The Interplay between the Contract Type and the Management of Cost Groups

Exploring the relationship between the contract type and the management of cost groups in Dutch national infrastructure projects

K. M. van der Kruis

Master Thesis

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By

Ing. K.M. (Kevin) van der Kruis

In partial fulfillment of the requirements for the degree of

Master of Science in Construction Management and Engineering

At the Delft University of Technology

To be defended on October 1st, 2019 at 15:00

At the Delft University of Technology

COLOPHON

Document

Document title	The Interplay between the Contract Type and the Management of Cost Groups
Subtitle	Exploring the relationship between the contract type and the management of cost groups in Dutch national infrastructure projects
Version	Public
Place and date	The Hague, 01-10-2019

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Preface

This thesis entails the end of my study career which started eight years ago at the University of Applied Sciences in Amsterdam with the goal to become a structural engineer. The study civil engineering taught me to look at the world from a technical point of view. However, it also showed me that my true interests were more on a process level. After a gap year I decided to start with the master Construction Management & Engineering and thereby continuing my study career as a student at the University of Technology in Delft. During my time in Delft I was introduced to the ongoing search for better contract types which resulted in a wide array of construction contracts. In the meantime, I started noticing the repeating media coverage of construction projects that do not meet budget or deadlines. Risk allocation and collaboration were recurring reasons for these failed projects. This quest for new contract types combined with failing projects has sparked my interests and eventually led to my research topic.

This topic started my graduation thesis which has been written in partial fulfillment of the requirements for the degree of Master of Science in Construction Management and Engineering at the Delft University of Technology. After seven months of reading articles, performing statistical analyses, and interviewing specialists I believe I have had the unique opportunity to analyse financial data and to interpret these results on a process- and project management level. Before presenting this thesis to you, I would like to thank the people that have been supporting me throughout this process.

First, I would like to thank my graduation committee of the TU Delft for their constructive criticism. These often-difficult questions let me reach a true academic level. A special thanks to my first supervisor, Leon Hombergen, for his supportive comments which forced me to reflect on my own work on numerous occasions. Additionally, to my second supervisor, Leonie Koops, for providing clarity in the first few weeks of this journey. Moreover, my professor, Hans Bakker, for his trust and valuable comments during the entire process.

In addition, I would like to thank Dura Vermeer for providing me with a database that made this thesis possible. A special thanks to Guus Keusters, for showing me the intricacies of a contractor while providing critical and supporting comments throughout. Second, Pim van Veen for his everlasting enthusiasm and weekly guidance during this thesis. Furthermore, a special thanks to all employees of Dura Vermeer who participated in an interview during my research. Thank you for your time and effort showing me the practical implications of my data analysis and forced me to evaluate my own convictions.

Last but not least I wish to thank all the people that supported me during this graduation process and my study career. First, my parents for providing me with the opportunities to pursue my goals. Second, my girlfriend Monique for cheering me up and putting things into perspective. Additionally, to my fellow graduate student Daniël for his time, reflecting om my research and discussing how to deal with the struggles of writing a thesis. Thanks to all of you this thesis has become more gratifying than I had anticipated.

Enjoy reading!

Kevin van der Kruis

Den Haag, October 2019

Executive Summary

Construction projects are argued to be the most complex of all production undertakings (Baccarini, 1996). Williams (2002, 2005) states that the complexity of these projects is a contributing factor to project failures, such as cost overrun, which are commonly seen in infrastructure project (Cantarelli, Molin, Van Wee, & Flyvbjerg, 2012). As one of the first Morris & Hough (1988) describe that cost overruns are common and that many projects appear as failures, while Flyvbjerg et al. (2003) agrees with Morris & Hough, by stating that this is a long-lasting problem since cost estimates have not improved and cost escalations have not decreased in the past 70 years. They concluded that optimism bias and/or strategic misrepresentation seemingly best explain cost underestimation. More recent news articles in Cobouw, an independent weekly magazine about the construction industry, illustrate that cost overruns on construction projects still occur in the Netherlands. The sea lock in IJmuiden, Gaasperdammertunnel, A15MaVa, and the Uithoflijn are all examples of infrastructure projects that incurred cost overruns (ANP, 2018; Koenen, 2018b, 2019c). However, between the 1990s and 2000s, western governments were reassessed and more tasks were privatized (England & Ward, 2007; Pollit & van Thiel, 2007). Governments expected that private contractors would be able to innovate more, deliver quicker, reduce costs, and operate more efficient (Savas, 2000). This has resulted in six integrated contract types to this date, including the building team, Engineering & Construct, Design & Construct, DBM, DBFM(O), and the alliance. Combined with the traditional RAW contract brings the number of contract types to seven. However, the fact that the British government will no longer use Private Finance Initiatives indicates that a transfer of tasks to the market does not always result in positive project results for the client and the contractor, as stated by Hertogh & Hombergen (2018) in an opinion article in Cobouw. This raises the question if the reasoning of Flyvbjerg et al. (2002) is still applicable, 17 years later, to the reliability of budget estimations of projects with integrated contract forms? Or has the reliability of certain budgets, i.e. cost groups, improved with integrated contract forms which has been overlooked due to the aim on total cost overrun in recent studies? Therefore, this research aims to provide insight into the relationship between contract type and the management of cost groups in order to improve cost management. To achieve this, the following main research question is formulated:

What is the relationship between the contract type and the management of cost groups, in Dutch national infrastructure projects and can this relationship be used to improve cost management?

To provide an answer to the main research question, both quantitative and qualitative research is conducted. First, a literature study is performed that describes the theoretical context concerning the different contract types used in Dutch national infrastructure projects. In addition, the process of cost estimation is described, and the causes of cost overruns and influential project characteristics are explored. Based on the theoretical framework, six hypotheses have been formulated. These hypotheses are tested using statistical analysis of a database with budget and cost performance data of 68 infrastructure projects with contract types including, RAW (n=24), E&C (n=22), and D&B(M) (n=22). Cost performance is defined as the accuracy of a budget by subtracting the working budget from the realized costs and dividing this by the working budget. Based on the results eight findings have been formulated that subdivide the accepted hypothesis one and two. The findings are discussed with an expert panel through four semi-structured interviews that have been conducted with employees of Dura Vermeer.

Based on the literature study, the statistical analysis, and the performed interviews four key findings can be identified. First, this study is unable to demonstrate the existence of a relationship between the contract type and the cost performance of infrastructure projects. Since *engineering* is the only cost group out of the nine analysed cost groups, that showed a statistically significant (p=0.041) difference between E&C and D&B(M) as illustrated in Figure 1. Applying clusters based on project characteristics that are suggested by scholars to influence cost overruns, including project type, type of client, project location or project size does not significantly change the difference between the cost performance of RAW, E&C, or D&B(M). Surprisingly, all interviewees have stated that they understand that the cost performance of D&B(M) projects is lower without knowing that this difference is only marginally and insignificant. The underlying reasoning of the interviewees is judged to be originating from the difference between E&C and D&B(M) projects concerning *engineering* costs

combined with the engineering process. Since the results show that D&B(M) projects have significantly higher cost overruns on *engineering* compared to E&C projects and most interviewees used engineering process examples to explain why D&B(M) projects incur more cost overruns. This study, however, cannot definitely state that the underlying reasoning of the interviewees originated from the significant difference observed within the cost group *engineering* since this observation has not been validated.

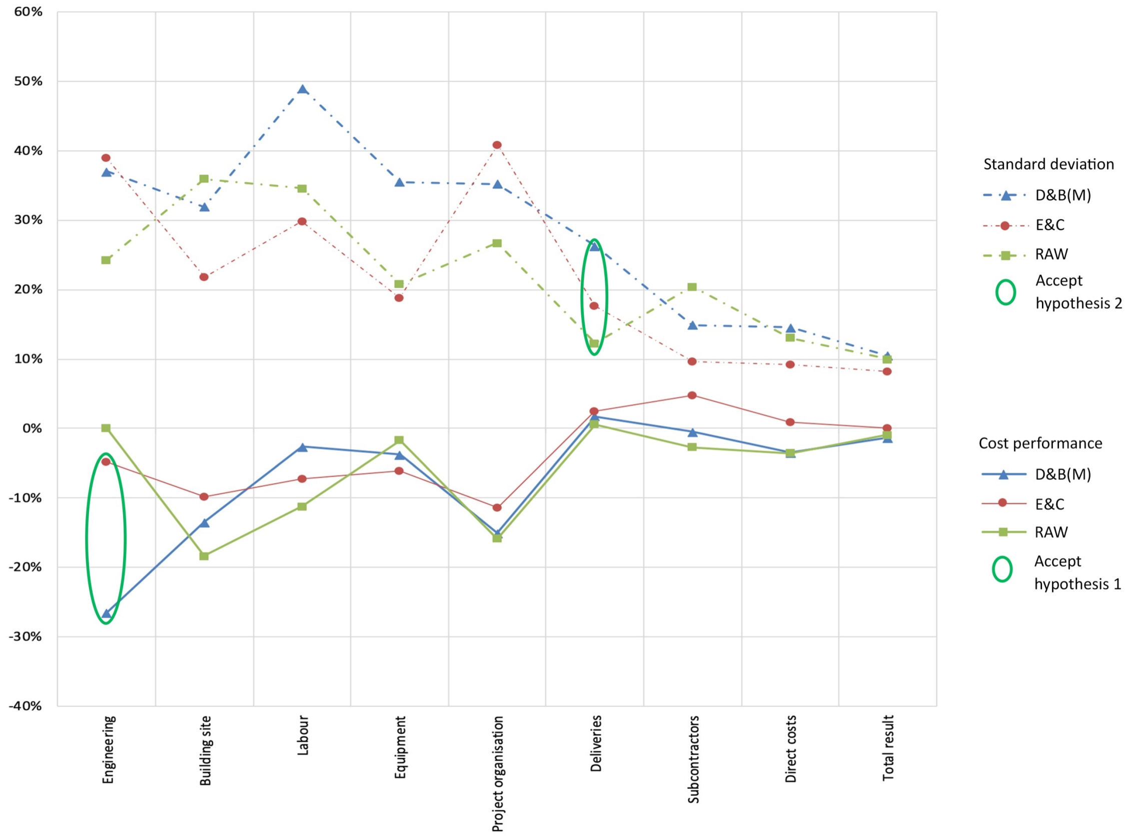

Figure 1 Cost performance and standard deviation per cost group, ordered from relatively small (Left) to large (Right) budgets

In addition, this study has found no evidence that the contract type, and thus the unavailability of information influences the uncertainty of the cost performance of infrastructure projects. Moreover, it is shown that in the case of *total costs*, *direct costs* and the cost groups *labour, equipment, subcontractors,* and *building site,* E&C projects have the lowest standard deviation as shown in Figure 1. However, the expert panel unanimously stated that more information at the moment of contracting would guarantee more certainty about the cost performance. McKinsey, a strategic advisory bureau, states that this belief can be found throughout the GWW-sector (Rijkswaterstaat, 2019). Based on this assumption McKinsey advises Rijkswaterstaat to apply a new "two-phases-method" in which the cost estimation of the execution phase happens after the design phase. However, the current study illustrates that the unavailability of information based on the moment of contracting does not influence the uncertainty of the cost performance. In addition, it shows that the allocation of design responsibilities nor changing levels of design specificity have an influence on the difference in cost performance of cost groups between contract types. Thus, this study expects that solely the separation of design and execution as proposed by McKinsey will not result in less uncertainty about the cost performance. Instead, this study illustrates that Dura Vermeer experiences difficulty with their performance on relatively small, often indirect cost groups even though Dura Vermeer confidently uses predetermined percentages to estimate these cost groups. Figure 2c illustrates which cost groups have a high delta and are therefore perceived to be certain, based on the use of percentages, but have an uncertain cost performance. The indirect cost groups are important to the project since their combined relative size is roughly one-third of the total budget. Instead, the current study suggests that it should be a combined effort of both client and contractor to improve the process of constructing large complex infrastructure projects instead of focussing on the allocation of design responsibilities and risks.

Last, this study illustrates that both cost underestimation and inefficient process are key reasons for cost overruns for a contractor. Thereby, the reasoning of Flyvbjerg and his colleagues, based on the clients perspective, being optimism bias seemingly best explains cost overruns is not acknowledged by this study, from a contractors perspective (e.g., Flyvbjerg, 2009; Flyvbjerg, Skamris Holm, et al., 2004; Flyvbjerg et al., 2002, 2003). Since interviewees mentioned in the current study that cost underestimation is a factor combined with inefficiencies during the design and execution process. Verweij (2015) previously clarified this by stating that one should accept that infrastructure projects are complex systems in which unforeseen events inevitably occur. This insight is perfectly described by the sociologist, William Bruce Cameron who stated: “not everything that counts can be counted and not everything that can be counted counts” (Cameron, 1963, p. 13).

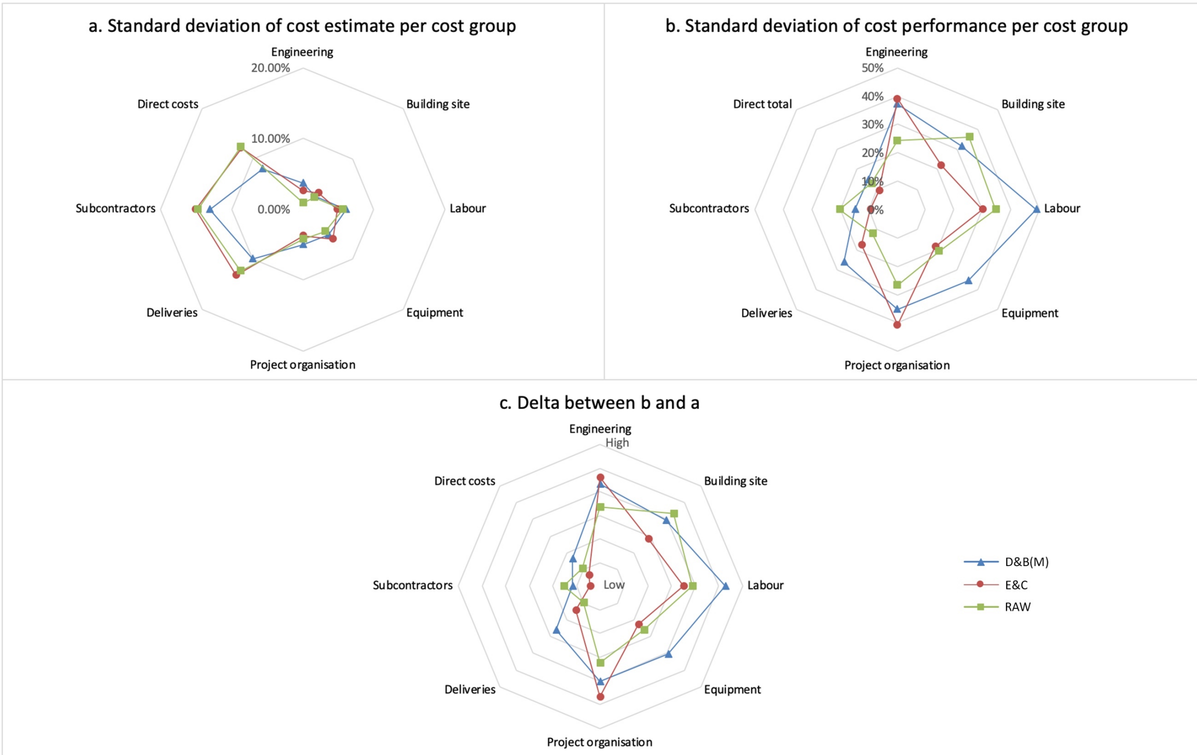

Figure 2 a. Standard deviation of cost estimation per cost group. b. Standard deviation of cost performance per cost group. c. Delta between figure b and a. Clockwise ordered from relatively small to large budgets

It can be concluded that this study has been unable to find a relationship between the contract types RAW, E&C, and D&B(M) and the cost management of Dutch national infrastructure projects. However, it has been observed that project members of a contractor overestimate the relationship that D&B(M) projects should have higher cost overruns. This study concludes that the cost performance, of cost groups other than *engineering*, differ insignificantly and marginally small between contract types with varying design responsibilities. Moreover, the expert panel assumes that more information leads to less uncertainty and risks resulting in less cost overruns. Which is a common reasoning as stated in the GWW market analysis performed by McKinsey. However, this study concludes that the unavailability of information depending on the moment of contracting does not have an influence on the uncertainty of the cost performance nor the cost performance itself. Therefore, this study does not believe that the “two-phase-process” as proposed by McKinsey will contribute to less uncertainty about the cost performance. Instead, this study illustrates that Dura Vermeer confidently applies percentages to estimate relatively small, often process-related indirect cost groups which on average incur a cost overrun. Therefore, both the client and contractor should improve the process of constructing large complex infrastructure projects.

The generalizability of this study is limited by six factors in total. First, the methodological choice to use a database with Dura Vermeer projects combined with interviews with Dura Vermeer employees could create a bias towards the contractor’ perspective. Moreover, a larger sample size would further strengthen the conclusion of this study. In addition, only three out of seven contract types were analysed during this study. While seven cost groups could not be analysed due to data quality. Moreover, the conclusions that are drawn from the statistical analysis apply to a not clustered situation that does not take into account any project characteristics including, type of client, project type, project size, or project location. Last, due to the size of the expert panel, the difference in opinions between functions could not be analysed.

This study recommends Dura Vermeer to improve cost management in four ways. A first quick win is to use the quantitative results of this study as a frame of reference. An infographic is included in Appendix E to facilitate this process for Dura Vermeer. A second, more long-term, recommendation for Dura Vermeer is to improve their control over relatively small, often process-related indirect cost groups. Which can be achieved by improving the administration and thereby the data quality of the cost groups including *conditioning, financial, chance and risks, contractual changes, general, provisional sums,* and *procurement results*. Consequently, machine learning techniques could be applied to assist in estimating costs when the data quality is improved. In addition, Dura Vermeer should improve the implementation of process-related cost groups by improving the process of constructing infrastructure projects together with the client instead of concentrating on the allocation of design responsibilities and risks. Last, the usability of the database can be improved by considering the large spread that exists in the database. Combined with increasing the sample size and creating additional subdivisions in the cost group *subcontractors* to gain insight in the cost performance of different types of subcontractors.

In addition, this study recommends conducting further research into the difference between the perspectives of the client and the contractor concerning the cost performance of different contract types. Furthermore, replicating this study on a database owned by a different contractor can validate the conclusions of this study. Besides, the current analysis can be extended in three ways by first analysing the database clustered by project characteristics. Second, including additional contract types such as alliance and/or building team contracts since these contract types aim to improve collaboration. Last, the influence of a Most Economically Advantageous Tender (MEAT) component on the cost performance could be further analysed. In addition, further research can investigate if D&B(M) projects are more affected by the inefficiencies compared to E&C projects as suggested by interviewees.

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List of Abbreviations

CBS	Cost Breakdown Structure
D&B	Design & Build
DBFMO	Design, Build, Finance, Maintain & Operate
DO	Detailed design
E&C	Engineering & Construct
GWW	Ground, Road, and Water sector
LTU	Low, Top, and Upper values
MEAT	Most Economically Advantageous Tender
NOK	Norwegian krone
PDM	Product Delivery Model
PFI	Private Finance Initiatives
PPP	Public-Private Partnership
RAW	Rationalisatie en Automatisering Grond-, Water- en Wegenbouw
SD	Standard Deviation
UAV	Uniforme Administratieve Voorwaarden
UAV-GC	Uniforme Administratieve Voorwaarden - Geïntegreerde Contracten
UO	Construction design
VO	Preliminary design

1 Introduction

1 INTRODUCTION

This chapter illustrates the reason for this research by providing the context, including the problem statement, in Section 1.1. Section 1.2 provides an insight into the research demarcation and the underlying objective. Based on the preceding Sections, the main research question with supporting sub-questions is formulated in Section 1.3. Consequently, Section 1.4 motivates the relevance of the research. The approach of this research is presented in Section 1.5 followed by the reading guide in Section 1.6.

1.1 CONTEXT & PROBLEM STATEMENT

According to the Project Management Institute (2004), the definition of a project is: *"A temporary endeavour with a beginning and an end and it must be used to create a unique product, service or result"*. It is argued that construction projects are complex and could be viewed as the most complex of all production undertakings (Baccarini, 1996). Understanding the complexity of projects is the subject of a large number of scientific papers, illustrating the importance of complexity (Bosch-Rekveldt & Mooi, 2008; Bosch-Rekveldt, Jongkind, Mooi, Bakker, & Verbraeck, 2011; Dombkins & Dombkins, 2008; Geraldi & Adlbrecht, 2007; Hass, 2007; Maylor & Vidgen, 2008; Vidal, 2008; Williams, 2002). According to Williams (2002, 2005), the complexity of projects is a contributing factor to project failures. A type of project failure is cost overrun which is commonly seen in infrastructure projects (Cantarelli, Molin, et al., 2012). One of the first who describes cost overruns are Morris & Hough (1988) (through Dalcher (2012)). Morris & Hough (1988) describes that cost overruns are common and that many projects appear as failures. Flyvbjerg et al. (2003) agrees with Morris & Hough, by stating that this is a long-lasting problem since cost estimates have not improved and cost escalations have not decreased in the past 70 years. During this period several studies have been performed to illustrate the frequency and magnitude of cost overruns. Table 1 illustrates that cost overruns appear on a global scale. To illustrate, searching for cost overrun in the ABI/INFORM database provides more than 20 countries world-wide in which scholars conducted research in the area of cost overrun. Furthermore, these publications date from 1973 to 2019, illustrating that cost overrun is a widely discussed topic among scholars. Table 1 also presents that all studies show that cost overruns are indeed frequent with a magnitude ranging from 4 per cent to more than 50 per cent. One might ask themselves, why is there such a large range. A contributing factor in this large range is an inconsistent definition of cost overrun used in literature. To illustrate, Nijkamp & Ubbels (1999) ,Flyvbjerg, Skamris Holm, & Buhl (2002) and Odeck (2004) defined a cost overrun as the difference between forecasted and actual construction costs. The forecasted budget in this case is the *budget at the time of decision to build*. Alternatively, Rowland, (1981) and Hinze, Selstead, & Mahoney (1992) define a cost overrun as the difference between the original contract value, i.e. *budget at moment of contracting*, and the actual construction costs.

Table 1 Frequency and magnitude of cost overruns found in literature. [a] (Source: Cantarelli et al. (2012))

Study	*Geographical area*	*Frequency cost overrun (%)*	*Magnitude of cost overrun*							
			Road		*Rail*		*Fixed*		*Other*	
			%	*N*	*%*	*N*	*%*	*N*	*%*	*N*
Merewitz, (1973)	US	79	26	49	54	17				
Morris, (1990)	India				164	23			4	1
Pickrell (1990, 1992)	US	88			61	8				
Auditor General of Sweden (1994)	Sweden		86	8	17	7				
Nijkamp & Ubbels (1999)	Netherlands, Finland	75							0-20	8
Bordat, McCullouch, Labi, & Sinha (2004)	US	55	5	2668[b]						
Odeck (2004)	Norway	52	8	620						
Dantata, Touran, & Schneck (2006)	US	81			30	16				
Ellis, Pyeon, Herbsman, Minchin, & Molenaer (2007)	US		9	3130						
Lee (2008)	South Korea	95	11	138	48	16	34	33		

a: In which: %: the percentage cost overrun and N: the number of projects with cost overruns

b: Projects include: Road and bridge construction and rehabilitation projects; maintenance projects, with road maintenance and resurfacing

Cantarelli et al. (2012) argue that the studies of Flyvbjerg, (2007); Flyvbjerg et al., (2002, 2003); Flyvbjerg, Skamris Holm, & Buhl, (2005) can be treated as the leading research into cost overruns because of the extensive sample size of 258 transportation infrastructure projects. This sample size covers a long time period, including various project types from different geographical locations. Flyvbjerg et al. (2002) has stated that optimism bias and/or strategic misrepresentation seemingly best explain cost underestimations which result in cost overruns.

More recent news articles in Cobouw, an independent weekly magazine about the construction industry, illustrate that cost overruns on construction projects still occur in the Netherlands. To illustrate, the sea lock in IJmuiden currently has a growing cost overrun of more than €272 million, on an initial contract value of €600 million (Koenen, 2019c). Furthermore, several tunnels in the Netherlands have been constructed with concrete that does not comply with fire safety standards. This resulted in a cost overrun of more than €200 million for the Gaasperdammertunnel (Koenen, 2019c). Another project which received negative media attention is A15MaVa largely because of the problems with the availability of the Botlek bridge. In April of 2018, it was chosen to replace all 64 wheels that raise the bridge in order to solve the availability problems (Koenen, 2018b). The exact costs of this replacement have not been published but it is clear that the availability problems have resulted in a multi-million cost overrun. A final example is the Uithoflijn in Utrecht, which incurred a cost overrun of more than €100 million due to bad collaboration between client and contractor (ANP, 2018).

1.1.1 From traditional to integrated contracts

Between the 1990s and 2000s new public management ideas sparked a transition of western governments (Osborne & Gaebler, 1992). Governments were reassessed and more and more tasks were privatized (England & Ward, 2007; Pollit & van Thiel, 2007). The fundamental idea behind this transfer of tasks was, the expectations that private contractors would be able to innovate more, deliver quicker, reduce costs, and operate more efficient (Savas, 2000). Until then, the Dutch Ministry of Infrastructure and Water Management and their executive agent, Rijkswaterstaat, used a 'RAW-bestek' as a contract form in which the desired solution was described (Lenferink, Tillema, & Arts, 2013). This description included technical design, and fundamental calculations for materials and construction time. Based on the estimates made by the client, the contractor had the possibility to tender for the contract by calculating its price. The contractor with the lowest bid was awarded the contract. From 1990, Rijkswaterstaat started to use different contract types to construct, re-construct, and maintain their assets (Lenferink et al., 2013).

First, the responsibility for the technical design was transferred to the contractor in Engineering and Construct (E&C) contracts. Based on positive experiences with E&C contracts, the Design & Construct (D&C) contract followed, which became the standard contract type for procuring infrastructure for Rijkswaterstaat (Lenferink et al., 2013; Rijkswaterstaat, 2008). With this contract, the client no longer provided a design but instead specified output specifications which formed the basis of the tender procedure. This integration of tasks was continued by including the maintenance, finance, and operation in the contract. Resulting in the Design, Build & Maintain (DBM) contract and the Design, Build, Finance, Maintain & Operate (DBFMO) contract. Integrated contract forms are called a Public-Private Partnership, or PPP, which refers to a contractual agreement formed between a government agency and a private sector entity that allows for greater private sector participation in the delivery of public infrastructure projects (Eggers & Startup, 2006). An overview of this development over time is presented in Figure 3. The

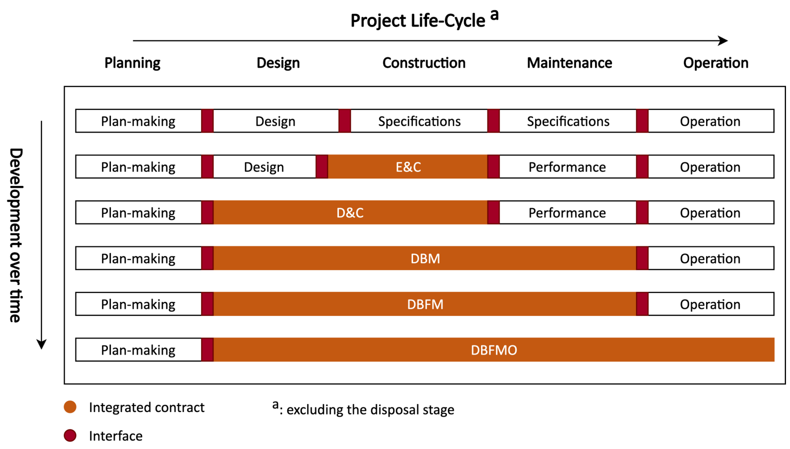


Figure 3 Development of integrated contracts in the infrastructure project lifecycle (Source: Lenferink et al. (2013))

United Kingdom and Australia were first to implement PPP under the name Private Finance Initiative (PFI). In 2003, the United Kingdom's National Audit Office reported that non-PFI construction projects were in 73 per cent overbudget, which is in line with the studies of Flyvbjerg et al. (2002). PFI projects however were reported overbudget in only 22 per cent of the cases (National Audit Office, 2003). A more recent benchmarking study in Australia, reported the performance of PPP projects. This study defines a PPP as a contracting arrangement in which a private party takes responsibility for financing and long-term maintenance to provide long term service outcomes (Duffield, Raisbeck, & Ming, 2008). Duffield et al. (2008) concluded that PPP projects provide greater cost certainty than traditional contracts, since PPP contracts had an average cost escalation of 4.3 per cent compared to 18 per cent for traditional projects. This shows that PPPs have the potential to deliver projects on-budget.

The fundamental idea behind the transfer of tasks was, as earlier described, the expectations that private contractors will be able to innovate more, deliver quicker, reduce costs, and operate more efficiently. However, recent developments in England, indicate the contrary for DBFM(O) contracts. The National Audit Office (2018) states that the expected benefits from PFI's cannot be substantiated due to a lack of data. In response, the British Minister of Finance, Hammond published a statement, on 29 October 2018, indicating that the government will no longer use PFI's (HM Treasury, 2018). Thereby reconciling that a transfer of tasks to the market often resulted in negative project results for both the client and the contractor, as stated by Hertogh & Hombergen (2018) in an opinion article in Cobouw.

Cost overruns in traditional contracts, until 2002, are thus common and have not been decreasing in the past 70 years. Recent news articles in Cobouw have shown that cost overruns still occur today. Optimism bias and/or strategic misrepresentation seemingly best explains cost underestimations (Flyvbjerg et al., 2002). Even though, PPPs were considered better than traditional contracts, the decision of the British government indicates that the transfer of tasks to the market is not always the appropriate approach. Is the reasoning of Flyvbjerg et al. (2002) still applicable, 17 years later, to the reliability of budget estimations of projects with integrated contract forms? Or has the reliability of certain budgets, i.e. cost groups, improved with integrated contract forms which has been overlooked due to the aim on total cost overrun in recent studies? This uncertainty indicates a need to better understand the relationship between the type of contract and the management of cost groups.

In response to this need, the aim of this research is formulated in the following problem statement:

> *Responsibilities within the Dutch infrastructure sector have shifted from the client to the contractor with integrated contract forms. More integrative contract forms should improve cost control, however quantitative studies and recent news articles have shown that total cost overruns are still common. The relationship between the type of contract and the management of cost groups in Dutch national infrastructure projects is not clearly defined in theory or in practice. Therefore, this research aims to obtain insights into this relationship in order to improve cost management.*

1.2 RESEARCH DEMARCATION & OBJECTIVE

Verschuren & Doorewaard (2015, p. 134) state that the demarcation of research is primarily conceptual instead of technical, despite the misconception that this is the other way around. The first conceptual demarcation is the formulation of the problem statement. The problem statement firstly states that: *"The Dutch construction sector is shifting more responsibilities, …"* which indicates a focus on the Dutch construction sector. The study of (Cantarelli, Flyvbjerg, & Buhl, 2012) underpins the focus on the Dutch construction sector since they concluded that the geographical location of a project matters for the performance of a project, to a changing degree per project type. Because the Dutch construction sector is too broad, a demarcation is needed. Therefore, this focus is further specified by only including Dura Vermeer Infra National Projects (DVILP). These projects consist of, e.g. dike-, road- and rail projects. The consequence of this focus is that the recommendations will be fully applicable to Dura Vermeer and only partially applicable to the entire Dutch construction sector.

The problem statement also states: *"More integrative contract forms should improve cost control…"*. This provides a second demarcation of this research because cost control is part of project management. However, the entire scope of project management is not feasible for this research. Therefore, this research focusses on cost management and more specific, the estimation of cost groups. Improving cost management and the estimation of cost groups can be done in various ways. This research will focus on providing insight into the relationship between the various aspects.

Contract forms can be viewed from the viewpoints of several stakeholders. This threatens the feasibility of this research; therefore, an additional demarcation is required. This literature study will focus on the perspectives of the client and the contractor, in this case, Dura Vermeer. It can be argued that the client acts on behalf of several stakeholders with several viewpoints which result in more than two viewpoints. However, this demarcation is deemed necessary to maintain focus in this research. Further analyses, which will be introduced in Section 1.5.2, will focus on the perspective of the contractor.

Lastly, within the Dutch construction sector various different contract forms are used. In order to safeguard the feasibility of this research, a demarcation is needed to exclude several contract forms. This research will focus on contracts based on the Uniforme Administratieve Voorwaarden (UAV) or the Uniforme Administratieve Voorwaarden - Geïntegreerde Contracten (UAV-GC). This includes contracts such as: RAW, Engineering & Construct (E&C), Design & Build (D&B), Design Build & Maintain (DBM), Alliance, and Design team. Design, Build, Finance, Maintain & (Operate) is not based on the UAV-GC but is included in this research. This demarcation excludes contracts such as FIDIC, and NEC4.

Based on the problem statement and the research demarcation, as summarized in Figure 4, the research objective is formulated as follows:

> *To provide insight in the relationship between the contract type and the management of cost groups in Dutch National infrastructure projects by illustrating how and why the contract type can influence the control of cost groups and thereby improve cost management.*

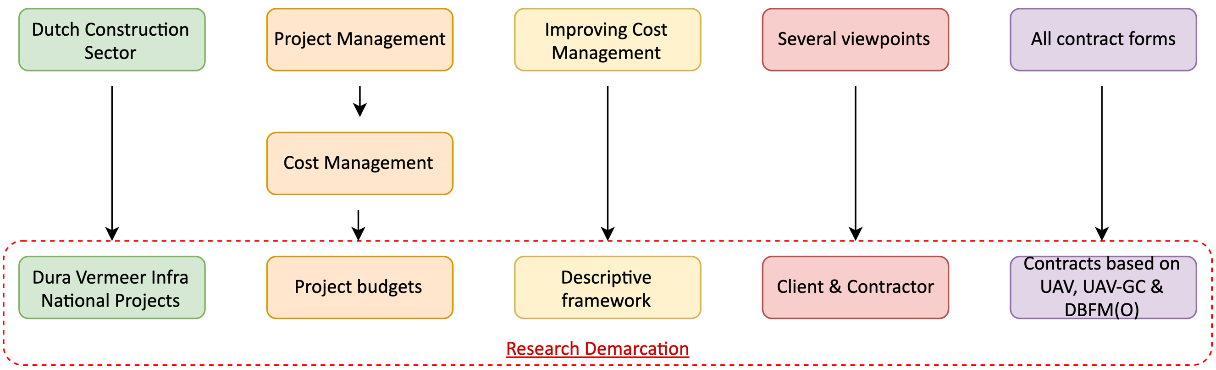


Figure 4 Summary of research demarcation (own illustration)

1.3 RESEARCH QUESTION

Based on the context, problem statement, and research objective the main research question can be formulated. Verschuren & Doorewaard (2015) state that a research question should be formulated in such a manner that the answer is needed to accomplish the research objective. Furthermore, the most important criteria of a research question are its efficiency, its steering capability, and its demarcation (Verschuren & Doorewaard, 2015). Efficiency relates to the amount of knowledge that answering the main research question contributes to the research objective. The steering capability of the research question shows which steps have to be performed in the research.

Taking these guidelines into consideration, the following research question is formulated:

What is the relationship between the contract type and the management of cost groups, in Dutch national infrastructure projects and can this relationship be used to improve cost management?

In order to answer the main research question, and guide the research, the following sub-questions are formulated:

1. Which type of contracts are used in Dutch national infrastructure projects?
2. Which type of cost groups are used in Dutch national infrastructure projects to subdivide the total project budget and how are these cost groups estimated?
3. What is the relationship between the contract type and the management of cost groups in practice?
4. What causes the relationship between the type of contract and the management of cost groups?
5. How could the obtained insight be used to improve cost management?

1.4 RESEARCH RELEVANCE

This research has scientific and practical relevance. The study of Flyvbjerg et al. (2002) can be, as previously mentioned, considered one of the leading research into cost overruns. On the contrary, Flyvbjerg et al. (2002) only compares total costs instead of individual cost groups. Furthermore, the type of contract has not been a variable while studying the database. Studying these variables could lead to surprising new insights or an acknowledgement of reasoning of Flyvbjerg et al. (2002). Therefore, this study aims to fill this gap in knowledge by focusing on different cost groups and contract types. Furthermore, a study which explores the relationship between the type of contract and the control of cost groups is, to the best of the authors' knowledge, nonexistent in literature.

The practical relevance of this research can be viewed from the client's and the contractor's perspective. The client chooses which type of contract is going to be used. The type of contract is chosen to match the project characteristics and to assure project success. However, because this choice is made during an early stage, a limited amount of project-specific information is available. In addition to the project characteristics, insight into the relationship between the type of contract and the control of cost groups, provided by this research could provide new information when considering the contract type. Furthermore, insight into the control of cost groups in different contract forms could provide a cost group that is likely to require more attention during the management of that particular contract.

From the contractor's perspective, insights into the relationship between the type of contract and cost groups are valuable because this knowledge can assist in two ways. First, a contractor can use these insights during the tender phase in order to assign resources to certain parts of a project to better control the corresponding cost groups, thereby aiming to create a competitive bid. During a time in which tendering becomes a risk in itself, it is very valuable to use quantitative insights to your advantage. Second, in the event that the contractor is awarded the contract, it is valuable to know how the control of the cost groups is likely to be influenced by the type of contract. The contractor could use its resources during the different phases, to control these cost groups and thereby aiming for a successful project.

1.5 RESEARCH APPROACH

The research objective is to provide insight in the relationship between the contract type and the management of cost groups. The chosen research method aims to reach this objective by incorporating both quantitative and qualitative research. Figure 5 presents a first overview of the applied research methodology. A further explanation is provided in Sections 1.5.1, 1.5.2, and 1.5.3.

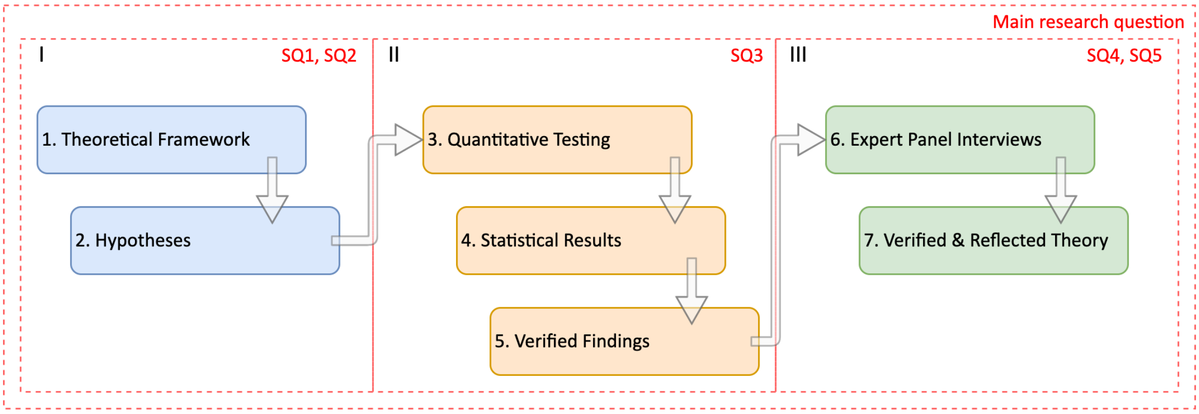


Figure 5 Research methodology (own illustration)

1.5.1 PHASE ONE – LITERATURE STUDY

The first phase is a theoretical phase in which a literature study is performed in order to answer sub-questions one and two, as shown in blue in Figure 5. In order to answer sub-question one and two, the aim of this literature review is to gain insight into which contracts are used in the Dutch national infrastructure domain, how a total project budget is divided into cost groups, how these cost groups are estimated, and by which factors they are influenced. Several procedures were followed to ensure a high-quality review of literature on the aforementioned topics. Four databases will be used, including ABI/INFORM complete, IEE Xplore Digital Library, Web of Science and Google Scholar. For this literature study, several inclusion criteria are formulated. Firstly, articles must be directly related to either (integrated) contracts forms, cost control, project budgets, cost groups, or factors influencing cost overrun. Secondly, all articles must be peer-reviewed and published in a journal. Thirdly, articles must be less than 30 years old. This period of 30 years is chosen because the body of knowledge on project management is slowly evolving. Therefore, an important insight made 30 years ago is still applicable today. However, literature about the use of contracts in Dutch national infrastructure projects should be less than 20 years old since the change from traditional contracts to integrated contracts has taken place during the last 20 years. Lastly, the studies can be both qualitative and quantitative. The hypotheses based on the theoretical framework will be the point of departure for the second research phase.

1.5.2 PHASE TWO – STATISTICAL ANALYSIS

The second phase is a quantitative research phase and aims to answer sub-question three. This phase is divided into three steps, as shown in orange in Figure 5. An already existing database, owned by Dura Vermeer, will be used to perform statistical analysis. The statistical analysis will be based on the hypotheses of phase I and aims to formulate findings. This database in question, consists of financial data of projects realised by DVILP, excluding housing projects. These projects comply with the following conditions:

- ≥ 95 per cent complete,
- procured in 2012 or later,
- based on UAV, UAV-GC, or DBFM(O) agreements,
- and have a capital value of €2.5 million or higher.

In total 69 projects, during the period 2012 - 2018, are included in the database with a total monetary value of more than €1.9 billion euro. This database includes four types of contracts including RAW, E&C, D&B(M), and DBFM. The M will be placed in-between parentheses since it is unclear whether the D&B contracts had a maintenance component or not. Twenty-four (n=24) projects have a RAW contract with a combined monetary value of €140 million euro. The contract types E&C and D&B(M) both include 22 projects with a summed monetary value of €550 million and €1.1 billion respectively. Unfortunately, it is unclear from this database which projects have a maintenance component and which do not. Furthermore, the database only includes incurred costs during the definition and execution phase. Maintenance costs are controlled in separate projects and are therefore not included in the database. To conclude the composition of the database, only one DBFM project is included in the database with a monetary value of €190 million. A single DBFM project does not allow for statistical analyses and will therefore be excluded from further analyses. Descriptive statistics of the total costs per contract type and the total database are summarized in Table 2.

Table 2 Descriptive statistics of total contractual value

Contract type	*N*	*Min.*	*Max.*	*Sum*	*Mean*	*Std. Deviation*
RAW/STABU	24	€ 3,172,896	€ 14,494,226	€ 140,506,117	€ 5,854,421	€ 2,736,571
E&C	22	€ 3,243,154	€ 144,647,072	€ 550,747,247	€ 25,033,966	€ 31,454,390
D&B(M)	22	€ 3,283,823	€ 499,394,602	€ 1,111,815,189	€ 50,537,054	€ 104,724,737
DBFM	1	€ 190,417,105	€ 190,417,105	€ 190,417,105	€ 190,417,105	.
Total	69	€ 3,172,896	€ 499,394,602	€ 1,993,485,658	€ 28,891,096	€ 66,501,260

The database holds several variables alongside the *total contractual value*, including *total result, labour, engineering, subcontractors, deliveries, engineering, building site, project organisation, conditioning, financial, chance and risks, contractual changes, general, provisional sums, procurement results*. Furthermore, the type of client, and the project type, size, and location are included in the database. Table 21 in Appendix A presents an overview of all variables present in the database. The statistical analyses that will be performed in this research will be discussed in the following sections. These analyses will be executed on the total result of a project and individual cost groups.

Descriptive statistics

Firstly, the quality of the database has to be evaluated since this could have an impact on the outcome of the statistical analysis. Descriptive statistics will be used to analyse the different dependent variables, being the cost groups. The cost groups with potential missing cases and very large standard deviations will be further investigated to assess whether they are included or excluded from the analysis.

Comparing contract types

In order to assess whether there is a relationship between the contract type and the accuracy of cost groups, it has to be determined if there is a significant difference between the contract types for each separate cost group. This relationship will be analysed based on an unordered and an ordered database. The database will be ordered based on the variables*, type of client, project type, project size, and project location*. This clustering will be used to include different perspectives on the database.

The one-way ANOVA is a technique that can be used to determine whether there are any statistically significant differences between the means of two or more independent groups (Laerd Statistics, 2018). The dependent variables in this research will be the cost groups. The independent variable in this research will be the type of contract because each type of contract entails a different distribution of tasks between the client and contractor. Based on the above, it can be stated that the ANOVA technique is suited to determine, for each individual cost group, if there is a difference between the different contract types. To safeguard the statistical validity of ANOVA several assumptions have to be made. When a dependent variable fails one of the assumptions of the one-way ANOVA, the Kruskal-Wallis H test will be used. However, the Kruskal-Wallis H test has its own characteristics and assumptions that must be taken into account. A more comprehensive explanation of the assumptions of one-way ANOVA and the assumptions of the Kruskal-Wallis H test can be found in Appendix B. When a significant difference is found, post hoc tests will be used to assess between which contract types this difference occurred.

Correlation Analysis

A correlation analysis will be performed in order to view the relationship between the contract type and the cost categories from a different perspective. The correlation analysis will assess the correlation between cost groups within a certain contract type. After performing this analysis for each contract type, the correlations will be compared between contract types. These results will provide further insight into the relationship between the contract type and the accuracy of cost groups. The correlation analysis will use the Pearson or Spearman correlation to test whether there is a significant correlation between the cost groups.

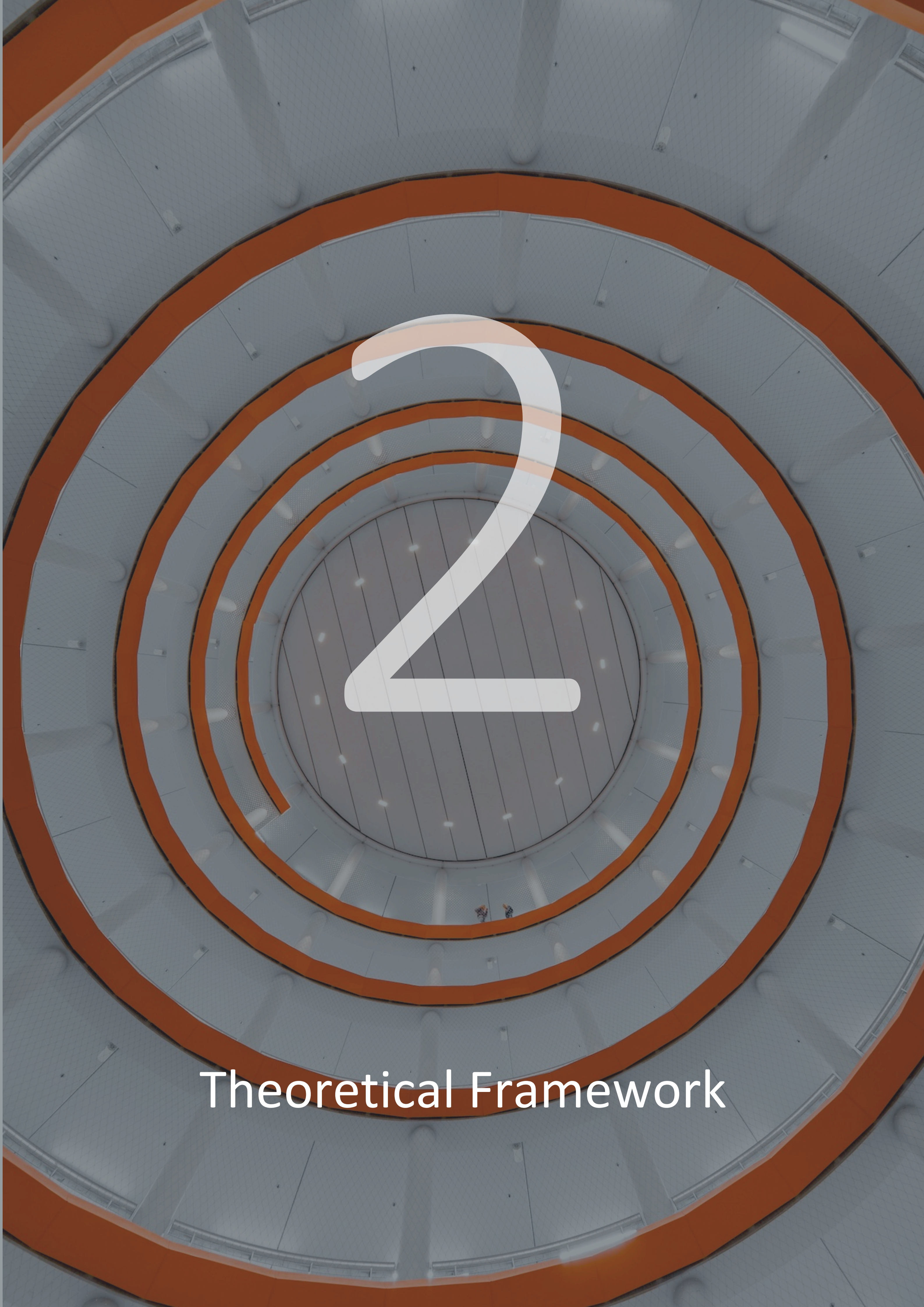
The one-way ANOVA, post hoc test, and the correlation analysis will result in statistical findings which will verify the hypotheses formulated in phase one. Based on the verified hypotheses, several findings will be formulated which form the starting point for phase three.

1.5.3 PHASE THREE – EXPERT PANEL INTERVIEWS

The third and final phase is a qualitative research phase in which the aim is to uncover the causes of the verified findings and asses how the findings can improve the accuracy of cost group estimations. Thereby, phase three will provide an answer to sub-questions four and five, as shown in green in Figure 5. The findings will be discussed in four separate interviews with employees of Dura Vermeer. Combined these interviewees will act as an expert panel that reflects on the findings based on their experience in practice. The interviews will be performed in a semi-structured manner, in order to incorporate the findings and to maintain flexibility during the interview to allow for new insights. The verified and reflected findings will be used to provide insight into the relationship between the contract type and cost management.

1.6 READING GUIDE

In order to obtain the proposed research aim, the structure of this report will follow the three steps of the research methodology. First, Chapter 2 will describe the theoretical context concerning the different contract types used in Dutch national infrastructure projects. In addition, the process of cost estimation is described. Last, the causes of cost overruns and influential project characteristics are discussed. Chapter 3 presents a clear overview of the statistical results organized by cost group followed by Chapter 4 describing the insights obtained from the conducted interviews with the expert panel. In addition, Chapter 5 compares the insights from literature, statistical analysis, and the expert panel in order to analyse the performed research. Chapter 6 concludes this research by answering the main research question while providing limitations and recommendations for future studies and Dura Vermeer. Last, Chapter 7 will include a personal reflection on the complete process of writing this thesis.



2

Theoretical Framework

2 THEORETICAL FRAMEWORK

2.1 CONTRACT TYPES IN THE DUTCH NATIONAL INFRASTRUCTURE SECTOR

The Dutch Infrastructure sector has a long history with procuring assets. An important element of the procurement procedure is the project delivery model (PDM). The PDM describes the distribution of tasks between the participants of the building process and forms the basis of the contract (PIANOo, 2019f). A PDM is defined by Miller, Garvin, Ibbs, & Mahoney (2000) as 'a system for organizing and financing design, construction, operations and maintenance activities that facilitates the delivery of a good or service'. This definition shows that a PDM can encompass a wide array of activities. The extensive body of knowledge on PDMs and PDM selection models indicates its importance to project management (Al Khalil, 2002; Alhazmi & McCaffer, 2000; Chan, Ho, & Tam, 2001; Chen, Lui, Li, & Lin, 2011; Tran, Harper, Molenaar, Haddad, & Scholfield, 2013). Hosseini et al. (2016) argue that the PDM has a considerable impact on the project outcome and is one of the determinants of project success. Design-Bid-Build (DBB), Construction Management, and Design-Build (DB) are the most commonly used PDMs (Hosseini et al., 2016). These PDMs are described as follows (Hosseini et al., 2016):

- Design-Bid-Build, commonly known as the traditional model in which the client prepares the design, with or without a design firm, and receives bids, based on this design, from contractors. The client then selects a contractor, often based on the lowest price. This model requires the client to sign a contract with the design firm and the contractor with the design contract being finalized before the start of the construction contract.
- Construction Management is a PDM in which the client appoints a competent firm, i.e. the construction manager. This manager has an advisory role and performs all required jobs necessary during the (pre-)construction phase.
- Design-Build is a PDM in which one contractor is responsible for both the design and the construction.

PDMs are the starting point of the different contract types which are used in the Dutch construction sector. The Dutch construction law divides these contracts based on the level of control of the client, and the allocation of risks and liabilities (Chao-Duivis, Koning, & Ubink, 2013). The Dutch construction law allows clients to freely choose a PDM and a corresponding contract type. Clients, however have developed standardized contracts based on PDMs. Chao-Duivis et al. (2013) state that there are four contract models: traditional model, the design team model, the integrated model, and the alliance model. These models will be elaborated further in Sections 2.1.1, 2.1.2, and 2.1.3.

2.1.1 THE TRADITIONAL MODEL & DESIGN TEAM MODEL

De Ridder & Noppen (2009) describe several contract forms in lecture notes prepared for use at the Faculty of Civil Engineering and Geosciences of the Delft University of Technology. According to de Ridder & Noppen (2009), the DBB model is characterized by its uniformity, unambiguousness, and the clear separation of parties and their function. Even though the DBB is an unambiguous model, disputes still occur. As mentioned before, the client is responsible for the design and specifies the design in a standardized system, e.g. RAW. After awarding the contract, the contractor is responsible for the construction in accordance with the technical and administrative conditions (de Ridder & Noppen, 2009). DBB contracts are based on the Uniform Administrative Conditions for Execution of Works and Technical Installation Works 2012 (UAV-2012) (Chao-Duivis et al., 2013). The process of a DBB contract is depicted in Figure 6. The key advantages of the DBB model are: less reason for discussion due to detailed and standard clauses, parties know their role and responsibilities within the contract, and the client is able to properly supervise the contractor (de Ridder & Noppen, 2009). Furthermore, transaction costs are low and bids are competitive (PIANOo, 2019g). However, there are disadvantages to the traditional model. First, due to the sequential character, the overall building process is slowed down. Second, the expertise of the contractor cannot be used during the design phase, resulting in a high chance of additional works during the construction phase (de Ridder & Noppen, 2009; PIANOo, 2019g). A more extensive list of (dis)advantages of the DBB model is included in Appendix C.

The building team model mitigates the second disadvantage by involving the contractors in the design phase (Chao-Duivis et al., 2013). The contractors who are invited to the design phase are not immediately selected for the construction phase, meaning design and construction is still separated (PIANOo, 2019g). When the contractor is part of the building team, he obtains a competitive position compared to other contractors because he has involved himself in the design and preparation phase. A second advantage for the contractor, that is part of the building team, is that he has the right to submit the first bid. Thereby enlarging his own opportunity to win the contract.

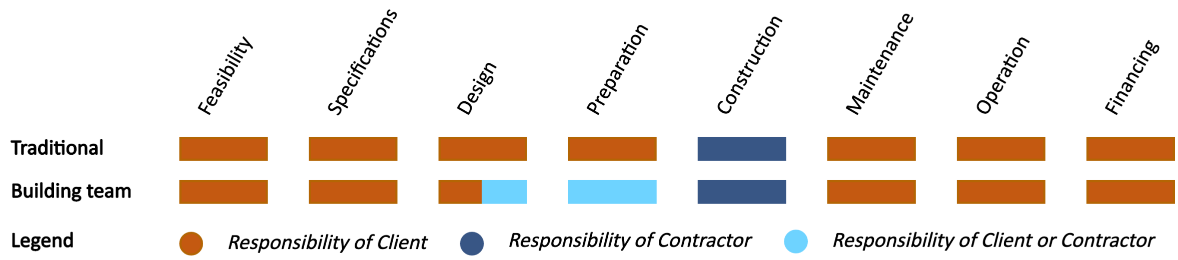


Figure 6 Distribution of responsibilities in the traditional and building team contract model (own illustration)

2.1.2 THE INTEGRATED MODEL

In integrated contract models, different phases of the construction process are combined and described in one contract. Integrating different phases results in the following contract models: Engineering & Construct; Design & Build; Design, Build & Maintain; Design, Build, Finance, Maintain, (Operate) (PIANOo, 2019f). These models are based on the Uniform Administrative Conditions Integrated Contracts (UAV-GC 2005), except for DBFM(O) contracts. The development over time of these contract models has been depicted in Figure 3. The Engineering & Construct contract model is the first step towards fully integrated contract models in which the contractor is responsible for the finalization of the design and the construction phase, as shown in Figure 7. The E&C model is applicable if a preliminary design is made by the client and the contractor only needs to perform engineering work before the contractor can start construction work (PIANOo, 2019e). The availability of a preliminary design diminishes the risk profile for the contractor because the client is mainly responsible for the design. A key advantage of E&C is that the contractor is able to optimize the design during the engineering phase. However, these optimizations are minimal due to the fact that the design is partially made by the client. A more extensive list of (dis)advantages of the E&C model is included in Appendix C.

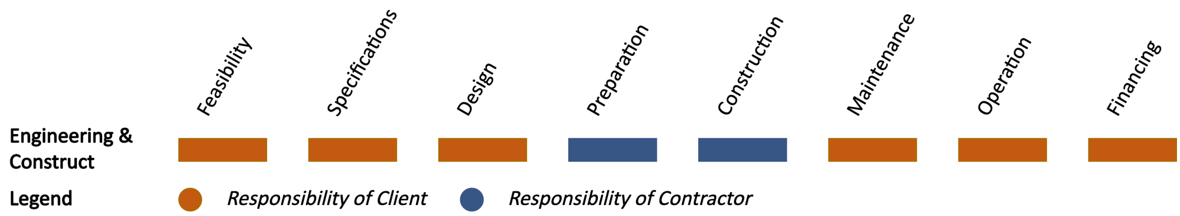


Figure 7 Distribution of responsibilities in the Engineering & Construct contract model (own illustration)

The Design & Construct model shifts the responsibility for the design towards the contractor, as shown in Figure 8. This provides the contractor with the opportunity to further introduce its construction knowledge into the design phase (de Ridder & Noppen, 2009; PIANOo, 2019d). A major difference from the E&C model is that the client specifies functional specifications in the contract instead of technical specifications (PIANOo, 2019d). The design made by the contractor has to comply with these functional specifications. The client benefits from this model because she only has to deal with one party during the design and construction phase (Chao-Duivis et al., 2013). Furthermore, this model aims for fewer discussions about liabilities since one contractor is liable for the design and the construction. This, however, does not imply that all risks are transferred to the contractor. The distribution of risks is, ideally, dependent on the parties who can best manage the risks and the type of reimbursement system (e.g. DB-cost plus or DB-fixed-price) (de Ridder & Noppen, 2009). According to de Ridder & Noppen (2009), an advantage for both parties is that the cost and time estimates should be more reliable. Furthermore, the main advantage for the contractor is that he is able to coordinate and optimize the design based on the construction method and thereby mitigating potential risks. These optimizations ideally lead to better solutions. To illustrate, the amount of rebar needed to construct reinforced concrete is a potential area for design optimizations. Even though the D&C is commonly used in the Dutch national infrastructure sector, there are disadvantageous for both the client and the contractor. First, because the contractor is only responsible for the design and the construction of the asset, maintenance optimizations are not, by definition, part of the design (de Ridder & Noppen, 2009; PIANOo, 2019d). This lack of maintenance optimizations could result in higher life-cycle costs for the client. Second, describing the desired asset with functional requirements is difficult and requires certain capabilities (PIANOo, 2019d). Clients that operate on a national level have more experience with describing functional requirements compared to clients that operate on a regional level. A more extensive list of (dis)advantages of the D&C model is included in Appendix C.

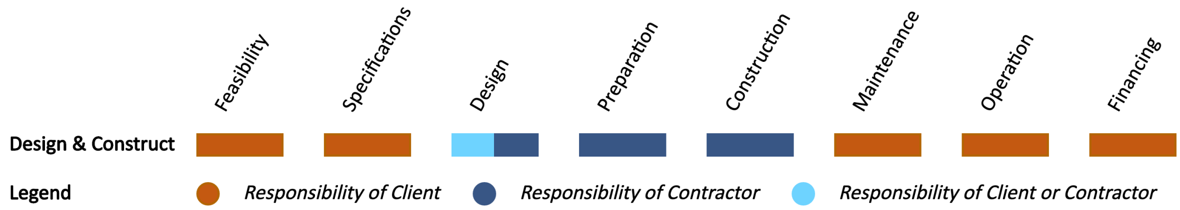


Figure 8 Distribution of responsibilities in the Design & Construct contract model (own illustration)

The contract model Design, Build & Maintain is made in order to incorporate life-cycle costing into the building process. By assigning the responsibility of the maintenance to the contractor, as shown in Figure 9, a more integrated and sustainable solution can be implemented (PIANOo, 2019c). With this contract model, the total construction costs can be higher in favour of the maintenance costs which can be lower which is beneficial for the client and the contractor. A second advantage for the client is that there is only one contractor responsible for the asset, which results in fewer risks originating from the interfaces between the design, build, and maintenance phases (PIANOo, 2019c). The main advantage for the contractor is that a DBM contract allows the contractor to optimize the design and construction with the maintenance requirements. However, there are also disadvantages for the client and the contractor in a DBM contract model. First, the client has limited possibilities to implement scope changes because a scope change could have a large impact on the design, construction methodology, and maintenance strategy of the contractor (PIANOo, 2019c). A DBM contract model requires a different way of working from the client. The client has to steer the process instead of evaluating sub products, which requires more attention and is not self-evident (PIANOo, 2019c). A more extensive list of (dis)advantages

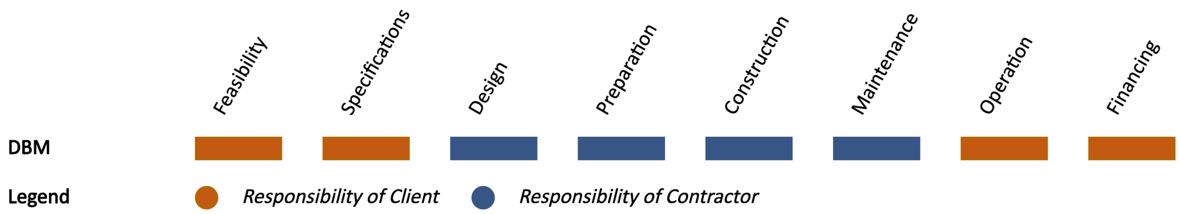


Figure 9 Distribution of responsibilities in the Design, Build & Maintain contract model (own illustration)

of the DBM model is included in Appendix C.

As described in Section 1.1.1, the fully integrated contract model is the Design, Build, Finance, Maintain & (Operate) model. This extends the responsibilities of the contractor with the financing of the project and an option to operate the asset, as shown in Figure 10. The main difference of DBFM(O) compared to other integrated contract forms is that in the case of DBFM(O), the contractor aims to deliver a service to the client instead of a product (PIANOo, 2019b). This service could, for example, be the availability of a road.

The main advantage of a DBFM(O) contract model is that the client and the contractor both benefit from a successful project because the contractor is incentivized, through the Finance component, to aim for a successful project (PIANOo, 2019b). The Finance component incentivises the contractor because the payment scheme is often coupled with the availability of the asset. Meaning, the contractor will not be paid if the asset is not available. Furthermore, by extending the integration a more fit for purpose solution can be implemented by the contractor. Theoretically, resulting in lower failure costs and eventually a competitive price (PIANOo, 2019b).

However, the disadvantages of DBFM(O) are that it requires professional capabilities to write a DBFM(O) contract which takes a long time resulting in high transaction costs. Furthermore, recent developments have shown that the benefits of a DBFM(O) project are hard to measure and that it is difficult to implement innovations due to the high risks involved in DBFM(O) projects as described by Hertogh & Hombergen (2018). For example, in December 2018, the Dutch contractor, VolkerWessels, announced to stop with the tender procedure for the DBFM project ViA15 and with DBFM projects altogether due to the high risks and disproportionate rewards as described in an article of Cobouw (Doodeman, 2018b). In addition: Sacyr, Ballast Nedam, Fluor, Strukton, BAM, Heijmans, and TBI all decided to stop with the tender for ViA15. Currently, there are only two consortia part of the tender procedure for the ViA15 (Koenen, 2018a, 2019a). More recently, March 2019, the combination Ballast Nedam and Fluor decided to stop with the tender for the DBFM project A9 BaHo (Koenen, 2019a). The decreasing attention for large infrastructure projects was the reason for Rijkswaterstaat to ask McKinsey, a strategic advisory bureau, to conduct an analysis of the Dutch infrastructure sector. McKinsey concluded that the risks associated with large scale infrastructure projects are too large while the margins are too low (Koenen, 2019b). Large scale infrastructure projects are often procured with a DBFM(O) contract. A more extensive list of (dis)advantages of the DBFM(O) model is included in Appendix C.

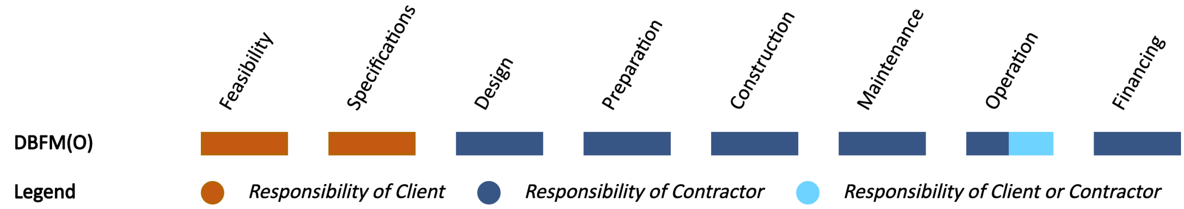


Figure 10 Distribution of responsibilities in the DBFM(O) contract model (own illustration)

2.1.3 The Alliance

The alliance model creates an equal relationship between the client and the contractor. Scheublin (2001) states that a project alliance approach has some characteristics of a joint venture and is established to perform the design and construction. The traditional and integrated contract models have a clear distribution of responsibilities (PIANOo, 2019a). The alliance, however, is not a building contract but is more a partnership contract in which both parties are involved in the building process, as shown in Figure 11 (Scheublin, 2001). This is often done to share risks of certain activities that cannot be mitigated by a single party. Because standardized agreements for the alliance model are absent, the application of the alliance model is minimal in the Dutch construction sector (Chao-Duivis et al., 2013). When the project is finalized, all involved parties share profit and loss (Scheublin, 2001). The alliance approach is supported by contractors, such as Dura Vermeer. The chairman of the Board of Directors of Dura Vermeer, Job Dura, has stated in an interview with Cobouw that the alliance approach is a pleasant way to work due to the collaborative approach to risk management (Doodeman, 2018a). A more extensive list of (dis)advantages of the Alliance model is included in Appendix C.

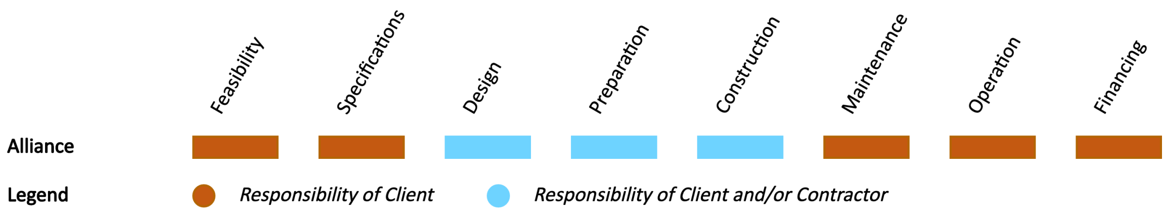


Figure 11 Distribution of responsibilities in the Alliance model (own illustration)

2.2 THE PROCESS OF COST MANAGEMENT

In order to understand the process of cost management, one starts by defining and assessing cost management during the project life cycle. This will be done in Section 2.2.1 and 2.2.2 respectively. Followed by Section 2.2.3 in which a systematic approach towards cost management is presented. This approach is based on the Standaardsystematiek voor Kostenramingen and further compared to the method applied by Dura Vermeer.

2.2.1 DEFINING COST MANAGEMENT AND COST CONTROL

Costs for a client can be defined as the expenses incurred by the contractor for material, labour, utilities, services, overheads and the profit of the contractor (Vasista, 2017). Cost management, is defined as the process of controlling the expenditure on a construction project at all stages from initiation to completion, within the approved budget (Vasista, 2017).

Cost management thus starts with the client with an estimation of the costs at the initiation phase. Estimating costs is considered a very important subject in the construction industry (Akintoye, 2000). The end result of a project depends on the estimates made during the conceptual phase of the project through to a very detailed estimate during the construction phase (Ahuja, Dozzi, & AbouRizk, 1994). Kwakye (1994) defines cost estimating as the technical process which assesses and predicts the total cost of executing work. This work is executed in a certain timeframe while making use of available resources and project information (Kwakye, 1994). These estimates are always a prognosis of the eventual costs but can influence the feasibility and/or the profitability of a project (Portas & AbouRizk, 1997). Based on these insights, this research will use the following definition of cost estimation: *Cost estimation is the technical process which assesses and predicts the total cost of a project with a certain confidence level*. This definition is applicable to both the client and the contractor. The difference, however, lies in the moment in time when the client or the contractor estimate their costs. This difference will be further explained in Section 2.2.2.

The purpose of a cost estimate is twofold. The first goal is to provide information to manage the costs and come to decisions, such as policy choices, assigning budgets, and assessing tenders. Secondly, the cost estimation should provide a frame of reference for future cost estimations and allows the client to evaluate the bids of contractors when the project is procured (CROW, 2010). In order to provide a frame of reference, it is important that costs are estimated with the same method. A commonly applied method in the Dutch building sector will be introduced in Section 2.2.3.

After cost estimation when money starts to be spent cost control is necessary. Cost control is defined as; *the actions and reactions to project cost fluctuations during a project in order to maintain the project cost within the project budget* (Olaoluwa, 2013). Once the project is completed the forecasted budget can be compared to the actual construction costs. A cost overrun occurs when the actual construction costs exceeds the forecasted budget. Cost overruns or underruns can also be measured in relative terms, i.e. the cost performance in which a positive measure reflects a cost underrun and a negative measure a cost overrun. Therefore, this study defines cost performance as; *a relative measure for the amount by which actual construction costs exceeds the budget at moment of contracting*. As previously illustrated in Section 1.1, the forecasted budget depends on the baseline one choses. The baseline, budget at moment of contracting, used by this study will be further elaborated on in Section 2.2.2.

2.2.2 COST MANAGEMENT DURING THE PROJECT LIFE CYCLE

As previously mentioned, cost management is a process that occurs in all phases of a project. Therefore, it is important to understand what the effect of each phase is on cost management. An infrastructure project typically follows four phases, which are defined by Nicholas & Steyn (2017, pp. 68–70) as follows:

1. **Conception phase.** During the conception phase, the problem is recognised, and the objective and feasibility of the project will be assessed. The client will estimate the total cost of the project which includes an estimation of the costs of the contractor and the costs of its own project organisation. With a traditional PDM, the client will progress to phase two without an agreement with a contractor. In a more integrated PDM, the client specifies functional specifications followed by the evaluation of the

proposals, i.e. bids, of the contractors by the client. The bids of the contractor are based on a cost estimation of the entire project. This estimation includes costs for design, construction, and the project organisation of the contractor. The difference between the bids of contractors are often related to the availability of materials and/or equipment. The result of phase one with an integrated PDM is an agreement between the client and the contractor. This phase includes the phases feasibility and specifications which are used in Figure 6 to Figure 11.

2. **Definition phase.** In a traditional PDM, the client will design a solution and describe technical specifications. Followed by the evaluation of the bids of contractors and an agreement with a contractor. With an integrated PDM, the contractor will finalize the design and develop construction methods. This phase includes the phases design, preparation, and financing which are used in Figure 6 to Figure 11.
3. **Execution phase.** In the execution phase, the work specified in phase one and two will be constructed. This phase includes the phase construction which is used in Figure 6 to Figure 11.
4. **Operation phase.** During the operation phase, the asset is deployed, the client starts operating the asset, and the maintenance is done by the client (traditional PDM) or the contractor (integrated PDM). The operation phase can last for years or decades in which the asset is kept viable and useful with improvements and enhancements. Once the asset reaches its end of life it can be either demolished or modified to fulfil new requirements. In the latter case, the modification becomes a new project which starts at phase one and thereby completing the circle. This phase includes the phases maintenance and operation which are used in Figure 6 to Figure 11.

The aforementioned phases show that the scope of a project changes during the project life cycle from idea to reality. During the early phases, uncertainty exists about the, for example, level of ambition, geotechnical conditions, technical standards, and project interfaces. Hence, this uncertainty also applies to the estimated costs and will typically reduce throughout the project phases as more information becomes available. This process is described by Thompson & Perry (1992) as the torpedo or projectile effect of risks on cost estimations. This process is depicted in Figure 12.

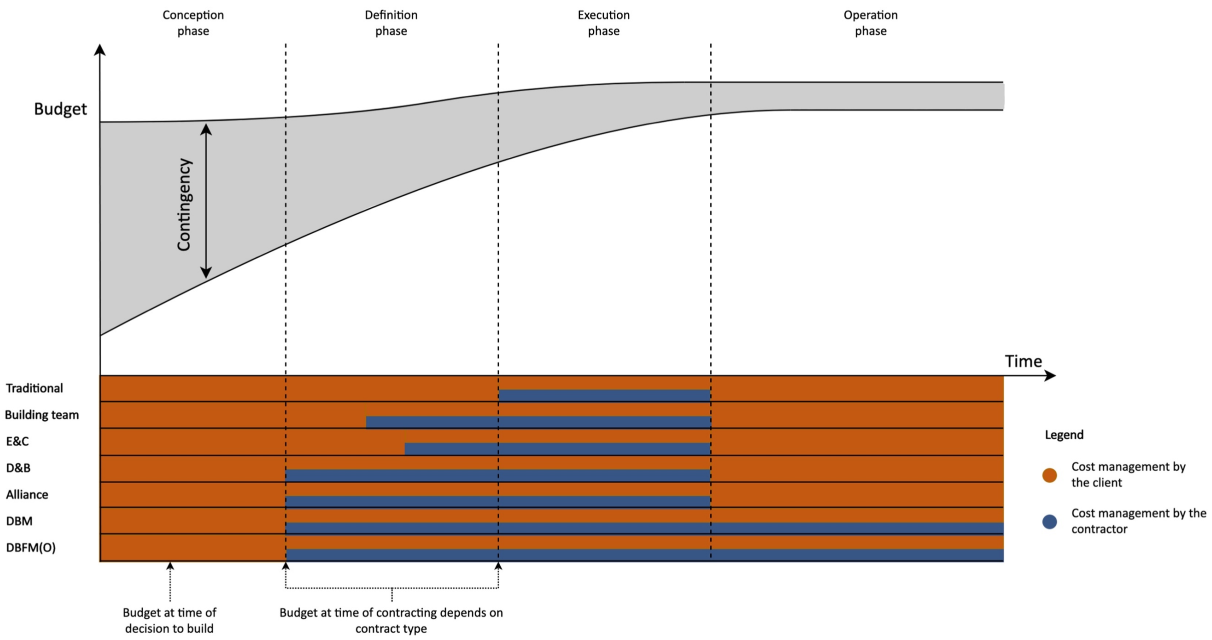


Figure 12 Cost management by the client and the contractor during the project life cycle (own illustration, based on CROW (2010) and Nicholas & Steyn (2017, pp. 68–70))

As shown in Figure 12, uncertainty diminishes over time due to the availability of information. Flyvbjerg et al. (2018) argue that cost estimations are made at different time points, i.e. baselines, in the project life cycle. Flyvbjerg et al. (2018) argue that “the baseline one chooses for measuring cost overrun depends on what one wants to understand and measure”. Since the current research is aimed to understand the relationship between the contract type and the management of cost groups, the baseline used is the *budget at moment of contracting*.

When the *budget at time of contacting* occurs earlier in the project life cycle, depending on the contract type, the contractor has to deal with more uncertainty when estimating the costs, as illustrated in Figure 12. Therefore, integrated PDM's are judged to inherently deal with more uncertainty, compared to the traditional PDM.

2.2.3 A SYSTEMATIC APPROACH TO COST MANAGEMENT

As previously mentioned, cost management is required during all stages of the project life cycle. In order to do so, a systematic approach is required. Kishk et al. (2003) state that there are two costing methods that can be identified in the literature: systems' costing and detailed costing. Systems' costing allocates costs to the functional elements of an asset (Kishk et al., 2003). The detailed costing approach breaks down the asset into separate elements with distinguishable costs (Kishk et al., 2003). Both approaches can be considered as a cost breakdown structure (CBS). According to the PMI, WBS is "the process of subdividing project deliverables and project work into smaller, more manageable components" (Project Management Institute, 2004, p. 125). The extensiveness and complexity of a CBS depend on the scope and the objectives of the cost management (Kishk et al., 2003). Therefore, there isn't a certain CBS that is applicable for every project or company. However, in the review of Kishk et al. (2003), six desirable characteristics have been identified. First, all cost categories should be considered and identified in the CBS. Second, cost categories should have an unambiguous definition. Third, the number of sublevels of the CBS should be sufficient to provide the visibility required in the decision-making process. An increasing number of sublevels decreases the visibility of the CBS and thereby potentially hampers decision-making. Fourth, the CBS should be designed in a way that different levels of data could be inserted within various categories. Fifth, the coding of the CBS should facilitate an analysis which focusses on a certain area while ignoring another. Last, the CBS should align with various information systems in which costs are reported.

Cost Breakdown Structure

A commonly applied approach in the Dutch Infrastructure sector for estimating costs is the Standaardsystematiek voor Kostenramingen (SSK) (CROW, 2010). The SSK is created by CROW in collaboration with parties from within the Dutch building sector. The SSK enables clients and contractors to estimate costs in an unambiguous manner. The SSK describes a systematic approach which makes sure that cost estimates are intuitive and can be compared with each other.

The SSK applies a standard accounting technique within cost management, called the classification of costs. The classification of costs involves the separation of costs into different groups with common characteristics (AccountingTools, 2018). The SSK applied a classification of costs by traceability in order to divide the cost into separate groups. i.e. a CBS. These groups are: determined direct costs, to be determined direct costs, indirect costs, and contingency reserves (CROW, 2010). Firstly, the SSK defines determined direct costs as costs that are directly linked to the production or delivery of a product or service and which can be clearly assigned to this product or service. Determined direct costs are expressed in quantity or unit multiplied by a unit price (CROW, 2010).

Secondly, to be determined direct costs are added to determined direct costs to account for foreseen but not yet extensively elaborated cost items (CROW, 2010). Touran (2006, p. 16) defines to be determined direct costs as project allowances and states that *"project allowances are estimates used to account for project components that are hard to estimate either because the design is not complete or because based on available information an accurate estimation is not feasible"*. Depending on the phase of the project, certain parts of the design are not finished. Therefore, the amount of effort it takes to further elaborate on these parts becomes disproportionate to the seemingly certain cost estimation of only one type of solution. The to be determined direct costs are expressed in quantity or unit multiplied by a unit price or as a percentage of the determined direct costs (CROW, 2010).

Thirdly, indirect costs are costs that cannot be assigned to the production or delivery of a product or service. This could, for example, be one-time costs, execution costs and general costs. Indirect costs are expressed in quantity or unit multiplied by a unit price or as a percentage of the direct costs (CROW, 2010). If percentages are used to calculate multiple cost items a cumulative percentage is used to determine the indirect costs. To be determined indirect costs are not used because this group is hardly used in practice as a result of the use of percentages in direct cost estimation.

Lastly, contingency budgets are funds which are reserved for unforeseen, possibly negative influences on the cost estimation. These negative influences could arise due to risks, uncertain situations, or undesirable events. Contingency budgets are divided into object unforeseen and project unforeseen. Object unforeseen are contingency budgets which can be assigned to a specific object. Project unforeseen are contingency reserves which could be used to cover unique events which cannot be assigned to a specific object. Contingency budgets are expressed in probability multiplied by consequences or as a percentage of the cumulative amount of direct costs (CROW, 2010). The contract will explicitly state which risks need to be managed by the contractor. These risks will be included in the cost estimate of the client and the contractor. In addition, the contractor will include a contingency budget for general construction risks, such as weather conditions, inefficient use of materials, and failures of sub-contractors.

In order to create a clear distinction between costs, the SSK subdivides every cost group in several cost categories. These cost categories are building costs, real estate costs, engineering costs, other additional costs, and life-cycle costs. Firstly, building costs are related to the physical realization of the object. Often building costs are costs associated with the eventual construction contract and are a summation of man-hours, material-hours, material costs, rent costs, and supplier costs. Depending on the phase of the project, building costs are expressed in detailed quantity or unit multiplied by a unit price or more broad unit prices (CROW, 2010). Secondly, real estate costs are costs related to acquiring and using the site on which will be built. This includes the costs of preparing the site for construction and compensation for loss of income or any other harm inflicted by the project (CROW, 2010). Thirdly, engineering costs are costs related to the technical aspect of the project and the associated organizational, environmental, legal, and economic aspects (CROW, 2010). Fourthly, other additional costs are costs that cannot be included in the previous categories. This could, for example, be costs for permits, tolls, fees, and/or replacement transportation (CROW, 2010). If necessary, an additional category can be used to incorporate life-cycle costs in the cost estimation. Life cycle costs involve all costs made after the object has been realized and handed over in order to retain the function of the object (CROW, 2010). This could, for example, be costs for maintenance, exploitation, and financing.

Even though the SSK is a commonly applied approach in the Dutch Infrastructure sector, it is not mandatory by law in the Netherlands. Therefore, every client and/or contractor is free to apply a CBS that fits their needs. Dura Vermeer also choses to apply a classification of costs by traceability for their cost management of infrastructure projects. The following cost groups are used: direct costs, indirect costs, and overhead costs. The definitions of direct and indirect costs that are applied within Dura Vermeer correspond with the definitions of the SSK, which are previously introduced. Within Dura Vermeer, overhead costs are considered one-time costs, general costs, provisional sums, and profit. Furthermore, direct costs have the following underlying costs categories: labour, equipment, deliveries, and subcontractors. The cost categories of indirect costs are engineering, project organisation, building site, miscellaneous, conditioning, chance and risks, financial, and contractual changes. The CBS, used by Dura Vermeer, is presented in Figure 13.

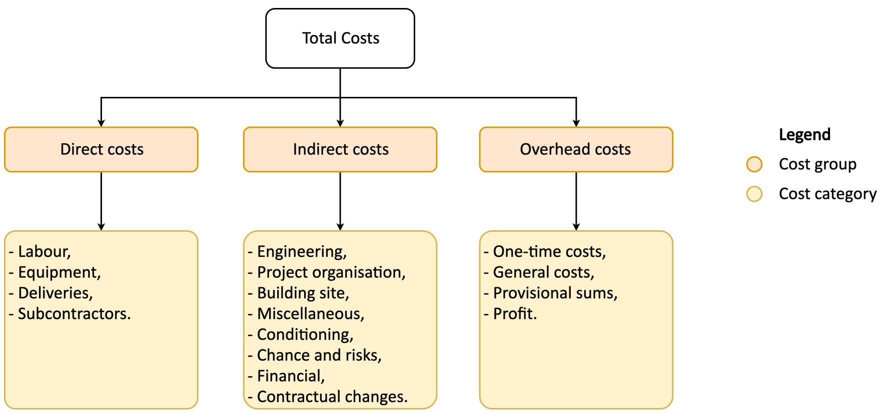


Figure 13 CBS of Dura Vermeer (own illustration)

Cost estimation

The process of estimating costs is a cyclic process which follows the Plan, Do, Check, Act scheme (CROW, 2010). This process is both applicable to the client and the contractor. The present paragraph will further elaborate on this scheme and underpin it by referring to the Project Management Institute (2004). During the Plan stage, the need for a cost estimate arises. The challenge is to assess the boundaries of the scope and to identify the degree of interrelatedness between objects during this early phase. The client will determine the scope based on its own needs and requirements. The contractor however has to determine the scope by interpreting the contract documents. To do so, the contractor creates a tender team which includes a tender manager, designer, planner, cost estimator, and executor. During this first stage, a cost estimator primarily needs a planning, phasing, execution times, and above all a tender design. Based on this information, several construction methods will be compared by the tender team. Furthermore, the cost estimator determines the main cost drivers based on a very rough estimation during this first phase. The importance of this first stage, for the contractor, is illustrated by the following quote:

> *"The first phase, obtaining the right scope, is the most important. … The added value of cost estimation is in the first phase in which you aim for the cheapest design."*
>
> *Interviewee #2*

After the client and the contractor have independently defined their scope, they follow a similar scheme. With the scope defined, the cost estimator can assess what data is necessary to narrow the bandwidth of the cost estimation, this stage is called data analysis. In addition to project data such as technical details, the PMI states that the project charter, company environmental factors, and organizational process assets are input for the data analysis (Project Management Institute, 2004, p. 197). During this stage a contractor starts by contacting subcontractors, assessing market conditions, and assess future price fluctuations by performing an indexation analysis. The project data is organized into either objects, activities, geography, or processes by means of a WBS. This stage is called project decomposition and is part of the Do phase. After the WBS is made, a cost estimate is made with the available information. This cost estimate is checked during the Check phase. During this check, it will be determined if the uncertainty of the estimate has to be reduced to the desired confidence level. If this is the case, the cost estimate will be updated and evaluated to account for scope changes and to reduce the uncertainty. The PMI also emphasises the importance of reviewing and refining the cost estimate to reflect additional details as they become available (Project Management Institute, 2004, p. 201).

The SSK proposes two methods to estimate costs: the deterministic or probabilistic method. These methods have the following techniques at their disposal: price multiplied by quantity, chance multiplied by consequence, and a percentage.

First, the deterministic method often referred to as the traditional method, has been common practice in the ground, road, and water (GWW) construction sector. Preconditions for this method are a clear project decomposition and a design with a level of detail corresponding with the project phase. The extent to which the project is decomposed is dependent on the complexity of the project and the degree in which it is designed. This decomposition of the project leads to a number of cost items. A deterministic estimation is based on the multiplication of a quantity and a unit price. The quantity can be estimated based on the design and the unit prices are often expert knowledge and a valued secret of the estimator. The deterministic method estimates the most likely cost, i.e. the top value for each cost item. To be determined cost items are added, estimated based on expert knowledge, in order to derive the total project cost. The deterministic method does not account for uncertainties because only most likely values are applied. The result is a single point estimation which does not include any uncertainty range.

In order to include uncertainty into a deterministic method, experts determine the unforeseen costs by making use of expert judgement. According to Thompson & Perry (1992), the most common way to express the unforeseen costs is to add a percentage to the summation of the foreseen costs. The range or bandwidth is not expressed in monetary terms but an expert determines a percentage based on the risk profile and the phase of the project. Thompson & Perry (1992) state that this method has several weaknesses. Firstly, the percentage used is most likely not project specific. Secondly, there is a risk of double counting. Double counting occurs if an allowance is included in certain cost items combined with the use of an allowance percentage. Thirdly, adding a percentage still results in a point estimate which implies a degree of certainty which is unfounded. Lastly, the percentage only includes adverse risks and ignores the risks that favourably affect the project.

Considering the downsides, the deterministic method is suitable for quickly estimating costs for which detailed information is available. In the case of for example a RAW contract, given that extensive detailed information is available, the deterministic method could be chosen in order to estimate the total project costs. The cost estimation process within Dura Vermeer is primarily based on the deterministic approach.

Second, the SSK proposes the probabilistic method. A probabilistic method is applied because there is a tendency for estimators to incorporate an extended buffer in the contingency estimates when applying a deterministic method (Mak & Picken, 2000). Personal bias and a personal risk attitude are the origins of this overestimation. Schnek et al., (2009, p. 121) state that the probabilistic method is "based on the statistical and probability analyses of project risk and estimation of potential cost variances due to each risk". The general idea is that the range of the total project budget is estimated with a bottom-up approach. This means that the expected value and the range of individual cost items are input to calculate the expected value and the range of the total project costs. The SSK proposes to estimate the expected value and range of individual cost items with Lower, Top, and Upper values, i.e. LTU-values. The L value indicates the lowest possible value. The T value describes the most likely value and the U value is the highest value possible. These values are all estimated based on expert knowledge. Together the LTU-values describe a triangular probability density function, which is illustrated in Figure 14. This probability density function describes the range in which the quantity or price is most likely to lie. The shape, or symmetry of the probability density function describes if the chance for a value higher, equal, or lower than the mean is smaller, equal, or larger than 50 per cent. For example, Figure 14 is right skewed which indicates that that the chance for a value greater or equal to the mean, larger is than 50 per cent. The LTU-values can be used for all beforementioned techniques, being; price multiplied by quantity, chance multiplied by consequence, and a percentage.

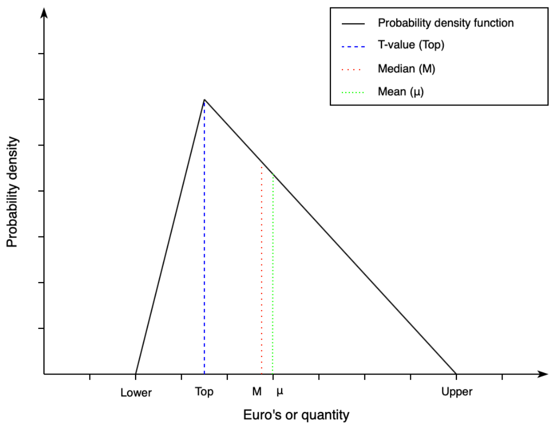


Figure 14 Illustrative representation of a triangular probability density function with LTU-values (own illustration)

First, the SSK states that both price and quantity can be assessed with LTU-values (CROW, 2010). The estimation of the cost item is determined through the multiplication of two probability density functions. In the case of multiplying two probability density functions, the correlation between the probability density functions becomes very important. Correlations have a large influence on the bandwidth or variation of the cost estimation. The SSK states that due to the high labour intensity of assigning individual correlations, the following method is applied in practice: a fully independent (correlation = 0) and a fully dependent (correlation = 1) calculation (CROW, 2010, p. 80). A fully independent calculation allows for an individual sensitivity analysis of cost items but is considered, by experts, to show a more favourable bandwidth of the total cost estimation. A fully dependent calculation presents a more realistic bandwidth. Reference projects have shown that the fully dependent calculation provides the most relevant information. However, the fully dependent calculation is still an approximation of the true bandwidth.

Second, the SSK uses the chance multiplied by consequence approach to cover uncertainty about the future, i.e. favourable or adverse risks. This approach uses a discrete probability function which entails that the consequences are only included if the risk occurs. If the risk does not occur, the consequences are equal to zero. After a risk analysis has been performed, the risk register is the input of the discrete probability density function. The consequences can be evaluated with LTU-values if needed.

Lastly, the SSK can use percentages to estimate cost items. With this approach, a percentage is taken from an already estimated cost item. It is important to state the reasoning and the basis of the percentage. The percentages can be taken from a T-value or the mean of an already estimated cost item. The mean is favoured from a statistical point of view but in practice, the T-values are commonly used.

The probabilistic approach is also applied within Dura Vermeer in order to better determine main cost drivers and to calculate contingency budgets during the estimation process. Cost categories which remain difficult to estimate are labour, engineering, and project organisation.

Cost control

Once the costs have been estimated and a contractor is awarded the contract, the controlling of cost starts. Cost control at Dura Vermeer will be explained based on the interview with a project controller at Dura Vermeer. A complete transcript of this interview can be found in Appendix G. First, cost estimations are translated into a working budget. The working budget divides the total costs into numerous individual budgets in order to manage the cost during the project. These individual budgets are often standardized but there is room to create a project-specific working budget. It is important to note that the total costs agreed in the contract forms the basis for the working budget. Therefore, the working budget is always equal to the total contract value.

Once a working budget is created, a project controller starts by managing the cost for engineering and the project management team. When the design is finished and the execution phase starts, the project controller shifts its focus to managing actual unit prices and quantities. Labour, equipment, and the project organisation become the largest variables and challenging cost groups during the execution phase. Cost control for the contractor ends when his contractual obligations towards the client have been fulfilled, therefore, end of work is the main concern of the project controller.

2.3 INFLUENTIAL FACTORS IN COST MANAGEMENT

The aim of cost management, as stated before is to deliver a project within the approved budget. In order to deliver a project within budget, a proper starting estimate is required. The definition of cost control illustrates that cost fluctuations occur during the project. These cost fluctuations are caused by certain factors. Identifying these factors is important for scholars and industry because it allows for mitigation strategies to be developed in order to improve cost control. Sections 2.3.1 and 2.3.2 will present a state-of-the-art review of influential factors for cost escalation and thereby cost management.

2.3.1 FACTORS AFFECTING COST OVERRUNS

As earlier mentioned, Morris & Hough (1988) were one of the first who studied project failure and cost overruns. Based on an extensive literature review and eight case studies they identified nine key reasons or factors for cost overruns. Furthermore, Shane, Molenaar, Anderson, & Schexnayder (2009) identified and categorized 18 factors into two categories, internal and external. Internal being factors that can be directly controlled by the project owner while external factors are outside the control of the project organisation. Their literature review consisted of research reports and publications, government reports, news articles, and other published sources. The identified factors have been verified through interviews with more than 20 state highway agencies around the United States of America. The findings of Shane et al. (2009) are supported by the literature review of Ali & Kamaruzzaman (2010) in which the cost performance for building construction projects was studied. The identified factors are judged to be similar to the factors identified by Shane et al. (2009). Furthermore, Odediran & Windapo (2014) have performed an extensive literature review of 25 studies in order to identify 15 factors influencing cost overrun on construction projects. The reviewed studies have been performed during the period 1997 until 2013, both locally (Nigeria) as internationally. In addition, Larsen, Shen, Lindhard, & Brunoe (2016) have identified 26 factors that affect time, quality, and cost. These 26 factors were identified by interviewing eight Danish public agency project and property managers. A literature study was performed to verify if previous studies used similar factors. Larsen et al. (2016) state, without underpinning this claim, that factors from other geographical areas should not be considered given the different construction processes and complications. Larsen et al. (2016) conducted a questionnaire with 56 respondents, including architects, engineers, and building surveyors. The respondents were all employed by the four Danish public construction agencies. Based on the results of this questionnaire, five factors were identified based on statistical analysis.

This first review has provided a general overview of factors that affect cost overruns. When comparing and combining these factors based on semantics, a selection of 25 factors can be established, as shown in Table 3. These 25 factors are categorised based on inside and outside of the influence of the project organisation. This categorisation is chosen since the client and the contractor can only react to factors inside the influence of the project organisation. In order to narrow down the 25 selected factors and to obtain an understanding of which factors are important to Dura Vermeer, three interviewees were asked to rank the 25 factors identified in literature, by dividing 10 points in total. This amount of points has been chosen to make sure that interviewees were forced to make a selection of factors while providing room for interviewees to include priorities. A selection of nine factors can be made based on the selection criterion of at least two points received from the interviewees. This selection criterion has been chosen to select factors that interviewees perceive as more influential in cost overruns. These selected factors include; *bias*, *engineering and construction complexities, scope changes, poor estimating, faulty execution, market conditions, improper planning, poor project management, and contract document conflicts*. Complete transcripts of the interviews can be found in Appendix G.

2.3.2 PROJECT CHARACTERISTICS

The current literature does not only study factors that influence cost overrun. In addition, the influence of certain project characteristics on cost overrun have been studied. The subsequent sections will illustrate the potential influence a project characteristic can have on cost overrun based on the current literature.

Table 3 Comparison of factors found in literature (Source: own illustration)

	Factor	**Geo-graphical Area**	**Study**					**Identified during internal interviews***
			Morris & Hough (1988)	Shane et al. (2009)	Ali et al. (2010)	Odediran & Windapo (2014)	Larsen et al. (2016)	
Inside project organisation influence	Bias	US, W		*x*	*x*			*x (2)*
	Delivery/procurement approach	US, W		*x*				
	Project schedule changes	US, W	*x*	*x*	*x*			*x (1)*
	Engineering and construction complexities	US, W	*x*	*x*	*x*	*x*		*x (3)*
	Scope changes	US, W, D	*x*	*x*		*x*	*x*	*x (2)*
	Scope creep	US, D	*x*	*x*				*x (1)*
	Poor estimating	US, W	*x*	*x*	*x*	*x*	*x*	*x (3)*
	Inconsistent application of contingencies	US		*x*				
	Financial management	W				*x*		
	Project financing	W			*x*			
	Faulty execution	US, W		*x*	*x*	*x*		*x (3)*
	Ambiguous contract provisions	US, W, D	*x*	*x*		*x*		
	Contract document conflicts	US, W, D	*x*	*x*		*x*	*x*	*x (2)*
	Labour cost and requirements	W				*x*		
	Lack of experience	W, D			*x*			
	Poor project management	W			*x*			*x (3)*
	Improper Planning	W			*x*	*x*		*x (3)*
	Lack of preliminary examination before design or tendering	D					*x*	
Outside project organisation influence	Local concerns and requirements	US, D		*x*			*x*	
	Effects of inflation	US, W	*x*	*x*	*x*	*x*		*x (1)*
	Market conditions	US, W		*x*	*x*	*x*		*x (2)*
	Unforeseen events	US		*x*				*x (1)*
	Unforeseen conditions	US, W	*x*	*x*	*x*	*x*		*x (1)*
	Scope changes	US, W, D		*x*				*x (1)*
	Scope creep	US, D		*x*				*x (1)*
	High cost of machineries	W			*x*			
	Errors or omission in consultant material	D					*x*	

US: United States, W: World, D: Denmark

I: Internal, E: External

* Amount of points shown between parentheses (10 points per interviewee)

Project type

The study of Cantarelli, Van Wee, et al. (2012) has identified that rail projects have better cost performance compared to road and fixed link projects. Furthermore, road projects are found to be particularly vulnerable to cost overruns. Lastly, cost overruns mainly appear, for all project types, in the pre-construction phase. On the contrary, Odeck (2004) concludes, to his own surprise, that project type did not influence the level of cost overrun. Overall these findings indicate that scholars are not in agreement on the influence of project type on cost overruns. Therefore, this study will include project type to assess if the relationship between contract type and cost overrun is dependent on the project type.

Geography

Based on the TOE-framework of Bosch-Rekveldt et al. (2011) it can be stated that the complexity of a project is also dependent on the environment, which is dependent on the location of the project. The location of a project (e.g. urban or rural) is a common project characteristic to analyse cost overruns in transport projects (Lundberg, Jenpanitsub, & Pyddoke, 2011). Based on this insight it can be hypothesised that the location of a project (e.g. urban or rural) has an influence on cost overruns through the complexity of the location.

Type of client

It can be hypothesised that the experience of the client with describing functional requirements plays a role in the number of contract document conflicts. Nationally operating clients have more experience with functional requirements simply because they procure more integrated contracts. Compared to regionally operating clients who have to deal with integrated contract forms once every few years, or even less frequent. There are no studies performed that underpin this hypothesis. However, Drew, Skitmore, & Po (2001) state that the type of client has an influence on the bidding strategy of a contractor, which indicates that type of client could be an interesting project characteristic to include in the data analysis.

Project size

Rowland (1981) showed that both the number of change orders and the contract size increased. While, Randolph, Rajendra, & Campfield, (1987) found the contrary, that the contract size increases when the number of change orders decreases. More recently, the study of Verweij, van Meerkerk, & Korthagen (2015) analysed 45 infrastructure project of Rijkswaterstaat and reviewed 2804 contract changes. Verweij et al. (2015) concluded that both in terms of quantity and their value, scope changes were found to be the most significant reason for contract changes in Dutch infrastructure projects. Furthermore, it was found that the average project has 13.37 per cent of the contract value as contract change costs. However, the average relative percentage of contract change costs is 22.37 per cent. Meaning smaller project have higher contract change costs. This relationship, however, was found not significant. In addition, Verweij et al. (2015) suggest that DBFM could result in lower contract change costs for the client. However, because of the small sample of DBFM projects (n=5) and the fact that the DBFM projects in the database of Verweij et al. (2015) were still being implemented no conclusions could be drawn regarding DBFM contracts.

It is important to note that the client and the contractor have a different perspective on scope changes. Scope changes for a client are seen as a risk since the client is obliged to compensate the contractor for the additional work when this work was not part of the contract and therefore not part of the scope. The contractor sees a scope change from the client as an opportunity to claim this change with the client. While a scope change due to an incomplete scope assessment during the tender phase is seen as a risk by the contractor when the contractor is responsible for the design of the project. The contractor sees this as a risk because the responsibility of the design lies with the contractor which is, therefore, unable to claim the additional costs when he missed an element of the scope. Based on these insights one can hypothesise that traditional contracts incur lower cost overruns for a contractor since they can claim their scope changes with the client, compared to integrated contracts where the contractor cannot claim all scope changes.

Furthermore, Odeck (2004) suggested that bigger projects are often under better management compared to smaller projects. This suggestion of Odeck is based on the results of statistical analyses of 620 road projects. Odeck (2004) concluded that cost overruns appear to be more common among smaller projects compared to larger projects. Odeck (2004) defines smaller projects based on an actual cost lower than 100 million Norwegian krone (NOK) (± 10 million EUR). The study of Cantarelli, Van Wee, et al. (2012), which focusses on Dutch projects, agrees with Odeck (2004) by stating that 'the problem of cost overruns is most severe for small projects'. However, Cantarelli, Van Wee, et al. (2012) also conclude that there is no significant influence of project size on cost overrun. Meaning, that small projects incur the highest cost overruns, in average percentages, but the impact of project size on cost overruns is small (Cantarelli, Van Wee, et al., 2012). Similar results were presented by Charles & Ashe (1990), after analysing 1576 construction projects and concluding that larger projects are more likely to have a cost overrun of 1 per cent to 11 per cent compared to smaller projects. However, cost overruns larger than 11 per cent occurred more often on smaller projects.

Overall these findings indicate that project size plays a role in cost overruns. Based on these insights and the fact that larger projects often have an integrated PDM, it can be hypothesised that traditional contract types, which are often used for smaller projects, tend to have higher average cost overruns.

Execution phase

The first to test whether projects with longer execution phases tend to have larger cost overruns, is the study of Flyvbjerg, Skamris Holm, et al. (2004). This study, with an internationally oriented, client-based, database, concluded that cost overruns are highly dependent ($p<0.001$) on the length of the execution phase of the project. Odeck (2004) agrees by stating that “cost overrun increases with completion time (i.e. execution time) up to medium sized projects” (<350 million NOK, <36 million EUR).

In addition, Cantarelli, Van Wee, et al. (2012) studied, from a client perspective, the execution and the pre-execution phase of Dutch projects in more detail. The main findings for the pre-execution phase are first, that road projects have the smallest cost overrun and rail projects the largest. Second, road and rail projects incur more cost overruns than cost underruns. Last, rail projects have both the largest cost underruns and overruns, 12 per cent and 41 per cent respectively followed by road projects with an average cost overrun of 26 per cent. When considering the execution phase, Cantarelli, Van Wee, et al. (2012) find that road and rail projects incur, on average, cost underruns of 3 per cent and 7 per cent, respectively. Furthermore, cost underruns occur more often than cost overruns. Lastly, rail projects have the largest cost overruns and road projects have the largest cost underruns. These findings indicate that the duration of the pre-execution phase has a strong (positive) relationship with cost overruns. While the length of the execution phase has a weak (negative) relationship with cost overruns. Cantarelli, Van Wee, et al. (2012) therefore state that ‘the focus should lie on the pre-execution phase when searching for causes and cures for cost overruns, at least for the Netherlands’.

D&B contracts integrate the pre-construction phase, compared to traditional, RAW, contracts which only include the execution phase. Early studies indicated that D&B outperforms traditional contracts when looking at cost performance (Konchar & Sanvido, 1998; Molenaar, Songer, & Barash, 1999; Songer & Molenaar, 1997). The literature review of Hale, Shrestha, Gibson Jr., & Migliaccio (2009) illustrated that several studies concluded that cost overruns for D&B contracts were lower compared to traditional contracts (Konchar & Sanvido, 1998; Roth, 1995; Shrestha & Migliaccio, 2007; Warne, 2005). However, more recent studies showed that cost overruns for D&B contracts were higher compared to traditional contracts (Ibbs, Kwak, & Odabasi, 2003; U.S. Department of Transportation Federal Highway Administration, 2006). In addition, Hale et al. (2009) compared 39 traditional projects and 38 D&B projects and reported that based on time and cost growth, DB is superior to DBB when used on military housing projects.

However, the interpretation of these findings requires caution because of two reasons. First, the majority of these studies is based on small sample sizes. The exact sample size of each study can be found in Appendix D. Second, these studies solely compare cost performance based on contract type and do not include other influential factors, such as e.g.: management capabilities, or project characteristics. The study of Park & Kwak, (2017) compared 1512 traditional and D&B public transportation projects in the United States and included project characteristics in this comparison. The project characteristics that were included are: original contract amount to represent project size, duration to represent external influences since longer projects are more likely to be influenced by external influences, and the type of project to account for project scope. Park & Kwak, (2017) concluded, in agreement with Hale et al. (2009) that cost overruns in D&B project are lower compared to traditional when comparing original contract amount to production cost. However, the results were found to be insignificant after accounting for project characteristics.

Based on these findings one can hypothesise that contract forms that integrate the pre-construction phase, i.e. the definition phase, and the construction phase offer more possibilities to search for causes and cures for cost overruns and thereby reducing cost overruns.

Optimism bias

Optimism bias is not a project characteristic but could be considered as a characteristic of people working on a project, since Flyvbjerg et al. (2002) state that cost estimations are biased because of a systematic underestimation. This systematic underestimation has four potential explanations, according to Flyvbjerg et al. (2002), including technical, economic, psychological, and political.

Technical explanations involve simple mistakes or fundamental problems with predicting the future. Economic explanations are divided into two types. First, self-interest occurs when a stakeholder influences the estimation process to create a situation which benefits its self-interest (Flyvbjerg et al., 2002). Second, public interest occurs when project members which are favourable to the project deliberately underestimate costs to save the public's money. Political explanations question if cost estimators are biased in order to serve the interests of project managers who aim to get a project funded and/or started. Psychological explanations try to describe a personal bias of cost forecasters. Flyvbjerg et al. (2002) state that appraisal optimism is the most commonly used psychological explanation. Appraisal optimism occurs when forecasters are overly optimistic about project outcomes during the conception phase (Flyvbjerg, Glenting, & Rønnest, 2004).

Flyvbjerg et al. (2002) conclude by stating that political and economic explanations best explain optimism bias and that deception and lying are used as a tactic, aimed at project approval. Flyvbjerg et al. (2018) state that "according to behavioural science, the causal chain starts with human bias which leads to the underestimation of scope during planning which leads to unaccounted for scope changes during delivery which lead to cost overrun". The reasoning of Flyvbjerg and his colleagues is questioned by Love, Edwards, & Irani (2012) since they state that "to simply assume that strategic misrepresentation and optimism bias are overarching actions that lead to the unsuccessful delivery of social infrastructure projects is misleading considering the complex array of conditions and variables that interact with one another during the project's procurement". As Verweij (2015) clarifies, the work of Flyvbjerg and colleagues assumes that the implementation phase of infrastructure projects can be calculated and thus focuses on identifying actors that are accountable for cost overruns. This worldview does not encourage to learn from the evaluations of execution phases of infrastructure projects. Accepting that the complexity of infrastructure projects will result in unforeseen events occurring, means dismissing the notion that these events occur due to optimism bias or strategic misrepresentation (Verweij, 2015). It is important to stress that the studies of Flyvbjerg apply to public clients and not contractors. The contractor, however, operates in a competitive market in which a large number of contractors are in search of work. Combined with applied procurement procedures that compare bids based on price or a fictive price, which takes into account the quality of the bid. This combination creates a different incentive for the contractor to adjust the estimates downwards to achieve a competitive bid, in order to maximise the chance of winning the contract. According to an interviewee, this comes down to eagerness and bidding policy.

> *"What you do with a high-risk project, depends on eagerness and bidding policy. …*
> *You could opt for 50% or 70% certainty, depending on the risk you are willing to*
> *take. This comes down to a prudential, i.e. economic, decision."*
>
> *Interviewee #2*

Optimism bias could also be seen as opportunistic behaviour of a contractor based on the assumption that contractors lower their bid to win the contract, in order to recover this by claiming additional work during the project. Verweij et al. (2015) concluded in their research that there is a very weak positive (0.07) relationship between the relative procurement result and the relative contract changes. However, this correlation was found to be insignificant. These results mean that Verweij et al. (2015) could not find evidence of opportunistic behaviour of contractors. Based on these findings one could also state that contractors do behave opportunistically but overestimate the contractual changes they can claim with the contractor. Applying this reasoning of optimism bias to a contractor could explain a situation in which a contractor takes on more risks, by lowering his bid in order to maximise their chance to win the tender procedure of a prestigious project. In recent years large, complex, and prestigious projects have been based on integrated PDMs. Thus, one can hypothesise that optimism bias with a contractor has an influence on more integrated PDMs, resulting in higher cost overruns compared to traditional contracts.

2.4 CONCLUSION THEORETICAL FRAMEWORK

The literature study first set out to identify which contracts are used in Dutch national infrastructure projects. Dutch national infrastructure projects can use a range of contracts including RAW, building team, E&C, D&C, DBM, DBFM(O), and an alliance. Each contract type separates the responsibilities between the client and the contractor in a different manner. This difference creates both advantages and disadvantages for clients and contractors. Most importantly, the contract defines the time during the project life cycle when the contractor becomes involved with the project. Hence, the moment of contracting is dependent on the contract type.

The second aim of the literature study was to obtain insight into the cost management process. It can be concluded that both the client and the contractor use similar techniques when classifying and estimating costs. The interesting difference, however, lies in the time during the project life cycle when the client and the contractor estimate their costs. Because a client estimates her costs during the conception phase, a lot of uncertainty results in a large bandwidth around the estimate. While a contractor estimates his costs during the definition phase. Since, uncertainty diminishes during the project life cycle, due to the availability of information, the amount of uncertainty for a contractor is dependent on the moment of contracting and thus on the contract type. After the moment of contracting the control of cost starts for both the client and the contractor which continues throughout the execution and operation phase. Throughout these phases, cost overruns will materialise due to several influential factors.

In order to better understand cost overruns and to provide a theoretical framework, influential factors to cost overruns have been assessed. Cost overrun factors are widely studied, resulting in an extensive body of knowledge concerning cost overrun factors. Based on a literature review and a ranking provided by interviewees at Dura Vermeer, eight factors have been selected including *bias*, *engineering and construction complexities, scope changes, poor estimating, faulty execution, market conditions, improper planning, poor project management, and contract document conflicts*. However, this literature review has shown that the body of knowledge concerning cost overrun in relation to the project delivery model is small. In 2018, Flyvbjerg et al. stated that the influence of project delivery models on cost overrun would be an interesting area for further research. However, Flyvbjerg et al. (2018) do hypothesise that the project delivery model is only a cause and not a root cause. Furthermore, the literature study has shown that studies considering individual cost groups instead of aggregated results are non-existent in literature. Cantarelli, Van Wee, et al. (2012) do propose to disaggregate cost overruns in different types of costs as an area for further research. These insights further increase the theoretical relevance of this research.

Incorporating the eight factors in a quantitative analysis remains difficult since not all factors are quantifiable. The identified project characteristics, however, are measurable and can therefore be incorporated in the subsequent data analysis. These project characteristics include project type, geography, type of client, and project size. Based on the literature review concerning these project characteristics in relation to cost overrun, six hypotheses have been formulated:

H1 The earlier the moment of contracting occurs during the project life cycle, the higher the cost overrun due to the unavailability of information.

H2 The earlier the moment of contracting occurs during the project life cycle, the higher the uncertainty of the cost performance will be due to the unavailability of information.

H3 Project type has an influence on the relationship between contract type and cost performance.

H4 The location of a project (urban/rural) has an influence on the relationship between contract type and cost performance.

H5 The type of client has an influence on cost overruns through their experience with integrated PDMs.

H6 Project size has an influence on the relationship between contract type and cost overrun.

3

Results and Analysis

3 RESULTS AND ANALYSIS

3.1 DATA SAMPLING

In order to compare projects of different capital values and to maintain confidentiality, the financial data is presented as a percentage, i.e. the cost performance. The cost performance shows the accuracy of a budget by subtracting the working budget from the realized costs and dividing this by the working budget. Table 4 presents the descriptive statistics regarding the relative results of projects with RAW, E&C, and D&B(M) contracts.

Table 4 Descriptive statistics of relative total results

Cost group	*Contract type*	*N*	*Min.*	*Max.*	*Mean*	*Median*	*Std. Dev.*	*Skewness*		*Kurtosis*		*Independent-Samples Kruskal-Wallis H Test*		
								Statistic	*Std. Error*	*Statistic*	*Std. Error*	*Test Statistic* [1]	*Degrees of Freedom*	*Asymptotic Sig. (2-tailed test)*
Total result relative to budget	RAW/STABU	24	-37.71%	14.99%	-0.93%	0.37%	9.95%	-2.17	0.47	7.71	0.92	0.053	2	0.974
	E&C	22	-14.44%	18.25%	0.10%	-1.12%	8.18%	0.14	0.49	-0.18	0.95			
	D&B(M)	22	-36.88%	16.86%	-1.36%	-0.01%	10.47%	-1.74	0.49	5.84	0.95			
	Total	68	-37.71%	18.25%	-0.73%	-0.01%	9.47%	-1.52	0.29	5.15	0.57			

1. The test statistic is adjusted for ties.

Based on the minimum and maximum values presented in Table 2 (p.8), it can be stated that the database includes both small and large projects, in terms of monetary value. Furthermore, the minimum, maximum, and mean values of Table 4 illustrate that the database includes projects with a positive and negative outcome while the mean values remain around zero per cent. Together, Table 2 and Table 4 show that the database is a neutral representation and not 'sugar-coated'. Furthermore, Table 4 reveals a small difference in mean values between the contract types RAW (n=24, -0.93%), E&C (n=22, 0.10%), and D&B(M) (n=22, -1.36%). Whereby RAW and D&B(M) projects confirm hypothesis 1. However, the median values of RAW (0.37%), E&C (-1.12%) and D&B(M) (-0.01%) indicate that the cost overrun for all contract types has a tendency to be closer to 0%, indicating that the mutual difference is small. This observation is verified by performing a Kruskal-Wallis H test to determine if there were differences in the total result, between the three groups of contracts. As Table 4 indicates this test returned an insignificant result (p=0.974), meaning the total result does not differ significantly between contract types. Upon closer inspection of Table 4, it shows a slight increase in standard deviation (SD) from E&C (8.18%), to RAW (9.95%), to D&B(M) (10.47%). This increase can be considered an increase in uncertainty about the cost performance of a project with a given contract type. Based on the availability of information at the moment of contracting it is expected that D&B(M) projects have the highest SD and RAW projects the lowest. However, Table 4 illustrates that E&C projects have the lowest SD while the difference between RAW and D&B(M) projects is marginally small, thereby partially confirming hypothesis 2. In order to understand why this difference between contract types occurs, the statistical analysis will focus on individual cost groups from this point forward.

When reviewing the descriptive statistics of the individual cost groups presented in Table 24 in Appendix H, the following insights are obtained. First, the data of several cost groups is incomplete. The cost groups *conditioning, financial, chance and risks, contractual changes, general, provisional sums,* and *procurement results* are incomplete and show irregularities. Respectively these cost groups have the following number of missing cases 12, 3, 3, 23, 1, 23, and 20. The absence of data is a reason to question the data quality of these cost groups. After consultation with Dura Vermeer, it was found that the above-mentioned cost groups are known for their poor administration. Furthermore, these cost groups are all indirect cost groups and are often used to transfer budgets within a project. Based on the above, the empirical and comparative value diminishes since the above-mentioned cost groups potentially play different roles in each project. Therefore, the cost groups *conditioning, financial, chance and risks, contractual changes, general, provisional sums,* and *procurement results* are excluded from further statistical analysis. Second, the remaining cost groups have a large spread, illustrated by the large ranges between the minimum and the maximum values combined with large standard deviations. This enlarges the chance of outliers in the database. The presence of outliers is confirmed by visual inspection of the boxplots of all cost groups. In consultation with Dura Vermeer, it is acknowledged that outliers can be caused by administrative errors or special events. These extreme outliers can have a large influence on the results of the statistical analysis. Therefore, a uniform selection criterion is applied to the relative results of each individual cost group. The selection criterion is formulated as follows: -100% ≤ [relative result of cost group] ≤ 100%. This selection criterion affects cost groups including *labour, equipment, deliveries, engineering, building site, and project organisation / UTA*. The sample sizes vary from 68 to 51, 66, 67, 61, 63, and 66 respectively. The selection criterion is not applied to the data of the cost group budget relative to the total budget since this data did not show extreme outliers.

3.2 STATISTICAL ANALYSIS

The aim of this research is to obtain insight into the relationship between the type of contract and the management of cost groups in Dutch national infrastructure projects. In order to assess this relationship, the six hypotheses formulated in Section 2.4 will be tested on each individual cost group. The statistical results and the hypothesis tests of the cost groups including *labour, equipment, subcontractors, deliveries, engineering, building site, and project organisation / UTA* will be presented in Sections 3.2.1 to 3.2.7. The statistical analysis of the aggregated cost group direct costs, which includes *labour, equipment, subcontractors, and deliveries* is presented in Appendix I since all individual cost groups will be included in the subsequent Sections 3.2.1, 3.2.2, 3.2.3, and 3.2.4 respectively. The statistical analyses have been conducted in accordance with the research approach as presented in Section 1.5.2. However, based on the skewness and kurtosis it is observed that within each cost groups at least one contract type does not follow a normal distribution. After assessing skewness and kurtosis values of all cost groups while applying different types of clusters, it can be stated that the data does not follow a normal distribution. Consequently, the one-way analysis of variance (ANOVA) test cannot be used in this analysis since the dependent variable (cost group) must be approximately normally distributed for each group of the independent variable (contract type). Therefore, the Kruskal-Wallis H test will be applied throughout this analysis.

3.2.1 LABOUR

As described in Appendix A the cost group *labour* relates to physical labour in terms of man-hours which is performed by Dura Vermeer instead of a subcontractor. In general, the importance of a cost group to the overall project budget can be assessed by calculating its relative share at the moment of contracting. Table 5 presents the statistics concerning the relative share of the cost group *labour* across contract types.

Table 5 Statistics of labour budget relative to total budget and labour total costs relative to budget (no clustering applied)

								Skewness		*Kurtosis*		*Independent-Samples Kruskal-Wallis H Test*		
Cost group	*Contract type*	*N*	*Min.*	*Max.*	*Mean*	*Median*	*Std. Dev.*	*Statistic*	*Std. Error*	*Statistic*	*Std. Error*	*Test Statistic* [1]	*Degrees of Freedom*	*Asymptotic Sig. (2-tailed test)*
Labour budget relative to total budget	RAW/STABU	24	0.48%	23.70%	6.14%	4.32%	5.69%	1.38	0.47	2.48	0.92	1.515	2	0.469
	E&C	22	0.47%	18.53%	6.43%	5.44%	4.87%	1.25	0.49	1.63	0.95			
	D&B(M)	22	0.28%	22.14%	5.44%	2.71%	6.19%	1.90	0.49	3.05	0.95			
	Total	68	0.28%	23.70%	6.01%	5.54%	5.54%	1.47	0.29	1.99	0.57			
Labour total costs relative to budget	RAW/STABU	17	-93.38%	75.96%	-11.23%	-12.43%	34.57%	0.19	0.55	3.18	1.06	0.23	2	0.891
	E&C	16	-59.06%	51.53%	-7.24%	-6.34%	29.81%	0.02	0.56	-0.44	1.09			
	D&B(M)	18	-98.39%	84.86%	-2.64%	-13.55%	49.04%	0.28	0.54	-0.07	1.04			
	Total	51	-98.39%	84.86%	-6.95%	-10.24%	38.46%	0.32	0.33	0.84	0.66			

1. The test statistic is adjusted for ties.

Table 5 illustrates that on average 6.01 per cent of the total budget is allocated to labour. Which illustrates that Dura Vermeer does not employ a lot labour itself but instead uses subcontractors. The mean percentages differ slightly between RAW (n=24, 6.14%), E&C (n=22, 6.43%), and D&B(M) (n=22, 5.44%) projects. The Kruskal-Wallis H test confirms that there is no statistically significant difference between contract types in the allocation of labour budgets relative to the total budget of a project (p=0.469). The SD for both RAW (5.69%) and E&C (4.87%) is lower than the mean and can, therefore, be considered low. The SD can be considered a measure for uncertainty since it illustrates how large the spread around the mean is and thus how certain planners are in estimating a certain budget. The SD of D&B(M) (6.19%) projects is higher than its mean which indicates, that there is slightly more uncertainty present when estimating labour budgets in D&B(M) projects compared to RAW and E&C projects. Since the differences between the SD of the contract types is marginally small, the uncertainty in each contract type should be considered equal. Even though only 6.01 per cent of the total budget is allocated to labour, a strong correlation is found between the total costs of labour relative to its budget and the total result of a project. Based on a Spearman correlation analysis, as presented in Table 6, it is found that projects with a RAW contract have a correlation of r=0.553 (p=0.021) compared to E&C projects which have a correlation of r=0.512 (p=0.043). D&B(M) projects have the strongest correlation of r=0.567 (p=0.014). All correlations are plotted in the scatterplot depicted in Figure 19 (Appendix J). Since the difference between these correlations is very small, it can be stated that all contract types have an equally strong correlation between the results of *labour* and the total project.

Table 6 Results Spearman correlation analysis

Cost group	*Contract type*	*Spearman's rho*	Labour	Equipment	Subcontractors	Deliveries	Engineering	Building site	Project Organisation / UTA	Direct costs
Total result	RAW/STABU	Correlation coefficient	0.553*	-0.114	0.374	0.161	-0.254	0.242	0.020	0.704**
		Sig. (2-tailed)	0.021	0.594	0.072	0.452	0.254	0.291	0.926	0.001
		N	17	24	24	24	22	21	24	22
	E&C	Correlation coefficient	0.512*	0.147	0,512*	0.208	0.329	-0.137	0.782**	0.700**
		Sig. (2-tailed)	0.043	0.526	0.015	0.366	0.170	0.565	0.001	0.001
		N	16	21	22	21	19	20	21	21
	D&B(M)	Correlation coefficient	0.567*	0.566**	0.396	0.394	0.178	0.312	0.419	0.649**
		Sig. (2-tailed)	0.014	0.007	0.068	0.070	0.100	0.158	0.058	0.001
		N	18	21	22	22	20	22	21	20

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

The descriptive statistics of the total costs of the cost group *labour* relative to its budget, as presented in Table 5 and with the corresponding boxplots in Figure 15, show that on average a cost overrun of 6.95 per cent occurs. When assessing the difference between contract types RAW (n=17), E&C (n=16), and D&B(M) (n=18) it is observed that the mean value increases from -11.23 per cent, too -7.24 per cent, too -2.64 per cent respectively. This does not confirm hypothesis 1, which assumed that the cost performance would decrease sequentially from RAW to E&C to D&B(M). The percentage for RAW contracts is surprisingly high since one would expect a focus on labour costs considering the main responsibility of RAW contracts is the construction of a project. The seemingly low percentage of D&B(M) projects (-2.64%) should be interpreted with caution since the median value is -13.55 per cent which indicates that the cost overrun on labour of D&B(M) projects has a tendency to be higher than -2.64 per cent. A potential explanation for the low mean value of D&B(M) projects could be the possibility to integrate execution techniques into the design, which could result in lower cost overruns on labour for D&B(M) projects. Based on a Kruskal-Wallis H test this difference between contract types is found to be insignificant (p=0.891). When clustered by project type (p>0.615), project location (p>0.413), type of client (p>.090), or project size (p>0.152) the difference between contract types remains insignificant, thereby rejecting hypotheses 3, 4, 5, and 6 respectively. These results are summarized in Appendix J.

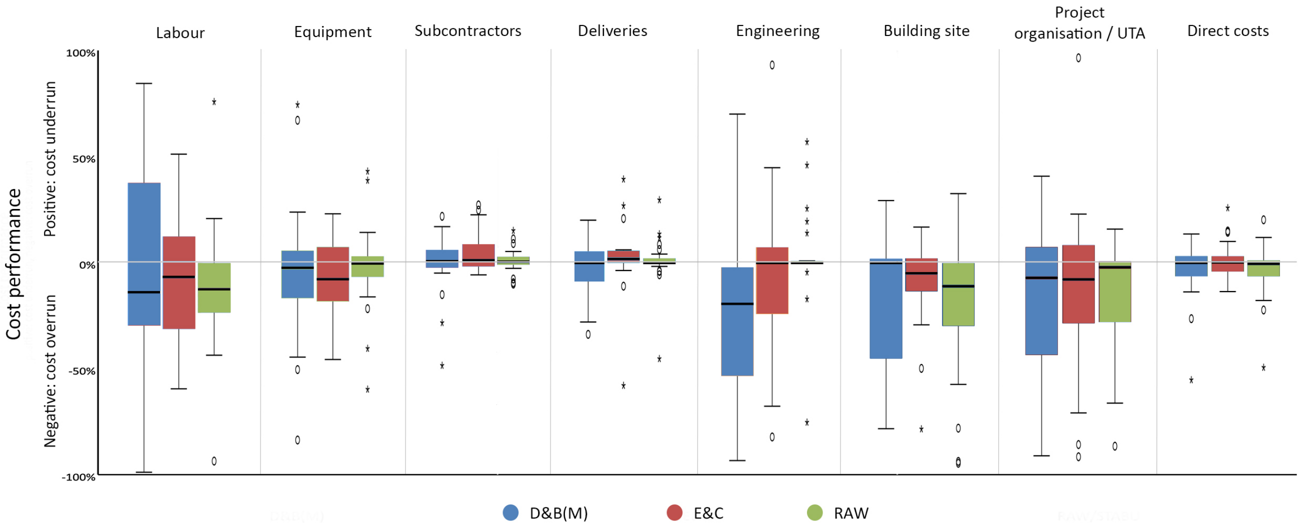


Figure 15 Cost performance per cost group, by contract type

However, an interesting aspect of Table 5, labour total costs relative to the budget, is that the mean cost overrun decreases from RAW to E&C to D&B(M), while the SD increases. Meaning, the average result of labour improves with integrated contracts whilst the uncertainty about the result of labour also increases. Since E&C contracts have an earlier moment of contracting compared to RAW contracts, the SD is expected to be higher. However, Table 5 shows that the SD of D&B(M) (49.04%) is highest, as expected, followed by RAW (34.57%), and E&C (29.81%). These results do not confirm hypothesis 2 since they do not follow the presumed order of D&B(M), E&C, and RAW when ordered by decreasing uncertainty. An overview of all hypothesis tests for *labour* is presented in Table 7. When comparing the SD values of budget relative to total budget and total costs relative to budget, a large difference is easily recognizable. Meaning, planners are fairly certain how large the budget for *labour* should be, but the eventual result remains very uncertain.

Table 7 Results of hypotheses tests for the cost group labour

Cost group	*Hypothesis 1* "Cost performance"	*Hypothesis 2* "SD of cost performance"	*Hypothesis 3* "Project type"	*Hypothesis 4* "Project location"	*Hypothesis 5* "Type of client"	*Hypothesis 6* "Project size"
Labour	Rejected	Rejected	Rejected	Rejected	Rejected	Rejected

3.2.2 Equipment

As described in Appendix A the cost group *equipment* relates to the use of equipment during construction. The relative share of the cost group *equipment*, as presented in Table 8, illustrates that the mean budget for *equipment* is largest in E&C (n=22, 9.02%) projects and the smallest in D&B(M) (n=22, 5.96%) projects while the mean value for RAW projects (N=24, 8.20%) is closest to the overall mean of 7.74 per cent. The relative budget of 9.02 per cent for E&C projects is surprising since it is expected to be lower than RAW due to higher relative direct costs in RAW contracts. The relative direct costs are expected to be higher for RAW contracts because the engineering and management responsibilities are considerably smaller in RAW projects. The difference in relative budgets between contract types, however, is found to be insignificant (p=0.074), based on the Kruskal-Wallis H test.

Table 8 Statistics of equipment budget relative to total budget and equipment total costs relative to budget (no clustering applied)

Cost group	Contract type	N	Min.	Max.	Mean	Median	Std. Dev.	Skewness Statistic	Skewness Std. Error	Kurtosis Statistic	Kurtosis Std. Error	Independent-Samples Kruskal-Wallis H Test: Test Statistic [1]	Degrees of Freedom	Asymptotic Sig. (2-tailed test)
Equipment budget relative to total budget	RAW/STABU	24	0.13%	21.90%	8.20%	7.99%	4.50%	1.06	0.47	2.79	0.92	5.213	2	0.074
	E&C	22	1.45%	26.71%	9.02%	8.42%	6.03%	1.22	0.49	2.10	0.95			
	D&B(M)	22	0.27%	16.63%	5.96%	4.27%	5.20%	1.03	0.49	-0.17	0.95			
	Total	68	0.13%	26.71%	7.74%	6.55%	5.33%	1.05	0.29	1.47	0.57			
Equipment total costs relative to budget	RAW/STABU	24	-59.35%	43.42%	-1.69%	0.00%	20.77%	-0.48	0.47	2.78	0.92	0.599	2	0.741
	E&C	21	-45.25%	23.43%	-6.02%	-7.41%	18.76%	-0.27	0.50	-0.63	0.97			
	D&B(M)	21	-83.20%	74.84%	-3.76%	-2.01%	35.49%	0.20	0.50	1.36	0.97			
	Total	66	-83.20%	74.84%	-3.72%	-0.85%	25.53%	0.04	0.30	2.42	0.58			

1. The test statistic is adjusted for ties.

Closer inspection of Table 8 shows that the SD illustrate that there is slightly more uncertainty present when estimating equipment budgets in E&C (6.03%) projects and D&B(M) projects (5.20%) compared to RAW projects (4.50%). This result is similar to the cost group *labour*. However, since the SD is below the mean, it can be considered low. Meaning the uncertainty surrounding the estimation of equipment budgets is low. While the mean value of the equipment budget relative to the total budget decreases from E&C (9.02%) to RAW (8.20%) to D&B(M) (5.96%) it can be expected that the correlation between the total costs of equipment relative to its budget and the total result of a project will decrease as well. Table 6, in section 3.2.1, illustrates, somewhat counterintuitively, that there is only a significant positive correlation for D&B(M) projects r=0.566 (n= 21, p=0.007) and no significant correlation for RAW and E&C projects. All correlations are plotted in the scatterplot depicted in Figure 20 (Appendix J).

The descriptive statistics of the total costs of the cost group *equipment* relative to its budget, as presented in Table 8 and with the corresponding boxplots in Figure 15 (p. 33), show that on average a cost overrun of 3.72 per cent occurs. When assessing the difference between contract types E&C (n=21), D&B(M) (n=21), and RAW (n=24), it is observed that the mean value increases from -6.02 per cent, too -3.76 per cent, too -1.69 per cent respectively which rejects hypothesis 1 since the cost performance of E&C projects is worse compared to D&B(M) projects. This difference in cost performance between contract types, however, is found to be insignificant (p=0.741), based on the Kruskal-Wallis H test. When clustered by project type (p>0.335), project location (p>0.511), type of client (p>0.311), or project size (p>0.536) the difference between contract types remains insignificant, thereby rejecting hypotheses 3, 4, 5, and 6 respectively. These results are summarized in Appendix J. More interestingly, the SD illustrates that all contract types have a large dispersion around their mean values. This indicates that the cost performance of *equipment* is very uncertain while the uncertainty surrounding the budget was small, which could indicate cost underestimation. However, the SD of D&B(M) (35.49%) and RAW (20.77%) does not confirm hypothesis 2 since the SD of E&C (18.76%) was expected to be between D&B(M) and RAW. An overview of all hypothesis tests for *equipment* is presented in Table 9. Similar to *labour*, the largest uncertainty is observed among D&B(M) projects which can be expected since the availability of information at moment of contracting makes it more difficult to estimate which equipment you need and especially for how long. More surprising is the fact that while the cost performance of *equipment* for RAW projects is very uncertain, the mean cost overrun is lowest compared to other contract types. The lower mean cost overrun of RAW projects could be caused by the dependence between equipment cost and time. Since RAW projects are often smaller projects, their time overrun tends to be smaller. Hence, the lower cost overrun on equipment for RAW projects.

Table 9 Results of hypotheses tests for the cost group equipment

Cost group	Hypothesis 1 "Cost performance"	Hypothesis 2 "SD of cost performance"	Hypothesis 3 "Project type"	Hypothesis 4 "Project location"	Hypothesis 5 "Type of client"	Hypothesis 6 "Project size"
Equipment	Rejected	Rejected	Rejected	Rejected	Rejected	Rejected

3.2.3 Subcontractors

As described in Appendix A the cost group *subcontractors* relates to work executed by subcontractors. The relative share of the cost group *subcontractor*, as presented in Table 10, illustrates that roughly one-third of the total budget of a project is allocated to subcontractors. Based on the mean values, E&C projects (n=22, 32.81%) have slightly smaller budgets for subcontractors compared to RAW (n=24, 33.19%), and D&C(M) (n=22, 36.77%) projects. The uncertainty surrounding the estimation process of budgets for subcontractors seems small since SD values of all contract types are below their mean values. However, compared to *labour* and *equipment*, the SD values can be considered fairly high. Based on the mean and SD values it can be argued that the budget for subcontractors relative to the total budget is independent of contract types. This is confirmed after performing a Kruskal-Wallis H test which indicated a statistically insignificant (p=0.634) difference between contract types. Since Table 10 has shown that the budget for subcontractors is fairly large relative to the total budget, a strong correlation is expected. However, Table 6, in section 3.2.1, illustrates that only E&C projects (n=22) have a significant positive correlation (r=0.512, p=0.015) between the total costs of subcontractors relative to its budget and the total result of a project. The correlations for RAW (n=24, r=0.374, p=0.072) and D&B(M) (n=22, r=0.396, p=0.068) projects are slightly weaker but remain insignificant based on the Spearman correlation analysis. All correlations are plotted in the scatterplot depicted in Figure 21 (Appendix J).

The descriptive statistics of the total costs of subcontractors relative to its budget, as presented in Table 10 and with the corresponding boxplots in Figure 15 (p.33), show that on average a cost underrun of 0.45 per cent occurs. However, RAW (n=24) and D&B(M) (n=22) projects show a cost overrun of 2.70 per cent and 0.48 per cent respectively, while E&C projects (n=22) have an average cost underrun of 4.81 per cent. Thus, not confirming hypothesis 1 which hypothesised that the cost performance would decrease sequentially from RAW to E&C to D&B(M). The cost underrun of E&C projects is surprising since it was expected that RAW projects would have the best cost performance with subcontractors. This was expected since the moment of contracting in a RAW project provides the contractor with the opportunity to precisely define what he needs from a subcontractor. Integrated contracts, however, have to deal with more uncertainty resulting in a premium for the subcontractor. Contrary to the theory, Table 10 reveals that integrated contracts have better cost performance compared to RAW projects. Despite a clear difference in mean values between contract types, the Kruskal-Wallis H test showed that this difference is statistically insignificant (p=0.741). When clustered by project type (p>0.528), project location (p>0.217), type of client (p>0.221), or project size (p>0.423) the difference between contract types remains insignificant, thereby rejecting hypotheses 3, 4, 5, and 6 respectively. These results are summarized in Appendix J.

Table 10 Statistics of subcontractors budget relative to total budget and subcontractors total costs relative to budget (no clustering applied)

Cost group	*Contract type*	*N*	*Min.*	*Max.*	*Mean*	*Median*	*Std. Dev.*	*Skewness*		*Kurtosis*		*Independent-Samples Kruskal-Wallis H Test*		
								Statistic	*Std. Error*	*Statistic*	*Std. Error*	*Test Statistic*[1]	*Degrees of Freedom*	*Asymptotic Sig. (2-tailed test)*
Subcontractors budget relative to total budget	RAW/STABU	24	4.84%	60.64%	33.19%	35.93%	14.79%	-0.18	0.47	-0.38	0.92			
	E&C	22	8.26%	58.96%	32.81%	33.05%	15.14%	0.10	-0.49	-0.99	0.95	0.91	2	0.634
	D&B(M)	22	10.10%	60.54%	36.77%	36.40%	13.16%	0.03	0.49	-0.31	0.95			
	Total	68	4.84%	60.64%	34.23%	34.56%	14.30%	-0.07	0.29	-0.63	0.57			
Subcontractors total costs relative to budget	RAW/STABU	24	-94.86%	15.22%	-2.70%	0.61%	20.44%	-4.29	0.47	19.96	0.92			
	E&C	22	-5.60%	27.36%	4.81%	1.28%	9.66%	1.24	0.49	0.70	0.95	0.599	2	0.741
	D&B(M)	22	-48.37%	21.98%	-0.48%	0.86%	14.93%	-1.74	0.49	4.60	0.95			
	Total	68	-94.86%	27.36%	0.45%	1.11%	15.89%	-3.59	0.29	20.03	0.57			

1. The test statistic is adjusted for ties.

Assessment of the SD values presents a situation in which, in contrast with hypothesis 2, D&B(M) (14.93%) and E&C (9.66%) have less uncertainty about the total costs relative to budget compared to RAW (20.44%) projects. Since this is not conform hypothesis 2, it raises the question if more available information results in better contracts with subcontractors. An overview of all hypothesis tests for *subcontractors* is presented in Table 11. When comparing the SD values of budget relative to total budget and total costs relative to budget, a small difference is observed for all contract types. Meaning, planners are equally certain about how large a budget should be and how large the eventual result will be. These findings illustrate that, since subcontractors is a relatively large budget, the degree of uncertainty surrounding subcontractors is included in the estimation process, potentially contributing to an average cost underrun of 0.45 per cent.

Table 11 Results of hypotheses tests for the cost group subcontractors

Cost group	*Hypothesis 1* *"Cost performance"*	*Hypothesis 2* *"SD of cost performance"*	*Hypothesis 3* *"Project type"*	*Hypothesis 4* *"Project location"*	*Hypothesis 5* *"Type of client"*	*Hypothesis 6* *"Project size"*
Subcontractors	Rejected	Rejected	Rejected	Rejected	Rejected	Rejected

3.2.4 DELIVERIES

As described in Appendix A the cost group *deliveries* relates to the delivery of materials and supplies. Table 12 illustrates that the delivery budget relative to the total budget decreases in size from 22.85 per cent for RAW projects (n=24), to 19.99 per cent for E&C projects (n=22), and 15.14 per cent for D&B(M) projects (n=22). Similar to the results found in the cost group *subcontractors*, the SD values indicate that the uncertainty surrounding the estimation process of the budget for deliveries is larger compared to other cost groups. Since the SD values differ only slightly between contract types it can be stated that the uncertainty surrounding the estimation of the budget for deliveries can be considered equal. Based on the Kruskal-Wallis H test the budget for deliveries relative to the total budget has been compared between contract types. Resulting in a statistically insignificant (p=0.089) difference. Although, the budget for deliveries is a considerable part of the total budget. No significant correlation between the result for deliveries and the result of the total project has been identified based on Spearman correlation analysis, as illustrated in Table 6, in section 3.2.1. The correlation in D&B(M) projects (n=22, r=0.394, p=0.070) is almost significant, while the correlation in RAW (n=24, r=0.161, p=0.452) and E&C projects (n=22, r=0.208, p=0.366) are clearly insignificant. All correlations are plotted in the scatterplot depicted in Figure 22 (Appendix J). An explanation for the absence of a correlation could lie in the type of costs that are part of the cost group deliveries. The costs for delivering materials and supplies are low on risks since cost overruns can often be claimed with the company that delivered the materials or supplies.

Table 12 Statistics of deliveries budget relative to total budget and deliveries total costs relative to budget (no clustering applied)

								Skewness		*Kurtosis*		*Independent-Samples Kruskal-Wallis H Test*		
Cost group	*Contract type*	*N*	*Min.*	*Max.*	*Mean*	*Median*	*Std. Dev.*	*Statistic*	*Std. Error*	*Statistic*	*Std. Error*	*Test Statistic* [1]	*Degrees of Freedom*	*Asymptotic Sig. (2-tailed test)*
Deliveries budget relative to total budget	RAW/STABU	24	3.06%	44.74%	22.85%	24.08%	12.40%	0.02	0.47	-1.00	0.92			
	E&C	22	1.31%	55.34%	19.99%	17.05%	13.18%	1.06	0.49	1.13	0.95	4.83	2	0.089
	D&B(M)	22	0.19%	40.89%	15.14%	15.31%	9.98%	0.75	0.49	0.52	0.95			
	Total	68	0.19%	55.34%	19.43%	17.45%	12.20%	0.64	0.29	-0.04	0.57			
Deliveries total costs relative to budget	RAW/STABU	24	-45.19%	29.68%	0.60%	0.00%	12.23%	-1.75	0.47	9.61	0.92			
	E&C	21	-57.80%	39.43%	2.44%	1.89%	17.70%	-1.50	0.50	7.27	0.97	2.092	2	0.351
	D&B(M)	22	-33.65%	99.45%	1.75%	0.01%	26.30%	2.46	0.49	9.11	0.95			
	Total	67	-57.80%	99.45%	1.55%	0.00%	19.17%	1.45	0.29	11.14	0.58			

1. The test statistic is adjusted for ties.

The total costs of deliveries relative to its budget, as presented in Table 12 and the corresponding boxplots in Figure 15 (p. 33), illustrated that on average a cost underrun of 1.55 per cent occurs. E&C projects (n=21) have the largest mean cost underrun of 2.44 per cent, followed by 1.75 per cent for D&B(M) projects (n=22). RAW projects (n=24) have a, below average, cost underrun of 0.60 per cent. Thereby not confirming hypothesis 1 since the cost performance does not decreases sequentially from RAW to E&C to D&B(M). The result of the Kruskal-Wallis H test shows that the between contract types difference is insignificant (p=0.351). When clustered by project type (p>0.150), project location (p>0.450), type of client (p>0.098), or project size (p>0.337) the difference between contract types remains insignificant, thereby rejecting hypotheses 3, 4, 5, and 6 respectively. These results are summarized in Appendix J. It should be noted that the cost group *subcontractors* and *deliveries* are the only cost groups with an average cost underrun compared to *labour, equipment, engineering, building site*, and *project organisation / UTA*. When assessing the SD values, Table 12 illustrates that, as expected due to the moment of contracting, uncertainty increases from RAW (12.23%) to E&C (17.70%) to D&B(M) (26.30%). Thereby accepting hypothesis 2 as illustrated in an overview of all hypothesis tests for *deliveries* as presented in Table 13. When comparing the SD values of budget relative to total budget and total costs relative to budget, a small difference is observed for RAW and E&C projects. Meaning, planners are equally certain about how large a budget should be and how large the eventual result will be. However, the results for D&B(M) projects show an underestimation since the difference is considerably larger compared to RAW and E&C. This underestimation could potentially cause the slightly lower cost underrun of D&B(M) projects.

Table 13 Results of hypotheses tests for the cost group deliveries

Cost group	*Hypothesis 1* *"Cost performance"*	*Hypothesis 2* *"SD of cost performance"*	*Hypothesis 3* *"Project type"*	*Hypothesis 4* *"Project location"*	*Hypothesis 5* *"Type of client"*	*Hypothesis 6* *"Project size"*
Deliveries	Rejected	Accepted	Rejected	Rejected	Rejected	Rejected

3.2.5 ENGINEERING

As described in Appendix A the cost group *engineering* relates to all work associated with engineering. The relative share of the cost group *engineering*, as presented in Table 14, illustrates a considerable difference between RAW (n=24, 0.77%) and E&C (n=22, 3.22%) and D&B(M) (n=22, 4.63%) projects. The Kruskal-Wallis H test (p=0.001) confirms a statistical difference between RAW, E&C, and D&B(M). Post hoc analysis has shown that this difference lies between RAW and D&B(M) projects. This difference was expected since RAW contracts by definition do not include engineering work, apart from small often temporary structures, as illustrated by Section 2.1.1. Consequently, RAW projects will be disregarded during the analysis of the cost group, engineering. Since E&C and D&B(M) have similar mean and SD values, it can be expected that the correlation between the total costs of engineering relative to its budget and the total result of a project will be similar as well. Spearman correlation analysis, as presented in Table 6 in section 3.2.1, resulted in insignificant correlations for both E&C and D&B(M) projects. Which means the result of a project is not statistically dependent on the result of the cost group *engineering*. All insignificant correlations are plotted in the scatterplot depicted in Figure 23 (Appendix J).

Table 14 Statistics of engineering budget relative to total budget and engineering total costs relative to budget (no clustering applied)

Cost group	*Contract type*	*N*	*Min.*	*Max.*	*Mean*	*Median*	*Std. Dev.*	*Skewness*		*Kurtosis*		*Independent-Samples Kruskal-Wallis H Test*		
								Statistic	*Std. Error*	*Statistic*	*Std. Error*	*Test Statistic* [1]	*Degrees of Freedom*	*Asymptotic Sig. (2-tailed test)*
Engineering budget relative to total budget**	RAW/STABU	24	0.00%	3.20%	0.77%	0.43%	0.93%	1.29	0.47	0.94	0.92			
	E&C	22	0.00%	9.55%	3.22%	2.82%	2.66%	0.66	0.49	-0.07	0.95	23.68	2	0.001
	D&B(M)	22	0.12%	12.90%	4.63%	3.30%	3.74%	1.03	0.49	0.19	0.95			
	Total	68	0.00%	12.90%	2.81%	2.14%	3.09%	1.50	0.29	2.05	0.57			

Cost group	*Contract type*	*N*	*Min.*	*Max.*	*Mean*	*Median*	*Std. Dev.*	*Skewness Statistic*	*Skewness Std. Error*	*Kurtosis Statistic*	*Kurtosis Std. Error*	Independent-Samples Mann-Whitney U Test					
												Mann-Whitneu U	*Wilcoxon W*	*Test Statistic*	*Standard error*	*Standardized Test Statistic*	*Exact Sig. (2-tailed test)*
Engineering total costs relative to budget*	RAW/STABU	22	-75.16%	57.05%	3.04%	0.00%	24.27%	-0.85	0.49	5.63	0.95						
	E&C	19	-82.01%	93.32%	-4.79%	0.00%	38.93%	0.35	0.52	1.66	1.01	117.0	327.0	117.0	35.6	-2.05	0.041
	D&B(M)	20	-93.13%	70.17%	-26.50%	-19.27%	37.02%	0.46	0.51	1.25	0.99						
	Total	61	-93.13%	93.32%	-9.09%	0.00%	35.43%	-0.05	3.06	1.05	0.60						

1. The test statistic is adjusted for ties.

* A significant difference within the group at the 0.05 level (2-tailed).

** A significant difference within the group at the 0.001 level (2-tailed).

The descriptive statistics of the total costs of engineering relative to its budget, as presented in Table 14 and the corresponding boxplots in Figure 15 (p. 33), shows a large difference in mean cost overruns between E&C (n=19, 4.79%) and D&B(M) (n=20, 26.50%). However, the median values of E&C (0.00%) and D&B(M) (-19.27%) indicate that the cost overrun for E&C and D&B(M) has a tendency to be lower than the mean value. While taking this into consideration these results confirm hypothesis 1 since the contract type with an earlier moment of contracting, i.e. D&B(M), has a higher average cost overrun compared to E&C. The Mann-Whitney U test, based on mean ranks, found the difference between E&C (23.84) and D&B(M) (16.35) to be significant (p=0.041). The dissimilar distributions of D&B(M) and RAW projects limit the extent to which this result can be interpreted. Taking this into consideration, this result indicates that D&B(M) projects have significantly higher engineering cost overruns compared to E&C projects based on mean ranks. When clustered by project type (p>0.177), project location (p>0.068), type of client (p>0.093), or project size (p>0.236) the difference between contract types is insignificant, thereby rejecting hypotheses 3, 4, 5, and 6 respectively. These results are summarized in Appendix J. The SD values do not show a difference between E&C (38.93%) and D&B(M) (37.02%) which indicates that the degree of uncertainty surrounding the result for the cost group *engineering* is equally high. Thereby, rejecting hypothesis 2 since this result contradicts the theory about the availability of information and the moment of contracting which should have resulted in less uncertainty for E&C projects. Moreover, the SD values for the budget compared with the SD values for the eventual result illustrate a large underestimation of uncertainty during the budget estimations. An overview of all hypothesis tests for *engineering* is presented in Table 15.

Table 15 Results of hypotheses tests for the cost group engineering

Cost group	*Hypothesis 1 "Cost performance"*	*Hypothesis 2 "SD of cost performance"*	*Hypothesis 3 "Project type"*	*Hypothesis 4 "Project location"*	*Hypothesis 5 "Type of client"*	*Hypothesis 6 "Project size"*
Engineering	Accepted	Rejected	Rejected	Rejected	Rejected	Rejected

3.2.6 BUILDING SITE

As described in Appendix A the cost group *building site* relates to costs for the use of a building site, e.g. a site office. The cost group *building site* is, relative to the total budget, a smaller budget with an average of 3.69 per cent, as illustrated by Table 16. This percentage increases from 3.14 per cent for RAW projects (n=24), to 3.95 per cent for E&C (n=22), and 4.03 per cent for D&B(M) projects (n=22). A possible explanation for this increase could be that D&B(M) projects are often larger projects that consequently need a larger building site. Since the difference between RAW, E&C, and D&B(M) is rather small, the Kruskal-Wallis H test revealed this difference to be insignificant (p=0.382). Extending the comparison, The SD values of RAW (3.28%), E&C (3.20%), and D&B(M) (2.54%) are all equally low. Indicating that the degree of uncertainty surrounding the estimation of the budget for building site is low. Since the cost group *buildings site* is small and does not include high-risk activities, it can be expected that a correlation between the total cost of building site relative to its budget and the total result of a project is nonexistent. The Spearman correlation analysis, as presented in Table 6 in section 3.2.1, confirms this by reporting insignificant correlations for all contract types. All insignificant correlations are plotted in the scatterplot depicted in Figure 24 (Appendix J).

Table 16 Statistics of engineering budget relative to total budget and engineering total costs relative to budget (no clustering applied)

								Skewness		*Kurtosis*		*Independent-Samples Kruskal-Wallis H Test*		
Cost group	*Contract type*	*N*	*Min.*	*Max.*	*Mean*	*Median*	*Std. Dev.*	*Statistic*	*Std. Error*	*Statistic*	*Std. Error*	*Test Statistic* [1]	*Degrees of Freedom*	*Asymptotic Sig. (2-tailed test)*
Building site budget relative to total budget	RAW/STABU	24	0.43%	11.94%	3.14%	2.90%	2.38%	2.23	0.47	7.61	0.92			
	E&C	22	0.73%	12.66%	3.95%	3.48%	3.20%	1.67	0.49	2.95	0.95	1.923	2	0.382
	D&B(M)	22	0.86%	11.32%	4.03%	3.27%	2.54%	1.27	0.49	1.90	0.95			
	Total	68	0.43%	12.66%	3.69%	3.11%	2.71%	1.67	0.29	3.25	0.57			
Building site total costs relative to budget	RAW/STABU	21	-94.42%	32.68%	-18.38%	-10.93%	35.93%	-0.96	0.50	0.30	0.97			
	E&C	20	-78.31%	16.92%	-9.77%	-4.85%	21.88%	-1.94	0.51	4.58	0.99	0.815	2	0.665
	D&B(M)	22	-78.11%	29.41%	-13.46%	0.00%	31.92%	-0.93	0.49	-0.38	0.95			
	Total	63	-94.42%	32.68%	-13.93%	-2.79%	30.34%	-1.15	0.30	0.67	0.60			

1. The test statistic is adjusted for ties.

The descriptive statistics of the total costs of the cost group *building site* relative to its budget, as presented in Table 16 and the corresponding boxplots in Figure 15 (p. 33), illustrates that on average a cost overrun of 13.93 per cent occurs. RAW projects (n=21) have the highest average cost overrun of 18.38 per cent, followed by D&B(M) projects (n=22, 13.46%) and E&C projects (n=20, 9.77%). However, the median values of RAW (-10.93%) and particularly D&B(M) (0.00%) indicate that the cost overrun for RAW and D&B(M) has a tendency to be lower than the mean value. While taking this into consideration the results do not confirm hypothesis 1 since the cost performance does not decrease sequentially from RAW to E&C to D&B(M). These results are surprising since it was not expected that a low-risk cost group would, on average, always incur a cost overrun and contradict the theory of availability of information. Based on the results of a Kruskal-Wallis H test the difference between contract types is found to be insignificant (p=0.665). When clustered by project type (p>0.488), project location (p>0.284), type of client (p>0.420), project size (p>0.623) the difference between contract types remains insignificant, thereby rejecting hypotheses 3, 4, 5, and 6 respectively. These results are summarized in Appendix J. Upon further inspection of Table 16 it is observed that the SD is high for every contract type, ranging from 21.88 per cent for E&C, too 31,92 per cent for D&B(M), and 35.93 per cent for RAW projects. Surprisingly, this indicates that the degree of uncertainty surrounding the result for the cost group *building site* is high. This result is counterintuitive since the cost group *building site* is perceived as a cost group with standardized elements. An explaining factor could be an underestimation of the dependency on time of the cost group *building site* which is illustrated by the large difference between SD values of the budget and the eventual result in Table 16. More surprisingly, this underestimation seems most severe with RAW and D&B(M) contracts since these projects have the lowest SD values for the budget and the highest SD values for the eventual result. This observation is surprising since it contradicts with the theory about availability of information and the moment of contracting which should have resulted in a lower uncertainty for RAW projects. Therefore, this result rejects hypothesis 2 as illustrated in an overview of all hypothesis tests for *building site* as presented in Table 17.

Table 17 Results of hypotheses tests for the cost group building site

Cost group	*Hypothesis 1* *"Cost performance"*	*Hypothesis 2* *"SD of cost performance"*	*Hypothesis 3* *"Project type"*	*Hypothesis 4* *"Project location"*	*Hypothesis 5* *"Type of client"*	*Hypothesis 6* *"Project size"*
Building site	Rejected	Rejected	Rejected	Rejected	Rejected	Rejected

3.2.7 PROJECT ORGANISATION / UTA

As described in Appendix A the cost group *project organisation / UTA* relates to costs for project management, e.g. a planner or project manager. Larger projects require more project management. Since larger projects often have an integrated contract type it is expected that the budget for project organisation relative to the total budget is larger for integrated contracts compared to RAW. This is confirmed by the mean values in Table 19. The budget for project organisation increases relatively from 7.30 per cent for RAW projects (n=24), to 8.68 per cent for E&C projects (n=22), and 10.78 per cent for D&B(M) projects (n=22). Based on the Kruskal-Wallis H Test, this difference is found to be statistically significant ($\chi^2(2) = 6.859$, p=0.032). Subsequently, pairwise comparisons were performed using the procedure of Dunn (1964) with a Bonferroni correction for multiple comparisons to identify which contract types differ significantly. This post hoc analysis, based on mean ranks reveals a significant difference (p=0.027) between D&B(M) and RAW projects with mean ranks of 42.32 and 27.04 respectively (Table 18). The dissimilar distributions of D&B(M) and RAW projects limit the extent to which this result can be interpreted. Taking this into consideration, this result indicates that D&B(M) projects have a significantly larger project organisation budget relative to the total budget compared to RAW projects based on mean ranks.

Table 18 Pairwise comparisons for project organization / UTA budget relative to total budget (no clustering applied)

Cost group	*Comparison of Contract type*	*Test Statistic*	*Standard Error*	*Standardized Test Statistic*	*Significance*	*Adjusted Significance*
Project organisation /	D&B(M) - E&C	-7.500	5.962	-1.258	0.208	0.625
UTA budget relative to	D&B(M) - RAW*	-15.277	5.836	-2.617	0.009	0.027
total budget	E&C - RAW	-7.777	5.836	-1.332	0.183	0.548

* A significant difference between contract types at the 0.05 level.
Asymptotic significances (2-tailed tests) are displayed.
Significance values have been adjusted by the Bonferroni corrrection for multiple comparisons.

Furthermore, Table 19 illustrates that the SD values of RAW (4.18%), E&C (3.84%), and D&B(M) (4.97%) are all low and close together, indicating that the degree of uncertainty surrounding the estimation of the budget for project organisation is low for all contract types. Since the relative budget of project organisation becomes larger with integrated contracts and even significantly larger from RAW to D&B(M), a correlation is expected between the total cost of project organisation relative to its budget and the total result of a project for both E&C and D&B(M). Table 6, in section 3.2.1, presents, based on a Spearman correlation analysis, that E&C projects (n=21) indeed have a strong positive correlation r=782 (p=0.001) while the positive correlation for D&B(M) projects (n=21) is slightly weaker r=0.419 and marginally insignificant (p=0.058). The result on project organisation for RAW projects (n=24) is, as expected, uncorrelated (r=0.020) and insignificant (p=0.926). All correlations are plotted in the scatterplot depicted in Figure 25 (Appendix J).

Table 19 Statistics of project organization/UTA budget relative to total budget and UTA total costs relative to budget (no clustering applied)

Cost group	Contract type	N	Min.	Max.	Mean	Median	Std. Dev.	Skewness Statistic	Skewness Std. Error	Kurtosis Statistic	Kurtosis Std. Error	Independent-Samples Kruskal-Wallis H Test: Test Statistic [1]	Degrees of Freedom	Asymptotic Sig. (2-tailed test)
Project organisation / UTA budget relative to total budget*	RAW/STABU	24	1.79%	17.93%	7.30%	6.54%	4.18%	1.16	0.47	0.67	0.92	6.859	2	0.032
	E&C	22	2.39%	16.27%	8.78%	8.68%	3.84%	0.37	0.49	-0.73	0.95			
	D&B(M)	22	5.58%	25.87%	10.78%	9.49%	4.97%	1.91	0.49	4.15	0.95			
	Total	68	1.79%	25.87%	8.90%	7.54%	4.52%	1.26	0.29	2.50	0.57			
Project Organisation / UTA total costs relative to budget	RAW/STABU	24	-86.60%	15.71%	-15.85%	-2.27%	26.71%	-1.31	0.47	0.96	0.92	0.098	2	0.952
	E&C	21	-91.59%	96.44%	-11.40%	-8.01%	40.78%	0.17	0.50	1.97	0.97			
	D&B(M)	21	-91.13%	40.65%	-15.07%	-7.25%	35.24%	-0.48	0.50	-0.34	0.97			
	Total	66	-91.59%	96.44%	-14.19%	-6.53%	33.91%	-0.23	0.30	1.26	0.58			

1. The test statistic is adjusted for ties.

* A significant difference within the group at the 0.05 level (2-tailed).

When assessing the project organizations total costs relative to its budget, as presented in Table 19 and the corresponding boxplots in Figure 15 (p. 33), it can be observed that, on average, a cost overrun of 14.19 per cent occurs. RAW projects (n=24) have the highest average cost overrun of 15.85 per cent, followed by D&B(M) (n=21, 15.07%) and E&C (n=21, 11.40%) projects. However, the median values of RAW (-2.27%) and D&B(M) (-7.25%) indicate that the cost overrun for RAW and D&B(M) projects has a tendency to be lower than the mean value. These results are surprising since it was not expected that a seemingly standardized cost group would, on average, always incur a cost overrun. In addition, since the cost performance of RAW is lower compared to D&B(M) and E&C, hypothesis 1 is rejected which assumed that the cost performance would decrease sequentially from RAW to E&C to D&B(M). An explaining factor could be the underestimation of the dependency on time. The Kruskal-Wallis H Test confirmed that the difference between contract types is insignificant (p=0.952). When clustered by project type (p>0.171), project location (p>0.392), type of client (p>0.214), or project size (p>0.055) the difference between contract types remains insignificant, thereby rejecting hypotheses 3, 4, 5, and 6 respectively. These results are summarized in Appendix J. When assessing the SD values for RAW (26.71%), E&C (40.78%), and D&B(M) (35.24%) projects it can be observed that firstly the standard deviation is high for all contract types. Furthermore, the SD values for the budget compared with the SD values for the eventual result illustrate a large underestimation of uncertainty during the budget estimation. This underestimation is most severe with E&C projects. Second, the SD values increase from RAW to D&B(M) and E&C which indicates that the degree of uncertainty surrounding the result that can be achieved on project organization increases from RAW to integrated contracts. Since the SD of E&C is higher than D&B(M) this result is only partly in line with the theory of availability of information and therefore hypothesis 2, which assumes that the uncertainty increases sequentially from RAW to E&C to D&B(M), is rejected. An overview of all hypothesis tests for *Project organisation / UTA* is presented in Table 20.

Table 20 Results of hypotheses tests for the cost group project organisation / UTA

Cost group	Hypothesis 1 "Cost performance"	Hypothesis 2 "SD of cost performance"	Hypothesis 3 "Project type"	Hypothesis 4 "Project location"	Hypothesis 5 "Type of client"	Hypothesis 6 "Project size"
Project organisation / UTA	Rejected	Rejected	Rejected	Rejected	Rejected	Rejected

3.3 Conclusion results & analysis

This data analysis set out to identify the relationship between the contract type and the management of cost groups in practice. After assessing data quality, seven individual cost groups (*labour, equipment, subcontractors, deliveries, engineering, building site, project organisation / UTA*) and one aggregated cost group (*direct costs*) have been statistically analysed to test the six hypotheses formulated in Section 2.4.

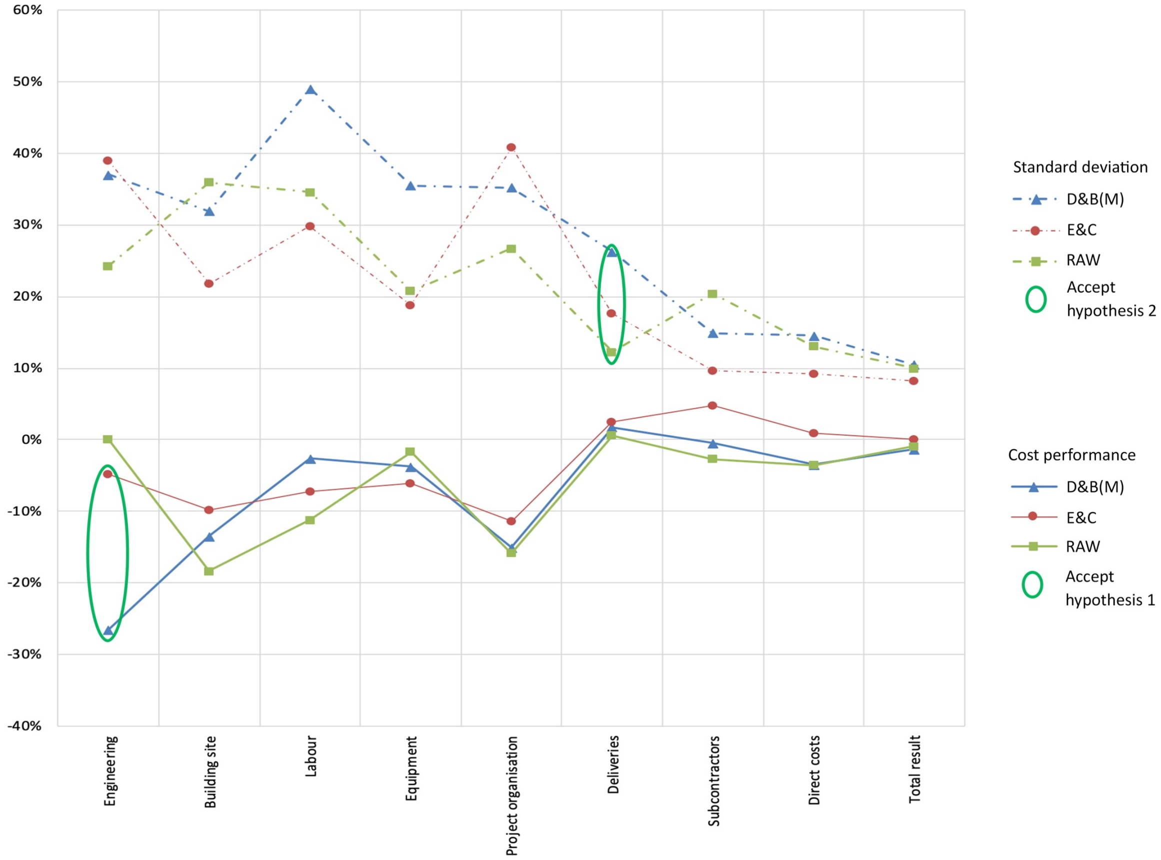


Figure 16 Cost performance and standard deviation per cost group, ordered from relatively small (left) to large (right) budgets

The statistical results which are used to test hypothesis 1 and 2 are visualized in Figure 16 and Figure 17. Both Figure 16 and Figure 17 are ordered from relatively small to large budgets. Hypothesis 1 assumed that an earlier moment of contracting during the project life cycle would result in higher cost overruns due to the unavailability of information. Meaning the cost performance would decrease sequentially from RAW to E&C to D&B(M). In addition, hypothesis 2 assumed that an earlier moment of contracting during the project life cycle would result in higher uncertainty of the cost performance due to the unavailability of information. Meaning the standard deviation of the cost performance increases sequentially from RAW to E&C to D&B(M). Based on Figure 16 and Figure 17 several interesting observations can be made. These observations are translated into findings which will be discussed with an expert panel in Chapter 4.

The first observation in Figure 16 is that the cost group *engineering* is the only cost group that accepted hypothesis 1, which assumed that the cost performance of D&B(M) would be lower compared to E&C due to the unavailability of information. On the contrary, the majority of the cost groups including, *building site, labour, equipment, project organisation, deliveries, subcontractors,* and *direct costs* have rejected hypothesis 1. Which illustrates that once the design has been made, the contract type, and thus the availability of information, does not influence the cost performance. These observations are formulated into findings one and two. Besides, the mean cost performance of E&C projects is better than expected based on hypothesis 1 in case of the cost groups; *subcontractors, deliveries, building site, project organisation / UTA,* and *direct costs*. To discuss this observation, finding three has been formulated. When focussing on the cost performance of the entire projects, i.e. total result, Figure 16 illustrates that D&B(M) projects have a marginally higher average total cost overrun compared to RAW followed by E&C projects. This difference is reported to be insignificant which could have been caused by the large SD values of all contract types. However, this finding is not in line with hypothesis 1, which assumed that the cost performance would decrease sequentially from RAW to E&C to D&B(M). Even though this finding is insignificant, it remains interesting to assess if the expert panel recognises the marginal difference in cost performance between contract types. This observation is formulated in finding four.

When assessing the standard deviation of the cost performance, the cost groups *labour, equipment, deliveries, project organisation / UTA,* and *direct costs* illustrate that the uncertainty about the eventual result increases from RAW to D&B(M) contracts. This observation is in accordance with hypothesis 2 which assumed that the uncertainty of the cost performance increased sequentially from RAW to E&C to D&B(M). Based on this observation, finding five has been formulated. This finding, however, does not fully accept hypothesis 2 since it does not apply to E&C projects. The SD of the cost performance of E&C projects is lower compared to RAW and D&B(M) in case of the cost groups; *buildings site*, *labour*, *subcontractors*, *direct costs*, and *total result*. This observation is translated into finding six.

#1	*Making a design, as part of a D&B(M) project, results in higher cost overrun on the cost group engineering, compared to E&C projects.*
#2	*More information at the moment of contracting does not guarantee better cost performance of a cost group.*
#3	*E&C projects have better average cost performance compared to RAW or D&B(M) on an individual cost group and total cost level*
#4	*D&B(M) projects incur more cost overruns compared to RAW and E&C projects.*
#5	*More information at the moment of contracting guarantees more certainty about the cost performance of a cost group.*
#6	*The cost performance of individual cost groups in E&C projects is better to predict compared to RAW or D&B(M) projects.*

Another result to emerge from the data is illustrated in Figure 17. Figure 17a illustrates the SD of the budgets relative to the total budget which indicates the degree that the relative budgets differ between projects. Based on Figure 17a, it can be stated that in the case of the cost groups *labour, equipment, engineering, building site,* and *project organisation / UTA* Dura Vermeer applies similar relative budgets on projects. Since these cost groups are often estimated with predetermined percentages a low SD in Figure 17a indicates a certain confidence in these percentages. On the contrary, the relative budgets for the cost groups *subcontractors, deliveries*, and the cumulative *direct costs* vary more between projects which could be caused by the economic climate and the process of signing a contract with a subcontractor. Figure 17b shows the SD of the total costs relative to the budget of a cost group. Which is illustrative of how uncertain the cost performance of a cost group is. The delta between the SD of the cost performance and the cost estimate is presented in Figure 17c. A high delta indicates that even though the same relative budgets are used during the cost estimation process, the result of this cost group remains uncertain. While a low delta shows that different relative budgets are estimated combined with a cost performance that is better to predict. Together with an average cost overrun, Figure 17c shows that the cost for relatively small cost groups, including *labour, equipment, engineering, building site,* and *project organisation / UTA* are perceived to be certain when estimated but are uncertain in the end. Together these budgets account for roughly 30 per cent of the overall budget. Surprisingly, only a small difference between the SD of budgets and the SD of the total costs is observed, combined with an average cost underrun within the relatively larger cost groups *subcontractors* and *deliveries*. Which indicates that the results are more certain since the budget appears to consider the uncertainty surrounding the cost group. Together these cost groups account for roughly 50 per cent of the total budget.

Based on Figure 17 it can be observed that these findings differ only slightly between contract types. It can, therefore, be stated that this insight is independent of the type of contract. These insights have been formulated in findings seven and eight, to be discussed during the interviews with the expert panel.

#7 *Relatively small cost groups, such as labour, equipment, engineering, building site, and project organisation have, on average, a negative cost performance.*

#8 *Relatively large cost groups, such as subcontractors and deliveries have, on average, better cost performance.*

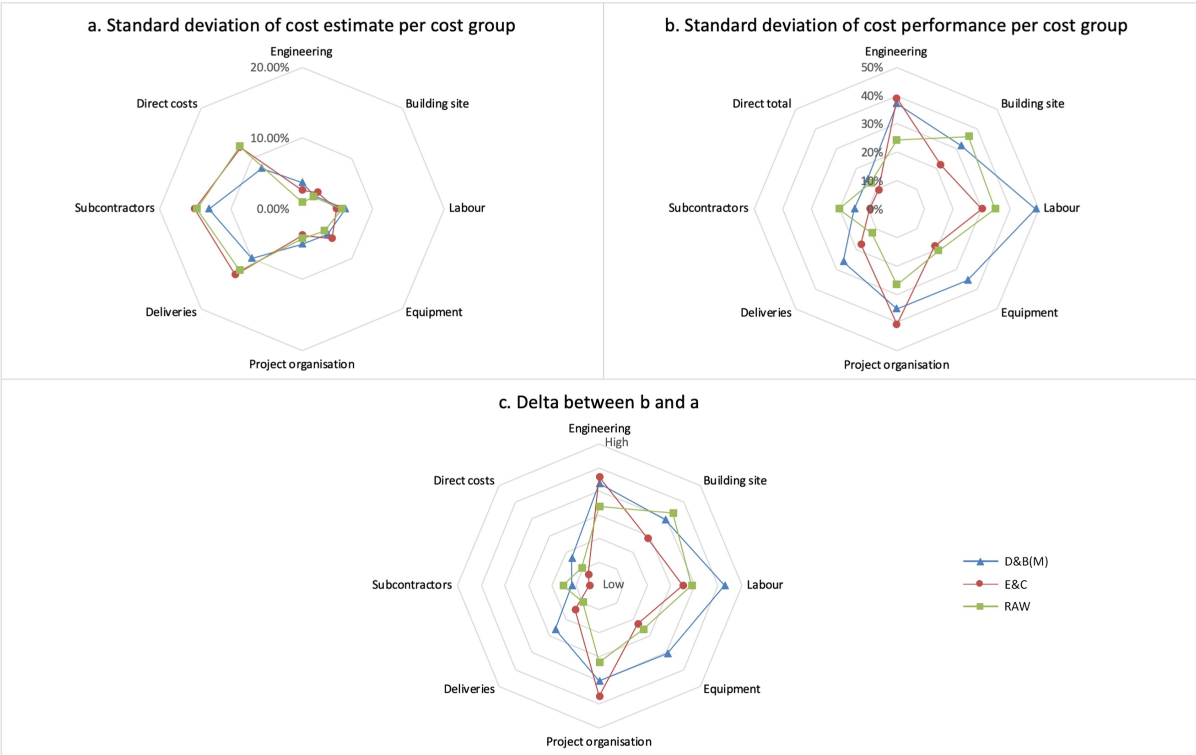


Figure 17 a. Standard deviation of cost estimation per cost group. b. Standard deviation of cost performance per cost group. c. Delta between figure b and a. Clockwise ordered from relatively small to large budgets

The analysed cost groups have rejected hypothesis three, four, five and six since there is no statistically significant evidence that project type, type of client, project location or project size respectively, have a significant influence on the difference in cost performance between contract types. However, the descriptive statistics of each cluster (project type, type of client, project location, project size) have not been analysed which thereby limits this study. In addition, the reported correlations in Table 6 have not been used throughout the conclusion of the statistical results because the correlations did not show a clear relationship with the descriptive statistics.

In summary, the statistical analysis is not able to demonstrate a relationship between the cost performance of an infrastructure project and the unavailability of information based on the contract type. Since *engineering* is the only cost group out of the nine analysed cost groups, that showed a statistically significant difference between E&C and D&B(M) that followed the sequential character of hypothesis 1. In addition, the relationship between the uncertainty of the cost performance and the contract type is also non-apparent based on the statistical analysis. Since five cost groups have illustrated that the uncertainty about the cost performance increases from RAW to D&B(M) contracts. This finding, however, does not fully accept hypothesis 2 since it does not apply to E&C projects. The SD of the cost performance of E&C projects is lower compared to RAW and D&B(M) in case of the cost groups; *buildings site*, *labour*, *subcontractors*, *direct costs*, and *total result*. Furthermore, the statistical analysis shows that relatively smaller cost groups, on average incur a cost overrun while their budgets are perceived to be certain when estimated but have an uncertain cost performance. On the contrary, relatively larger cost groups incur, on average, a cost underrun while their budget estimates vary more in relative size while the uncertainty of the cost performance is lower compared to relatively smaller cost groups.

4

Expert panel

4 Expert panel

The eight findings presented in Section 3.3, have been discussed following the method as introduced in Section 1.5.3. In total, four semi-structured interviews have been conducted in which the participants were asked if they disagreed, agreed or were neutral towards the findings. Transcripts of all interviews can be found in Appendix G. Each finding was presented on a flashcard to force the interviewee to focus on a single finding. This method has received positive feedback from multiple interviewees. The following section will elaborate on the answers provided by the interviewees and provide an insight into their underlying reasoning. Figure 18 illustrates that 5 findings have been unanimously acknowledged by the interviewees. Furthermore, two findings have been either disagreed or agreed and one finding received a neutral response based on the majority.

	Findings	Disagree	Neutral	Agree
1	Making a design, as part of a D&B(M) project, results in higher cost overrun on the cost group engineering, compared to E&C projects.	0		4
2	More information at the moment of contracting does not guarantee better cost performance of a cost group.	2		2
3	E&C projects have better average cost performance compared to RAW or D&B(M) on an individual cost group and total cost level.	2	1	1
4	D&B(M) projects incur more cost overruns compared to RAW and E&C projects.	0		4
5	More information at the moment of contracting guarantees more certainty about the cost performance of a cost group.	0		4
6	The cost performance of individual cost groups in E&C projects is better to predict compared to RAW or D&B(M) projects.	3		1
7	Relatively small cost groups, such as labour, equipment, engineering, building site, and project organisation have, on average, a negative cost performance.	0		4
8	Relatively large cost groups, such as subcontractors and deliveries have, on average, better cost performance.	0		4

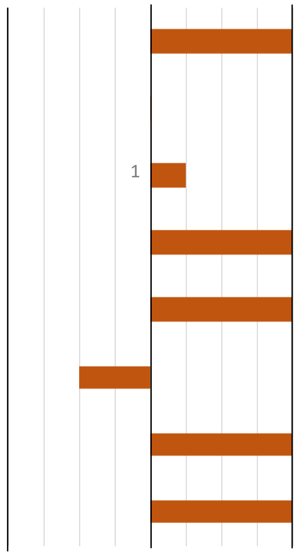


Figure 18 Summarised answers provided by interviewees during expert panel interviews

Finding one is unanimously agreed. The underlying reasoning as addressed by the interviewees is twofold. First, D&B(M) projects have to complete the design process of preliminary design (VO), detailed design (DO) and construction design (UO) while E&C projects only partially go through this process. The design develops from coarse to fine during this process. However, due to the influence of internal and external stakeholders on the design team, this process has inherent inefficiencies. For example, the design process of the contractor runs asynchronously with the governing authority. When contractors apply for permits, the governing authority asks a degree of specificity that cannot be delivered by the contractor at that phase resulting in inefficiencies. Second, interviewees state that the design is often inefficiently organised due to less focus of the design manager on time and money and too much focus on the quality of the design. This can result in a design that is very detailed but has exceeded the available budget for engineering. When asked if the percentage used to estimate engineering costs in D&B(M) projects is accurate, several interviewees responded by stating that the cost overrun is not solely due to a wrong initial estimate but also due to the further detailing in terms of people of that estimate.

An interesting observation can be made between the difference in responses towards the use of percentages and especially the meetings in which these percentages are discussed. Project managers state that higher management often does not agree with the percentage proposed by the project manager, which is based on a planning or thorough estimation. Project managers either interpret this as if they wasted their time or as if they have to defend their opinion against a, from their perspective naïve, opinion of the higher management. However, the higher management states that their goal is to challenge the percentages but never to cut them short. An interviewee mentioned that it is old behaviour to knowingly cut percentages. This behaviour was not uncommon five years ago but is not common practice any more at Dura Vermeer.

Finding two has received a neutral result since two interviewees were in accordance with the finding while the other two interviewees were in disagreement with the finding. The underlying reasoning of the interviewees that were in disagreement is that more available information reduces the risk profile of a project and thus reduces the chance of a cost overrun. When little information is available, it is the search for information in a short timespan that increases the risk profile. On the contrary, the interviewees that are in accordance with the finding state that although D&B(M) projects start earlier in the project life cycle, there is still a large amount of information handed to the contractor from the client. The challenge for the contractor is, therefore, identifying the right information that is valuable for the project. Furthermore, an interviewee considers the quality of the information and its contractual status to be more important than the quantity of the information. These mixed responses do not continue when interviewees are asked if more information reduces the uncertainty about the eventual result of cost groups. On the contrary, finding five is accepted by all interviewees with the underlying reasoning that more information decreases the uncertainty surrounding the project, resulting in a lower risk profile.

Finding three received mixed responses, since two interviewees were in accordance with the finding while one was neutral, and another disagreed with the finding. The underlying reasoning differs among all interviewees. First, it is stated that E&C projects perform better since D&B(M) projects are described as a black box and RAW has an inherent incentive for the contractor to search for additional work resulting in overestimating of the capabilities of the contractor by the contractor itself. The second and third interviewees gave a neutral and affirmative response to the finding but stressed that this can differ between cost groups since E&C contracts are known for their varying levels of specificity between contracts but also between parts of an E&C contract. This variation amongst E&C projects could explain the first reasoning when this interviewee had worked on an E&C project with a high level of specificity. The fourth interviewee disagreed with the finding since it was stated that RAW and E&C can be very similar in the infrastructure domain and therefore E&C projects do not have better cost performance by definition.

Finding four is agreed by all interviewees while the underlying reasoning differs slightly among interviewees. First, the level of specificity of the contract, decreasing from RAW to E&C and D&B(M), influences the risk profile for the contractor. Since D&B(M) projects have the lowest specificity compared to RAW and E&C projects, this offers the possibility for a contractor to search for chances and optimisations in a contract. However, interviewees state that chances are slim in D&B(M) contracts since clients define the scope very well. When these chances and optimisations are estimated too optimistically the contractor has to bear the consequences. A second explanation is the increasing amount of people working on a project. D&B(M) projects are often larger projects compared to RAW and E&C projects which results in an increasing amount of people with more unique disciplines. More people and disciplines create inefficiencies due to the lack of proper collaboration.

Finding six received a more unanimous response with three interviewees in disagreement with the finding and one interviewee in agreement. The majority states that RAW projects are best to predict followed by E&C and D&B(M). However, it is also stated that D&B(M) projects with a MEAT component are possibly better to predict since the contractor can incorporate a good price and win the tender based on quality. Furthermore, the lack of an unambiguous level of specificity for E&C projects could cause E&C projects to be harder to predict. The interviewee that agrees with the finding states that E&C projects are better to predict since it is not a black box such as D&B(M) and there are no inherent incentives that stimulate overestimating.

Findings seven and eight are unanimously agreed by the interviewees. The overall opinion of the interviewees is that smaller cost groups are cost groups that are managed by the contractor himself. These are estimated based on percentages and previous projects and are mostly time-bound cost groups. A first explanation of the higher cost overruns is an over-optimistic estimation during the tender phase. However, a more comprehensive explanation is that the collaboration between the project manager, design manager, and the operational manager is below standards and inefficient. It should be the shared responsibility of this triangle of people to control both price and quantity in order to safeguard the estimated total price and simultaneously create an interdisciplinary team on the construction site. Besides, this triangle should realize that once the contract is awarded to the contractor, both price and design should follow the VO, DO, and UO process from coarse to fine even though the price is estimated to a very fine level during the tender phase. The long-term goal, once this type of collaboration is achieved, is to work with recurring team compositions. Stable team composition is a building block to facilitate a better learning curve within teams and reduce inefficiencies. Furthermore, all interviewees stated that small, indirect cost groups should never be cut to arrive at a competitive bid. The tender team should trust the percentages and focus on the direct costs since that is where a winning bid is made. The better cost performance of larger cost groups such as subcontractors and deliveries is recognized by the interviewees and explained by stating that these cost groups include clustered work packages with a negotiated price during the tender phase. Since these contracts with subcontractors have a fixed price, the risks for the main contractor are decreased hence smaller cost overruns occur. However, interviewees mention that cost overruns can still occur on larger cost groups since these cost groups have a higher dependency on the project phase and the market conditions.

Finally, all interviews were concluded with a final question relating to the possibility of this study to improve the reliability of cost group estimations and thereby cost management. Several interviewees mentioned that the cost performance per contract type and cost groups can improve awareness amongst project members. Which can be achieved by illustrating that percentages of cost groups can differ slightly between contract types. These insights can be used during the final meetings in which percentages for tenders have to be chosen. An additional analysis that is suggested is to include an additional measuring point in time. The current research compares two points in time, the budget at moment of contracting and the final budget. The suggested additional measuring point is the budget as calculated before the final meeting. The interviewee states that this provides an opportunity to analyse if changes made during the final meetings had a positive or negative effect on the final cost performance. However, this study does not agree with the suggested additional measuring point since it only facilitates a comparison between two values of which one will most likely be higher. The value after the final meeting will most likely be higher since it is the goal of these meetings to arrive at a sharper bid. Therefore, analysing these differences and concluding that the cost overruns originate from these final meetings will not provide new insights. Finally, two interviewees stated that the analysis of hard data could create awareness that a soft skill should be improved. The soft skill, in this case, being the collaboration between the project manager, design manager, and the operational manager and the realization that both price and design develop from coarse to fine as previously described.

Based on the results of the interviews in can be stated that findings one, two, four, seven, and eight are acknowledged by the expert panel. While findings three, five, and six are not, since the responses provided by the interviewees were not unanimous. The responses and underlying reasoning of the expert panel about both acknowledged and rejected findings will be compared with the results of the data analysis and the theoretical framework in Section 5.1.

5

Discussion

5 DISCUSSION

In previous chapters, quantitative and qualitative research is performed to determine the existence of a relationship between the contract type and the management of cost groups. This chapter will combine the obtained insights and discuss the key findings and their implications.

5.1 KEY FINDINGS

When combining the insights obtained from the literature study, the statistical analysis, and the performed interviews four key findings can be identified.

First, this study is unable to demonstrate the existence of a relationship between the contract type and the cost performance of infrastructure projects. Since *engineering* is the only cost group out of the nine analysed cost groups, that showed a statistically significant difference between E&C and D&B(M). The other eight analysed cost groups did not confirm hypothesis 1, which assumed that the cost performance would decrease sequentially from RAW to E&C to D&B(M) due to the unavailability of information. Surprisingly, all interviewees have stated that they understand that the cost performance of D&B(M) projects is lower without knowing that this difference is only marginally and insignificant.

This raises the question of why all interviewees understood and expected that the cost performance of D&B(M) projects was lower compared to E&C and RAW projects. Interviewees clarify that the level of specificity of the contract, decreasing from RAW to E&C and D&B(M), influences the risk profile for the contractor and thus the cost performance. This reasoning is in line with hypothesis 1 of this study that an earlier moment of contracting would result in higher cost overruns for a contractor, due to the unavailability of information. However, this reasoning does not align with the results of the data analysis. The underlying reasoning of the interviewees is judged to be originating from the difference between E&C and D&B(M) projects concerning *engineering* costs combined with the engineering process, which is based on two observations. First, the difference in cost performance between E&C and D&B(M) is statistically significant, indicating that D&B(M) projects have significantly higher cost overruns on *engineering* compared to E&C projects. Second, most interviewees used engineering process examples to explain why D&B(M) projects incur more cost overruns. These examples include inefficiencies in the design process, insufficient focus on time and money by the design manager, and lack of collaboration between the project manager, design manager, and operational manager. This study, however, cannot definitely state that the underlying reasoning of the interviewees originated from the significant difference observed within the cost group *engineering* since this observation has not been validated.

Furthermore, this study has found no evidence that the contract type, and thus the unavailability of information influences the uncertainty of the cost performance of infrastructure projects. Moreover, it is shown that in the case of *total costs*, *direct costs* and the cost groups *labour, equipment, subcontractors,* and *building site,* E&C projects have the lowest standard deviation. Thereby, illustrating that the cost performance of E&C projects should be better to predict. This contradicts hypothesis 2 that assumed that the uncertainty would increase sequentially from RAW to E&C to D&B(M). However, the expert panel unanimously stated that more information at the moment of contracting would guarantee more certainty about the cost performance. Moreover, McKinsey, a strategic advisory bureau, states that this belief also exists in the entire GWW-sector (Rijkswaterstaat, 2019). Based on the analysis and the interviews performed by McKinsey, they stated that more information leads to less uncertainty and risks resulting in less cost overruns. Based on this assumption McKinsey advises Rijkswaterstaat to apply a new “two-phases-process” in which the cost estimation of the execution phase happens after the design phase (Rijkswaterstaat, 2019). According to McKinsey, this would result in more time and information to assess risks resulting in less cost overruns (Rijkswaterstaat, 2019). However, the statistical analysis of this study has shown that the unavailability of information based on the moment of contracting does not influence the uncertainty of the cost performance. Furthermore, the current study showed that the allocation of engineering responsibilities does not influence cost groups, other than *engineering* since the cost performance of these cost groups differs only marginally between RAW, E&C, and D&B(M). Moreover, the expert panel mentions that the changing levels of design specificity of sub-parts in E&C contracts, which would further complicate the design phase, would result in more cost overruns. However, the current study illustrates that the changing level of design specificity does not affect the cost performance of cost groups in E&C projects. Again, illustrating that the engineering responsibility does not influence cost performance. Thus, this study expects that solely the separation of design and execution as proposed by McKinsey will not result in less uncertainty about the cost performance. Instead, this study illustrates that Dura Vermeer experiences difficulty with their performance on relatively small, often indirect cost groups. The indirect cost groups are important to the project since their combined relative size is roughly one-third of the total budget. Especially the average cost overrun of the cost group *project organisation / UTA* exemplifies the fact that Dura Vermeer experiences difficulty with process-related cost groups. Therefore, the current study suggests that it should be a combined effort of both client and contractor to improve the process of constructing large complex infrastructure projects instead of focussing on the allocation of design responsibilities and risks.

In addition, this study shows that clustering by project type, type of client, project location or project size does not significantly change the difference between the cost performance of RAW, E&C, or D&B(M) projects. This illustrates that the relation between the contract type and the cost performance is not influenced by project characteristics, which are suggested by scholars to influence cost overruns.

Based on the above, sub-question three can be answered. Sub-question three asks *what the relationship is between the contract type and the management of cost groups in practice*. This study concludes that the estimation and control of costs are not affected by the contract type. In addition, the relationship between the contract type and cost performance is nonapparent based on the performed quantitative analysis while this relationship is overestimated in practice. The difference between cost performance of RAW, E&C, or D&B(M) projects remains insignificant when clustered by project type, type of client, project location or project size. This relationship is overestimated since all interviewees stated, without question, that D&B(M) project should have the worst cost performance, compared to RAW and E&C, while only one out of nine analysed cost groups show a result in accordance with this expectation. This study suggests that the overestimation of the influence of the contract type is caused by the only significantly differing cost group, *engineering* and the engineering process. Based on the significant difference between D&B(M) and E&C in cost performance of *engineering*, this study has verified that engineering costs overruns are higher for D&B(M) projects compared to E&C projects. In the case of E&C projects, the cost performance of cost groups can be similar to either RAW or D&B(M) which is expected in practice. In addition, this study concludes that a relationship between the contract type and the standard deviation of the cost performance has not been identified. Since, only one cost group (*deliveries*) confirmed hypothesis 2, which assumed that the uncertainty and thus the standard deviation of the cost performance would increase sequentially from RAW to E&C to D&B(M) due to the unavailability of information. Besides, the uncertainty surrounding the cost performance of E&C projects appears to be overestimated in practice since the quantitative analysis shows that cost performance of E&C projects have the lowest standard deviation in six out of nine cost groups compared to RAW and D&B(M) projects while interviewees expected RAW projects to have to lowest standard deviation.

Last, this study illustrates that both cost underestimation and an inefficient process are key reasons for cost overruns for a contractor. This differs from the reasoning of Flyvbjerg and his colleagues, being optimism bias seemingly best explain cost overruns (e.g., Flyvbjerg, 2009; Flyvbjerg, Skamris Holm, et al., 2004; Flyvbjerg et al., 2002, 2003). Based on this reasoning, it could be concluded that the negative cost performance of small cost groups, which are the responsibility of the contractor, is a clear sign that the contractor overestimated his capabilities which results in cost underestimation. However, based on the interviews performed during this study, the line of reasoning of Flyvbjerg can be challenged. Cost underestimation, i.e. optimism bias, by the contractor is certainly an explaining factor which is also mentioned by interviewees. However, another reason mentioned by all interviewees is inefficiencies during the design and execution process and within the project team combined with the composition and size of the team. Moreover, five out of nine factors causing cost overruns identified by employees of Dura Vermeer in Table 3 (p.24) are process-related. These five factors, including engineering and construction complexities, scope changes, faulty execution, poor project management, and contract document conflicts, illustrate the importance of the process to cost overruns. Thereby, demonstrating that drawing the conclusion that costs are always underestimated solely based on financial statistics is ill-advisable and, as Verweij (2015) clarified, one should accept that infrastructure projects are complex systems in which unforeseen events inevitably occur. This insight is perfectly described by the sociologist, William Bruce Cameron who stated: “not everything that counts can be counted and not everything that can be counted counts” (Cameron, 1963, p. 13). Therefore, the reasoning of Flyvbjerg from the client’s perspective, being; cost overrun is a consequence of underestimation and the root cause of underestimation is human bias is not acknowledged by this study, from a contractor’s perspective.

Based on the above, sub-question four can be answered. Sub-question four states, *what causes the relationship between the type of contract and the management of cost groups*. Since this study shows that there is no clear relationship between the cost performance of a project and the unavailability of information based on the contract type it becomes unnecessary to identify its underlying reasoning. However, it remains interesting to follow the reasoning emerging from the interviews explaining the difference observed in the cost group *engineering* and between the relatively large and small cost groups. Based on the findings of this study it can be hypothesised that the inefficiencies of the design process play a larger role in a D&B(M) project compared to an E&C project since D&B(M) projects have to complete the entire design process whereas E&C projects only partially. It should be noted that the length of the design process can differ per subpart of and E&C project. Furthermore, the project team is suggested to influence the inefficiencies of the construction process in several ways. First, D&B(M) projects have, due to their larger size, larger project teams. Project teams with more than 200 people become difficult to manage, as stated by interviewees, which creates inefficiencies. Second, design managers focus too much on quality and not enough on time and money, resulting in budget overruns. Last, interviewees mention that the collaboration amongst the project manager, design manager, and operational manager sis inefficient since they do not share the responsibility to control both price and quantity in order to safeguard the estimated total price. This should be done while realizing that both price and design should follow the VO, DO, UO process from coarse to fine.

6

Conclusion

6 CONCLUSION

This study aimed to obtain insight into the relationship between the contract type and the management of cost groups in order to improve cost management. The following main research question was formulated to achieve this insight:

> *What is the relationship between the contract type and the management of cost groups, in Dutch national infrastructure projects and can this relationship be used to improve cost management?*

It can be concluded that this study has been unable to find a relationship between the contract types RAW, E&C, and D&B(M) and the cost estimation and cost performance of Dutch national infrastructure projects. Applying clusters based on project characteristics that are suggested by scholars to influence cost overruns, including project type, type of client, project location or project size does not significantly change the difference between the cost performance of RAW, E&C, or D&B(M). However, it has been observed that this relationship is overestimated in practice. This overestimation appears in two areas. First, the expert panel believes that the design phase has an influence on the cost performance of other cost groups and the total costs of a project. On the contrary, this study concludes that the cost performance, of cost groups other than *engineering*, differ insignificantly and marginally small between contract types with varying design responsibilities. This overestimation is suggested to originate from the significantly higher cost overruns on *engineering* costs of D&B(M) projects compared to E&C projects combined with inefficiencies in the engineering process. This study, however, cannot definitively conclude that the underlying reasoning of the interviewees originated from the significant difference observed within the cost group *engineering* since this observation has not been validated. Last, the expert panel assumes that more information leads to less uncertainty and risks resulting in less cost overruns. Which is a common reasoning as stated in the GWW market analysis performed by McKinsey (Rijkswaterstaat, 2019). However, this study concludes that the unavailability of information depending on the moment of contracting does not have an influence on the uncertainty of the cost performance nor the cost performance itself. An implication of this finding is that this study expects that, solely the separation of design and execution in the "two-phase-process" as proposed by McKinsey will not result in less uncertainty about the cost performance. Instead this study illustrates that Dura Vermeer experiences difficulty with their performance on relatively small, often process-related indirect cost groups. Therefore, it should be a combined effort of both client and contractor to improve the process of constructing large complex infrastructure projects instead of focussing on the allocation of design responsibilities and risks.

Since no definitive relationship has been identified during this study, improving cost management is suggested based on insights obtained from the data analysis and performed interviews. This study recommends using the quantitative results of this study as a frame of reference for future cost estimations. While improving the cost management of relatively small, often indirect cost groups. In addition, the current study suggests that it should be a combined effort of both client and contractor to improve the process of constructing large complex infrastructure projects instead of focussing on the allocation of design responsibilities and risks. These recommendations will be further elaborated in Section 6.2.

6.1 LIMITATIONS

Acknowledging the limitations of this study is important to demonstrate its credibility. Throughout this study, six factors limit the generalizability of this study. First, the methodological choice to use a database with Dura Vermeer projects combined with the use of Dura Vermeer employees to reflect on the findings. This choice limits the generalizability of this study since it only uses the perspective of a contractor. This could create a bias towards the contractor in the performed study. Based on the applied methodology, this study only applies to infrastructure projects from a contractor's perspective meaning the conclusion should not be used for the entire Dutch infrastructure domain. Although the entire Dutch infrastructure domain is beyond the scope of this study, it remains important to acknowledge the applicability of this study.

In addition, the sample size. A sample size of 68 is sufficient for statistical analyses. However, large standard deviations were observed in the data that minimized the chance of finding significant results and decreased the certainty of the calculated averages. Enlarging the sample size will strengthen the conclusion of this study since a selection criterion has been applied to deal with extreme values and the large standard deviations.

Moreover, the included contract types. The database of Dura Vermeer included three contract types, including RAW, E&C, and D&B(M). Since there are seven contract types, this study provides limited insights into the existence of a relationship, considering all contract types. Therefore, the insights of this study are limited to the included contract types RAW, E&C, and D&B(M).

Furthermore, the data quality of seven cost groups. The data of seven cost groups showed missing values and irregularities which resulted in their exclusion from the statistical analysis. Therefore, the current study does not apply to the cost groups *conditioning, financial, chance and risks, contractual changes, general, provisional sums,* and *procurement results*. Improving the administration of these cost groups will, most likely, improve the data quality of these cost groups.

Besides, due to time constraints the results of the clustered cost groups have not been extensively analysed. All clustered cost groups have been analysed for statistically significant differences, but descriptive statistics have not been analysed. However, analysing descriptive statistics can provide meaningful insights, as illustrated by the insights obtained from analysing the descriptive statistics of not clustered cost groups. Therefore, the conclusions that are drawn from the statistical analysis apply to a not clustered situation that does not take into account any project characteristics including, type of client, project type, project size, or project location.

Last, the size of the expert panel. In total four interviews have been conducted with two project managers, one project director, and one director of Dura Vermeer. During the interviews, it has been observed that the type of function one holds within a company influences their perspective on the process of cost management. Since only one director and one project director have been interviewed, the obtained insights are limited to their overlapping opinions. To include insights obtained from the difference in opinions between functions, multiple interviews per type of function should be conducted.

6.2 RECOMMENDATIONS

6.2.1 RECOMMENDATIONS FOR DURA VERMEER

Since this research is performed in conjunction with Dura Vermeer, several recommendations apply solely to Dura Vermeer. These recommendations will form the answer to sub-question five, which states, *how could the obtained insight be used to improve cost management.* This study recommends improving cost management in four ways.

A first quick win is to use the quantitative results of this study as a frame of reference that provides Dura Vermeer with three insights. First, the cost performance results will illustrate that the difference in cost performance between contract types is marginally small and does not follow the common reasoning that D&B(M) projects have worse cost performance compared to RAW and E&C projects. Second, the relative size combined with the cost performance of cost groups can be used by cost estimators when estimating budgets or compare the cost performance of a project. All of these insights are combined in one infographic which is included in Appendix E.

A more long-term recommendation for Dura Vermeer is to improve their control over relatively small, often process-related indirect cost groups by firstly improving the percentages used to estimate these cost groups. In order to do so the administration of the cost groups including *conditioning, financial, chance and risks, contractual changes, general, provisional sums,* and *procurement results* must be improved since the data quality of these cost groups did not facilitate quantitative analysis. As this study illustrates, performing quantitative analysis is an important way to obtain insights about cost performance. In addition, once the data quality is improved, machine learning techniques can be applied to assist in estimating costs. To illustrate, when project characteristics are included, machine learning techniques can estimate costs on an individual function level. When this technique has proven its value, it could be applied to other indirect cost groups in the future. However, Dura Vermeer should realize that this technique is not an exact representation of the real world, data analysis provides contours but never a clear picture. While Dura Vermeer improves the percentages used to estimate these cost groups, the implementation of the process-related costs groups should be improved. Which can be achieved by focussing on the process of constructing large complex infrastructure projects instead of concentrating on the allocation of design responsibilities and risks. Dura Vermeer should actively involve clients in their objective to improve the process of constructing infrastructure projects since the process is dependent on both parties.

Last, it is recommended to improve the current database itself and its use in three ways. First, when the current database is used to provide insight for business decisions, it is recommended to consider the large spread existing in the database. This study suggests using either mean values in conjunction with median values or use error bars to inform users if calculated averages tend to be lower or higher. Second, increase the sample size to decrease the standard deviations and thereby improve the reliability of the calculated mean values. Last, create additional subdivisions in the cost group *subcontractors* to gain insight in the cost performance of different types of subcontractors.

6.2.2 Recommendations for future research

Based on the limitations of this study several recommendations for future research can be made. First, since this study is limited to a contractor' perspective it is recommended to do further research on the difference between the perspectives of the client and the contractor concerning the cost performance of different contract types.

Second, by replicating this study on another database owned by a different contractor the findings of this study can be validated and thereby extending the applicability of the obtained insights of contractors in the Dutch infrastructure domain in general.

Third, it is recommended to extend the current data analysis in three ways. First, analyse the descriptive statistics of the database clustered by type of client, project type, project size, project location. This study has not found evidence that these project characteristics have a statistically significant influence on the difference between contract types. However, analysing descriptive statistics can provide additional insights as was the case in this study. Analysing these project characteristics can provide points of attention during the estimation of new projects. In addition, it is recommended to include alliance and/or building team contracts in the statistical analysis when data about these projects becomes available. This analysis could be insightful since these contract types aim to improve collaboration between contractor and client and thereby reducing inefficiencies during the design process. Moreover, analyse if a contract with a MEAT component has better cost performance and improved predictability as suggested by several interviewees. This could provide insights that can be used during the tender- and cost estimation process.

Last, this study has suggested that the inefficiencies of the design and execution process are a cause of the statistically significant difference between E&C and D&B(M) of the cost performance of engineering. It is recommended to perform further research, through case studies, to identify if D&B(M) projects are indeed more affected by the suggested inefficiencies compared to E&C projects. In addition, this study can provide solutions for the identified inefficiencies.

7

Reflection

7 REFLECTION

The graduation research is described as one of the first projects you need to manage and execute yourself. In hindsight, I believe I successfully managed my graduation project which resulted in a relatively smooth process. However, I still describe writing my graduation thesis as a process with ups and downs while constantly revising my work. This process started with a research proposal in which it became clear that my research would consist of three phases, including a literature review, a statistical analysis, and interviews. Since I never conducted a statistical analysis, I initially questioned if it was a good idea to incorporate this technique in my research methodology when I had no prior experience with it. In hindsight, I am glad I included the statistical technique in my research since it provided me with insights that transcend this research. In addition, I have learned to apply, interpret, and report several statistical techniques in such a way the reader is able to understand the underlying meaning of statistical results.

During the literature study, I realized that the opportunity Dura Vermeer gave me was exceptional since the body of knowledge concerning cost overruns was focused on the client' perspective and not the contractor' perspective. Moreover, a statistical comparison of financial data of a contractor has not yet been done. This gave me the confidence that my research would contribute to the body of knowledge. On the contrary, the absence of contractor focused literature made the literature study harder than expected since I needed other literature to describe the theoretical context. This is when I realized that the difference in cost overrun between the client' and the contractor' perspective is dependent on the moment in time when the budget is calculated. While the factors causing cost overruns can be considered similar.

After the literature study, I familiarised myself with the process of conducting statistical research. I experienced statistical research as frustrating at times when I could not find the desired results. It, however, forced me to constantly review my findings and to identify what the statistics tell me but also what they did not tell me. Since the primary goal of any researcher that conducts statistical research is to find statistically significant findings, I was sometimes demotivated when I realized my analysis would not result in major significant findings. The choice to analyse the descriptive statistics forced me to again reassess and revaluate my work. This choice made to ensure I could progress to the following stage in which I conducted interviews with an expert panel that would turn out to be critical to the outcome of this research. Based on this I can conclude that due to performing statistical research I have obtained a more objective view of data and data analyses. Thereby improving my scientific writing and reading skills.

Out of the entire process of writing my graduation research, I most enjoyed conducting the interviews with the expert panel. During the interviews, I realized that an insignificant result is still very interesting when it does not align with the expectations within Dura Vermeer. This insight gave me renewed confidence that the results of my study could provide valuable recommendations for Dura Vermeer. Furthermore, this stage of my research showed me that statistical analyses only show the contours of reality while its interpretation is influenced by the conviction and experience of the person conducting the data analysis. I was not immune to this since the formulation of my research question and methodology shows that I expected to find a relationship thereby explaining my disappointment when this relationship resulted to be nonapparent. In addition, this insight has led me to question the statements of Flyvbjerg and his colleagues in a way I did not see myself doing during the initial literature review. I realized that the studies of Flyvbjerg et al solely compare two monetary values with different moments in time disregarding the process that took place between these moments in time. Through this process, I have obtained a more objective view of performed studies. I believe that my objective and critical view will assist me throughout my career.

Looking back at my graduation project, I have enjoyed my time at Dura Vermeer in which I experienced first-hand the importance of remaining critical of your work. I have further improved my scientific writing and reading skills and learned to apply, interpret, and report statistical tests. In addition, I now know that there is more to cost overruns than meets the eye.

8

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Appendix A Database Variables

(1 page)

Table 21 Description of variables present in the database.

Variables	*Unit*	*Description*
Labour	%	The accuracy of all cost estimations related to physical labour in terms of man hours. Percentage is determined by subtracting the working budget from the realized costs devided by the working budget.
Labour relative	%	The total budget for labour costs relative to the total budget.
Equipment	%	The accuracy of all cost estimations related to the use of equipment during construction. Percentage is determined by subtracting the working budget from the realized costs devided by the working budget.
Equipement relative	%	The total budget for equipment costs relative to the total budget.
Subcontractors	%	The accuracy of all cost estimations related to work executed by subcontractors. Percentage is determined by subtracting the working budget from the realized costs devided by the working budget.
Subcontractors relative	%	The total budget for subcontractors costs relative to the total budget.
Deliveries	%	The accuracy of all cost estimations related to the delivery of materials and supplies. Percentage is determined by subtracting the working budget from the realized costs devided by the working budget.
Deliveries relative	%	The total budget for delivery costs relative to the total budget.
Engineering	%	The accuracy of all cost estimations related to engineering work. Percentage is determined by subtracting the working budget from the realized costs devided by the working budget.
Engineering relative	%	The total budget for engineering costs relative to the total budget.
Building site	%	The accuracy of all cost estimations related to the building site. Percentage is determined by subtracting the working budget from the realized costs devided by the working budget.
Building site relative	%	The total budget for building site costs relative to the total budget.
Project organisation / UTA	%	The accuracy of all cost estimations related to project organisation. Percentage is determined by subtracting the working budget from the realized costs devided by the working budget.
Project organisation / UTA relative	%	The total budget for Project organisation / UTA costs relative to the total budget.
Conditioning	%	The accuracy of all cost estimations related to conditioning. Percentage is determined by subtracting the working budget from the realized costs devided by the working budget.
Financial	%	The accuracy of all cost estimations related to finance. Percentage is determined by subtracting the working budget from the realized costs devided by the working budget.
Chance and risks	%	The accuracy of all cost estimations related to chances and risks. Percentage is determined by subtracting the working budget from the realized costs devided by the working budget.
Contractual changes	%	The accuracy of all cost estimations related to contractual changes. Percentage is determined by subtracting the working budget from the realized costs devided by the working budget.
General	%	The accuracy of all cost estimations related to general costs. Percentage is determined by subtracting the working budget from the realized costs devided by the working budget.
Provisional sums	%	The accuracy of all cost estimations related to provisional sums. Percentage is determined by subtracting the working budget from the realized costs devided by the working budget.
Profit	%	The accuracy of all cost estimations related to profit. Percentage is determined by subtracting the working budget from the realized costs devided by the working budget.
Procurement result	%	The accuracy of all cost estimations related to procurement results. Percentage is determined by subtracting the working budget from the realized costs devided by the working budget.
Direct costs	%	The average accuracy of all cost estimation related to labour, equipment, deliveries, and subcontractors. Percentage is determined by subtracting the working budget from the realized costs devided by the working budget.
Direct costs relative	%	The total budget for direct costs relative to the total budget.
Total Budget	€	The value of the contract(s) of the project at time of contracting.
Total Result	%	The total result of the project at completion. Percentage is determined by subtracting the working budget from the realized costs devided by the working budget.
Year of procurement	Year	The year in which the contract is signed.
Construction duration	Days	The length of the construction phase measured in days.
Contract type	1 - 4	Contract types included in the database are: 1: RAW/STABU, 2:E&C, and 3: D&B(M).
Type of client	1 - 9	Type of clients included in the database are: 1: Rijkswaterstaat, 2: Province, 3: Municipality, 4: ProRail, 5: Havenbedrijf, 6: Tennet, 7: Private, 8: Water board, 9: Schiphol.
Project type	1 - 5	Type of projects included in the database are: 1: Civil, 2: Road, 3: Rail, 4: Water, 5: Industry.
Project size	1 - 4	Projects are devided by size in the following categories: 1: Small (€2.5 mil. - €10 mil.), 2: Medium (€10 mil. - €50 mil), 3: Large (€50 mil. - €150 mil.) 4: Extraordinarily (>€150 mil.)
Project location	1 - 2	Project location is categorised as follows: 1: Urban, 2: Rural.

Appendix B Explanation statistical tests

(1 page)

This appendix will shortly describe, based on the informative website Laerd Statistics, the statistical techniques which are used in this research. First, one-way ANOVA will be elaborated followed by the Kruskal-Wallis H test.

One-way ANOVA

One-way ANOVA is a statistical technique which determines if there are any statistically significant differences between the means of two or more independent groups. The one-way ANOVA is an omnibus test statistic which means its result illustrate whether there are at least two independent groups significantly different. It therefore does not tell you which specific groups are different from each other. The result of a post hoc test will illustrate which specific groups are different from each other.

In order to perform a one-way ANOVA, six assumptions need to be considered.

- *Assumption 1.* One-way ANOVA needs one dependent continuous variable, e.g. height, temperature, age, academic achievements, or in the case of this research cost overruns.
- *Assumption 2.* One-way ANOVA needs one independent variable consisting of two or more categorical groups, e.g. ethnicity, profession, or in the case of this research contract types.
- *Assumption 3.* One-way ANOVA needs independent observations, meaning there is no relationship between the observations in each group of the independent variable. When there is a relationship between the observations, e.g. by using the same participants in each group, a one-way repeated measures ANOVA is more appropriate.
- *Assumption 4.* There should be no significant outliers of the dependent variable in each independent group. A significant outlier is a value that is extremely small or large compared to other values in that group. Outliers can have a large influence on the mean and standard deviation a thereby influencing the result of a one-way ANOVA. There are four ways to proceed when outliers are present in the dataset. First, perform a non-parametric Kruskal-Wallis H test. Second, replace the outliers with less extreme values. Third, transform the dependent variable. Last, perform the one-way ANOVA with the outliers if you the effect of the outliers on the result of the one-way ANOVA will be marginal.
- *Assumption 5.* The dependent variable must be approximately normally distributed for each group of the independent variable. Because the one-way ANOVA is considered "robust" to some violations of normality an approximately normally distributed variable will still provide valid results. The Shapiro-Wilk test for normality is often applied to test this assumption.
- *Assumption 6.* The variance of each group of the independent variable is equal. Levene's test of equality of variances can be performed to test this assumption.

Kruskal-Wallis H test

The Kruskal-Wallis H test is a rank-based nonparametric test which can be used to determine if there are statistically significant differences between two or more groups of an independent variable on a continuous or ordinal dependent variable. The Kruskal-Wallis H test also has assumptions which must be met. The first three assumption are identical to the first three assumption of one-way ANOVA. The fourth and last assumption reflects the nature of the data because it must be determined if the distribution of each group of the independent variable should are equal or different from each other. This assumption will determine the interpretation of the results. When the distributions have a different shape, the Kruskal-Wallis H test will show if there is a significant difference is the distributions of the groups. However, when the distributions have the same shape, the results will show whether there is a significant difference between the medians of the groups. In the event that only two groups hold cases, the Mann-Whitney U test is applied to determine if there are differences between two groups.

Spearman's rank-order correlation

The Spearman's rank-order correlation calculates a coefficient r_s or ρ which is a measure of the strength and direction of the association between two continuous or ordinal variables. The required assumptions for performing this test are first two continuous and/or ordinal variables. Second, these variables must represent pared observations. Last, the relationship between the two variables needs to be monotonic.

Appendix C (Dis)advantages of contract types

(2 pages)

Table 22 (dis)advantages of contract models used in the Dutch building sector.

Contract model	*Advantages*	*Disadvantages*	*Source*
Traditional	• Clear relationship between client and contractor. • Procurement based on lowest price is the best option since a complete design is available. • Low transaction cost. • Fixed prices for each unit of material or labour. • The client can be fairly certain about the quality since he/she made the design. • A building team uses the expertise of the market in a traditional contract model. • It provides the client with the possibility to check the contractor.	• Slowdown effect of the building process due to the sequential character. • The contractor can only use its expertise during the construction phase, not during the design phase. • As a result of a lack of knowledge of the contractor during the design phase, a high chance of additional works arises. • Life-Cycle-Costing is not always a priority for the contractor.	(de Ridder & Noppen, 2009) (PIANOo, 2019g) (PIANOo, 2012)
Engineering & Construct	• The responsibility and the risks of the construction phase are partly owned by the contractor. • The client has a relatively large influence on the design. • The client is flexible to implement changes to the design. These changes come with high costs. • The client assesses the work of the contractor based on technical specifications or a preliminary design.	• The client has less influence on the design compared to the traditional contract model • The contractor has limited possibilities to optimize the design. • Life-Cycle-Costing is not always a priority for the contractor. • The design is often not optimised for the maintenance phase. • Scope changes are very expensive to incorporate.	(PIANOo, 2019e)
Design & Construct	• A single contractor is responsible for the entire project which improves the communication between the involved parties. • Given the functional specifications are detailed, the contractor has more certainty about his cost estimates. • The design is optimized with construction knowledge of the contractor. Resulting in improved execution. • Fewer discussions about liabilities since the contractor is also responsible for the design. • Cost and time estimates are more reliable.	• The number of companies capable of performing DC projects is limited, since design competencies are required. • When the functional specification is ambiguous, disagreements could arise. • Due to the lack of unit prices, the bids of contractors are more difficult to compare for the client. • The client is bound to adhere to contractual obligations, while the desire of the client is to have freedom during the early stages.	(de Ridder & Noppen, 2009) (PIANOo, 2012)

Table 22 continued (dis)advantages of contract models used in the Dutch building sector.

Contract model	*Advantages*	*Disadvantages*	*Source*
Design, Build & Maintain	• One contractor is responsible for design, construction and maintenance of the asset which improves the communication between the involved parties. • The contractor has the opportunity to implement optimizations throughout the entire building process of design, construction, and maintenance. • A clear distribution of risks between contractor and client.	• Limited flexibility to implement scope changes by the client. • Higher transaction costs during the procurement phase. • Combining investments and exploitation requires a different working method of the client. • The need for unambiguous functional specifications could endanger the design flexibility of the contractor.	(PIANOo, 2019c) (PIANOo, 2012)
DBFM(O)	• Public expenditure can be distributed over a longer period of time. • Costs are estimated over the entire lifecycle of the asset. • Provides possibility for integrated building teams and supply chain management. • The service is often earlier available than planned. • Lower failure costs due to less interfaces because a higher level of integration. • The client can maintain focus on core tasks because the asset is procured in an integrated manner.	• The procurement procedure is considerably longer compared to other integrated contract models. • DBFM(O) project require a high level of expertise. • The transaction costs during the procurement phase are very high. • The DBFM(O) is not suitable for projects with a total investment sum below 20 million euro.	(PIANOo, 2019b) (PIANOo, 2012)
Alliance	• Open communication and cooperation between parties' results in less conflicts which potentially saves costs.	• Open communication and cooperation take a lot of time to achieve. • The 'open book' might be beyond the contractors liking.	(de Ridder & Noppen, 2009)

Appendix D Results of studies comparing DB and DBB

(1 page)

Table 23 Overview of studies comparing DB and DBB (based on Hale et al. (2009); Park & Kwak (2017))

Study	*Sample size*		*Project type*	*Project size*	*Findings*
	DBB	*DB*			
(Roth, 1995)	6	6	Navy child care facilities	N/A	Cost growth for DB was lower than that for DBB.
(Songer & Molenaar, 1996)	N/A	108	Industrial, housing, and highways	N/A	Reduced cost and shortened duration were the top ranked factors for selecting DB.
(Konchar & Sanvido, 1998)	116	155	Industrial and housing	N/A	Unit cost was 6% and cost growth was 5.2% less in DB.
(Molenaar et al., 1999)	N/A	104	Industrial, housing, and highways	N/A	59% of DB projects were with 2% or better of the estimated budget.
(Ibbs et al., 2003)	30	24	Housing	\$5 M to \$1 B	Cost growth for DB was 7.8% higher than that for DBB.
(Warne, 2005)	N/A	21	Highways	\$83 M to \$1.3 B	76% of DB projects were finished ahead of schedule. DB offered greater price certainty and reduced cost growth.
(U.S. Department of Transportation Federal Highway Administration, 2006)	11	11	Highways	\$5 M to \$20 M	Cost growth for DB was 3.8% higher than that for DBB.
(Shrestha & Migliaccio, 2007)	7	4	Highways	\$50 M to \$1.3 B	Cost growth for DB was 9.6% lower than that for DBB.
(Hale et al., 2009)	39	38	Housing	\$3 M to \$38 M	Based on time and cost growth, DB is superior to DBB when used on military housing projects.
(Park & Kwak, 2017)	1257	255	Public transportation	\$ 4000 to \$243 M	Cost overruns are in DB project are lower compared to DBB when comparing original contract amount to production cost. However, the results were found to be insignificant after accounting for project characteristics.

Appendix E Infographic Dura Vermeer

(1 page, A3+ format)

Literature

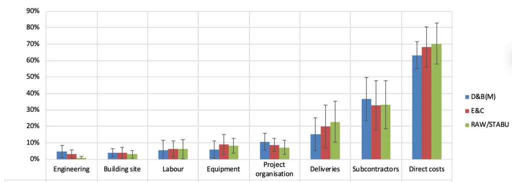
Expectation prior to research

- Transfer of tasks from the client to the contractor would reduce costs for the client.
- Availability of information affects the uncertainty of risks and thus affects cost estimations
- Optimism bias seemingly best explains cost overruns.

- Design & Build projects have more cost overruns compared to RAW and Engineer & Construct projects.
- RAW projects are best to predict followed by E&C and D&B(M) projects.
- Key reason behind cost overruns are inefficient design process and inefficient collaboration.

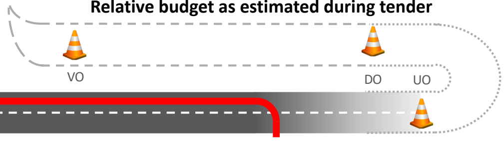
Dura Vermeer

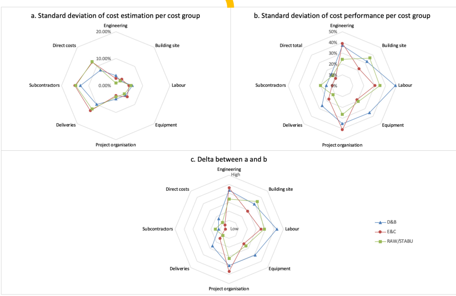
Budget relative to total budget per cost group



	Engineering	Building site	Labour	Equipment	Project organisation	Deliveries	Subcontractors	Direct costs
D&B(M)	5%	4%	5%	6%	11%	15%	37%	63%
E&C	3%	4%	6%	9%	9%	20%	33%	68%
RAW/STABU	1%	3%	6%	8%	7%	23%	33%	70%

Relative budget as estimated during tender

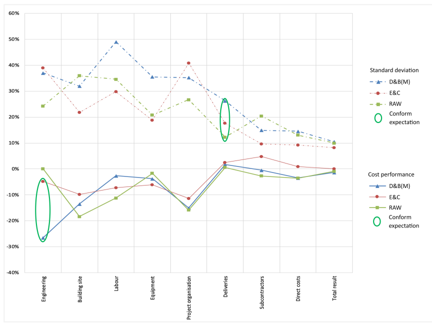




High delta: same relative budgets are used during the cost estimation process while the cost performance of this cost group remains uncertain.

Low delta: different relative budgets are estimated combined with a cost performance that is better to predict.

Cost performance and standard deviation per cost group



Insights

1.
- No relationship between contract types RAW, E&C, and D&B(M), and thus the unavailability of information, and the uncertainty of the cost performance and the cost performance itself of Dutch infrastructure projects.
  - Engineering is only cost group conform expectation.
  - Changing levels of design specificity of sub-parts in E&C contracts does not result in more cost overruns.

2.
- Project members at Dura Vermeer overestimate the relationship between the contract type and cost performance in two areas:
  - Project members believes that the design phase has an influence on the cost performance of other cost groups and the total costs of a project.
  - Project members assume that more information leads to less uncertainty and risks resulting in less cost overruns.

3.
- Relatively small, often indirect, cost groups, including *labour, equipment, engineering, building site,* and *project organisation / UTA* are perceived to be certain when estimated but are uncertain in the end combined with an average cost overrun.
- Cost overruns are not solely caused by cost underestimation, i.e. optimism bias but also due to inefficiencies in the design process and collaboration among project manager, design manager, and operational manager.

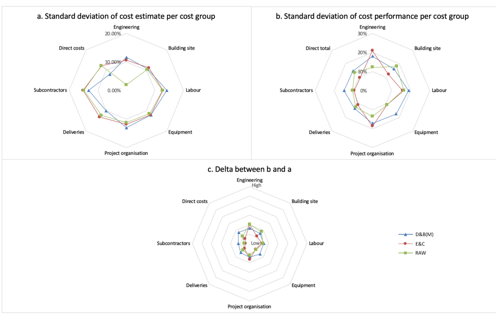
Recommendations

1.
- A first quick win is to use the quantitative results of this study as a frame of reference.

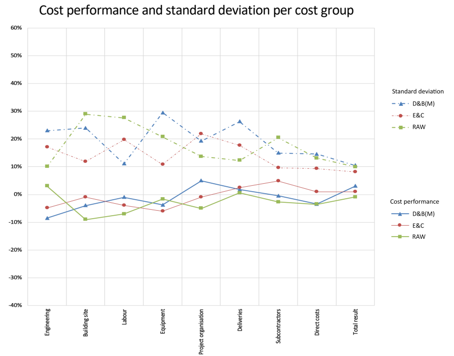
2.
- A long term recommendation is to improve the control over relatively small, often process-related indirect cost groups. By:
  - Improving the administration (data quality) of excluded cost groups (see full report).
  - Once data quality is improved machine learning techniques can be applied to assist in estimating costs.
  - Dura Vermeer should actively involve clients in their objective to improve the process of constructing infrastructure projects since the process is dependent on both parties.

3.
- Improve the usability of the database of Project Intelligence.
  - Consider the large spread in the data by using mean and median values or error bars,
  - Increase the sample size to strengthen the conclusions,
  - Create additional subdivisions in the cost group subcontractors to gain further insight.

Intended situation after implementation of recommendations



Cost performance and standard deviation per cost group



Appendix F Protocol interviews Dura Vermeer

(2 pages)

Protocol oriënterende interviews

Datum	-
Interviewer	K.M. (Kevin) van der Kruis
Geïnterviewde	-
Organisatie	Dura Vermeer

Bij voorbaat dank voor uw deelname en tijd aan dit onderzoek. Voordat het interview begint wil ik vragen of u akkoord bent met het maken van een audio-opname van dit interview, t.b.v. het transcriberen?

Even voorstellen

- Kevin van der Kruis, master student aan de TU Delft (Construction Management & Engineering)
- Onderzoek wordt uitgevoerd onder Dura Vermeer Infra Landelijke Projecten, onder begeleiding van Guus Keusters en Pim van Veen.
- Wat is uw functie binnen Dura Vermeer?

Doel van het onderzoek

Het doel van mijn onderzoek is het geven van inzicht in de relatie tussen het contract type en het management van kostengroepen beschrijft. Dit onderzoek tracht dit te doen door middel van het onderzoeken van hoe en waarom het contract invloed kan hebben op de controle van kostengroepen. Omdat dit onderzoek gebruikt maakt van data van Dura Vermeer ligt de focus van dit onderzoek op de periode vanaf het tekenen van het contract tot en met de voltooiing van het project.

Doel van het interview

Het doel van dit interview is om inzicht te krijgen in het proces van kosten ramen en cost control en op welke manier het contract hierop invloed kan hebben.

Structuur van het interview

Dit interview is semigestructureerd ingevuld en bestaat uit 2 delen. In eerste instantie zal het interview zich richten op het proces van kosten ramen en cost control. Hierbij zal de nadruk liggen op welke uitdagingen men tegenkomt tijdens dit proces. Het tweede deel van het interview richt zich op de persoonlijke mening van de geïnterviewde over de verschillende contractvormen die gebruikt worden binnen het civiele domein en wat deze voor uitdagingen met zich meebrengen binnen de functie van de geïnterviewde.

Interview

Onderwerpen

- Kosten ramen:
- Proces,
- Kansen & uitdagingen.
- Cost control:
- Stap van raming naar werkbegroting,
- Proces,
- Kansen & uitdagingen.
- Contract type:
- Op welke manier kom je in aanmerking met de verschillende contractvormen die gebruikt worden binnen het civiele domein?
- Welke uitdagingen brengen deze contractvormen met zich mee?

Bedankt voor je bijdrage en tijd. Dit interview zal getranscribeerd worden en ter goedkeuring naar je worden opgestuurd. Bij voltooiing van mijn onderzoek ontvangt je uiteraard een kopie.

Protocol expert panel interviews

Datum	-
Interviewer	K.M. (Kevin) van der Kruis
Geïnterviewde	-
Organisatie	Dura Vermeer

Bij voorbaat dank voor uw deelname en tijd aan dit onderzoek. Voordat het interview begint wil ik vragen of u akkoord bent met het maken van een audio-opname van dit interview, t.b.v. het transcriberen?

Even voorstellen

- Kevin van der Kruis, master student aan de TU Delft (Construction Management & Engineering)
- Onderzoek wordt uitgevoerd onder Dura Vermeer Infra Landelijke Projecten, onder begeleiding van Guus Keusters en Pim van Veen.
- Wat is uw functie binnen Dura Vermeer?

Doel van het onderzoek

Het doel van mijn onderzoek is het geven van inzicht in de relatie tussen het contract type en het management van kostengroepen beschrijft. Dit onderzoek tracht dit te doen door middel van het onderzoeken van hoe en waarom het contract invloed kan hebben op het management van kostengroepen. Omdat dit onderzoek gebruikt maakt van data van Dura Vermeer ligt de focus van dit onderzoek op de periode vanaf het tekenen van het contract tot en met de voltooiing van het project.

Doel van het interview

Het doel van dit interview is om te discussiëren over de resultaten verkregen uit de data-analyse.

Structuur van het interview

Dit interview is semigestructureerd ingevuld en bestaat uit 2 delen. In eerste instantie zullen negen stellingen worden voorgelegd aan de geïnterviewde. Bij iedere stelling zal gevraagd worden of de geïnterviewde het eens of oneens is met de stelling gevolgd door de waarom vraag. Het interview zal afgesloten worden met de vraag op welke manier het inzicht verkregen uit de stellingen kan bijdragen aan het verbeteren van kosten management.

Interview

Onderwerpen

- Kostenoverschrijding per contract type (RAW, E&C en D&B(M)).
    - Totale kosten,
    - Kostengroep engineering.
- Het effect van de beschikbare informatie tijdens het tenderproces op het management van kostengroepen.
- E&C projecten.
- Onderschatting van kosten tijdens de tenderfase.
    - Grote kostengroepen zoals onderaannemers en leveranciers.
    - Kleine kostengroepen zoals arbeid, materieel, engineering, bouwplaats en projectorganisatie/UTA.
- Verbeteren van kosten management.

Bedankt voor uw bijdrage en tijd. Dit interview zal getranscribeerd worden en ter goedkeuring naar u worden opgestuurd. Bij voltooiing van mijn onderzoek ontvangt u uiteraard een kopie.

Appendix G Transcripts interviews

(1 page)

The transcripts of the interviews have been excluded from the public version of this thesis to maintain confidentiality.

Appendix H Descriptive statistics cost groups

(2 pages)

Table 24 Descriptive statistics of all (15) cost groups prior to selection criterion.

Cost group	*Contract type*	*N*	*Min.*	*Max.*	*Mean*	*Std. Dev.*	*Skewness*		*Kurtosis*	
							Statistic	*Std. Error*	*Statistic*	*Std. Error*
Labour	RAW/STABU	24	-468.33%	1240.94%	10.97%	292.28%	3.33	0.47	14.76	0.92
	E&C	22	-566.15%	190.69%	-42.05%	154.46%	-2.00	0.49	6.08	0.95
	D&B(M)	22	-188.70%	1043.28%	23.05%	238.95%	3.99	0.49	17.67	0.95
	Total	68	-566.15%	1240.94%	-2.27%	235.57%	3.25	0.29	16.78	0.57
Equipment	RAW/STABU	24	-59.35%	43.42%	-1.69%	20.77%	-0.48	0.47	2.78	0.92
	E&C	22	-146.61%	23.43%	-12.41%	35.13%	-2.79	0.49	10.29	0.95
	D&B(M)	22	-161.97%	74.84%	-10.95%	48.35%	-1.27	0.49	4.03	0.95
	Total	68	-161.97%	74.84%	-8.15%	35.93%	-1.88	0.29	7.37	0.57
Subcontractors	RAW/STABU	24	-94.86%	15.22%	-2.70%	20.44%	-4.29	0.47	19.96	0.92
	E&C	22	-5.60%	27.36%	4.81%	9.66%	1.24	0.49	0.70	0.95
	D&B(M)	22	-48.37%	21.98%	0.48%	14.93%	-1.74	0.49	4.60	0.95
	Total	68	-94.86%	27.36%	0.45%	15.89%	-3.59	0.29	20.03	0.57
Deliveries	RAW/STABU	24	-45.19%	29.68%	0.60%	12.23%	-1.75	0.47	9.61	0.92
	E&C	22	-57.80%	249.56%	13.67%	55.44%	3.92	0.49	17.49	0.95
	D&B(M)	22	-33.65%	99.45%	1.75%	26.30%	2.46	0.491	9.11	0.953
	Total	68	-57.80%	249.56%	5.20%	35.59%	5.11	0.29	34.26	0.57
Engineering	RAW/STABU	24	-186.11%	57.05%	-9.37%	49.46%	-2.41	0.47	7.06	0.92
	E&C	22	-164.84%	93.32%	-22.37%	58.57%	-0.74	0.49	0.96	0.95
	D&B(M)	22	-382.80%	70.17%	-53.83%	96.75%	-2.49	0.49	6.83	0.95
	Total	68	-382.80%	93.32%	-27.96%	72.13%	-2.59	0.29	9.55	0.57
Building site	RAW/STABU	24	-169.60%	32.68%	-35.96%	58.20%	-1.20	0.47	0.46	0.92
	E&C	22	-245.33%	16.92%	-30.44%	70.11%	-2.64	0.49	6.25	0.95
	D&B(M)	22	-78.11%	29.41%	-13.46%	31.92%	-0.93	0.49	-0.38	0.95
	Total	68	-300.06%	96.44%	-20.42%	50.81%	-2.73	0.29	13.44	0.57
Project Organisation / UTA	RAW/STABU	24	-86.60%	15.71%	-15.85%	26.71%	-1.31	0.47	0.96	0.92
	E&C	22	-152.57%	96.44%	-17.82%	49.90%	-0.67	0.49	2.33	0.95
	D&B(M)	22	-300.06%	40.65%	-28.02%	69.82%	-3.00	0.49	11.34	0.95
	Total	68	-300.06%	96.44%	-20.42%	50.81%	-2.73	0.29	13.44	0.57
Direct costs	RAW/STABU	24	-49.30%	20.35%	-3.53%	13.08%	-1.82	0.47	6.15	0.92
	E&C	22	-13.49%	25.90%	0.96%	9.28%	0.89	0.49	1.39	0.95
	D&B(M)	22	-55.15%	13.65%	-3.44%	14.55%	-2.35	0.49	7.31	0.95
	Total	68	-55.15%	25.90%	-2.04%	12.51%	-1.80	0.29	6.74	0.57

Table 24 continued Descriptive statistics of all (15) cost groups prior to selection criterion.

Cost group	*Contract type*	*N*	*Min.*	*Max.*	*Mean*	*Std. Dev.*	*Skewness*		*Kurtosis*	
							Statistic	*Std. Error*	*Statistic*	*Std. Error*
Conditioning	RAW/STABU	17	-100.00%	86.56%	-5.33%	35.36%	-0.24	0.55	5.33	1.06
	E&C	20	-762.15%	91.59%	-32.46%	176.59%	-4.08	0.51	17.56	0.99
	D&B(M)	19	-29.43%	100.00%	10.27%	30.67%	2.02	0.52	4.33	1.01
	Total	56	-762.15%	100.00%	-9.72%	108.52%	-6.24	0.32	43.80	0.63
Financial	RAW/STABU	24	-197.32%	115.91%	-9.79%	49.70%	-1.81	0.47	10.37	0.92
	E&C	20	-225.62%	100.52%	5.95%	68.54%	-1.97	0.51	6.63	0.99
	D&B(M)	21	-100.00%	1105.11%	78.31%	243.86%	4.06	0.50	17.77	0.97
	Total	65	-225.62%	1105.11%	23.51%	149.55%	5.97	0.30	44.06	0.59
Chance and risks	RAW/STABU	23	-1865.65%	208.74%	-82.76%	401.56%	-4.33	0.48	19.79	0.94
	E&C	20	-1751.79%	197.29%	-65.83%	406.03%	-4.15	0.51	17.96	0.99
	D&B(M)	22	-100.00%	100.05%	35.016%	51.79%	-0.61	0.49	0.47	0.95
	Total	65	-1865.65%	208.74%	-37.69%	328.70%	-5.04	0.30	25.99	0.59
Contractual changes	RAW/STABU	15	-2.15%	487.31%	61.67%	123.92%	3.28	0.58	11.58	1.12
	E&C	14	0.00%	100.00%	21.57%	28.49%	1.85	0.60	3.69	1.15
	D&B(M)	17	-4.95%	185.66%	27.28%	49.30%	2.44	0.55	6.46	1.06
	Total	45	-4.95%	487.31%	36.76%	78.67%	4.53	0.35	24.53	0.69
General	RAW/STABU	23	-42.45%	14.49%	-3.86%	13.86%	-1.79	0.48	3.16	0.94
	E&C	22	-40.50%	30.63%	-4.09%	15.81%	-1.09	0.49	2.49	0.95
	D&B(M)	22	-47.93%	12.26%	-3.06%	11.00%	-3.39	0.49	14.31	0.95
	Total	67	-47.93%	30.63%	-3.67%	13.50%	-1.70	0.29	3.90	0.58
Provisional sums	RAW/STABU	16	-90.00%	112.45%	13.36%	44.68%	0.24	0.56	2.22	1.09
	E&C	15	0.00%	76.73%	9.59%	20.45%	2.92	0.58	9.17	1.12
	D&B(M)	15	0.00%	216.09%	29.31%	62.10%	2.39	0.58	5.64	1.12
	Total	46	-90.00%	216.09%	17.33%	45.49%	2.22	0.35	8.07	0.69
Procurement result	RAW/STABU	17	-584.82%	100.00%	-24.50%	156.11%	-3.14	0.55	11.62	1.06
	E&C	15	-171.95%	6007.43%	449.67%	1539.89%	3.85	0.58	14.89	1.12
	D&B(M)	6	-3044.19%	100.00%	-148.88%	773.58%	-3.97	0.56	15.85	1.09
	Total	48	-3044.19%	6007.43%	82.22%	985.40%	4.11	0.34	30.86	0.67

Appendix I Statistical analysis of Direct costs

(2 pages)

The cost group *direct costs* is an aggregation of the costs groups *labour, equipment, deliveries* and *subcontractors*, as described in Appendix A. Combining these cost groups allows this study to analyse the influence of the contract type of costs that are directly related to a project. It would have been interesting to analyse the difference between direct and indirect costs. However, due to the exclusion of the cost groups; *conditioning, financial, chance and risks, contractual changes, general, provisional sums,* and *procurement results* which are largely indirect cost groups, a comparison between direct and indirect costs is not possible.

Table 26 illustrate, as expected, that on average RAW projects (n=24, 70.38%) have the largest direct budget relative to the total budget, followed by E&C project (N=22, 68.26%) and D&B(M) project (n=22, 63.30%). These results are expected since integrated contracts have a larger indirect budget due to design and management responsibilities. A larger indirect budget results in a smaller direct budget. The Kruskal-Wallis H test revealed a statistically significant difference between the contract types ($\chi^2(2) = 6.13$, $p = 0.047$).

Table 25 Pairwise comparisons for direct budget relative to total budget (no clustering applied)

Cost group	*Comparison of Contract type*	*Test Statistic*	*Standard Error*	*Standardized Test Statistic*	*Significance*	*Adjusted Significance*
Direct budget relative to total budget	D&B(M) - E&C	9.091	5.962	1.525	0.127	0.382
	D&B(M) - RAW*	14.333	5.836	2.456	0.014	0.042
	E&C - RAW	5.242	5.836	0.898	0.369	1.000

* A significant difference between contract types at the 0.05 level.
Asymptotic significances (2-tailed tests) are displayed.
Significance values have been adjusted by the Bonferroni corrrection for multiple comparisons.

Subsequently, pairwise comparisons were performed using the procedure of Dunn (1964) to identify which contract types differ significantly. This post hoc analysis, based on mean ranks reveals a significant difference (p=0.042) between D&B(M) and RAW projects with mean ranks of 26.50 and 40.83 respectively (Table 25). The dissimilar distributions of D&B(M) and RAW projects limit the extent to which this result can be interpreted. Taking this into consideration, this result indicates that D&B(M) projects have a significantly smaller direct budget relative to the total budget compared to RAW projects based on mean ranks. This result is expected since the amount of management responsibilities in D&B(M) projects increases, as illustrated in Section 3.2.7, while direct budgets such as *labour, equipment,* or *deliveries* in D&B(M) projects decrease. Furthermore, the SD values indicate that the uncertainty surrounding the estimation process of the direct budget is larger compared to smaller cost groups. However, these results are similar to the cost groups *subcontractors* and *deliveries* which are both considerable cost groups in size relative to the total budget. Since the SD values differ only slightly between RAW (12.39%) and E&C (12.28%) projects it can be stated that the uncertainty surrounding the estimation of the budget for direct costs can be considered equal for RAW and E&C. D&B(M) projects, however, have an SD of 8.11 per cent which is surprising since it contradicts the theory about availability of information. Since Table 26 has shown that the direct budget is a large amount of the total budget, a strong correlation is expected between the relative budget and the total result of a project. Based on the Spearman correlation analysis, Table 6 in section 3.2.1, illustrates that indeed all RAW, E&C, and D&B(M) projects show a strong and significant correlation of r=0.704 (n=24, p=0.001), r= 0.700 (n=22, p=0.001), and r=0.649 (n=22, p=0.001) respectively. This result shows that the dependency of the total result on the result of direct costs can be considered equal for RAW, E&C, and D&B(M) projects. All correlations are plotted in the scatterplot depicted in Figure 26 (Appendix J).

Table 26 Statistics of direct budget relative to total budget and direct total costs relative to budget (no clustering applied)

								Skewness		*Kurtosis*		*Independent-Samples Kruskal-Wallis H Test*		
Cost group	*Contract type*	*N*	*Min.*	*Max.*	*Mean*	*Median*	*Std. Dev.*	*Statistic*	*Std. Error*	*Statistic*	*Std. Error*	*Test Statistic* [1]	*Degrees of Freedom*	*Asymptotic Sig. (2-tailed test)*
Direct budget relative to total budget*	RAW/STABU	24	39.25%	92.84%	70.38%	72.61%	12.39%	-0.97	0.47	1.21	0.92	6.13	2	0.047
	E&C	22	43.29%	93.96%	68.26%	66.93%	12.28%	0.01	0.49	-0.17	0.95			
	D&B(M)	22	42.44%	78.03%	63.30%	63.34%	8.11%	-0.80	0.49	1.23	0.95			
	Total	68	39.25%	93.96%	67.41%	67.01%	11.38%	-0.26	0.29	0.24	0.57			
Direct total costs relative to budget	RAW/STABU	24	-49.30%	20.35%	-3.53%	-0.41%	13.08%	-1.82	0.47	6.15	0.92	1.047	2	0.593
	E&C	22	-13.49%	25.90%	0.96%	0.25%	9.28%	0.89	0.49	1.39	0.95			
	D&B(M)	22	-55.15%	13.65%	-3.44%	0.05%	14.55%	-2.35	0.49	7.31	0.95			
	Total	68	-55.15%	25.90%	-2.04%	-0.03%	12.51%	-1.80	0.29	6.74	0.57			

1. The test statistic is adjusted for ties.

* A significant difference within the group at the 0.05 level (2-tailed).

When assessing the direct total costs relative to its budget, as presented in Table 26 and in the corresponding boxplots in Figure 15, it can be observed that only E&C projects (n=22) have a cost underrun of 0.96 per cent compared to cost overruns 3.53 and 3.44 per cent for RAW (n=24) and D&B(M) (n=22) respectively. However, the median values of RAW (-0.41%) and D&B(M) (0.05%) indicate that the cost overrun for RAW and D&B(M) has a tendency to be lower than the mean value. The mean value for RAW projects is surprising since it contradicts with the theory of availability of information and therefore rejects hypothesis 1 which assumed that the cost performance would decrease sequentially from RAW to E&C to D&B(M). The difference is found to be insignificant after performing a Kruskal-Wallis H test (p=0.593). When clustered by project type (p>0.158), project location (p>0.160), type of client (p>0.059), or project size (p>0.400) the difference between contract types remains insignificant, thereby rejecting hypotheses 3, 4, 5, and 6 respectively. These results are summarized in Appendix J.

Based on the SD values for RAW (13.08%), E&C (9.28%), and D&B(M) (14.55%) projects it can be observed that the standard deviations are high for all contract types. Indicating that the result that can be achieved on direct costs is very uncertain. However, since RAW has a higher degree of uncertainty compared to E&C, hypothesis 2 is rejected which assumed that the uncertainty increased sequentially from RAW to E&C to D&B(M). An overview of all hypothesis tests for *direct costs* is presented in Table 27. However, the difference between RAW and D&B(M) is marginally small. Thus, RAW and D&B(M) have the same degree of uncertainty according to the SD. One would expect that RAW projects have lower cost overruns with less uncertainty since direct costs should be, according to the theory, estimated more precise due to the availability of more information.

Table 27 Results of hypotheses tests for the cost group direct costs

Cost group	*Hypothesis 1* "Cost performance"	*Hypothesis 2* "SD of cost performance"	*Hypothesis 3* "Project type"	*Hypothesis 4* "Project location"	*Hypothesis 5* "Type of client"	*Hypothesis 6* "Project size"
Direct costs	Rejected	Rejected	Rejected	Rejected	Rejected	Rejected

Appendix J Statistical analyses

(18 pages)

Table 28 Statistical analysis of difference in total result between contract types (no clustering applied).

Cost group	*Contract type*	*N*	*Median*	*Independent-Samples Kruskal-Wallis H Test*			Independent-Samples Mann-Whitney U Test					
				Test Statistic [1]	*Degrees of Freedom*	*Asymptotic Sig. (2-tailed test)*	*Mann-Whitney U*	*Wilcoxon W*	*Test Statistic*	*Standard Error*	*Standardized Test Statistic*	*Exact Sig. (2-tailed test)*
Total result	RAW/STABU	24	0.37%									
	E&C	22	-1.12%	0.053	2	0.974						
	D&B(M)	22	-0.01%									

1. The test statistic is adjusted for ties.

Table 29 Statistical analysis of difference in cost groups between contract types (no clustering applied).

Cost group	*Contract type*	*N*	*Median*	*Independent-Samples*			Independent-Samples Mann-Whitney U					
				Test Statistic [1]	*Degrees of Freedom*	*Asymptotic Sig. (2-tailed test)*	*Mann-Whitney U*	*Wilcoxon W*	*Test Statistic*	*Standard Error*	*Standardized Test Statistic*	*Exact Sig. (2-tailed test)*
Labour	RAW/STABU	17	-12.43%									
	E&C	16	-6.34%	0.23	2	0.891						
	D&B(M)	18	-13.55%									
Equipment	RAW/STABU	24	0.00%									
	E&C	21	-7.41%	0.599	2	0.741						
	D&B(M)	21	-2.01%									
Subcontractors	RAW/STABU	24	0.61%									
	E&C	22	1.28%	0.766	2	0.682						
	D&B(M)	22	0.86%									
Deliveries	RAW/STABU	24	0.00%									
	E&C	21	1.89%	2.092	2	0.351						
	D&B(M)	22	0.01%									
Engineering*	RAW/STABU	22	0.00%									
	E&C	19	0.00%	12.27	2	0.002						
	D&B(M)	20	-19.27%									
Building site	RAW/STABU	21	-10.93%									
	E&C	20	-4.85%	0.815	2	0.665						
	D&B(M)	22	0.00%									
Project Organisation / UTA	RAW/STABU	24	-2.27%									
	E&C	22	-8.01%	0.098	2	0.952						
	D&B(M)	22	-7.25%									
Direct costs	RAW/STABU	24	-0.41%									

Table 30 Statistical analysis of difference in cost groups between contract types clustered by project type.

					Independent-Samples Kruskal-Wallis Test			Independent-Samples Mann-Whitney U Test					
Cost group	*Project type*	*Contract type*	*N*	*Median*	*Test Statistic*[1]	*Degrees of Freedom*	*Asymptotic Sig. (2-tailed test)*	*Mann-Whitney U*	*Wilcoxon W*	*Test Statistic*	*Standard Error*	*Standardized Test Statistic*	*Exact Sig. (2-tailed test)*
Labour	Civil	RAW/STABU	4	-12.75%									
		E&C	0	.				10.00	25.00	10.00	4.08	0.00	1.000
		D&B(M)	5	-31.34%									
	Road	RAW/STABU	8	0.00%									
		E&C	4	-14.18%	0.973	2	0.615						
		D&B(M)	7	42.12%									
	Rail	RAW/STABU	5	-19.35%									
		E&C	6	-21.28%	0.934	2	0.627						
		D&B(M)	5	-9.62%									
	Water	RAW/STABU	0	.									
		E&C	2	-4.14%				1.00	2.00	1.00	0.82	0.00	1.000
		D&B(M)	1	-17.47%									
	Industry	RAW/STABU	0	.									
		E&C	4	9.75%									
		D&B(M)	0	.									
Equipment	Civil	RAW/STABU	5	0.00%									
		E&C	1	20.48%	2.187	2	0.335						
		D&B(M)	7	-2.30%									
	Road	RAW/STABU	11	-1.76%									
		E&C	8	10.15%	0.871	2	0.647						
		D&B(M)	8	-23.22%									
	Rail	RAW/STABU	7	10.04%									
		E&C	5	-7.41%	1.434	2	0.488						
		D&B(M)	5	1.31%									
	Water	RAW/STABU	0	.									
		E&C	3	-7.49%				3.00	4.00	3.00	1.12	1.34	0.500
		D&B(M)	1	-0.15%									
	Industry	RAW/STABU	1	0.00%									
		E&C	4	6.60%				3.00	13.00	3.00	1.41	0.71	1.000
		D&B(M)	0	.									
Subcontractors	Civil	RAW/STABU	5	0.00%									
		E&C	1	-4.29%	1.277	2	0.528						
		D&B(M)	8	0.16%									
	Road	RAW/STABU	11	1.84%									
		E&C	8	0.52%	0.282	2	0.868						
		D&B(M)	8	0.38%									
	Rail	RAW/STABU	7	2.08%									
		E&C	6	1.87%	0.763	2	0.683						
		D&B(M)	5	6.17%									
	Water	RAW/STABU	0	.									
		E&C	3	8.85%				1.00	2.00	1.00	1.12	-0.45	1.000
		D&B(M)	1	0.01%									
	Industry	RAW/STABU	1	0.00%									
		E&C	4	4.84%				3.00	13.00	3.00	1.41	0.71	1.000
		D&B(M)	0	.									

1. The test statistic is adjusted for ties.

Table 30 continued Statistical analysis of difference in cost groups between contract types clustered by project type.

Cost group	Project type	Contract type	N	Median	Independent-Samples Kruskal-Wallis Test: Test Statistic [1]	Degrees of Freedom	Asymptotic Sig. (2-tailed test)	Independent-Samples Mann-Whitney U Test: Mann-Whitney U	Wilcoxon W	Test Statistic	Standard Error	Standardized Test Statistic	Exact Sig. (2-tailed test)
Deliveries	Civil	RAW/STABU	5	0.00%									
		E&C	1	-57.80%	3.797	2	0.150						
		D&B(M)	8	-2.95%									
	Road	RAW/STABU	11	0.00%									
		E&C	8	0.55%	3.373	2	0.185						
		D&B(M)	8	1.93%									
	Rail	RAW/STABU	7	4.18%									
		E&C	6	4.15%	1.08	2	0.583						
		D&B(M)	5	0.27%									
	Water	RAW/STABU	0	.									
		E&C	2	21.11%				0.00	1.00	0.00	0.82	-1.23	0.667
		D&B(M)	1	-0.07%									
	Industry	RAW/STABU	1	0.00%									
		E&C	4	2.15%				2.00	12.00	2.00	1.41	0.00	1.000
		D&B(M)	0	.									
Engineering	Civil	RAW/STABU	.	.									
		E&C	1	-24.00%				3.00	31.00	3.00	2.29	-0.22	1.000
		D&B(M)	7	-33.13%									
	Road	RAW/STABU	.	.									
		E&C	5	-31.92%				16.00	44.00	16.00	6.16	-0.24	0.876
		D&B(M)	7	-38.27%									
	Rail	RAW/STABU	.	.									
		E&C	6	1.69%				7.00	22.00	7.00	5.48	-1.46	0.177
		D&B(M)	5	-14.16%									
	Water	RAW/STABU	.	.									
		E&C	3	-13.82%				2.00	3.00	2.00	1.12	0.45	1.000
		D&B(M)	1	-10.01%									
	Industry	RAW/STABU	.	.									
		E&C	4	22.45%									
		D&B(M)	0	.									
Building site	Civil	RAW/STABU	4	-7.85%									
		E&C	0	.				16.00	52.00	16.00	5.85	0.00	1.000
		D&B(M)	8	-5.93%									
	Road	RAW/STABU	10	-5.47%									
		E&C	8	-4.85%	1.436	2	0.488						
		D&B(M)	8	0.42%									
	Rail	RAW/STABU	6	-21.18%									
		E&C	5	-2.79%	0.312	2	0.856						
		D&B(M)	5	0.67%									
	Water	RAW/STABU	0	.									
		E&C	3	-3.84%				2.00	3.00	2.00	1.12	0.45	1.000
		D&B(M)	1	1.96%									
	Industry	RAW/STABU	1	0.00%									
		E&C	4	-12.72%				1.00	11.00	1.00	1.41	-0.71	0.800
		D&B(M)	0	.									

1. The test statistic is adjusted for ties.

Table 30 continued Statistical analysis of difference in cost groups between contract types clustered by project type.

Cost group	*Project type*	*Contract type*	*N*	*Median*	*Independent-Samples Kruskal-Wallis Test*			Independent-Samples Mann-Whitney U Test					
					Test Statistic [1]	*Degrees of Freedom*	*Asymptotic Sig. (2-tailed test)*	*Mann-Whitney U*	*Wilcoxon W*	*Test Statistic*	*Standard Error*	*Standardized Test Statistic*	*Exact Sig. (2-tailed test)*
Project Organisation / UTA	Civil	RAW/STABU	5	0.00%									
		E&C	1	-91.59%	3.527	2	0.171						
		D&B(M)	7	-17.15%									
	Road	RAW/STABU	11	-9.90%									
		E&C	7	-13.47%	0.441	2	0.802						
		D&B(M)	8	-8.39%									
	Rail	RAW/STABU	7	-4.45%									
		E&C	6	-16.49%	0.939	2	0.625						
		D&B(M)	5	-4.23%									
	Water	RAW/STABU	0	.									
		E&C	3	-2.20%				2.00	3.00	2.00	1.12	0.79	1.000
		D&B(M)	1	7.46%									
	Industry	RAW/STABU	1	0.00%									
		E&C	4	6.66%				2.00	12.00	2.00	1.41	0.00	1.000
		D&B(M)	0	.									

Table 31 Statistical analysis of difference in cost groups between contract types clustered by project size

					Independent-Samples Kruskal-Wallis Test			Independent-Samples Mann-Whitney U Test					
Cost group	*Project size*	*Contract type*	*N*	*Median*	*Test Statistic* [1]	*Degrees of Freedom*	*Asymptotic Sig. (2-tailed test)*	*Mann-Whitney U*	*Wilcoxon W*	*Test Statistic*	*Standard Error*	*Standardized Test Statistic*	*Exact Sig. (2-tailed test)*
Labour	Small	RAW/STABU	17	-12.43%									
		E&C	6	-14.18%	3.761	2	0.152						
		D&B(M)	6	18.24%									
	Medium	RAW/STABU	0	.									
		E&C	6	-7.71%				20.00	56.00	20.00	7.746	-0.52	0.662
		D&B(M)	8	-30.32%									
	Large	RAW/STABU	0	.									
		E&C	4	7.82%				6.00	12.00	6.00	2.828	0.00	1.000
		D&B(M)	3	-17.47%									
Equipment	Small	RAW/STABU	24	0.00%									
		E&C	10	-3.71%	0.068	2	0.967						
		D&B(M)	9	-2.01%									
	Medium	RAW/STABU	0	.									
		E&C	7	-16.10%				34.00	70.00	34.00	8.641	0.694	0.536
		D&B(M)	8	-1.08%									
	Large	RAW/STABU	0	.									
		E&C	4	-1.43%				6.00	12.00	6.00	2.828	0.00	1.000
		D&B(M)	3	-0.15%									
Subcontractors	Small	RAW/STABU	24	0.61%									
		E&C	11	1.04%	1.719	2	0.423						
		D&B(M)	9	-2.25%									
	Medium	RAW/STABU	0	.									
		E&C	7	2.44%				27.00	72.00	27.00	9.447	-0.48	0.681
		D&B(M)	9	1.18%									
	Large	RAW/STABU	0	.									
		E&C	4	-0.12%				8.00	14.00	8.00	2.828	0.707	0.629
		D&B(M)	3	9.73%									
Deliveries	Small	RAW/STABU	24	0.00%									
		E&C	10	2.50%	2.178	2	0.337						
		D&B(M)	9	-1.75%									
	Medium	RAW/STABU	0	.									
		E&C	7	1.89%				29.00	74.00	29.00	9.447	-0.27	0.837
		D&B(M)	9	2.14%									
	Large	RAW/STABU	0	.									
		E&C	4	2.15%				8.00	14.00	8.00	2.828	0.707	0.629
		D&B(M)	3	7.39%									
Engineering	Small	RAW/STABU	.	.									
		E&C	9	0.00%				23.00	59.00	23.00	10.33	-1.26	0.236
		D&B(M)	8	-35.70%									
	Medium	RAW/STABU	.	.									
		E&C	6	-7.04%				17.00	53.00	17.00	7.746	-0.9	0.414
		D&B(M)	8	-30.52%									
	Large	RAW/STABU	.	.									
		E&C	4	22.45%				3.00	9.00	3.00	2.828	-1.06	0.400
		D&B(M)	3	-15.37%									

1. The test statistic is adjusted for ties.

Table 31 Continued Statistical analysis of difference in cost groups between contract types clustered by project size.

Cost group	*Project size*	*Contract type*	*N*	*Median*	*Independent-Samples Kruskal-Wallis Test*			Independent-Samples Mann-Whitney U Test					
					Test Statistic[1]	*Degrees of Freedom*	*Asymptotic Sig. (2-tailed test)*	*Mann-Whitney U*	*Wilcoxon W*	*Test Statistic*	*Standard Error*	*Standardized Test Statistic*	*Exact Sig. (2-tailed test)*
Building site	Small	RAW/STABU	21	-10.93%									
		E&C	9	-3.84%	0.946	2	0.623						
		D&B(M)	9	0.00%									
	Medium	RAW/STABU	0	.									
		E&C	7	-4.54%				34.00	79.00	34.00	9.447	0.265	0.837
		D&B(M)	9	-1.27%									
	Large	RAW/STABU	0	.									
		E&C	4	-12.72%				9.00	15.00	9.00	2.83	1.06	0.400
		D&B(M)	3	0.81%									
Project Organisation / UTA	Small	RAW/STABU	24	-2.27%									
		E&C	10	-14.16%	2.671	2	0.263						
		D&B(M)	8	8.97%									
	Medium	RAW/STABU	0	.									
		E&C	7	7.91%				13.00	58.00	13.00	9.447	-1.96	0.055
		D&B(M)	9	-17.15%									
	Large	RAW/STABU	0	.									
		E&C	4	-16.59%				8.00	14.00	8.00	2.828	0.707	0.629
		D&B(M)	3	-3.29%									
Direct costs	Small	RAW/STABU	24	-0.41%									

Table 32 Statistical analysis of difference in cost groups between contract types clustered by project location.

					Independent-Samples Kruskal-Wallis Test			Independent-Samples Mann-Whitney U Test					
Cost group	*Project location*	*Contract type*	*N*	*Median*	*Test Statistic* [1]	*Degrees of Freedom*	*Asymptotic Sig. (2-tailed test)*	*Mann-Whitney U*	*Wilcoxon W*	*Test Statistic*	*Standard Error*	*Standardized Test Statistic*	*Exact Sig. (2-tailed test)*
Labour	Urban	RAW/STABU	9	-18.98%									
		E&C	5	-29.58%	1.770	2	0.413						
		D&B(M)	6	-28.79%									
	Rural	RAW/STABU	8	-9.90%									
		E&C	11	6.25%	0.738	2	0.691						
		D&B(M)	12	-2.42%									
Equipment	Urban	RAW/STABU	11	-4.90%									
		E&C	5	-7.59%	1.342	2	0.511						
		D&B(M)	6	-19.15%									
	Rural	RAW/STABU	13	0.00%									
		E&C	16	-3.65%	0.850	2	0.654						
		D&B(M)	15	-0.15%									
Subcontractors	Urban	RAW/STABU	11	1.84%									
		E&C	6	-1.54%	1.278	2	0.528						
		D&B(M)	7	-1.64%									
	Rural	RAW/STABU	13	0.00%									
		E&C	16	3.31%	3.057	2	0.217						
		D&B(M)	15	1.18%									
Deliveries	Urban	RAW/STABU	11	0.00%									
		E&C	6	1.72%	1.595	2	0.450						
		D&B(M)	7	-1.32%									
	Rural	RAW/STABU	13	0.00%									
		E&C	15	1.89%	0.863	2	0.650						
		D&B(M)	15	0.01%									
Engineering	Urban	RAW/STABU	.	.									
		E&C	6	-28.03%				12.00	33.00	12.00	6.245	-0.96	0.394
		D&B(M)	6	-42.58%									
	Rural	RAW/STABU	.	.									
		E&C	13	0.00%				53.00	158.00	53.00	20.58	-1.85	0.068
		D&B(M)	14	-12.69%									
Building site	Urban	RAW/STABU	10	-14.16%									
		E&C	5	0.00%	2.516	2	0.284						
		D&B(M)	7	-45.08%									
	Rural	RAW/STABU	11	0.00%									
		E&C	15	-8.28%	2.278	2	0.320						
		D&B(M)	15	0.00%									
Project Organisation / UTA	Urban	RAW/STABU	11	-19.38%									
		E&C	6	-28.93%	1.875	2	0.392						
		D&B(M)	7	-57.39%									
	Rural	RAW/STABU	13	0.00%									
		E&C	15	3.10%	0.615	2	0.735						
		D&B(M)	14	-1.58%									
Direct costs	Urban	RAW/STABU	11	0.00%									

Table 33 Statistical analysis of difference in cost groups between contract types clustered by type of client.

					Independent-Samples Kruskal-Wallis Test			Independent-Samples Mann-Whitney U Test					
Cost group	*Type of Client*	*Contract type*	*N*	*Median*	*Test Statistic*[1]	*Degrees of Freedom*	*Asymptotic Sig. (2-tailed test)*	*Mann-Whitney U*	*Wilcoxon W*	*Test Statistic*	*Standard Error*	*Standardized Test Statistic*	*Exact Sig. (2-tailed test)*
Labour	Rijkswaterstaat	RAW/STABU	0	.									
		E&C	0	.									
		D&B(M)	1	-20.49%									
	Province	RAW/STABU	2	37.98%									
		E&C	0	.				3.00	9.00	3.00	1.73	0.00	1.000
		D&B(M)	3	64.40%									
	Municipality	RAW/STABU	8	-12.18%									
		E&C	5	-18.11%	0.930	2	0.628						
		D&B(M)	5	-38.72%									
	ProRail	RAW/STABU	3	-18.78%									
		E&C	6	-21.28%	0.589	2	0.745						
		D&B(M)	5	-9.62%									
	Havenbedrijf	RAW/STABU	2	-20.06%									
		E&C	0	.									
		D&B(M)	0	.									
	Tennet	RAW/STABU	0	.									
		E&C	0	.									
		D&B(M)	2	19.41%									
	Private	RAW/STABU	2	-24.99%									
		E&C	4	9.75%	4.821	2	0.090						
		D&B(M)	1	42.12%									
	Water board	RAW/STABU	0	.									
		E&C	1	23.99%									
		D&B(M)	0	.									
	Schiphol	RAW/STABU	0	.									
		E&C	0	.									
		D&B(M)	1	-31.34%									
Equipment	Rijkswaterstaat	RAW/STABU	0	.									
		E&C	1	-17.89%				1.00	2.00	1.00	0.50	1.00	1.000
		D&B(M)	1	-16.36%									
	Province	RAW/STABU	3	-1.76%									
		E&C	1	13.38%	2.333	2	0.311						
		D&B(M)	4	1.09%									
	Municipality	RAW/STABU	9	-4.90%									
		E&C	7	-7.59%	0.696	2	0.706						
		D&B(M)	5	-22.94%									
	ProRail	RAW/STABU	5	13.05%									
		E&C	5	-7.41%	3.088	2	0.214						
		D&B(M)	6	-7.02%									
	Havenbedrijf	RAW/STABU	2	5.02%									
		E&C	0	.									
		D&B(M)	0	.									
	Tennet	RAW/STABU	0	.									
		E&C	1	20.48%				1.00	4.00	1.00	0.82	0.00	1.000
		D&B(M)	2	37.42%									
	Private	RAW/STABU	5	0.00%									
		E&C	4	6.60%	0.575	2	0.750						
		D&B(M)	2	2.02%									
	Water board	RAW/STABU	0	.									
		E&C	2	-18.49%									
		D&B(M)	0	.									
	Schiphol	RAW/STABU	0	.									
		E&C	0	.									
		D&B(M)	1	-2.30%									

1. The test statistic is adjusted for ties.

Table 33 Continued Statistical analysis of difference in cost groups between contract types clustered by type of client.

					Independent-Samples Kruskal-Wallis Test			Independent-Samples Mann-Whitney U Test					
Cost group	*Type of Client*	*Contract type*	*N*	*Median*	*Test Statistic* [1]	*Degrees of Freedom*	*Asymptotic Sig. (2-tailed test)*	*Mann-Whitney U*	*Wilcoxon W*	*Test Statistic*	*Standard Error*	*Standardized Test Statistic*	*Exact Sig. (2-tailed test)*
Subcontractors	Rijkswaterstaat	RAW/STABU	0	.									
		E&C	1	-1.69%				1.00	2.00	1.00	0.50	1.00	1.000
		D&B(M)	1	9.73%									
	Province	RAW/STABU	3	1.98%									
		E&C	1	10.88%	1.208	2	0.547						
		D&B(M)	4	1.44%									
	Municipality	RAW/STABU	9	0.46%									
		E&C	7	0.00%	2.428	2	0.297						
		D&B(M)	6	-2.52%									
	ProRail	RAW/STABU	5	2.08%									
		E&C	6	1.87%	1.182	2	0.554						
		D&B(M)	6	6.10%									
	Havenbedrijf	RAW/STABU	2	4.58%									
		E&C	0	.									
		D&B(M)	0	.									
	Tennet	RAW/STABU	0	.									
		E&C	1	-4.29%				2.00	5.00	2.00	0.82	1.23	1.000
		D&B(M)	2	5.43%									
	Private	RAW/STABU	5	0.00%									
		E&C	4	4.84%	3.023	2	0.221						
		D&B(M)	2	-1.02%									
	Water board	RAW/STABU	0	.									
		E&C	2	10.67%									
		D&B(M)	0	.									
	Schiphol	RAW/STABU	0	.									
		E&C	0	.									
		D&B(M)	1	-1.03%									
Deliveries	Rijkswaterstaat	RAW/STABU	0	.									
		E&C	1	1.79%				1.00	2.00	1.00	0.50	1.00	1.000
		D&B(M)	1	20.16%									
	Province	RAW/STABU	3	0.00%									
		E&C	1	0.12%	1.269	2	0.530						
		D&B(M)	4	-0.04%									
	Municipality	RAW/STABU	9	0.00%									
		E&C	7	0.98%	1.646	2	0.439						
		D&B(M)	6	0.17%									
	ProRail	RAW/STABU	5	6.35%									
		E&C	6	4.15%	4.652	2	0.098						
		D&B(M)	6	-7.76%									
	Havenbedrijf	RAW/STABU	2	0.00%									
		E&C	0	.									
		D&B(M)	0	.									
	Tennet	RAW/STABU	0	.									
		E&C	1	-57.80%				2.00	5.00	2.00	0.82	1.23	1.000
		D&B(M)	2	17.25%									
	Private	RAW/STABU	5	0.00%									
		E&C	4	2.15%	1.712	2	0.425						
		D&B(M)	2	-3.17%									
	Water board	RAW/STABU	0	.									
		E&C	1	2.79%									
		D&B(M)	0	.									
	Schiphol	RAW/STABU	0	.									
		E&C	0	.									
		D&B(M)	1	0.01%									

1. The test statistic is adjusted for ties.

Table 33 Continued Statistical analysis of difference in cost groups between contract types clustered by type of client.

					Independent-Samples Kruskal-Wallis Test			Independent-Samples Mann-Whitney U Test					
Cost group	*Type of Client*	*Contract type*	*N*	*Median*	*Test Statistic*[1]	*Degrees of Freedom*	*Asymptotic Sig. (2-tailed test)*	*Mann-Whitney U*	*Wilcoxon W*	*Test Statistic*	*Standard Error*	*Standardized Test Statistic*	*Exact Sig. (2-tailed test)*
Engineering	Rijkswaterstaat	RAW/STABU	.	.									
		E&C	0	.									
		D&B(M)	1	-15.37%									
	Province	RAW/STABU	.	.									
		E&C	0	.									
		D&B(M)	3	-10.01%									
	Municipality	RAW/STABU	.	.									
		E&C	6	-37.85%				8.00	23.00	8.00	5.48	-1.28	0.247
		D&B(M)	5	-59.67%									
	ProRail	RAW/STABU	.	.									
		E&C	6	1.69%				7.00	28.00	7.00	6.25	-1.76	0.093
		D&B(M)	6	-14.57%									
	Havenbedrijf	RAW/STABU	.	.									
		E&C	0	.									
		D&B(M)	0	.									
	Tennet	RAW/STABU	.	.									
		E&C	1	-24.00%				2.00	5.00	2.00	0.82	1.23	1.000
		D&B(M)	2	2.46%									
	Private	RAW/STABU	.	.									
		E&C	4	22.45%				1.00	4.00	1.00	2.03	-1.48	0.267
		D&B(M)	2	-33.03%									
	Water board	RAW/STABU	.	.									
		E&C	2	9.03%									
		D&B(M)	0	.									
	Schiphol	RAW/STABU	.	.									
		E&C	0	.									
		D&B(M)	1	-60.87%									
Building site	Rijkswaterstaat	RAW/STABU	0	0.00%									
		E&C	1	-12.08%				1.00	2.00	1.00	0.50	1.00	1.000
		D&B(M)	1	0.81%									
	Province	RAW/STABU	3	0.00%									
		E&C	1	-9.29%	0.500	2	0.799						
		D&B(M)	4	-1.07%									
	Municipality	RAW/STABU	9	-12.62%									
		E&C	7	0.00%	1.737	2	0.420						
		D&B(M)	6	-22.53%									
	ProRail	RAW/STABU	4	-2.30%									
		E&C	5	-2.79%	0.090	2	0.956						
		D&B(M)	6	0.32%									
	Havenbedrijf	RAW/STABU	2	-38.94%									
		E&C	0	.									
		D&B(M)	0	.									
	Tennet	RAW/STABU	0	.									
		E&C	0	.									
		D&B(M)	2	14.07%									
	Private	RAW/STABU	3	0.00%									
		E&C	4	-12.72%	1.552	2	0.460						
		D&B(M)	2	0.00%									
	Water board	RAW/STABU	0	.									
		E&C	2	-26.76%									
		D&B(M)	0	.									
	Schiphol	RAW/STABU	0	.									
		E&C	0	.									
		D&B(M)	1	-10.59%									

1. The test statistic is adjusted for ties.

Table 33 Continued Statistical analysis of difference in cost groups between contract types clustered by type of client.

					Independent-Samples Kruskal-Wallis Test			Independent-Samples Mann-Whitney U Test					
Cost group	*Type of Client*	*Contract type*	*N*	*Median*	*Test Statistic* [1]	*Degrees of Freedom*	*Asymptotic Sig. (2-tailed test)*	*Mann-Whitney U*	*Wilcoxon W*	*Test Statistic*	*Standard Error*	*Standardized Test Statistic*	*Exact Sig. (2-tailed test)*
Project Organisation / UTA	Rijkswaterstaat	RAW/STABU	0	.									
		E&C	1	11.25%				1.00	2.00	1.00	0.50	1.00	1.000
		D&B(M)	1	-16.45%									
	Province	RAW/STABU	3	0.00%									
		E&C	1	22.79%	2.755	2	0.252						
		D&B(M)	4	2.09%									
	Municipality	RAW/STABU	9	-19.38%									
		E&C	6	-14.16%	3.086	2	0.214						
		D&B(M)	6	-58.50%									
	ProRail	RAW/STABU	5	-4.45%									
		E&C	6	-16.49%	0.741	2	0.690						
		D&B(M)	5	-4.23%									
	Havenbedrijf	RAW/STABU	2	-33.16%									
		E&C	0	.									
		D&B(M)	0	.									
	Tennet	RAW/STABU	0	.									
		E&C	1	-91.59%				2.00	5.00	2.00	0.82	1.23	1.000
		D&B(M)	2	-5.70%									
	Private	RAW/STABU	5	0.00%									
		E&C	4	6.66%	1.205	2	0.548						
		D&B(M)	2	18.56%									
	Water board	RAW/STABU	0	.									
		E&C	2	3.02%									
		D&B(M)	0	.									
	Schiphol	RAW/STABU	0	.									
		E&C	0	.									
		D&B(M)	1	-17.15%									

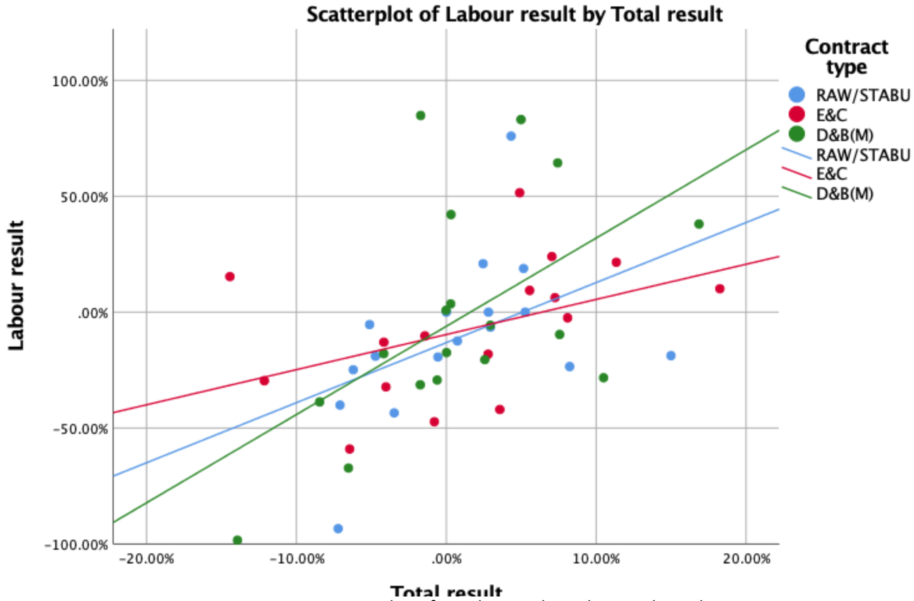


Figure 19 Scatterplot of result on Labour by Total result

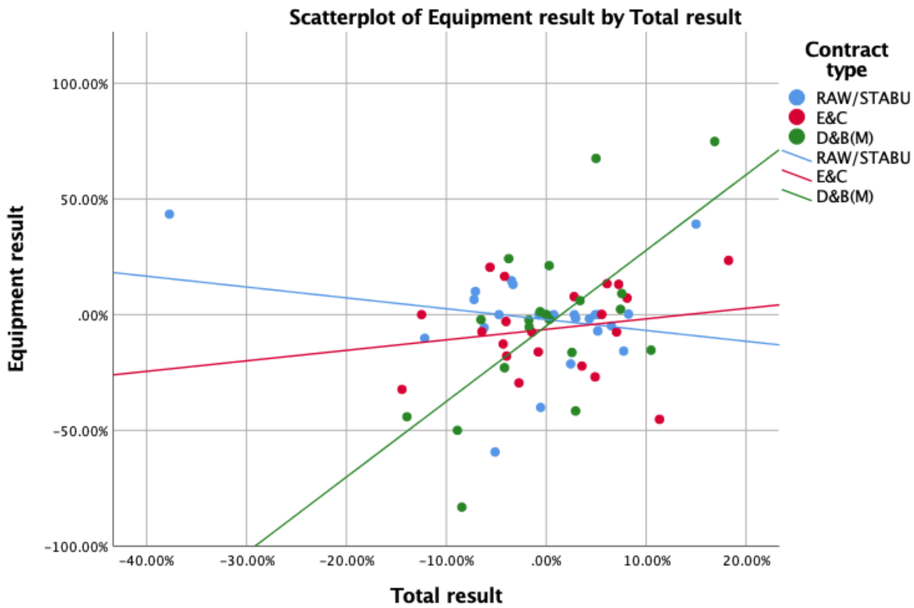


Figure 20 Scatterplot of result on Equipment by Total result

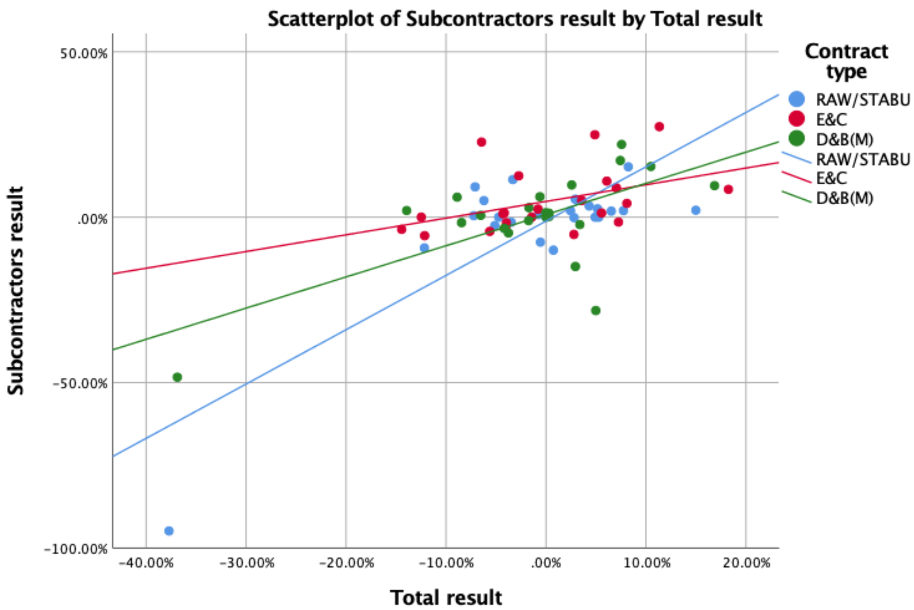


Figure 21 Scatterplot of result on Subcontactors by Total result

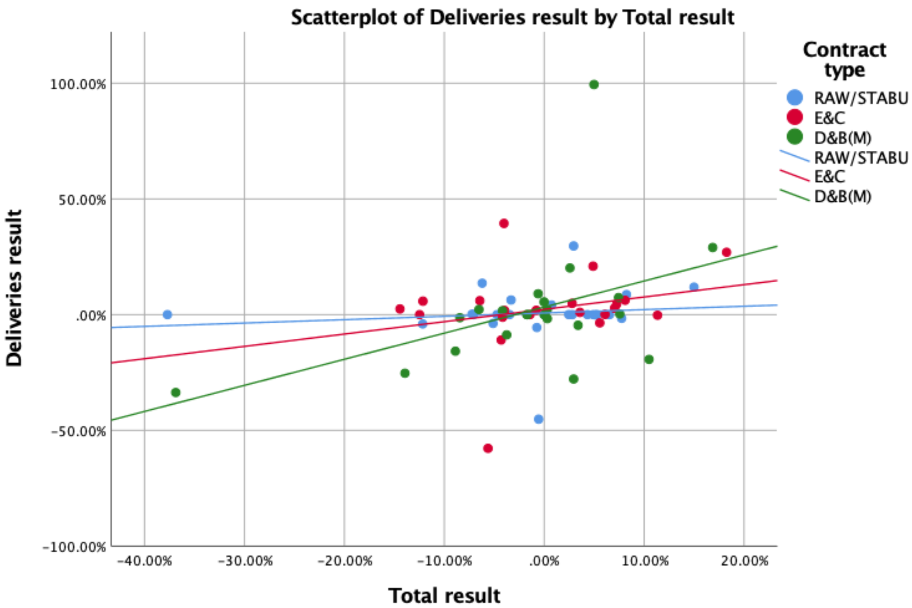


Figure 22 Scatterplot of result on Deliveries by Total result

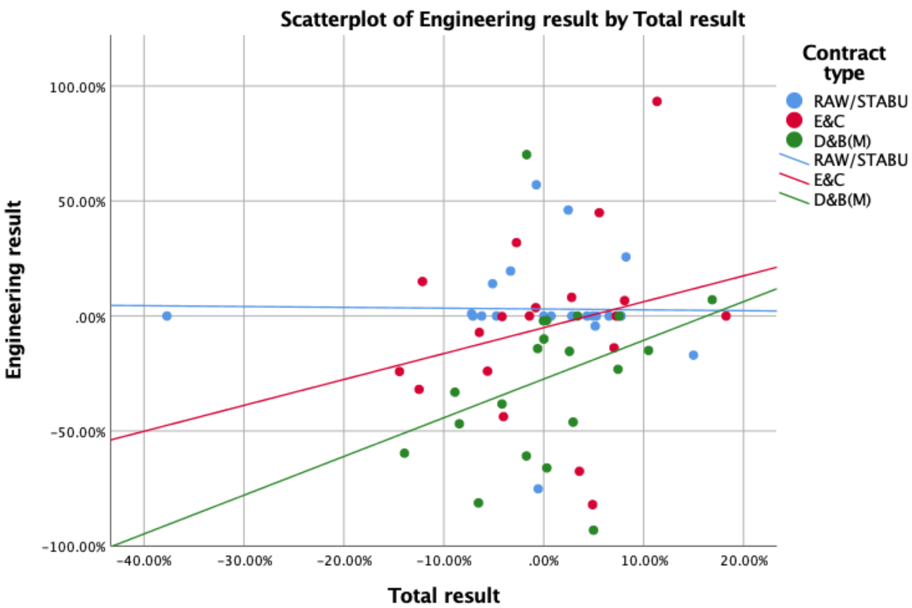


Figure 23 Scatterplot of result on Engineering by Total result

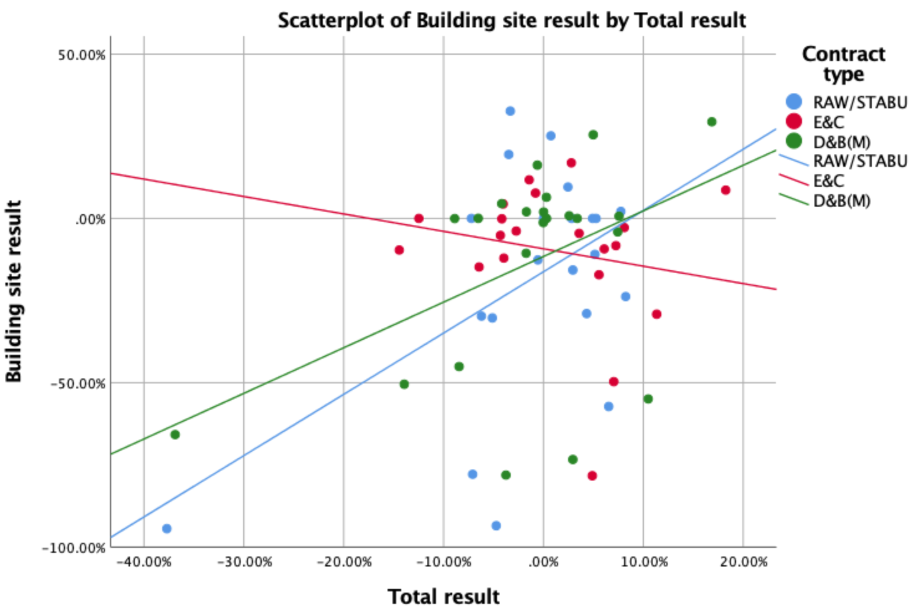


Figure 24 Scatterplot of result on Building site by Total result

Figure 25 Scatterplot of result on Project organisation by Total result

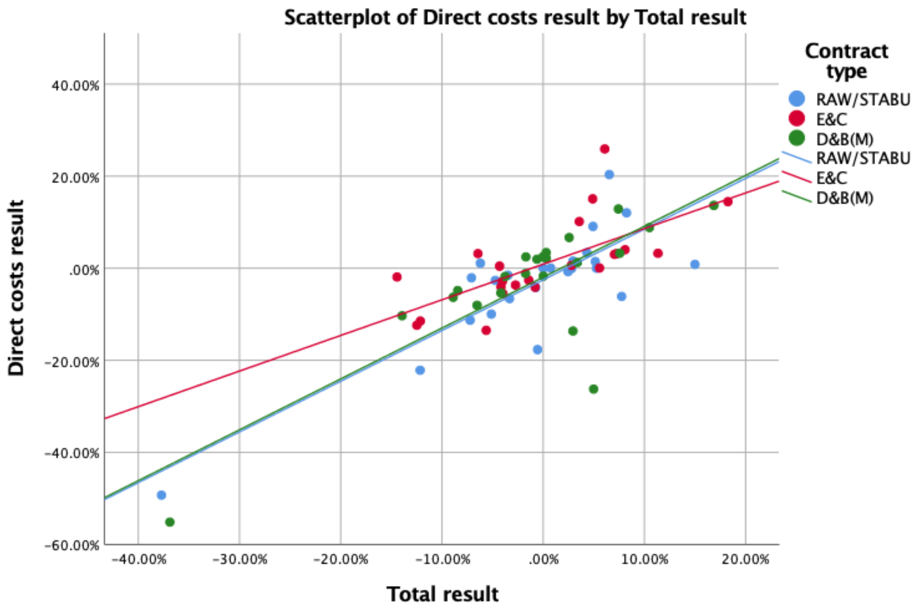
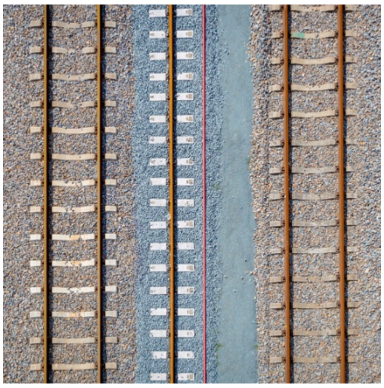


Figure 26 Scatterplot of result on Direct costs by Total result

NOTES





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