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Drivers of Contingency and Cost Reserve in Cost Risk Analysis

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Abstract

Cost risk analyses play a crucial role in budgeting and decision-making for large-scale public projects. This article investigates the factors that influence the size of contingency and cost reserves derived from such analyses. Based on a dataset of 107 real-life projects in Norway and regression modeling, the study finds that building projects typically have lower relative contingency and cost reserves, likely due to their standardized nature and more predictable cost structures. Projects in early planning phases (QA1) show significantly higher risk buffers, reflecting increased uncertainty and project immaturity. Notably, the identity of the assignment manager shows a significant effect, particularly on cost reserves, indicating the potential impact of individual judgment within group-based analysis processes. While the models explain a moderate share of the variation (R^2 = 0,20/0,32), the findings emphasize both technical and procedural factors that influence the outcomes of cost risk assessments. These insights may support efforts to strengthen methodological consistency and reduce subjective bias in future project evaluations.

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Keywords: Project management; Quality assurance; Cost risk analysis; Contingency and Cost Reserve

1. Introduction

Large-scale public investment projects are often characterized by significant cost uncertainty. As a response to recurring cost overruns and project delays, many governments have introduced formal procedures for project quality

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assurance, including structured cost risk analyses. In Norway, the Government's Project Model requires that all state-financed projects exceeding a certain budget threshold undergo two external quality assurance phases as part of the decision-making process.

These phases include mandatory cost risk analysis which forms the basis for setting cost management targets. The analysis typically results in an S-curve representing the probability distribution of total project cost, where the P50 and P85 percentiles are used to define probabilistic cost thresholds. While the quantification of uncertainty is supported by structured methodologies, it remains partly dependent on subjective judgments and assumptions made by analysts and project stakeholders. Consequently, the size of the resulting contingency and cost reserve may vary significantly between projects, even when using similar methodologies.

This study aims to investigate the factors that influence the relative size of contingency and cost reserve. This raises the following research question:

"*What factors influence the size of the contingency and cost reserve resulting from cost risk analyses in large-scale projects?*

Answering this question is essential not only for improving the transparency and consistency of project budgeting but also for ensuring that public resources are allocated effectively and responsibly.

2. S-curve, P50, P85, Contingency and Cost reserve

The S-curve is a key output from a cost risk analysis and presents the probability distribution of the project's final cost [1]. In the S-curve P50 represents the project cost that, according to the analysis, has a 50% probability of not being exceeded. P85 represents the cost with an 85% probability of not being exceeded, based on the same analysis. Figure 1 shows an example of an S-curve. It is important to emphasize that the base estimate corresponds to a single deterministic value and may lie at any point along the cumulative cost distribution curve, depending on the underlying assumptions and estimation methodology. In contrast, P50 and P85 are probabilistic outputs derived from the cost risk analysis and are fixed percentiles on the cumulative probability axis.

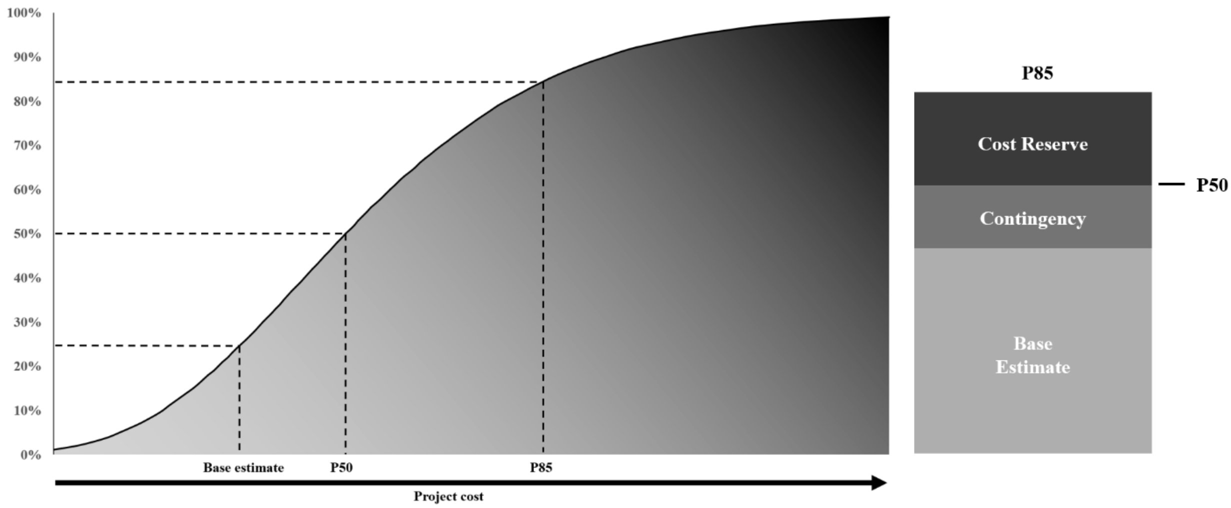

Figure 1: S-curve with Base Estimate (illustrative), P50 and P85 marked on the X-axis. The relationship between base estimate, contingency, and cost reserve is shown to the right. Contingency and cost reserve is added to the base estimate to acquire the P50 and P85 value.

3. Literature review

A risk analysis is a systematic approach for identifying, describing, and quantifying risk [2]. Risk analysis can be divided into a qualitative and a quantitative component [3]. The qualitative part involves describing risks, their causes, and the potential for wanted or unwanted consequences. The quantitative part focuses on assessing numerical values to the range of possible outcomes, enabling the use of these assessments for project prioritization and control.

All methods typically establish and describe a qualitative scenario model as a foundation for subsequent quantification [3]. The quantification process involves a standard probability distribution and defining the exact probability density function by identifying key points on the curve. In Norwegian methodologies, these points are commonly determined using a three-point estimate based on subjective judgment

The Government's Project Model in Norway demands that projects with a project cost above one billion Norwegian kroners (or 300 million Norwegian kroners for digitalization projects) shall go through a quality assurance process [4]. The quality assurance process is divided into two mandatory decision points: quality assurance 1 (QA1) and quality assurance 2 (QA2). As a part of both the quality assurance processes, a cost risk analysis is conducted to recommend a P50 and a P85 [5]. These analyses are conducted by professionals working with such analyses with input and insight from the project team. The results from the cost risk analysis and the quality assurance report are important for further processing and a possible investment decision.

Earlier studies have compared the results of cost risk analyses at QA2 with the final costs of completed projects. A 2019 study revealed that although management goals resulting from QA2 generally appear realistic, projects over time tend to shift from cost underruns to cost overruns relative to the contingency and cost reserve [6]. The study attributes this trend to an overly optimistic outlook on projects, leading to underestimated contingencies and cost reserves.

However, we found that previous research on cost risk analysis lacks studies identifying the specific factors that determine the size of a project's contingency and cost reserve. A recent study on IT projects shows what factors tend to increase the cost risk in IT projects [7]. Even though the study concludes that IT projects have greater cost risk compared to other types of projects, it does not directly identify drivers that affect the size of contingency or cost reserve.

4. Data

This paper reviews 107 cost risk analyses. 60 of them are standalone cost risk analyses and 47 are conducted as a part of the quality assurance process through The Government's Project Model in Norway. The 47 analyses conducted through the Project Model in Norway are part of either the QA1 or QA2 process. The projects included in the analysis are from five different industries. The distribution of the assignment types across the industries are shown in Table 1.

Table 1. Distribution of assignment types (Cost risk analysis, QA1 and QA2) per industry.

Project type	Total	Cost risk analysis	QA1	QA2
Building	47	28	11	8
Construction	51	30	11	10
Defence	4	0	1	3
Industry	1	1	0	0
IT and telecommunication	4	1	2	1

Examples of included projects in this paper are:

- New water supply in Oslo
- Trøndelag Commuter Rail
- Majorstuen metro station (One of Oslo's major metro stations)
- Hammerfest airport

5. Methodology

5.1 Collection of data

In order to analyze the research question, it was necessary to populate a database with relevant information. The database is populated with information from the reviewed 107 cost risk analyses where the majority are dated within the years 2019-2024. Table 2 shows the headers in this database.

Table 2. Columns in the established database.

Project name.	Project phase	Project type	Assignment manager	Base estimate	Contingency	Cost reserve	Rel. Contingency	Rel. Cost Reserve

The two rightmost columns, Relative Contingency and Relative Cost Reserve, are simply defined as Contingency and Cost Reserve divided by the Base estimate. This gives the relative size of these factors in regard to the base estimate.

5.2 Standardization of project types and categories

This study aims to investigate factors that can influence contingency and cost reserve, and how this may vary among different types of projects. To ensure a sufficient number of cases within each industry and enable a meaningful analysis, it was necessary to categorize the projects by industry type. The number of industry types was deliberately chosen to ensure a reasonable number of analyses within each industry to find a balance between having enough project within each industry for a reliable statistical analysis, while also ensuring that each industry was narrow enough to avoid grouping unrelated projects together.

The 107 analyses in the database have been sorted based on project description and a careful assessment of the relevant industry for each project category. This standardization process was conducted jointly by the authors and experienced internal professionals with experience in the industries and The Government's Project Model in Norway. Based on the characteristics of the projects in the dataset, five distinct industry types were defined: building, construction, defence, industry, and IT and telecommunication.

In several cases, the industry classification was straightforward – particularly for defence, industry, and IT and telecommunication. However, we found it necessary to distinguish between the building and construction industries, even though these are sometimes treated as overlapping in other contexts. In this study, the building category includes projects where the construction of a building is the primary focus, such as hospitals, renovation projects, kindergartens, and swimming facilities. In contrast, the construction category includes infrastructure-related projects, such as roads, quays, railways and airports.

The project types with corresponding categories applied in the database are presented in Table 3. The number of analyses per industry in this study is given to the right in the table.

Table 3: Project types and categories applied in the database.

Industry	Project categories included within the industry	Number of analyses
Building	Healthcare, schools, extensions/additions, new construction, renovation, cultural buildings, kindergarten, swimming facilities.	47
Construction	Roads, quay facilities, infrastructure, railway, airport.	51
Defence	Defence	4
Industry	Processing facility	1
IT and telecommunication	IT and telecommunication	4

5.3 Statistical analysis

The analysis was conducted using a multiple linear regression model estimated by ordinary least squares (OLS) to examine the relationship between the relative contingency / relative cost reserve and the categorical and continuous predictors shown in Table 2. The dataset was examined to not include missing values in key variables. A log transformation was applied to the cost estimate variable to address skewness. Categorical variables such as project phase, industry sector, and assignment manager were encoded using dummy variables. Regarding the assignment manager, separate groupings for the most frequently occurring assignment responsibles were established. This resulted in three categories for three distinct individuals and one group for all the "other" assignment responsible found in the database. These four groups included approximately the same number of datapoints. The names of the different assignment managers have been anonymized in the results and are therefore represented by numbers.

The regression was executed using the Statsmodels package in Python, a recognized and validated tool for econometric and statistical modeling. Equation (1) and Equation (2) below show the included models. These models quantify the effect of project characteristics and assignment managers on relative contingency and cost reserve.

$$RelContingency = \beta_0 + \beta_1\, BaseEstimate + \beta_2\, ProjectPhase(C) + \beta_3 ProjectType(C) + \beta_4\, Manager(C) + \epsilon \quad (1)$$

$$RelCostReserve = \beta_0 + \beta_1\, BaseEstimate + \beta_2\, ProjectPhase(C) + \beta_3 ProjectType(C) + \beta_4\, Manager(C) + \epsilon \quad (2)$$

Model diagnostics, including multicollinearity (VIF), visual inspection of Q-Q plots to assess normality, heteroskedasticity (Breusch-Pagan test), and autocorrelation (Durbin-Watson statistic), were performed to evaluate the validity of the model assumptions.

6. Results

An initial descriptive analysis highlights differences in the size of contingency and cost reserves across the dataset. Figure 3 shows two box plots visualizing the relative contingency and relative cost reserve resulting from the 107 reviewed cost risk analysis. The mean relative contingency is 19,4% whereas the mean relative cost reserve is 45%. As shown in the figure, both values vary, with relative contingency ranging from 2% to 88% and relative cost reserve ranging from 4% to 161%.

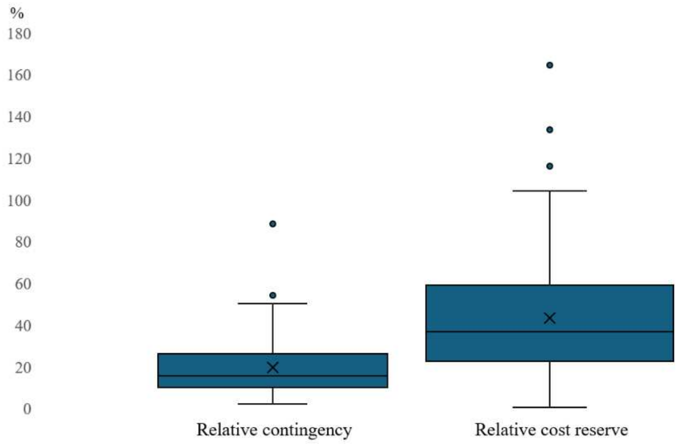

Figure 2. Box plot visualizing the relative contingency and the relative cost reserve resulting from the 107 reviewed cost risk analysis. The x shows the mean, and the middle line shows the median. The dots are classified as outliers.

6.1 Model nr. 1 - Relative contingency as the dependent variable

Table 4 shows the results from model nr. 1 with relative contingence as the dependent variable. In the model the R-squared value was 0,20. The model hence explains 20% of the variance in the relative contingency. As shown by asterisks` in the table the analysis results in several significant variables:

- Building projects have a significantly lower relative contingency compared to the other project types.
- The project phase “QA1” has a significant impact on increasing the relative contingency compared to ordinary cost risk analysis and projects within the “QA2” phase.
- Assignment Manager nr. 2 has a significant impact on decreasing the relative contingency compared to the other assignment managers.

Table 4. Regression results for model nr. 1 – Relative contingency as the dependent variable.
Significance levels are indicated by asterisks: * p < 0.10, ** p < 0.05, *** p < 0.01.

	Coefficients	Standard error	t Stat	P-value	Lower 2,5%	Upper 97,5%
β_0	0,23	0,07	3,30	0.00***	0,09	0,37
β_1 $Base\ Estimate\ (log)$	-0.01	0.01	-0,41	0.68	-0,02	0,01
β_2 $Building$	-0,08	0,03	-3,15	0,00***	-0,13	-0,03
β_2 $Defence$	-0,05	0,07	-0,78	0,44	-0,19	0,08
β_2 $Industry$	-0,00	0,13	-0,032	0,97	-0,26	0,25
β_2 IT and telecommunication	-0,10	0,07	-1,51	0,135	-0,24	0,03
β_3 $QA1$	0,09	0,04	2,12	0,036**	0,01	0,16
β_3 $QA2$	0,03	0,04	0,71	0,47	-0,06	0,12
β_4 $Manager\ nr.1$	0,04	0,04	0,91	0,36	-0,04	0,12
β_4 $Manager\ nr.2$	-0,07	0,04	-2,02	0,05*	-0,15	-0,01
β_4 $Manager\ nr.3$	-0,04	0,05	0,83	0,41	-0,05	0,13

6.2 Model nr. 2 – Relative cost reserve as the dependent variable

Table 5 shows the results from model nr. 2 with relative cost reserve as the dependent variable. In the model the R-squared value was 0,32. The model hence explains 32% of the variance in the relative cost reserve. As for model nr.1, the analysis results in several significant variables.

- Building projects have a significantly lower relative cost reserve compared to the other project types.
- The project phase “QA1” has a strong significant impact on increasing the relative cost reserve compared to ordinary cost risk analysis and projects within the “QA2” phase.
- Assignment Manager is significant across two of the individual assignment managers. Manager nr. 1 has a significant impact on increasing the relative cost reserve whereas manager nr. 2 has a significant impact on decreasing it.

Table 5. Regression results for model nr. 1 – Relative cost reserve as the dependent variable.
Significance levels are indicated by asterisks: * p < 0.10, ** p < 0.05, *** p < 0.01.

	Coefficients	Standard error	t Stat	P-value	Lower 2,5%	Upper 97,5%
β_0	0,36	0,13	2,69	0.00***	0,09	0,63
β_1 $Base\ Estimate\ (log)$	0.01	0.02	0,63	0.53	-0,02	0,05
β_2 $Building$	-0,19	0,05	-3,79	0,00***	-0,29	-0,09
β_2 $Defence$	0,04	0,13	0,29	0,77	-0,22	0,30
β_2 $Industry$	-0,11	0,25	-0,44	0,66	-0,60	0,38
β_2 IT and telecommunication	-0,19	0,13	-1,43	0,15	-0,45	0,07
β_3 $QA1$	0,29	0,08	3,77	0,00***	0,135	0,436
β_3 $QA2$	0,10	0,08	1,12	0,24	-0,07	0,26
β_4 $Manager\ nr.1$	0,13	0,08	1,67	0,09*	-0,02	0,28
β_4 $Manager\ nr.2$	-0,15	0,07	-2,20	0,03**	-0,29	-0,02
β_4 $Manager\ nr.3$	0,13	0,09	1,49	0,14	-0,04	0,30

6.3Modell diagnostic – both models

Visual inspection of the Q-Q plots for both models indicates that the residuals approximately follow a normal distribution, with only minor deviations at the tails. The conducted Breusch-Pagan tests provided no evidence of heteroskedasticity, supporting the assumption of constant variance. Durbin-Watson statistics indicated no serious autocorrelation in the residuals. Multicollinearity was assessed using the Variance Inflation Factor (VIF), with all predictor variables falling below the commonly accepted threshold of 5. The intercept showed a high VIF, which is expected and not considered problematic. Overall, the diagnostic tests suggest that the key regression assumptions are reasonably satisfied.

7. Discussion

Given that the analysis is based on real-life projects and actual cost risk assessments, the R-squared values observed in both models ($R^2 = 0.20$ and $R^2 = 0.32$) are considered reasonable. Project-specific factors and uncertainties are inherently complex and difficult to fully capture in a dataset, which limits the maximum explanatory power of the models. It is also intuitive that the explanatory power is higher for relative cost reserve compared to relative contingency, as the former typically represents a larger value and is likely more influenced by the inputs to the cost risk analyses. In contrast, contingency may be more constrained by project-specific frameworks or governance practices not captured in the data.

The finding that building projects tend to have significantly lower levels of both contingency and cost reserves is also logical. This suggests that the cost risk analyses perceive lower uncertainty in building projects compared to other project types. A likely explanation is the relative homogeneity of building projects, where many elements are repeated from project to project, allowing for more predictable outcomes. Additionally, construction estimates are often based on well-established tools and methods (e.g., cost per square meter), which can provide reliable estimates already in early project phases.

Regarding the effect of project phase, both models show that projects in the QA1 phase are associated with significantly higher relative contingency and cost reserves. This is consistent with expectations, as projects in this early phase typically have lower maturity, more unresolved decisions, and are further from execution. These are factors that generally increase uncertainty.

A particularly noteworthy finding is the significance of the assignment manager variable across both models, especially in the model for relative cost reserve, where the effect is statistically strong. While it is well-known that human factors influence the outcomes of risk assessments, it is still somewhat surprising to observe such a robust relationship. This highlights the importance of ensuring that assignment managers do not dominate group discussions during the risk analysis process, as their influence could systematically affect the estimated levels of both contingency and cost reserve.

8. Conclusion

This study has examined two regression models to explore which factors significantly influence relative contingency and relative cost reserves in real-life projects. The explanatory power of the models, although moderate, is considered reasonable given the complexity and context-dependency of project-based risk assessments. The diagnostics confirm that the models meet key statistical assumptions, supporting the validity of the findings.

The analysis highlights several important relationships. Building projects consistently show lower contingency and cost reserves, likely due to their standardized nature and more accurate cost estimation methods. Projects in early phases (QA1) are associated with higher risk buffers, reflecting their lower maturity and greater inherent uncertainty. Perhaps most notably, the identity of the assignment manager significantly affects the outcomes of the cost risk analyses. This underlines the importance of maintaining neutrality and procedural rigor in group-based risk assessments, as individual influence can materially affect the estimated financial buffers.

Future work should aim to expand the dataset with additional cost risk analyses to create a more solid empirical foundation for the research question. The limited sample size (N=107) and the highly uneven distribution of projects across sectors are significant limitations to this study. Furthermore, it would be valuable to investigate how greater process standardization, and the use of neutral facilitation practices may reduce individual biases and enhance the consistency of cost risk assessments.

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