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Case Study

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

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**Abstract:** Current literature shows that poor cost performance in projects has become routine. Research on cost performance has mostly focused on one of the involved parties, either the client or the contractor. Not many research efforts discuss the cost contingency performance of projects. This research discusses the cost performance and cost contingency of projects in the execution phase from the perspective of a client as well as a contractor. Using a case study approach, 95 projects are investigated: 44 client projects and 51 contractor projects. The results show that depending on the perspective, projects can have cost overruns or cost underruns. Comparing the total realized and estimated costs, projects experienced on average about 16% underrun from a client perspective. From a contractor perspective, projects experienced on average up to 2% overrun. The estimated cost contingency in the client's projects was on average 2.64% more than the required cost contingency. The estimated cost contingency in the contractor's projects was on average 5.41% less than the required cost contingency. These differences are explained by *pessimism bias* and technical reasons on the client's side. On the contractor side, *optimism bias* and technical and political reasons play a role, resulting in opportunistic behavior. The findings help practitioners to enhance their cost estimates by avoiding both pessimistic bias and optimism bias behavior—for example, by using historical data from earlier projects. Further investigation into the influence of market conditions on cost estimates is suggested. **DOI: 10.1061/(ASCE)ME.1943-5479.0000772.** 

**Author keywords:** Risk management; Contingency reserve; Cost estimate; Construction projects; Cost performance.



## Introduction

Cost is one of the basic elements of the iron triangle of project management and a crucial element in funding decisions of projects. It is also one of the most basic parameters for measuring project success. An accurate cost estimate is an important element in the cost control of a project. A cost estimate is a quantitative assessment, based on the available information at a given point in time, of the likely costs for resources required to complete a project (PMI 2013). To obtain an accurate cost estimate, comprehensive information, expanded knowledge, considerable expertise, and continuous improvement are required (Hatamleh et al. 2018). Accuracy in a cost estimate can be defined as an indication of the degree to which the final cost outcome of a project may vary from the estimated cost of the project (Ogilvie et al. 2012).

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

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

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

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is then added to the raw estimates (known as base costs) to form the cost baseline.

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

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

## Literature Review

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

Many scholars have studied the reasons for cost overrun. Among recent studies, research by Li et al. (2018) shows that cost overruns in projects are related to the level of trust between stakeholders. The shortage of skilled workers in North America has been identified as another factor with significant influence on cost overrun of projects (Karimi et al. 2018). Organizational behaviors such as the incentives or the reporting environment have a significant effect on the ability to create accurate cost estimates (Grau et al. 2017).

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

- Technical reasons include forecasting errors expressed in technical terms, such as imperfect forecasting techniques, inadequate data, and lack of experience.
- Economic reasons involve issues of either economic (self) interest or public interest. Project promoters deliberately underestimate costs in order to make projects look more attractive and thereby increase the chance of being selected.
- Psychological reasons comprise the concepts of planning fallacy and optimism bias. Planning fallacy means the tendency to underestimate the time needed to complete certain tasks, and optimism bias is the systematic tendency to be overoptimistic by overestimating benefits and underestimating costs.
- Political reasons include strategic misrepresentation through the deliberate and strategic underestimation of costs when forecasting the outcomes of projects.

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

## Problem Formulation and Research Objectives

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

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

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

This research answers the main research question by

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

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

## Methods

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

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

Scholars such as Flyvbjerg et al. (2002), Cantarelli et al. (2012c), Flyvbjerg et al. (2003), Hollmann (2012), and Cantarelli et al. (2012a) compare the estimated and realized costs in two moments of time: (1) the cost estimate at the time of formal decision to build (ToD); and (2) the realized costs at the year of completion.

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

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

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

### Data Collection of the Client's Projects

The data from the client part is collected from the archive of the Flood Protection Program [known as Hoogwaterbeschermingsprogramma (HWBP)] in the Netherlands. The program is part of the Ministry of Infrastructure and Water Management (in Dutch: Ministerie van Infrastructuur en Waterstaat) and is responsible for improving all the flood protection facilities (such as dikes, locks, pumps, etc.) in the Netherlands which do not meet the safety norms. The flood defense facilities in the Netherlands are examined every 5 years and each flood defense facility that does not meet the safety norms will be improved in a project. Each batch of projects is governed under a program of projects. The Flood Protection Program is responsible for approving the subsidy required for the

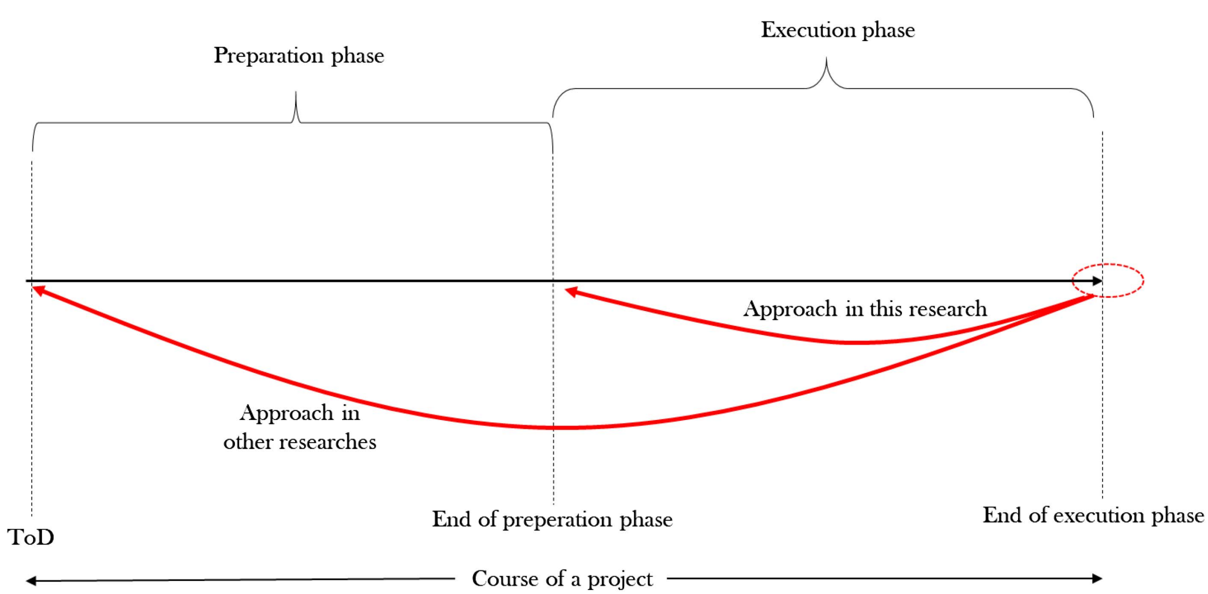


**Fig. 1.** Comparing the scope of this research with other research efforts in the course of a project.



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execution of these projects. The regional public organizations, known as waterboards, responsible for the flood defense facilities have to submit their estimated budgets to the program. The submitted estimate is reviewed and tested several times by the Flood Protection Program in the preparation phase, and the program provides the waterboards with the required funding by giving the approval of the final estimates. After this step, the project is awarded to a contractor. After project completion, the realized costs of the project are calculated. In the case of realized project costs being less than the estimated costs, the waterboards pay the remaining budget back to the Flood Protection Program. In the case of actual project costs being more than the estimated project costs, the Flood Protection Program pays the extra costs to the waterboard.

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

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

1. The projects are finished; and
2. The final cost estimate documents at the beginning of execution and the cost estimate documents showing the realized costs of the project after the project completion (Fig. 1) are available.

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

### Data Collection of the Contractor's Projects

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

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

### Calculating the Cost and Cost Contingency Performance of the Projects

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

1. The *estimated base cost* is equal to the summation of the estimated work packages of construction, engineering, real estate, and other costs, without the estimated cost contingency, before the start of the project execution. Real estate costs are the costs to buy the ground (or the building) that is the property of a third party which is located in (part of) the project location and should be bought for project execution. Real estate costs are the responsibility of the client and are, therefore, only collected from the client's projects.
2. The *estimated cost contingency* is the estimated amount of cost contingency to cover the uncertainties during the project execution.
3. The *total estimated costs* are the summation of the estimated base cost and the estimated cost contingency. This amount is the approved budget for the project execution (in the case of the client) or the contract amount (in the case of the contractor).

From the cost documents of the client and the contractor at the end of the execution phase, the *total realized costs* at the year of project completion are collected.

The cost performance, expressed in percentage, is calculated as shown in Eq. (1)

$$\%\text{Cost performance} = \frac{(\text{Total realized costs} - \text{Total estimated costs})}{\text{Total estimated costs}} \tag{1}$$

In the case of both the client and the contractor, the total realized costs are given in the documents as the summation of realized costs of different work packages (construction, engineering, real estate, and other) but the required cost contingency is not given separately. The amount of required cost contingency is covered in each work package. In other words, the required cost contingency of the projects cannot be extracted directly. To compare the estimated and the required cost contingency, the following information is still needed:

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

These costs are calculated by another approach.

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

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

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

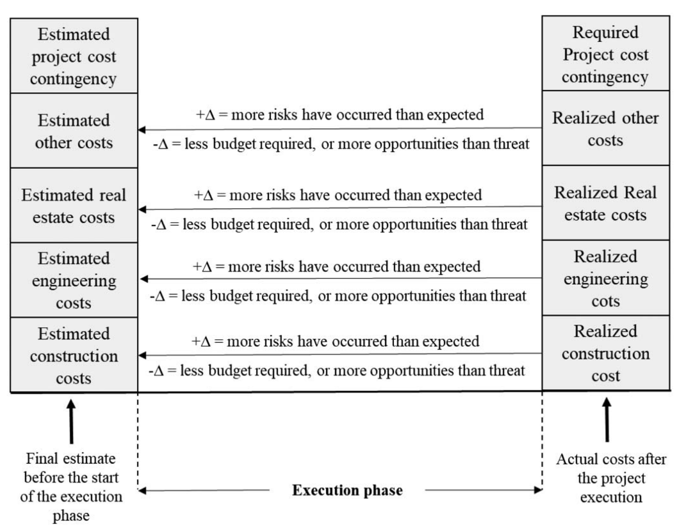



**Fig. 2.** Comparing the realized and estimated costs.

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

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

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

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

In Project 2 (Table 2), the realized engineering costs are less than estimated, so it has a $-\Delta$. This can be due either to grasping the opportunities or to mistakes in the estimate. The realized construction costs, real estate cost, and other costs are higher than the estimated costs, so they have a $+\Delta$. The project has finished with a cost overrun equal to €6,369,041. The required cost contingency to address the negative risks is equal to the summation of the $+\Delta$s of the work packages construction, other costs, and real estate costs (Table 2), which is €10,905,528. The $-\Delta$ of the engineering work package has contributed to a lower cost overrun at the end, but this amount is not considered to calculate the required contingency to cover the negative risks in the project.

The abovementioned arguments are summarized in Eq. (2). The required cost contingency is, therefore, equal to the summation of positive deltas

$$\text{Required cost contingency} = \sum_{i=1}^{p} \Delta_i^{+} \tag{2}$$

where $p$ = number of work packages with a $+\Delta$.

To calculate the required base cost, the costs that were actually needed for each work package are considered. The minimum amount of the estimated and realized costs for each work package is equal to the required costs of that work package because that is the amount that the project actually needed to realize that work package. For example, in the case of Project 1 (Table 1), in the engineering work package, the realized cost is the amount that the project actually required for that work package (i.e., the minimum amount between the estimated and realized costs for that work package). In the case of Project 1, the required base cost is, therefore, equal to the summation of the realized costs of the engineering work package (€728,938), the realized costs of the construction work package (€20,749,876), the realized costs of the other costs work package (€114,358), and the real estate work package (€0). The required base cost is calculated as shown in Eq. (3).

$$\text{Required base cost} = \sum_{i=1}^{p} \text{Min}(\text{Estimated work package}_i, \text{Realized work package}_i) \tag{3}$$

The percentage of required cost contingency is calculated as

$$\%\text{Required cost contingency} = \frac{\text{Required cost contingency}}{\text{Required base cost}} \times 100 \tag{4}$$

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

**Table 1.** First example of calculating the required cost contingency to address the negative risks

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

**Table 2.** Second example of calculating the required cost contingency to address the negative risks

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

## Results and Analysis

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

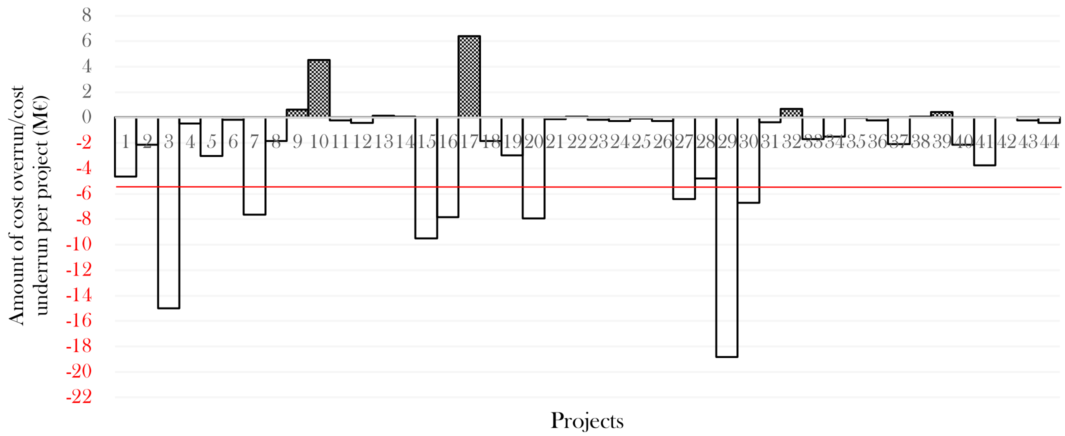



**Fig. 3.** Cost performance of the client's projects.

### *Investigating the Client's Projects*

#### Cost Performance in the Projects of the Client

Fig. 3 presents the cost performance of the client's projects. The cost performance is calculated by subtracting the total estimated costs from the total realized costs (cost performance = total realized costs − total estimated costs). A positive amount means that the project has cost overrun, while a negative amount means that the project has cost underrun. As shown in Fig. 3, most of the projects have cost underrun. For most of the projects with cost underrun, the amount of cost underrun is between zero and €5 million. The maximum amount of cost underrun is €18.82 million (Project 29). The total estimated costs of 44 projects are €1,130.52 billion (average of estimated costs is €25.7 million) and the total realized costs are €1,027.81 billion (average of actual costs is €23.4 million).

**Table 3.** Descriptive statistic of amount (in million euro, M€) of cost overrun and underrun in client's project

| Statistics description | Cost underrun (M€) | Cost overrun (M€) | Cost underrun (%) | Cost overrun (%) |
|---|---|---|---|---|
| Mean | −3.3 | 1.44 | −21.58 | 6.05 |
| Standard deviation | 4.40 | 2.35 | 16.37 | 9.09 |
| Sum | −115.66 | 12.95 | — | — |
| Count | 35 | 9 | 35 | 9 |

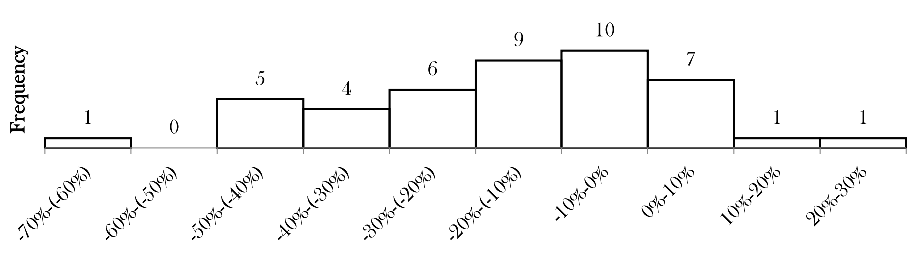
This means that the projects have a total of €102.71 million (9.09%) cost underrun. Only nine projects (Projects 9, 10, 13, 14, 17, 22, 32, 38, and 39, as shaded in the graph) out of 44 (20.45%) have experienced cost overrun, and the total amount of overrun for these nine projects is €12.95 million (1.15% of the total estimated cost). Except for Project 10 (with €4.53 million cost overrun) and Project 17 (with €6.41 million cost overrun), the amount of cost overrun for the rest of the projects is negligible.

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

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

#### Investigating the Estimated and Required Cost Contingency in the Client's Projects

Only 30 out of 44 projects have enough data to estimate the required cost contingency according to the procedure shown in Fig. 2.




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

**Fig. 4.** Distribution and statistical analysis of percentage of cost performance of the client's projects ($N = 44$).

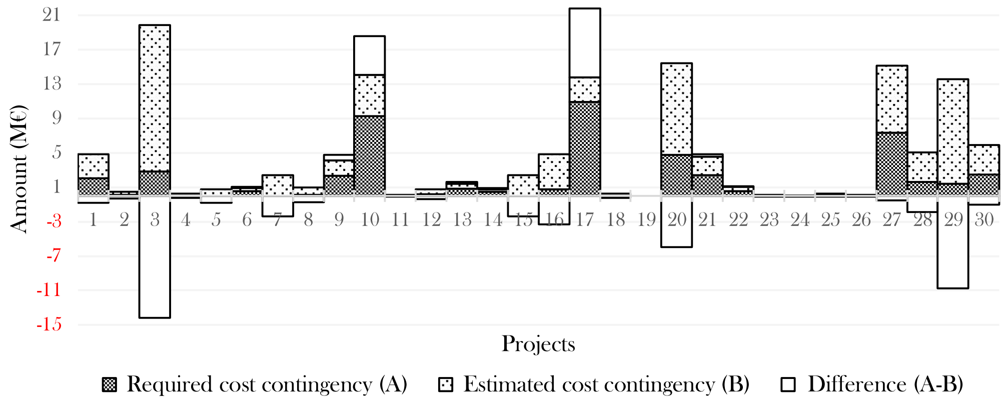



**Fig. 5.** Comparing the required and estimated cost contingency of the client's projects ($N = 30$).

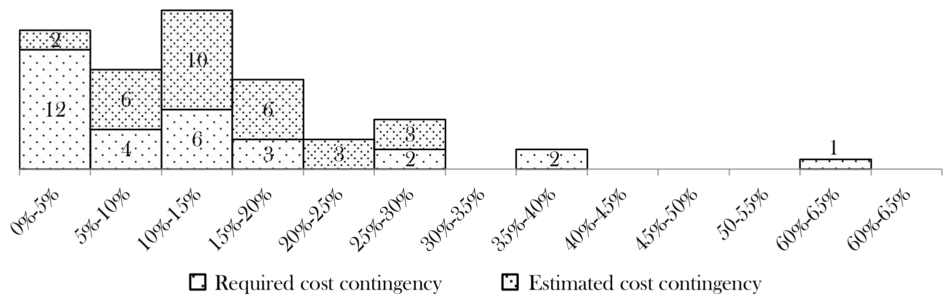



**Fig. 6.** Comparing the percentage of estimated and required cost contingency of the client's projects ($N = 30$).

The estimated cost contingency was extracted directly from the documents. The percentage and the amount of the required cost contingency of these 30 projects are calculated based on Eqs. (2) and (4). Fig. 5 compares the amount of required cost contingency (A), estimated cost contingency (B), and the difference between required and estimated cost contingency (A–B). Except for eight projects (Projects 6, 9, 10, 13, 14, 17, 21, and 22), the rest of the projects have higher cost contingency estimated than required. Projects 10 and 17 have the largest differences between estimated and required cost contingency (€4.53 million and €8.03 million, respectively). The total amount of estimated cost contingency is €83.20 million, while the required cost contingency is €51.18 million. This difference is about €32 million (38%).

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

The statistical analysis of the estimated and required cost contingency is provided in Table 4. The mean of the estimated cost contingency is €2.7 million, while the mean of the required cost contingency is €1.7 million, meaning that on average the projects have €1 million extra cost contingency. The average estimated cost contingency is 14.21%, and the average required cost contingency is 11.57% (on average 2.64% extra reservation).

The results show that the client's projects have higher estimated costs than required and most of the projects are realized below the estimated budget. Less required cost contingency than estimated cost contingency confirms that the projects were less risky and

**Table 4.** Statistical analysis of estimated and required cost contingency in M€ ($N = 30$)

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

uncertain than expected or that the opportunities in these projects were underestimated. The following section investigates the cost performance of the contractor's projects.

## Investigating the Contractor's Projects

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

### Cost Performance in the Projects of the Contractor

Fig. 7 shows the cost performance of the contractor's projects. Again, the cost performance is calculated by subtracting the estimated budget from the realized budget (cost performance = total realized costs − total estimated costs). From 51 projects, 26 (50.98%) have experienced cost overrun (shown by shaded bars on the graph). Only two projects have experienced cost overrun more than €3 million (Projects 2 and 5). The maximum amount

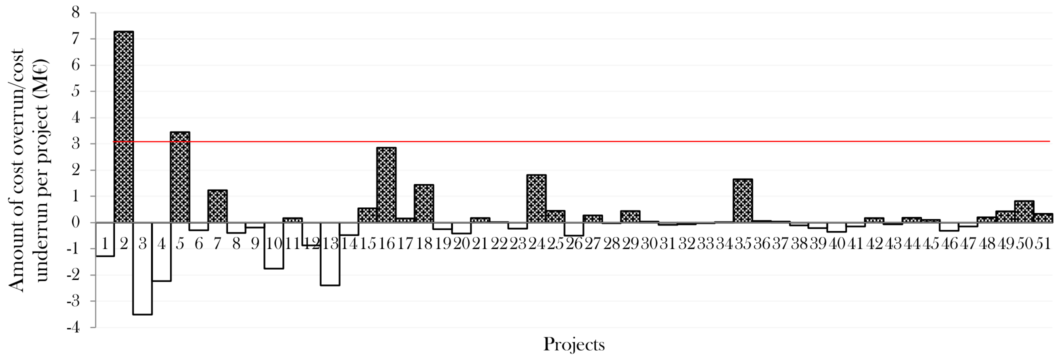



**Fig. 7.** Cost performance of the contractor's projects.

**Table 5.** Descriptive statistic of amount (in million euro, M€) of cost overrun and underrun in contractor projects

| Statistics description | Cost underrun (M€) | Cost overrun (M€) | Cost underrun (%) | Cost overrun (%) |
|---|---|---|---|---|
| Mean | −0.65 | 0.94 | −4.10 | 7.78 |
| Standard deviation | 0.9 | 1.57 | 3.2 | 7.8 |
| Sum | −16.28 | 24.38 | — | — |
| Count | 25 | 26 | 25 | 26 |

of cost overrun is €7.29 million (Project 2) and the maximum amount of cost underrun is €3.52 million (Project 3). The total estimated costs of the 51 projects are €711.75 million and the total realized costs are €719.84 million. This means that the projects have a total of €8.1 million (1.28%) cost overrun.

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

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

## Investigating the Estimated and Actual Cost Contingency in the Contractor's Projects

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

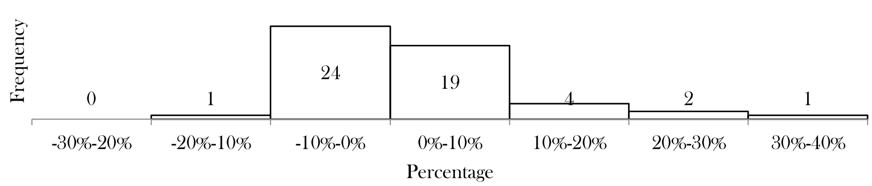
The histogram presented in Fig. 10 compares the percentage of estimated and required cost contingency in 51 contractor's projects. The percentage of required cost contingency is more skewed to the right, meaning that the projects have required more cost contingency than what was estimated. The estimated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

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

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

## *Comparing the Results of the Client's and the Contractor's Projects*

The results show that the contractor's projects have experienced more cost overrun than the client's projects. While the client's projects have on average −15.93% cost underrun (Fig. 4), the




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

**Fig. 8.** Descriptive analysis of percentage of cost performance of the contractor's projects.

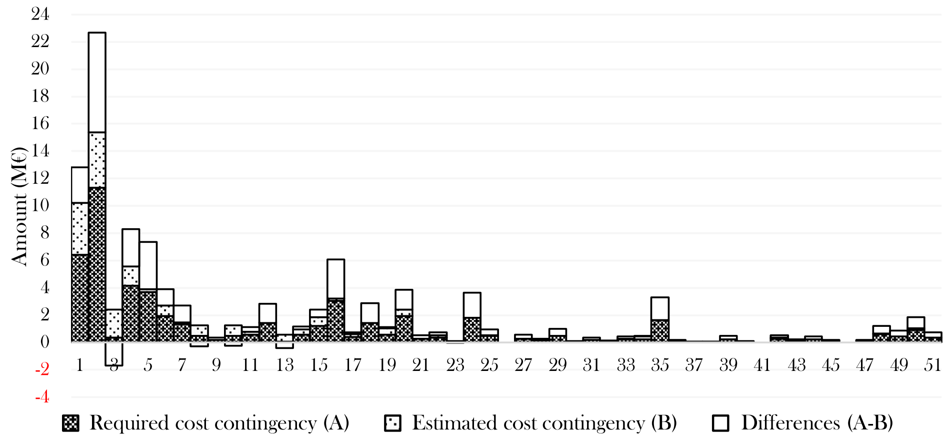



**Fig. 9.** Comparing the required and estimated cost contingency of the contractor's projects ($N = 51$).

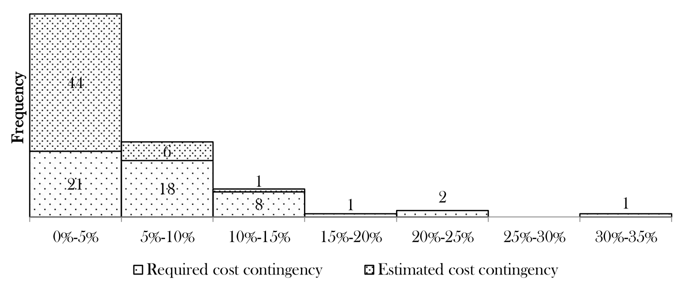



**Fig. 10.** Comparing the percentage of estimated and required cost contingency of the contractor's projects ($N = 51$).

**Table 6.** Statistical analysis of estimated and required cost contingency in M€ ($N = 51$)

| Statistics description | Estimated cost contingency (M€) | Required cost contingency (M€) | Estimated cost contingency (%) | Required cost contingency (%) |
|---|---|---|---|---|
| Mean | 0.35 | 1.01 | 1.65 | 7.06 |
| Standard deviation | 0.82 | 1.91 | 2.4 | 6.85 |
| Minimum | 0 | 0 | 0 | 0 |
| Maximum | 4.05 | 11.33 | 10.57 | 34.37 |
| Sum | 17.96 | 51.47 | — | — |

contractor's projects have 1.96% cost overrun (Fig. 8). Comparing the results of the contractor in Table 5 with the results of the client in Table 3, the contractor shows a larger percentage of cost overrun than the client's projects.

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

### *Comparing the Results of the Client's Projects with a Similar Study*

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

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

## Discussion

The research has investigated the cost performance and cost contingency of 44 client projects and 51 contractor projects in the



J. Manage. Eng., 2020, 36(4): 05020006

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

| Statistics description | Flood defense projects (client in this research) | Study by Cantarelli et al. (2012b) |
|---|---|---|
| Mean | −15.93% | −4.5% |
| Standard deviation | 18.82 | 14.4 |
| Range | −65.94%–28.18% | −35.4%–22.8% |
| Count | 44 | 37 |
| % of projects with cost underrun | 79.5 | 62 |

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

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

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

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

As mentioned earlier, Flyvbjerg et al. (2002) identify four main reasons for cost overrun: technical, economic, psychological, and political. For the contractor in this research, technical, psychological, and political reasons seem more convincing as the reasons for cost overrun. Due to the role of contractors, economic reasons are less applicable (i.e., a contractor could not make the project more attractive to get the funding). The cost overrun in the contractor's projects can be a result of mistakes in the estimates (technical reasons). The costs might be underestimated due to psychological reasons because the contractor was overoptimistic or due to political reasons to just win the contract. The fact that some projects have no or very little estimated cost contingency (Figs. 9 and 10) confirms the presence of either optimism bias (psychological reasons) or intentionally changing the estimates (political reasons). The study by Jung and Han (2017) demonstrated that risk opportunistic behavior in bid preparation by the contractor is not uncommon. The market conditions can lead to intentionally changing the estimates. The market conditions and number of contractors signing up for the tender can (negatively) affect the contractors' cost estimates. Liu and Napier (2010) mention that the contractor's tender prices are often a product of not only the estimating department but also managers' objectives; managers may reduce prices in an ad-hoc manner to unrealistic levels in an attempt to win the job (political reasons). The average estimated cost contingency is low (as shown in Table 6). It is possible that the contractor has cut contingency costs with the hope to win the contract and then secure the profit margins by claiming extra work.

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

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

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

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

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

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

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

## Conclusion and Recommendations

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

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

Regarding the cost contingency, the results endorse that the client's projects had on average €1 million extra cost contingency reserved (14.21% estimated cost contingency versus 11.57% required cost contingency). Contrariwise, most of the contractor's projects had a lack of cost contingency (1.65% estimated cost contingency versus 7.06% required cost contingency).

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

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

### Recommendation for the Practice

First, it is recommended that historical data of finished projects is collected for both the client and contractor organizations and is used to estimate the costs of new projects.

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

### Limitation and Future Research

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

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

This research has investigated the estimated and realized costs in two moments: (1) end of the preparation phase; and (2) end of the execution phase (Fig. 1). It is suggested that future research consider the moment of ToD as well and compare the costs in three moments as shown in Fig. 1.

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

## Data Availability Statement

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

## Acknowledgments

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