</th>
<th></th>
<th>Project B</th>
<th></th>
<th>Project C</th>
<th></th>
<th>Average</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Assumed ratio</td>
<td>Needed ratio</td>
<td>Assumed ratio</td>
<td>Needed ratio</td>
<td>Assumed ratio</td>
<td>Needed ratio</td>
<td>Assumed ratio</td>
<td>Needed ratio</td>
</tr>
<tr>
<td>Contingency reserve</td>
<td>70% 20%</td>
<td>45% 88%</td>
<td>50% 23%</td>
<td>55% 44%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Management reserve</td>
<td>30% 80%</td>
<td>55% 12%</td>
<td>50% 77%</td>
<td>45% 56%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Paragraph 4.2 concludes that the qualitative predictive value of the initial risk file is about 35%, which is based on the qualitative links between identified and actual occurred risks. The figures above are purely based on quantitative values of the initial estimation and the actual expenditure and therefore referred to as quantitative predictive value. On average, these projects should substantiate their project reserves for 44% during the tender phase to eventually cover the additional project costs.

5.2 External comparison

In this paragraph, the obtained research data is compared with previous research on complexities. As mentioned in chapter 2.1, Hertogh and Westerveld (2010) conclude on the distribution of complexities within large infrastructure projects in their research. The research area and methodology are slightly different, so only main differences are discussed and explained when possible. The used definitions of the complexities are similar.

Case studies versus previous research

Figure 26 below compares the average of estimation and expenditure in the case studies versus observed complexities in previous research (Hertogh & Westerveld, 2010).
There are two huge differences observed in Figure 26. The first major difference is found in the legal complexity, which is far more present in the case studies conducted. This huge difference is remarkable, but explainable. It can be caused by the indirect impact of political pressure from the ‘Spoedanpak’. Quality of project decisions and documents could be less because of the focus on time. Projects in such an environment should specify their risks towards these events, which is done as can be seen in the figure.

The second difference is in the social complexity. Hertogh and Westerveld stated that there is a huge amount of social complexity in large infrastructure projects. This complexity is observed in the case studies, but is not as dominant as prescribed. Involvement of the ‘Spoedaanpak’ can explain this difference, because the opportunities for participation are decreased. Opponents have fewer options for disturbing the project, which causes a declined social complexity.

Note that not all of the project complexities directly increase project uncertainty, which is indirectly related to the expenditure of project reserves. Playing with complexity (Hertogh & Westerveld, 2010) has a full project focus, while this research concentrates on uncertainties on its influence on the project reserves. Because of this, conclusions from this comparison are of little value.
5.3 Conclusions on the comparison

Through the internal and external comparisons an answer is found for the next research question.

SQ3

What are the differences and similarities between estimations in current practice and the actual expenditure of project reserves?

Both a qualitative and quantitative approach is used to gather insights into differences and similarities of the estimation and expenditure of the project reserves in the case studies. Conclusions on both approaches are elaborated briefly.

The first difference is seen in the project administration during estimation and expenditure. The budget estimation includes strict financial entries, where the difference is made between the contingency reserve and the management reserve. This distinction tends to blur during the project realization, where no connection to the initial budget estimation is made.

A qualitative impression is accomplished by observing the complexities included in the estimation and expenditure of the project reserves in the cases. There are quite some differences and similarities within the individual cases and most of them are explainable afterwards. The quality of the qualitative estimation is measured by the overlap in the complexities involved in the estimation and expenditure. This overlap is respectively 69%, 44% and 54% in the cases, resulting in an average of 56% of the complexities that is estimated correctly during the tender phase. It is remarkable that the overlap is significant improved when the average complexities within the case studies are analysed: 81%. This is explained by the fade out of incidental events.

In general, the data in the case studies results in a large amount of expenditure that is caused by technical and legal complexity. Projects are able to identify these complexities in some extent when observing Figure 25. The social complexity is largely underestimated in two of the cases.

The quantitative approach shows the quality of the quantitative estimation of the project reserves. The theoretical expenditure indicates a cost overrun of the project reserves in two of the cases. In these cases, there was respectively a factor 2.17 and 3.45 more reserves needed than initial estimated to finance the occurred events in the databases. This does not directly mean a cost overrun for these projects, because of the involvement of mechanisms like a positive tender result. Still, the initial assumptions and identified risks were not as valid as thought. Assessment of the data, suggests that these projects should substantiate their initial project reserves for 44% during the tender phase to eventually cover the additional project costs.
The comparison with the complexities in previous conducted research resulted in two major differences: this research observes less influence of the social complexity and observes more influence of the legal complexity in the case studies. Both observations could be explained by the application of the ‘Spoed aanpak’, because of political pressure. This pressure tends to decrease the social complexity by, for example, shortening the public inquiry procedure.
The following chapter continues on the project factors involved that result in the use of the project reserves. Further elaboration on the defined project factors from the previous chapter results in several significant and mutual correlations with respect to the actual spent amount of project reserves. These relations are eventually used to simulate the estimation of project reserves based on reference project circumstances.

Firstly, the derived main project factors from the case studies are complemented with more external factors that could hypothetically have influence on the use of project reserves. This group of most important project factors form the input for the project survey on 17 road-widening projects. The analysis of this project survey is elaborated in paragraph 6.2. Correlations between the factors are analysed to come to conclusions about the degree of influence for each factor. The suspected cause-effect relations from chapter 4 are tested in order to confirm or reject these relations. Conclusions on these topics give part of the answer to the following research question.
What project circumstances should be included by the project organization for a conscious and substantiated decision on the amount of project reserves in Dutch road-widening projects?

6.1 Deriving project factors

The project factors refer to the project circumstances, which could be assessable by the project members involved or could be linked to external sources of data. Before the analysis, hypothetical relations are argued by common sense in order to conclude about acceptance of found correlations. Table 13 indicates the project factors that are included in the analysis from the case studies, including the hypothetical relation with the actual spent project reserves. For example, more knowledge of the initial assets prevents additional modifications on the contract, so less project reserves are needed. This refers to a negative relation between those two variables. The hypothetical relation with the financial space within the governmental budget is based on Parkinson’s law: when a project tends to be more flexible in negotiations with more financial space, it could result in more costs for the same project scope.

Table 13: Included project factors from the case studies

<table>
<thead>
<tr>
<th>#</th>
<th>Project factors</th>
<th>Hypothetical relation with the actual spent project reserves</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Knowledge of the initial assets</td>
<td>Negative</td>
</tr>
<tr>
<td>2</td>
<td>Technical challenges in the project</td>
<td>Positive</td>
</tr>
<tr>
<td>3</td>
<td>Quality of initial functional requirements</td>
<td>Negative</td>
</tr>
<tr>
<td>4</td>
<td>Project preparation</td>
<td>Negative</td>
</tr>
<tr>
<td>5</td>
<td>Social resistance towards the project</td>
<td>Positive</td>
</tr>
<tr>
<td>6</td>
<td>Stability of the initial project scope</td>
<td>Negative</td>
</tr>
<tr>
<td>7</td>
<td>Cooperation of executing parties involved</td>
<td>Negative</td>
</tr>
<tr>
<td>8</td>
<td>Government efficiency</td>
<td>Negative</td>
</tr>
<tr>
<td>9</td>
<td>Political stability</td>
<td>Negative</td>
</tr>
<tr>
<td>10</td>
<td>Financial space within governmental budget</td>
<td>Positive</td>
</tr>
</tbody>
</table>
Next to these factors form the case studies, four other factors are included in the analysis: *population density around the project area, duration of the project, project size and state of contractors’ order books*. Motives for inclusion differ and are explained separately.

<table>
<thead>
<tr>
<th>#</th>
<th>Project factors</th>
<th>Hypothetical relation</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>Population density around the project area</td>
<td>Positive</td>
</tr>
<tr>
<td>12</td>
<td>Duration of the project</td>
<td>Positive</td>
</tr>
<tr>
<td>13</td>
<td>Project size</td>
<td>Negative</td>
</tr>
<tr>
<td>14</td>
<td>State of contractors’ order books</td>
<td>Negative</td>
</tr>
</tbody>
</table>

Firstly, the *surrounding population density* is referring to population growth in combination with a chronic shortage of space in the Netherlands. Construction projects in highly populated areas generally attract more uncertainty, so a positive relation with the reserves used in the projects is expected.

The overall *project duration* is also estimated during the tender phase. Presence of uncertainties can affect the duration in a negative way, which also results in additional costs, so a positive relation is expected towards this factor. *Project size* refers to more possibilities for uncertainties, but economies of scale should result in a reduction of project costs, so negative relation is expected. Engaging the order books of the contractors is explained on the next page, together with the main hypothesis.

**External resources**

Most of the factors from chapter 4 cannot be linked to objective index or scale. These are judged by project members to gain insight through an insider. Others are linked to external resources of information for a more objective view of the project circumstances. The following resources are used and applied to the corresponding factors.

- Worldwide Governance Indicators (Kaufmann, Kraay, & Mastruzzi, 2010)
  - Dutch Political Stability/Absence of Violence
  - Dutch Government Effectiveness index
- Dutch Central Planning Agency (Dutch: CPB)
  - Government budget deficit (financial space within the governmental budget)
  - Population
- Dutch Economical Institute for Construction (Dutch: EIB)
  - State of contractors’ order books
All these factors differ mainly per year and are applicable to all of The Netherlands, except for the population, which differs per region. The applied index per project is made dependent upon the year of tender to obtain possible predictive relations. The population is linked to the main province of the project.

Main hypotheses
There are three main hypotheses which require more elaboration. The conclusion reflects on these predictions after analysis.

Knowledge of the initial assets
Chapter 4 concludes about a lack of knowledge of the current state of the infrastructure. The perception of the project members is asked about the degree of knowledge on these initial assets. In theory, more knowledge should result in a decreased expenditure of the project reserves, so a negative relation is expected.

Project preparation
The effect of the degree of project preparation is ambiguous for the estimation of the project reserves. A good project preparation could increase the knowledge of possible unknown events: the known unknown increase, which increases the size of the risk file and indirectly the amount of project reserves. In relation with the actual expenditure of the project reserves, there should be just a negative relation: the better the preparation, the less reserves should be needed. The latter situation is appointed as dominant.

State of contractors’ order books
Another important project factor of the project environment is the tender climate, assigned during the interviews. In other words, the order books of the construction companies are expected to have huge influence on the project costs. The state of the constructors’ order books could have a bilateral effect. A filled order book could decrease the financial pressure on the constructor, so they could be more dedicated to satisfy the project organization. This should result in a negative relation between the order books of the constructors and the used project reserves. On the other hand, a full order book could result in a higher contract price, because they are less eager to win the tender. In this research, the first effect is considered as normative.
6.2 Data analysis

As stated in chapter 1.3.5, the core objective of this survey is to project the gained insights into the defined project factors on multiple road-widening projects of Rijkswaterstaat. All designated project factors are included in the project survey as independent variables towards the actual spent project reserves as dependent variable. In total, 17 road-widening projects did return the questionnaire for data gathering (response rate of 68%). In this paragraph, hypotheses are tested by the correlation values and regression analysis is done to simulate the possibility to estimate future project reserves based on the project factors.

6.2.1 Correlations between project factors

For proper regression analysis, the obtained data is considered as homogenous and stable. All projects are recently finished road-widening project in The Netherlands. The correlation coefficient defines the statistical relationship between two variables in the analysis. The Pearson correlation is used, which is defined by the following equation.

\[
\rho_{XY} = \frac{E[(X - \mu_X)(Y - \mu_Y)]}{\sigma_X \sigma_Y}
\]

In fact, calculation of the correlation is a single regression analysis. The relation between two variables is tested, without possible external influences from the system. Note that correlation does not necessarily mean causation (Price, 2000), but eventually regression analysis could aid in confirming a cause-effect relationship (Montgomery, Peck, & Vining, 2001). In this case, the case studies suggest some hypothetical cause-effect relations. This paragraph elaborates on the regression analysis and those possible cause-effect relations. The interpretation of the correlation coefficients is defined in Table 15.

<table>
<thead>
<tr>
<th>Values</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0 - 0.3</td>
<td>Weak relationship</td>
</tr>
<tr>
<td>0.3 - 0.7</td>
<td>Moderate relationship</td>
</tr>
<tr>
<td>0.7 - 1.0</td>
<td>Strong relationship</td>
</tr>
</tbody>
</table>

Table 15: Interpretation of the correlation values (Gerstman, 2005)
Table 16 shows the calculated correlation between the project factors and the used project reserves in the project survey data. The correlations are briefly discussed according to the hypothetical relation. The full correlation matrix is available in appendix F.

Table 16: Observed correlation between the independent variables and the used project reserves

<table>
<thead>
<tr>
<th>Project factor</th>
<th>Hypothetical relation</th>
<th>Observed correlation with the used reserves</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge of the initial assets</td>
<td>Negative</td>
<td>-0.62</td>
</tr>
<tr>
<td>Project size</td>
<td>Negative</td>
<td>0.52</td>
</tr>
<tr>
<td>Quality of initial functional requirements</td>
<td>Negative</td>
<td>-0.42</td>
</tr>
<tr>
<td>Stability of the initial project scope</td>
<td>Negative</td>
<td>-0.41</td>
</tr>
<tr>
<td>Duration of the project</td>
<td>Positive</td>
<td>0.27</td>
</tr>
<tr>
<td>Cooperation of executing parties involved</td>
<td>Negative</td>
<td>-0.25</td>
</tr>
<tr>
<td>Population density around the project area</td>
<td>Positive</td>
<td>0.21</td>
</tr>
<tr>
<td>Social resistance towards the project</td>
<td>Positive</td>
<td>0.19</td>
</tr>
<tr>
<td>Government efficiency</td>
<td>Negative</td>
<td>-0.16</td>
</tr>
<tr>
<td>Technical challenges in the project</td>
<td>Positive</td>
<td>0.15</td>
</tr>
<tr>
<td>Project preparation</td>
<td>Negative</td>
<td>-0.11</td>
</tr>
<tr>
<td>Political stability</td>
<td>Negative</td>
<td>-0.11</td>
</tr>
<tr>
<td>State of contractors’ order books</td>
<td>Negative</td>
<td>0.09</td>
</tr>
<tr>
<td>Financial space within governmental budget</td>
<td>Positive</td>
<td>-0.07</td>
</tr>
</tbody>
</table>

Firstly, there are no strong correlations between the dependent variable and the independent variable detected in the data. The strongest correlation is knowledge of the initial assets (-0.62), which is negative like expected. So the more knowledge of the current state of the infrastructure does result in fewer expenses of the project reserves. This relation is illustrated in Figure 28 as a scatter plot with its trendline. It confirms the hypothesis stated and the cause-effect relation which was suspected in chapter 4.

Also the correlation with the project size is shown moderate (0.52) as shown in the same figure. A negative relation was expected because of economies of scale, but it is quite remarkable that this rule is not applicable for these road-widening projects. A larger project seems to need a relative larger amount of project reserves.

A weak correlation is found between the used project reserves and both the project preparation and state of contractors’ order books (0.09). Previous paragraph describes possible bilateral effects on these factors and according to the correlations none of the effects is dominant. The hypothesis on this factor is rejected.
It is remarkable that factors with an external source of data show far less correlation with the actual spent project reserves. This implies that the use of reserves is mainly caused by internal project factors. After all, most of the correlations from the survey data are like expected, although the relations are not very strong.

Other correlations
There are also some other notable mutual correlations in the data, where some indicate a strong correlation and other an unexpected weak relationship. The following combinations of factors are correlated strongly, which are illustrated by the scatter plots shown in Figure 28.

1. Stability of the initial project scope and project preparation (0,76)
2. Project size and duration of the project (0,76)
3. Quality of initial functional requirements and knowledge of the initial assets (0,70)

The correlation between social resistance towards the project and population density around the project area (-0,64) is not defined as strong, but still pretty high. It could not be said that high-density population causes the social resistance towards projects, but the relation is suspicious.
The factors *project preparation* and *quality of initial functional requirements* correlate weakly (0.17), which is remarkable. By common sense, the *quality of the functional requirements* should be higher in combination with a better *project preparation* (quantitative or qualitative), but this expectation cannot be confirmed by this data.

### 6.2.2 Multiple regression analysis

Correlation is only a measure of association and is of little use in prediction (Montgomery et al., 2001), while multiple linear regression analysis includes multiple mutual relations in order to determine a prediction model for future values of the dependent variable: the actual spent project reserves. Regression analysis on the project survey data simulates the reserves estimation based upon project factors instead of the initial risk file.

Firstly, there is the danger of data overfitting, which is mostly caused by models that are excessively complex. This is defined as a model with too many parameters (independent variables) relative to the observations. Excessively complex regression models tend to fit perfectly to a set of historical data, but it will often predict new values very poorly (Montgomery et al., 2001).

Model calculation with all factors results in data overfitting, so several factors need to be selected in order to reduce the model complexity. The project factors are assessed by the backward elimination procedure on the survey data (Montgomery et al., 2001). This procedure starts with all 14 factors included and step-by-step the least significant factor is removed from the analysis. In this way, the most significant factors remain, which results in the following order of significance towards the actual spent project reserves. Through this analysis, a most significant combination of three regressors is selected for the model
calculation: *knowledge of the initial assets, project preparation and stability of the initial project scope*.

The model is validated by a 8-fold cross-validation. All observations are divided into 8 groups, where every group is excluded from model calculation once and functions as validation observations to calculate the mean square error (MSE). The following model is formulated according to this method.

\[
\text{Project reserves needed} = 0.63 - 0.13 \times x_1 + 0.20 \times x_2 - 0.23 \times x_3
\]

\[
x_1 = \text{Knowledge of the initial assets} \\
x_2 = \text{Project preparation} \\
x_3 = \text{Stability of the initial project scope}
\]

Model R-squared (adjusted) = 0.68  
Significance = 0.0029  
MSE = 2.61%

The p-value for the separate variable is less than 5% resulting in a significant relation to the dependent variable. Based on the available dataset, the model could be improved a little bit by trying other selection procedures and a possible negative prediction values also needs more attention. Further improvement of the model should also include non-linear relations between the variables.

The practical applicability of this model is very low, but the model proves the possibility to find mutual relations between project circumstances in order to eventually estimate the project reserves. Main difficulty for the practical applicability is including more project data, which illustrates the value of storing this project data in order to be able to predict future project reserves on the basis of this information.

## 6.3 Conclusions on the influence of project factors

The case studies resulted in project factors that eventually cause expenditure of the project reserves. The individual influence per project factor is assessed by regression analysis in order to answer part of the main research question.

**MQ**

*What project circumstances should be included by the project organization for a conscious and substantiated decision on the amount of project reserves in Dutch road-widening projects?*
In other words, what project factors do have the most influence on the expenditure of project reserves? Analysis on the project survey data results in the following observations and conclusions.

As an addition to chapter 4, the degree of influence for each project factors is determined through single and multiple regression analysis. Relations to the dependent variable actual spent project reserves are assessed by the correlation coefficient and result in the following top 5 of project factors.

1. Knowledge of the initial assets
2. Project size
3. Quality of initial functional requirements
4. Stability of the initial project scope
5. Duration of the project

The hypothetical cause-effect relation between the knowledge of the initial assets and the actual spent project reserves is confirmed by a pretty strong correlation in single and multiple regression analysis. The other two main hypotheses are rejected due to a very weak correlation.

Analysis results in the remarkable correlation between the project size and the used project reserves (0.52). Economies of scale seems to be not present according to the data collected, because the larger projects also need relative more project reserves. There are no direct explanations found for this observation, so project managers should be sharp to make actual use of economies of scale and decision-makers could include this knowledge in their consideration on the budget decision.

The conducted regression analysis simulates estimation of the reserves by using the mutual relations between project factors and the actual spent amount of reserves in road-widening projects. Although, the collected dataset is relative small, a significant model is calculated that could explain the actual spent reserves for 68%.

So, significant relations between project factors and the actually spent project reserves are found. This indicates the possibility to determine future project reserves based on assessment of the project circumstances instead of the identified risks. In the next chapter, the recommendations are stated to make a conscious and substantiated decision on the amount of project reserves.
Accurate estimation of the project budget – including its project reserves – should result in maximisation of the economic benefit. The importance of accurate estimation is widely recognized (Trost & Oberlender, 2003), but it is remarkable that it tends to be hard to explain and defend the principles used for the estimation and even harder to exactly point out the events that are financed by these project reserves. Six mechanisms are observed in the research, which disturb the search for an optimum amount of project reserves to maximize economic value and also affect the manageability of the reserves. The results and conclusions of the research are discussed in order to give an answer to each research question. In addition, this knowledge results in multiple recommendations to decrease the effects of the mechanisms and to improve the manageability of the project reserves. Finally, the preferred estimation of the reserves is given in order to achieve the research goal: to provide a more conscious and substantiated guideline for the amount of project reserves in road-widening projects in The Netherlands.
7.1 Obtained insights into the project reserves

A broad basis of data is obtained from the three parts of the research: cost experts survey, project case studies and the project survey. The resulting knowledge is presented following the structure of the research questions. The gathered insights are the basis for recommendations in the next paragraph.

Current practice of estimation

Theory contains many methods to generate cost estimations, including the project reserves. As mentioned, the decision on the project budget is very important, so the following question arises.

SQ1 What is the current practice within project organizations in estimating project reserves in road-widening projects?

In the current situation, expert judgment and quantitative risk analysis on the initial risk file dominate the estimation of the project reserves with minimal use of historical data. The management reserve is generally determined as a percentage of the contingency reserve, which varies per project. These differences are remarkable, because the cases are all road-widening projects, examined in the same phase. Given explanations regard the project circumstances and the quality of the risk analysis at that moment of the project. Both explanations are considered as invalid, because firstly, different project circumstances basically indicate different project uncertainties, which should be covered by the risk file. So, project circumstance should be covered by the contingency reserve and should not affect the ratio between both parts of the reserves. And secondly, it is exceptional that the quality of risk analysis may vary between these kinds of large infrastructure projects. Apparently, the possibility of different principles for the estimation of reserves is generally accepted.

Research observes that the risk file is used as a tool for risk management as well as a tool for decision-making concerning the project reserves. Questions arise about the quality of the decisions made in relation to the initial risk files. According to the case studies, projects assume that – on average – 55% of actually occurred risks are identified in the initial risk file. Research observes that only 25% of the occurred risks in these projects could actually be linked to the initial risk file. These anticipated occurred risks represent – on average – 44% of the expenditure of the project reserves. A note is made that these figures include occurred risks that were only partly identified initially, so it is concluded that the real predictive value of the initial risk files is between 25% and 44%.
Summarizing, a risk file is very useful as a tool for analysis of possible risks and how to anticipate on possible threats or opportunities. Still, this research concludes that the initial risk file is not the proper tool for decision-making on the amount of project reserves, firstly because about only 35% of the extra project spending is predicted by the initial risk file and secondly because of the huge involvement of subjectivity in the risk files.

*Disturbing mechanisms during the estimation*

During estimation of project reserves, there are mainly three mechanisms observed that disturb the search for maximum economic value of the projects: *subjective judgment*, *optimism bias* and *tender result*.

Firstly, *subjective judgment* is involved in multiple situations in order to estimate the project reserves. Examples of this subjectivity are the determination of the amount of identified risks; quantification of the risk’s probability and consequence and the used ratio between the contingency reserve and the management reserve. The cost experts survey shows a wide spread of estimations with little consistency. For example, cost experts are inconsistent about the involvement of exogenous effects. Besides that, there are no formal rules for the management reserves, so project managers chose this reserve in a way that they feel comfortable. Thus, estimation by experts remains very dependent on the person who is invited to do so. This conclusion has been confirmed during the organized meeting with experts in the field of project management.

Secondly, *tender result* is defined as the delta of the reserved contract budget minus the actual price of the contract, which is the first possible risk after budget decision. Two of three projects identify a negative delta as an exogenous risk, while a positive delta is most of the time awarded to the project. Defining a negative delta as exogenous is remarkable, because change of scope is not involved. Still, the cost estimation of potential constructors is also influenced by market forces, which is in contrast with the estimations of the public actor. According to experts in the experts’ meeting, these market forces are not manageable by the project organisation, so these are exogenous. In case of a positive delta, the project risk profile is adjusted to maintain the available project budget.

Thirdly, *Parkinson's law* is observed during the plan development phase of projects. The project budget decision is made in a very early stage, whereupon the project scope tends to be dependent on the available budget, which hinders the search for maximum economic value.

Lastly, *optimism bias* is observed in to project assumptions about the predictability of risk events during the project. As mentioned, the predictive value of the initial risk files seems to be lower than assumed for the determination of the management reserve in the three case studies.

Adjustment of the risk profile to maintain project budget could be an example of *strategic behaviour*. This could be an additional mechanism, but this behaviour is not directly observed within the research’s focus on the tender and realization phase. Strategic
estimations are more expected before the project’s point of no return (Flyvbjerg et al., 2002), which occurs before the tender phase of a project.

In short, there is a lot of space for improvement considering the estimation of the project reserves. This and the observed disturbing mechanisms during estimation are recognized as relevant for infrastructure projects in general during the expert meeting.

**Expenditure of reserves**

One of the defined problems is that even after project completion, there is no knowledge about the expenditure of the project reserves and the satisfaction of the initial goal. Answers to the following question provide more insights into this topic.

**SQ2**

> What kinds of events lead to the expenditure of project reserves and what are the underlying causes?

All occurred risks that lead to expenditure of project reserves are analysed for their underlying complexity, causes and project factors. Knowledge of these characteristics gives an overview of the kinds of events that lead to expenditure of reserves. In total 196 events have been assessed during the analysis.

**Complexities involved**

A focus on the underlying complexities gives more insights for a proper consideration about the kinds of risks that should be identified in the initial risk file. Figure 29 shows the average observed complexities in the cases studied. One can conclude that technical and legal complexities play major role in the three road-widening projects.

**Complexities observed in the expenditure of reserves**

Figure 29: Complexities according to the events that did use the project reserves
Causes for expenditure
The underlying causes for the occurrence of risks are evaluated. Analysis shows, for example, that legal complexity is mainly caused by changes in functional requirements and the legal validity of project decisions, which often result in a significant expenditure of project reserves. The presence of technical complexity is more related to uncertainty in technical knowledge or lack of knowledge.

Eventually, the following causes did lead to the biggest expenditure of project reserves. The percentage indicates the proportion of costs corresponding with the cause to the total amount of reserves spent in the three cases.

1. Legal failure of project decisions (51%)
2. Unclear or changing functional requirements (9%)
3. Political pressure (8%)
4. Lack of knowledge of the initial assets (8%)
5. Technical uncertainty (7%)

There is a distinction made between two types of causes for the use of the reserves: structural and incidental. A structural cause implies systematic use of project reserves. Three main structural causes have been found: unclear or changing functional requirements, lack of knowledge of the initial assets and political pressure. The huge consequences of the legal failure of a project decision in project A are seen as a typical example for an incidental cause of expenditure.

Disturbing mechanisms during project realization
There are also three mechanisms observed during the project realization that make it hard to define a theoretical optimum value for project reserves: exogenous influences, Parkinson’s law and strategic administration.

Firstly, exogenous influences are present in the expenditure of project reserves in contrast with the principles of the project management triangle. There is no consistency found among the cost experts about the involvement of exogenous influences in the estimation of project reserves. It follows from the case studies that – on average – 16% of the total assessed reserve expenses are caused by exogenous influences. This is in contrast with the assumed theory by the project organization. Many – relatively small – expenses often have exogenous influences. Apparently, project organizations turn a blind eye to these relatively small breaches of the project management triangle rule or the project sponsor forces the project to do so. This mechanism is discussed during the expert meeting and clearly recognized in other infrastructure projects.

Secondly, Parkinson’s law is also observed during the realization phase. In general, project costs tend to extend towards the budget available, so project organizations are more generous in negotiations when there is more financial space in the project budget.
Discussion in expert meeting concluded that the latter is true in negotiations with additional services and towards possible exogenous influences, but this generosity is not recognized in the negotiations with the main constructor.

Thirdly, *strategic administration* by the public client is observed. Organizational overhead costs are assigned to an individual project because of strategic motivations. Note that no extra costs are made in this case, only the costs are allocated in another administration. Still, these actions disturb optimal cost management within a project organization.

Comparison estimation and actual expenditure

Estimation of the project reserves is indirectly a forecast of future complexities, possible causes of extra costs and project circumstances. The quality of this initial forecast becomes clear during project realization. This is where the following sub question comes in.

SQ3

*What are the differences and similarities between estimations in current practice and the actual expenditure of project reserves?*

The first difference is seen in the project administration. Initial estimation of overall project cost defines strict financial borders, including the contingency reserve and the management reserve. These financial borders are not observed during the project realization in the case studies, because occurred risks were not linked to the contingency reserve nor the management reserve.

Internal comparison between the underlying complexities in both the estimation and expenditure of the project reserves provides part of the answer. Figure 30 illustrates the strong presence of technical and legal complexity in the case studies. The social complexity was overall underestimated.

Also the overlap between the estimated complexities and actual complexities is assessed, where it is remarkable that the overlap is significantly improved when using the average complexities in the case studies. This is explained by the fading out of extreme events.

Based on quantitative assessment of the data, it is suggested that the original project reserves of the cases should have substantiated for 44% by identified risks during the tender phase to eventually cover the additional project costs.

Additionally, an external comparison with previous research is made (Hertogh & Westerveld, 2010), which illustrated in Figure 30. This comparison resulted in two major differences: less influence on the social complexity was observed in the case studies and more on legal complexity. Both deviations can be explained due to the influence of the ‘Spoedaanpak’ program due to *political pressure*, which tends to decrease the social complexity by, for example, shorten the public inquiry procedure.
Infrastructure projects are exposed to different kinds of project circumstances, which are most of the time hard to manage. Insights into these circumstances and their relation towards extra project costs should increase the ability to estimate the needed project reserves. Answers to the main research question are needed to collect these insights.

**MQ**

*What project circumstances should be included by the project organization for a conscious and substantiated decision on the amount of project reserves in Dutch road-widening projects?*

Project circumstances are defined in this research as project complexities and project factors. The project case studies conclude about the complexities and factors involved, which are assessed during the project survey among the larger group of road-widening projects (n=17). Correlation analysis shows that the following project factors have the highest correlation with the actually used amount of project reserves.

1. Knowledge of the initial assets
2. Project size
3. Quality of initial functional requirements
4. Stability of the initial project scope
5. Duration of the project

These results confirm the hypothesis of a cause-effect relation between the knowledge of the initial assets and the actual spent project reserves. Extra focus on the initial assets is concluded as efficient measure to avoid additional costs, in this way avoidable costs are avoided.
Despite the fact that the project reserves are generally estimated relative to the project size, the relative needed reserves seem to be larger when the projects become larger, which is in contrast with the economies of scale. No direct explanations are found for this observation, so project managers should be sharp for benefits from economies of scale.

The defined project factors give an answer as to what project circumstances should be included by the project organization, but it does not directly result in a conscious and substantiated decision on the amount of reserves. The next paragraph continues on this topic, including recommendations to achieve this research objective.

### 7.2 Preferred management of the project reserves

The goal of project management is to successfully execute a project within the defined triangle of budget, time and scope. The above-described mechanisms disturb cost management, which emphasizes the relevance to general project management. It is clear that risk management cannot prevent all additional project costs, but the goal should be to eventually avoid all avoidable costs. Several recommendations on the handling of the mechanisms and management of reserves are given as an introduction to the preferred estimation method for project reserves in the next paragraph.

**Recommendations towards disturbing mechanisms**

All described disturbing mechanisms should be eliminated or minimized to create the conditions in order to strive for optimal project reserves. Four recommendations are given:

- **Respect the project management triangle** of budget, time and scope defined by the public client to keep exogenous influences out of individual projects. Every person interviewed emphasizes the importance of the project management triangle, but breaches to the rule are still observed multiple times. When exogenous influences still occur, it is recommended to make precise record of the influence to explain resulting deltas between costs, time and scope. The latter is also applicable for monitoring influences by strategic administration.

- **Do not call a negative tender result exogenous.** Technically, there is no change of scope and the consequences are (partly) manageable through tender conditions. Characterizing the tender result as endogenous also prevents additional effort by the project organization to secure the available budget in case of a positive tender result.
• **Make use of the positive effect of Parkinson’s law** when assigning budgets. Previous research (Kamma et al., 2013) found a significant increase of efficiency by a decreased availability of resources in combination with frequent monitoring.

• **Make use of correlations between project circumstances** to increase the use of historical project data and minimize subjective judgments and optimism bias in the important decision on the amount of project reserves. This recommendation is further explained in the next paragraph.

**Recommendations on managing the project reserves**

Avoidance of extra project costs starts with an overview of the current expenses of the project reserves. In other words, overview of the expenditure of the project reserves creates opportunities to avoid additional costs. This starts with a focus on improvement of the project reserves’ manageability. Several recommendations are given to improve the manageability of the reserves and create this overview of the current expenditure of the reserves.

• **Set the project organization as reference for the definition of exogenous.** The organization of Rijkswaterstaat is mainly chosen as reference for the distinction between endogenous and exogenous, while possible influences from Rijkswaterstaat are not manageable for the project organization. For improvement of the manageability it is recommended to set the project organization itself as a reference and handle influences from for example Rijkswaterstaat as exogenous. Eventually, Rijkswaterstaat does not manage the project, project organization does.

• **Manage the reserves as an external project entry.** Creation of strict financial boundaries results in direct insights into the causes for extra costs.

• **Retain the distinction between contingency and management reserve in the realization phase.** Both reserves are determined separately during the estimation phase, but the distinction blurs during project realization. Strict distinction forces project members to evaluate possible links to the initial risk file. It gives insights into the up-to-date state of the reserves, which also are the available financial resources for active handling of risks (treat, transfer, terminate or take). Based on the case studies, this research suggests that 44% on the project reserves need to be substantiated by risks during the tender phase.

• **Record expenditure data.** Make use of predefined categories to record underlying causes, complexities, predictability, exogenous influences and consequences of occurred risk events. This research provides a framework for continuous analysis of the recorded data, which provides up-to-date knowledge on possible causes of threats and exogenous influences. This gives direct opportunities to react and prevent future extra expenses. In other words, avoidable costs could be avoided through this continuous analysis.
7.3 Preferred estimation method for reserves

The dominant presence of uncertainty in large infrastructure project makes it hard to predict oncoming events and the corresponding costs. Decisions on the amount of project reserves are very important to eventually maximize economic value, where this research illustrates that the initial risk file is not sufficient as decision-making tool for the amount of reserves. It is concluded that initial identified risks are not sufficient for the substantiation of the project reserves, so what is the alternative? An estimation method based on project circumstances is recommended to secure a more objective decision for the project reserves.

Eventually, this preferred method is related to reference-class forecasting (Kahneman & Tversky, 1977), where the project factors in this research can be used as the reference-classes for future estimations of the reserves. Regression analysis on the project survey (n=17) simulates this estimation method and shows significant relations between project circumstances and the actual spent amount of reserves. The following three project factors were already able to explain 68% of the actual spent reserves on the basis of this relatively small database.

- Knowledge of the initial assets
- Project preparation
- Stability of the initial project scope

Reference is made to historical reference data through assessment of the future project circumstances of new projects. Qualitative analysis on underlying complexities and project factors establish the relation with the reference data. In this way, reserves estimations are based on ‘hard’ historical data with demonstrable significance.

Main difficulty for the practical use of this method is the collection of proper project data. The recommendation to record expenditure data generates directly more data that functions as supplement to the reference database, which increases the predictive value on oncoming estimations: leaning curve effects and memory-based learning (Maylor, 2010).

So, through the use of this type of reference-class forecasting, subjectivity in the traditional assumptions is avoided and learning curve effects are added by additional data in the reference database.
7.4 Overall

Summarizing, the answers to the four research questions are given to achieve a more conscious and substantiated decision on project reserves. A theoretical optimum of the project budget is not achieved in practice due to six disturbing mechanisms, but recommendations are given to eliminate or minimize the effects by these mechanisms. In general, this research proves that knowledge of the underlying complexities, causes and project factors in road-widening projects can be effective in producing estimates for the reserves in future projects.
Reflections on the research methodology, obtained data, conclusions and recommendations are given in this chapter. The purpose of this reflection is to place the research in the scientific and practical context. This includes the (1) scientific value of the research; (2) relevancy the field of application of the Construction Management and Engineering master; (3) shortcomings in the research and (4) recommendations for further research.
8.1 Scientific value of the findings

Many researches try to assess estimation accuracies during the estimation phase itself (Trost & Oberlender, 2003) or neglect scope changes during the project realization (Flyvbjerg et al., 2002). This research has a focus on both phases (estimation and realization) and does exclude scope changes in the analysis. Practical used principles for the estimation of reserves are tested and insight on the project factors that influence the actual expenditure are determined in order to give leads for further improvement of estimation of project reserves. This research also includes manageability of project reserves according to the inaccuracies of estimations as an addition to Flyvbjerg (2002) to remain control over project costs.

The figures and conclusions from the three case studies are considered as inductive, so validity of conclusions and recommendation on road-widening projects in general are questionable. This limitation of the research is partly covered by discussions of these conclusions with experts in the areas of project-, risk and cost management.

Complexities in large infrastructure project are applied to analyse Dutch road-widening projects as an addition to Hertogh and Westerveld (2010). Research shows the applicability and relevance to collect knowledge of underlying project circumstances like the defined project complexities.

New knowledge is obtained considering the correlations between project circumstances and the actual used reserves. It seems possible to predict the actual expenditure of project reserves by evaluating the circumstances. The regression analysis in this research delivers a model with significant evidence for the possibility to estimate project reserves based upon the project circumstances instead of the very subjective determined risks. More research on this topic should increase the applicability in practice.

8.2 Relevancy for Construction Management

This research is conducted as master thesis for the master Construction Management and Engineering (CME) at the TU Delft, so relevancy to this field of action is expected. This research is located on the area of risk management and cost management within general project management, which are integrated to tackle a decision-making and project management problem. Recommendations are made to increase the manageability of infrastructure projects and insights are given into the mechanisms that increase knowledge
for the management of construction projects. Due to this, this research is considered as highly relevant to the CME master.

8.3 Shortcomings in the research

Shortcomings are formulated to define the limitations and difficulties towards the research scope, methodology, assumptions and recommendations. These are briefly discussed in order to judge the applicability of the results.

Research scope

- Research units were hard to compare; although only road-widening projects are included, still projects should be approached as unique products or services as stated in chapter 2. The decision on the amount of project reserves has to be considered in every unique case. Still, the origin of the project is the same and structural causes of use of reserves and correlations are observed, which make the projects unique but comparable in the same way. This results in the assumption that the project data is homogenous and stationary.

- Variations in the overall project costs estimation are neglected; this research has a focus on the use of project reserves as financial basis to finance occurred risks. Eventually, occurred risks could also be covered by the variations on every entry in the project budget. Some entries have surpluses, others shortcomings, which are cancelled out by each other to some extent.

- True budget determination takes place in an earlier stage; eventually the budget is determined in a very early stage. So, a more accurate search for the theoretical optimum amount of project reserves requires involvement of the period before the tender phase. A more wide spread view over time was impossible for this research, because the time span from exploration phase till the events during the realization phase can take decades. Nobody is able to explain the principles used at that time. The mechanism of Parkinson’s law includes some conclusions about this pre-tender phase.

Methodology

- Possibility of misinterpretation by the respondents; the presented factors are judged and interpreted by the respondents in the cost expert and project survey.
Misinterpretation by some of respondents could cause more disturbances in the analysis. In that case, the variance in the results in more accurate than presented in the research. Systematic misinterpretation could cause a structural bias in the results. This is threatening, but considered as very low probability because of a minimum of remarks from the respondents about possible misinterpretation.

- **Assumed state of project administration**: All three case studies required another approach to determine the usage of the project reserves. Different definitions were used and needed adjustment of the researcher.

- **Minimal amount of cases within the selection criteria**: there is a limited amount of road-widening projects that are completed within a short time span. Because of this, less data than expected was collected in the project survey. Extraction of outliers in the data was impossible which made the prediction model less accurate.

## Assumptions

- **Differences in contracts and procedures**: possible differences between types of contracts are partly neglected in the research. Project B included a more integrated contract form (DBFM) and project C followed another time schedule on the procedures. The effects on both projects are mitigated by an extraction of a part of the project data.

- **Obtained project data is actual**: the assumption is made that the obtained data from the individual project is actual and contains the correct value for, for example, risk reservations and expenses of events.

## Recommendations

Research gives recommendations towards a better project administration, which is able to record project data. Research shows that this data could be used to identify possible causes for additional project costs and relations between project factors and consequences could be generated. This recommendation requires a change of the project administration, which is seen as the main difficulty for the implementation. The requirement for a very precise project administration by the project team members is proven to be pretty hard according to the expert in the expert meeting.

It is noticed that the project administration is part of the whole administration system, where the latter tends to be dominant. Interaction between these administrations is not part of the research.
8.4 Further research

Further research is needed to expand the project dataset and eventually increase the accuracy of the appointed figures. Also expansion of the type of projects and the contracts involved are very interesting. Further research is suggested on the following topics.

- **Automate the executed analysis for Rijkswaterstaat**: modification of the project administration of Rijkswaterstaat is needed in order to analysis the projects automatically on their performances. This topic in mainly related to IT-solutions, where the exact system requirements are lacking.
- **Correlation between the tender result and order books of the contractors**: no correlation was found with the used project reserves. Still, strategic behaviour of contractor in project negotiations is hypothetically correlated with the condition of their order books.
- **Parkinson’s law between the ‘budget decision for realization’ and the ‘implementation order’**: the project tends to define the scope dependent on the budget in the early phase of the project development. This disturbs the economical analysis for the assessment of project alternatives during the project selection. So, how to secure the maximization of financial and economical benefit, when developing project alternatives?
- **Reduction of main causes**: this research designate several main causes for expenditure of the project reserves. How to exactly prevent future structural use of the project reserves?
- **Economies of scale in infrastructure projects**: regression analysis shows a positive correlation with the actual spent reserves, which questions the applicability of economies of scale for large infrastructure projects. What is happening during the projects that cause absence of possible benefits from economies of scale?
- **Interaction between organization, program and project administrations**: the overall administration without Rijkswaterstaat is interrelated, which causes the one of the mechanisms that disturbs a proper overview on the project costs. Research on interaction between different administrations could result in recommendation for implementation of this research’s recommendations.


CROW. (2010). *Standaardsystematiek voor kostenramingen - SSK-2010.* Ede: CROW.


Rijkens, R. (2013, 3-5-2013). [Conversation about the decision-making process of infrastructure projects].


10 Appendices

The appendices contain additional information on the research.

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C. Global case descriptions

Project A
This road-widening project is located in the Randstad in suburban environment. The traffic density of the highway was very high, which resulted in daily traffic jams. The reason for the project is a further increase of traffic movements which leads to even more traffic flow problems on this specific highway. Previous situation of highway was 2x2 lanes over a length of approximately 20 km, which is widened to 3 lanes in both directions. The construction included the construction of main and parallel road system, where part of the main road is situation below subsurface to minimize the burden for surrounding neighbourhoods. There are also two rivers or canals crossing the route, resulting in the construction of two aqueducts.

The project also involves the development of small area near the route. This development forces the project organization to cooperate with multiple public authorities. The project is not subject of the Spoedwet Wegverbredingen, but most parts are constructed faster because of political pressure.

The contract type was design and build with a total project budget of about 700 million for the complete scope and the contract award was in the year of 2006.

Project B
This road-widening project is located in the middle of The Netherlands in a more suburban environment. It included the modification of 30 km of highway by upgrading the 2x2 lanes to 2x3, adjustment of the road connections and nature measurements. These latter measurements included the construction of about 25 bridges and facilities for nature. This project is executed and financed in cooperation with private construction companies through a DBFM contract. After construction, the private parties still are responsible for the highway maintenances in next 20 years. Eventually, the project is realized two years before planning.

The total project budget for construction was about 260 million and the contract award was in the year of 2010. Because of the contract type of DBFM the constructor is only awarded when the availability of the highway is achieved.

Project C
A project, where major maintenance and road-widening is included. The project is launched due to frequent traffic jams on the highway between two major cities in the middle of The Netherlands. Goal of the project is to increase the traffic flow on the short term as part of the Spoedwet Wegverbredingen. This goal is reached by adding an additional lanes or rush-hour lanes.
Because of political pressure, the project was forced to execute the plan procedure and construction parallel instead of in series. The plan procedure is required to meet the requirements on burden towards the environment. In the meantime construction of the main road is executed already. Consequence of this is an additional influence on the databases used for research. All influences from the plan procedure are cancelled out through data selection in order to make the data comparable to the other cases.

The total project budget for construction was about 250 million and the contract award was in the beginning of 2009 and is finished fall 2013. This involves a design and construct contract with the constructor.
D. Conducted interviews

Orientation interviews and conversations

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<td>Joost van Blokland</td>
<td>Consultant AT Osborne</td>
<td>7-3-2013</td>
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<td>Martijn Gesink</td>
<td>Cost expert Noord/Zuidlijn</td>
<td>15-4-2013</td>
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<td>Manager cost expert RWS</td>
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<td>Martin Schmidt</td>
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<td>23-4-2013</td>
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<td>Rudolf Rijkens</td>
<td>Consultant AT Osborne</td>
<td>3-5-2013</td>
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<td>Arno Kassing</td>
<td>Cost controller Noord/Zuidlijn</td>
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<td>Koen Schrader</td>
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<td>Paul Spruijt</td>
<td>Risk manager RWS</td>
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<td>Melvin van de Coterlet</td>
<td>Consultant operations RWS</td>
<td>28-8-2013</td>
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Case interviews

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E. Expert meeting

Time: 15:00 – 17:00
Date: 15-11-2013
Location: AT Osborne Office in Baarn

Participants expert meeting
Pau Lian Staal Sr. consultant, Infrastructure & Mobility, AT Osborne
Rudolf Rijkens Sr. consultant, Infrastructure & Mobility, AT Osborne
Mark van der Velde Sr. consultant, Infrastructure & Mobility, AT Osborne
Arjen van Esschoten Sr. consultant, Projecticum

Goal
• Discussion on the observation and preliminary conclusions
• Stipulate the recognition of the observation in infrastructure projects in general

Method
• Presentation of observations from the research
• Stipulation of the validity for the results
• Question to the experts as introduction to a short discussion

Discussed topics
• Principles used in practice for the estimation of the project reserves
• Impact of exogenous influences
• Impact of possible tender results
• Influences of Parkinson’s law in infrastructure projects
• Conceptual conclusions

Slides
The used PowerPoint slides for this expert meeting are attached in the following pages, but only available in Dutch.
**Omgang met project reserves**

Inzichten in de projectomstandigheden die invloed hebben op de raming en uitgaven van project reserves in wegverbreidingsprojecten

---

**Deze meeting**

- **Doel**
  - Ter discussie stellen van waarnemingen en conclusies
  - Bepalen van herkenbaarheid van de waarnemingen
- **Middel**
  - Presenteren van waarnemingen uit het onderzoek
  - Herkenbaarheid binnen de weginfrastructuur bepalen
  - Vraag aan experts als aanleiding voor korte discussie
- **Tijd**
  - Totaal 5 onderwerpen
  - Ongeveer 15 minuten per onderwerp
  - Totaal ongeveer 1,5 uur

---

**Introductie onderzoek**

- **Probleemstelling**
  - Veel subjectiviteit in raming van de hoeveelheid projectreserves
  - Achteraf weinig tot geen inzicht in waar deze reservering aan besteed is
- **Onderzoeksperspectief vanuit projectmanagement (projectorganisatie)**
- **Theoretische benadering**

---

**Onderwerpen**

1. Uitgangspunten voor raming post Onvoorzien
2. Exogene invloeden
3. Aanbestedingsresultaat
4. Parkinson’s Law
5. Conclusies

---

**Allereerst: Wat is het doel van de post Onvoorzien?**

- Voorkomen van negatieve invloeden van onzekerheden op de projectdoelen: budget, tijd en scope (project management triangle)
- Kernwoorden vanuit de interviews
  - Flexibiliteit
  - Efficentie
- **Meerdere perspectieven**
  - Project manager
  - Programma manager
  - (Politiek)

---

**Theoretische benadering**
1. Uitgangspunten voor raming post Onvoorzien

- Meerdere ramingsmethoden waargenomen tijdens de tenderfase
  - Op basis van kwantificering risicodossier
  - Op basis van de directe projectkosten
  - Op basis van het grootste benoemde risico
  - Op basis van de verwachte wijzigingen

- Onvoorzien Onvoorzien als verhouding ten opzichte van het
  Voorzien Onvoorzien

2. Exogene invloeden

- Project management triangle - verband tussen budget, tijd en scope
- Perspectief vanuit projectorganisatie
  - Extra besluiten vanuit externe partijen - inclusief RWS en Ministerie - is exogeen
- Kortom, in theorie zouden exogene gebeurtenissen geen onttrekking
  kunnen veroorzaken uit de post onvoorzien

3. Aanbestedingsresultaat

- Estimation of the project reserves
- Expenditure of the project reserves

Project phases

- Budget decisions
  - Realisatie besluit
  - Projectontwikkeling besluit
  - Tendering besluit

Contractual decisions

- Risico beoordeling
- Aantal risico's
- Verhouding tussen VOOO a 45/50/70% onderbouwd met risico's

- Gemiddeld kan ongeveer 30% van de onttrekkingen worden
  herleiden naar inheemse benoemde risico's

- Zijn deze uitgangspunten herkenbaar?

- Hoe steekhoudend is het uitgangspunt om de
  hoogte van de post Onvoorzien te baseren op benoemde risico's?

- Verschillende verhoudingen gekozen
  tussen VO/OO

- Veel mogelijkheden voor subjectiviteit
- Beoordeling risico's
- Aantal risico's
- Verhouding tussen VOOO a 45/50/70%
- Gemiddeld kan ongeveer 30% van de

- Verhouding ten opzichte van het
  Voorzien Onvoorzien

- Gemiddeld kan ongeveer 30% van de onttrekkingen worden
  herleiden naar inheemse benoemde risico's

- Zijn deze uitgangspunten herkenbaar?

- Hoe steekhoudend is het uitgangspunt om de
  hoogte van de post Onvoorzien te baseren op benoemde risico's?

- Verschillende verhoudingen gekozen
  tussen VO/OO

- Veel mogelijkheden voor subjectiviteit
- Beoordeling risico's
- Aantal risico's
- Verhouding tussen VO/OO

3. Aanbestedingsresultaat

- Negatief aanbestedingsresultaat bestempelt als
  exogeen risico

- Positief resultaat vaak binnen projectbudget gehouden
  voor mogelijke inschattingfouten

- Is dit herkenbaar?

- Wordt het risicoprofiel van het project daadwerkelijk
  vergroot bij een positief aanbestedingsresultaat?
4. Parkinson's Law

- Definitie: de vraag naar een middel neigt te groeien naar het beschikbare aanbod van het middel

4. Parkinson's Law

- Projecten zijn vrijgeviger in onderhandelingen als er financiële ruimte is
- Extra budget krijgen is makkelijker dan overschot aan geld teruggeven
- Is dit herkenbaar?
- Onderzoek naar werkgevaar toont aan dat een reductie (33%) van de beschikbare tijd leidt i.c.m. herhaaldelijke begeleiding. In hoeverre kan een dergelijke maatregel effectief zijn binnen projectorganisaties?

5. Conclusies

- Een theoretisch optimale reserve voor projecten is niet te bepalen door de aanwezigheid van verschillende 'mechanismes'
  - Aanbestedingsresultaat
  - Exogene invloeden
  - Subjectieve beoordelingen in de raming
  - Optimaal bias
  - Parkinson's Law
  - Strategisch/politieke administratie

5. Conclusies: vergroten beheersbaarheid van de reserves

- Behandel de reserves als externe post
  - Betere inzicht in de oorzaken van kostenoverschrijding
  - Sterke scheiding tussen VO en OO
    - Consistent aanpakken van onttrekkingsgegevens en projectomstandigheden
      - Continue analyseren van deze gegevens geeft mogelijkheden aan om te reageren
      - Dit onderzoek geeft een kader om deze analyse uit te voeren

- Waarom gebeurt dit binnen huidige project management niet?
- Wat zijn bijzondere moeilijkheden?

5. Conclusies: alternatieve ramingsmethode voor de reserves

- Gebruik projectomstandigheden van voorgaande projecten als referentie in de bijhorende 'onttrekking gegevens'
  - Specifieke projectomstandigheden en de gebruikte project reserves
  - Dit onderzoek laat significant correlation zien tussen projectomstandigheden en de gebruikte project reserves
  - Hiermee maakt je gebruik van harde historische informatie
    - Aantoonbare significantie van je raming
    - Subjectiviteit binnen de raming vermeerderd

Omgang met project reserves

Inzichten in de projectomstandigheden die invloed hebben op de raming en uitgaven van project reserves in wegverbindingsprojecten
F. Correlation matrix of the defined project factors

Strong correlations are marked green and moderate correlations are marked yellow.

<table>
<thead>
<tr>
<th></th>
<th>y</th>
<th>x1</th>
<th>x2</th>
<th>x3</th>
<th>x4</th>
<th>x5</th>
<th>x6</th>
<th>x7</th>
<th>x8</th>
<th>x9</th>
<th>x10</th>
<th>x11</th>
<th>x12</th>
<th>x13</th>
<th>x14</th>
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G. Statistical properties of the management reserve

This is appointed as confidential by the source of the data.