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ANALYSIS OF PRE-PROJECT DATA FOR FLEXIBLE OPPORTUNITIES ON ROAD PROJECTS IN NORWAY

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Abstract: This paper focused on pre-defined reduction lists as one of the flexibility options in large investment road projects and attempted to obtain knowledge about reduction lists and their relationship with uncertainty. As information in the front end of projects is scarce having historical data about general reductions could be informative for new projects which helps consultants in identifying reduction possibilities. Furthermore, literature is currently lacking on the relationship between reductions and uncertainty. Knowing this relation leads to the use of flexibility for better uncertainty management through investigating more reductions as well as to understand the perspective of consultants about potential reductions in the sample of transport road projects. This study was based on qualitative and quantitative evaluation of 80 transport road projects. Analysis of reduction types showed that there are similar reductions to those found in previous studies. Uncertainty level had a statistical relationship with the changes in reductions. Data from these projects could give good direction to decision-makers at the portfolio level on the value of reductions and their relation with estimated uncertainties. However, reduction lists are not the only way to tackle extra costs and contingencies can be exploited for better cost management in projects and to help uncover new opportunities.

Keywords: Pre-project phase, transport road projects, flexibility, reduction lists, uncertainty, Norway.

1. Introduction

Cost control is one of the major aspects of transport investment projects, including road projects. Chevroulet *et al.* (2012) explained that most transport infrastructure projects in the European Union experience cost overruns. In many cases, the planning phase of transport projects is complex, often leading to cost overruns (Welde and Odeck, 2017). Additionally, Flyvbjerg *et al.* (2004) point to cost escalation in many infrastructure projects. However, the Flyvbjerg *et al.* (2004) study has been challenged (Love and Ahiaga-Dagbui, 2018), and other studies paint a different picture. For example, Cantarelli *et al.* (2012) found that Dutch rail projects have relatively low-cost overruns. Still, cost control is essential to safeguarding the execution and reputation of transport infrastructure investments.

This paper focuses on reductions as a tool for cost control. Reductions can be considered as a flexible option in projects. Previous studies have demonstrated that flexible options are

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often used to tackle uncertainties in projects (Kreiner, 1995; Olsson and Magnussen, 2007; Paslawski, 2017; Evans and Bahrami, 2020). When a project faces potential cost overrun, there are several possibilities for reductions (Olsson and Magnussen, 2007). However, the applicability of reductions has been questioned. For example, Olsson (2015) referred to reductions as 'fewer desirable changes. Because they apply late in projects and might be hard for implementation or unsatisfactory.

In Norway, large transport infrastructure projects are subject to quality assurance in two phases. The first quality assurance (QA) gate occurs before concept selection (QA1), while the second (QA2) is performed before the final decision to finance the project. Since QA2 was implemented in 2000, more than 200 large public projects have gone through this quality assurance gate. QA2 is a central part of the quality assurance process and involves uncertainty and cost analysis. As part of the uncertainty and cost analysis, advice about possible scope reductions to avoid cost overruns should be provided. These potential scope reductions are labelled reduction lists. The purpose of this study is to investigate the development of such lists over time from 2000 to 2019.

Knowing types of reduction allows us to know them better and in projects try to identify most emergent reductions. From other perspectives, this information helps different actors to predict probable possibilities for reductions in projects. Some reductions are not pleasant for some stakeholders (Johansen *et al.*, 2019). For example, removing parking place in road projects might be satisfying for the contractor to reduce the cost. In the long run, it could add costs to other projects and might increase risks of future projects. Knowing the most emergent reductions might direct decision-makers to focus on different methods for cost reductions such as identifying opportunities. Besides in the pre-project phase as detailed information about projects is scarce having historical data could be a benefit for new projects.

We will compare recommended reductions with the size of the uncertainty in cost estimates (estimate uncertainty). Uncertainty related to cost estimates of projects covers two main types of uncertainties: estimate uncertainty and event uncertainty (Torp *et al.*, 2006). The size of the estimated uncertainty is represented by the standard deviation of the cost estimate. This paper gives evidence about a pre-project suggestion for cost reduction based on expected uncertainty in projects. The reduction of many projects in the portfolio of projects could help owners and decision-makers to have the opportunity for saving costs. Although reduction for each project is not a significant amount, in the projects' portfolio it is a significant amount. To find a pattern of relation between uncertainties and reductions in projects might guide decision-makers to set limits for the amount of reduction value and estimate uncertainty for each project. On the contrary, we may discover no connection between these two values in projects and find that decision-makers' abilities in identifying reductions in complex projects with high uncertainty decreases. The validity of this assumption will be tested based on pre-project data. The research questions (*RQs*) that arise are as follows:

- RQ1: What is the distribution of reduction lists over the period between 2000 to 2019?

- RQ2: What is the relationship between the level of reductions and the size of uncertainty?

The study will use data from QA2 for large Norwegian road projects The structure of the paper will be as follows: after the introduction, which explains the importance of the topic, part Two provides the theory on flexibility and the front end of the projects. Part Three describes the research design and methodology, and part Four explains the findings and discussion. The final section presents the conclusion of the paper and possibilities for future research.

2. Theoretical Background

The theoretical background covers three main theoretical aspects: flexibility, quality at entry of projects and reductions, and how flexibility can affect uncertainties.

1.1. About Project Flexibility

Flexibility is a particular adaptation of a system against uncertainties to survive (Günsel *et al.*, 2012). In a project context, flexibility is described as a tool to manage risks and uncertainties (Huchzermeier and Loch, 2001; Awe and Church, 2020). Shahu *et al.*(2012) found a strong positive correlation between project success and flexibility. Flexibility is therefore considered to be a project success factor. In the long term, flexibility can be seen as adding value by improving effectiveness and customer satisfaction. In the short term, flexibility can often be a threat to the projects' efficiency (Krane and Olsson, 2013). Furthermore, flexibility is not always pleasant. Olsson and Hansen (2010) showed that project stakeholders resist flexibility, both in the front-end and implementation phases.

Based on PMI, scope change control is the management of changes and extensions. There is significant existing research about the reasons for cost escalations in projects (PMBOK, 2013). Even though most research focuses on scope changes as causes of cost overruns, scope changes can be used as tools for cost management and cost reductions, such as target costing and value engineering. For example, Charles *et al.* (2015) studied changes during the construction phase to increase whole-life-value and reduce cost overrun. Value engineering contributes to minimizing project costs while still preserving the projects' main functions, and it has been applied successfully in cost-saving processes in transport projects (Olsson, 2015; FTA, 2016). Value engineering also has similarities to the reductions studied in this paper (Olsson, 2015).

2.2. Quality at the Entry of the Projects and Reductions

Quality at entry is essential for project success and used for forecasting and cost estimation (Samset and Volden, 2016; Welde and Odeck, 2017; Welde, 2018). Despite progress in project cost estimation methodologies and other approaches for estimation, cost overrun or underrun still occurs in many projects. There are several reasons for cost overrun. Many researchers have reflected this problem in their work (Flyvbjerg *et al.*, 2004; Odeck, 2004; Jasiukevicius and Vasiliauskaite, 2015; Welde and Odeck, 2017; Membah and Asa, 2015).

Before explaining the application of reductions, an introduction to the reduction value in the cost frame of Norwegian projects is presented. Regarding cost estimates, two key terms are P50 and P85, as depicted in Figure 1. P50 means that

there is a 50 percent probability that the cost will not exceed this value. P85 is higher than P50, with an 85 percent probability (Odeck *et al.,* 2015). This means that there is an 85 percent probability that the project is performed within this cost amount. Figure 1 shows that transport agencies commonly receive funding based on P50, while parliament allocates a higher sum as their cost frame, typically based on P85 and in some cases P85 minus the reduction lists. The difference between the sum allocated to the agency (P50) and the cost frame (P85 or P85 minus reduction) represents a contingency managed by the Ministry of Transportation.

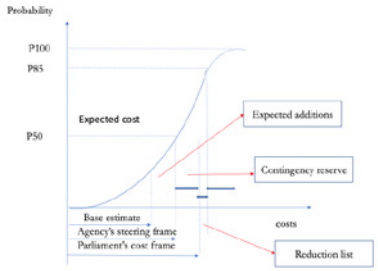

Fig. 1.
Cost Estimates and Key Terms adopted from Odeck et al. (2015)

Common reductions used in road projects are a) reductions related to rest areas, parking places, and other similar options; b) Taking smaller measures in existing roads; and c) safety-related reductions, such as lighting. The first method is the most common and the last is the least common (Olsson, 2014). Planned measures on existing roads are a type of well-known quality/functionality reduction. Reductions such as planting and surface treatment are related to aesthetic aspects, which means a low budget is dedicated to this project's portion. This type of reduction represents minor cost savings but can be applied relatively late in the project (Olsson, 2014).

QA2 advisors evaluate the reductions' opportunities in projects whose costs are estimated to be higher than expected (Olsson, 2015; Olsson, 2014). If the agency does not provide a reduction list, then the QA2 team may suggest reductions. Olsson and Magnussen (2007) developed a compilation of the proposed reductions in the first 47 QA2 reports and reviewed a total of 169 possible reductions among these 47 projects. They recognized two types of reduction proposals based on their reductions' categories: reductions related to volume/scope and quality/function. Olsson and Magnussen (2007) found that the numbers of reductions for quality and volume were 71 and 48, and the reductions' monetary values were similar, with 803 and 864 M.NOK (1NOK= 0.1 euro) for quality and volume, respectively. These reduction types of account for 75% of the economic potential for savings. In another study, Cui and Olsson (2009) found that the initial reduction lists in the QA2 reports ranged from almost 0 to 18% of project budgets. They evaluated data from 82 projects to measure the application of reduction lists for 7 years (Cui and Olsson, 2009). Later, Olsson (2015) studied possible reductions

in the projects' implementation phase and demonstrated that projects with high uncertainty were dedicated high contingency based on the consultant's suggestions.

2.3. Projects' Flexibility as a Way for Handling Uncertainties

Project flexibility is typically a response to uncertainty. Uncertainty can influence project outcomes such as time, cost, and quality and can be related to both risk and opportunities (Johansen *et al.,* 2019). Managing uncertainties can contribute to savings on project costs, reducing project time, and achieving better quality results, provided that projects have an appropriate uncertainty management strategy (Hillson, 2002; Hillson *et al.,* 2014).

Project managers perceive flexibility differently. The first perspective consists of minimizing changes and flexibility to focus on projects' efficiency because changes and flexibility may be a threat to project timelines, costs, and quality. The second perspective recognizes the lack of information in decision-making situations in a changing world and acknowledges the need for flexibility. Flexibility attempts to reduce information needs for decision-making by postponing decisions until enough information has been gathered (Olsson and Magnussen, 2007; Johansen *et al.,* 2019). In this paper, flexibility is mainly based on the first perspective but focuses on making changes while maintaining the efficiency of the project because reduction lists concentrate on options that require lower quality, volume, or other project attributes.

Reduction lists are a flexible approach that can be decided before beginning a project and used during project execution. However, there are some doubts about the applicability of reduction lists as an effective tool. Previous findings have shown that reduction lists cover a small amount of the total project budget (Olsson, 2015). In contrast, contingencies have significant value. Additionally, uncertainty has a direct relationship with the project size. Considering this assumption, when a project experiences high uncertainty, project management teams might present more reduction options to tackle this uncertainty in pre-project phase. The probability of this assumption will be tested based on the data in this paper.

3. Research Design

The study presented in this paper is exploratory and focuses on documented QA2 reports of road projects in Norway. In exploratory research, the focus is to find patterns and knowledge in less-discovered areas (Gray, 2014). The relation of reductions and uncertainty is the less discovered area and has the potential for further research. Furthermore, the research aims to increase knowledge of reduction lists over time. Data collection was conducted by literature study and document study, which mainly focused on reports from large road transport projects in Norway subjected to QA2 between 2000 to 2019. The concept research program provided the data. The Ministry of Finance in Norway established the concept research program in 2002 with the primary goal of developing knowledge and expertise at the front-end phase of projects (Klakegg, 2010).

A sample of 97 road projects was chosen for this study. Reductions value data and estimated uncertainty were based on analysis of highly experienced and expert

consultants on projects' cost estimation who are working by the same structure and procedure. Consultants' analysis led to high-quality reports about projects. These consultant companies are selected by ministry of finance after careful evaluations. Consultants works and reports are public and open for interpretations, and decision makers and researchers could evaluate their works regularly (Samset and Volden, 2013). We extracted the reduction lists from reports and sorted them based on the selected criteria of reduction types by Olsson and Magnussen (2007). Reduction values in Million Euro (M.Euro) and standard deviations of cost estimates (M.Euro) were obtained from a document study of 81 projects. 16 projects were removed from the list because their data related to reduction or uncertainty were not complete. First, we imported the extracted data to Excel to analyse their proportions and relationships. We analysed the reduction types and their quantity in projects. Then we did detailed analysis based on the four periods from 2000-2004, 2005-2009, 2010-2014, and 2015-2019 for reduction types and their distribution. Correlation analysis was applied to determine the relationship between reduction and estimate uncertainty. Finally, the relation of reduction and estimate uncertainty was conducted based on their proportion to P85 (cost frame managed by ministry of transportation) which both value of estimate uncertainty and reduction are part of P85.

Data analysis was both qualitative and quantitative. Different reduction lists in reports were qualitative data and the value of reduction lists, a standard deviation of cost estimate (estimate uncertainty) of projects were quantitative data. The value of reductions was based on information from the difference of P85 value and P50 for each project which was based on adjustment for reduction lists. This paper focuses on data from the pre-project phase of road construction projects. Therefore, this study does not answer actual reduction and uncertainties, and it only covers expected reduction and uncertainties. The research ignores the effect of different consultants on the evaluation of selected reports. Furthermore, this study does not cover other factors (except estimated cost), which could influence on reduction value in projects. For example, policies, projects' complexity (although uncertainty could include in this factor), owners' decisions, etc are influencing factors on reduction value are not covered in this research.

4. Findings

This section covers the pattern of suggested reductions in different periods. We also attempt to find a relationship between reductions and estimate uncertainties in projects.

4.1. Distribution of Reductions

We selected reduction types based on an earlier study of Olsson and Magnussen (2007) with some changes such as "preparation for other use" and "dependencies between projects" are considered inside other reduction because based on previous study were fewer in comparison with other reduction types. Four reduction types are compared, and the largest number was related to quality/functionality. The results showed that quality/functionality (Q/F) and volume (V) have the highest quantity and value for recognized reductions. For example, Quality

and functionality appeared 162 times in projects. Volume holds the highest value of reduction with around 50 percent of total reductions which is around 246.6 M.Euro. Both volume and quality cover more than 80 percent of reduction value in projects. Visual impression (VI) and other reductions (O) had lower values.

Table 1

Various Reductions Separately and Their Value for all Projects

Type of reductions	Total observation		Amount	
	Number of Reductions	Percentage	Value of Reductions (Mil.Euro)	Percentage
Quality, Functionality	162	44%	125.7	29.8%
Volume	139	38%	246.6	58.4%
Visual Impression	46	12%	29.5	7%
Other	21	6%	20.2	4.8 %
	368	100%	422	100%

Table 2 showed a detailed calculation of reductions for each period. 129, 84,86, and 69 is the total quantity of reductions for each period consecutively and from the first period to the final period the reducing trend was observable.140.5, 96.3, 92.3, and 84.5 M.Euro showed the value of reduction for each period which had the reducing trend as well as the number of reductions. Volume had the highest value in all periods for instance between 2005 to 2009 was 69.7 M.Euro and it had more than 50% of reductions in each period.

Table 2

Detail Analysis of Type, Quantity, and Value of Reductions for Each Period

Periods	Reduction Types	Quantity	Quantity of Reductions to the Total Number for Each Period (%)	Reduction Values	Value of Reduction to Total Reduction for Each Period (%)
2000-2004	Q/F	54	42	40	28.4
	V	47	37	74	52.7
	VI	21	16	19	13.5
	O	7	5	7.5	5.4
2005-2009	Q/F	32	38	20	20.7
	V	38	45	69.7	72.3
	VI	10	12	4.7	5
	O	4	5	1.9	2
2010-2014	Q/F	43	50	27.7	30
	V	29	34	57.9	63
	VI	11	13	4	4
	O	3	3	2.7	3
2015-2019	Q/F	33	48	38	44.8
	V	25	36	44.5	52.4
	VI	4	6	1.5	1.8
	O	7	10	0.9	1

4.2. Reductions' Relation with Uncertainties

In this section, correlation analysis was conducted on reduction values and estimate uncertainty in order to find the relation between estimate uncertainty and reduction value. The scatter diagram of this analysis has been shown in Figure 2. The result showed that there is a significant correlation between reduction value and estimate uncertainty (0.63 from Pearson analysis) in 81 projects. The coefficient value between 0.5 and 1 was a strong correlation and with the P-Value < 0.001 which showed statistically important correlation exists between two variables.

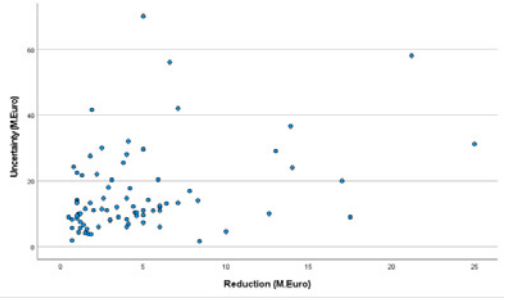

Fig. 2.
Correlation Analysis of Reductions to Estimate Uncertainty

Table 3 shows reduction value and estimate uncertainty in four periods based on quality assurance scheme periods. The average of standard deviation (estimate uncertainty) in third period was highest with 23.9 M.Euro.

Four projects were registered with more than 40 M.Euro value for uncertainty in this period which causes the average for this period increases. In other three periods we observed one project with estimated uncertainty bigger than 40 M.Euro.

It showed that in average for 14 projects in the period 2000 to 2004 the reduction value was 6.9 M.Euro. Reduction value from first to the second period became approximately half (3.8 against 6.9) and then increased in third period which showed that consultants reported more projects' reductions. It dropped in fourth period which showed unpredictable reductions' pattern. 12.9 M.Euro in column 3 showed the uncertainty value for 14 projects in first period. Uncertainty value had a significant growth in third period.

Table 3
The Proportion of Reductions to Estimate Uncertainty in Different Periods

Year	Number of Projects	Average Reduction Value (Mil.EUR)	Average Estimate Uncertainty (Mil.EUR)	The Average Proportion of Reduction Value to Estimate Uncertainty for Each Period
2000-2004	14	6.9	12.9	69%
2005-2009	25	3.8	13.1	48%
2010-2014	26	5.3	23.9	26%
2015-2019	16	4.6	18.1	32%
Total	81			

The final column in Table 3, showed the average proportion of reduction to estimate uncertainty in each period. It demonstrated that in first-period predefined reduction values accounted for 69% of total estimate uncertainty. In some cases, these reductions are not considered in the projects' contingency value. This number decreased during three periods. Another way for comparing column 3 and column 4 can be to measure to what extent the average reduction value could cover average estimate uncertainty. For instance, in the first period on average, a reduction value of 6.9 M.Euro could cover approximately half of the estimated uncertainty which is 12.9 M.Euro (6.9/ 12.9 = 53%). In the 2nd, 3rd, 4th periods reduction cover nearly 29 %, 22%, and 25% of estimate uncertainty.

For improving the analysis, we got into account the P85 in our calculations in order to compare results. Because both reduction value and estimate uncertainty are share of P85 as depicted in Figure 1 and their relative amount to P85 presents better evaluation and comparison. As illustrated in Figure 3, in most projects the reduction value could not cover the effect of estimate uncertainty and is less than it, except some projects in first period and one in second period. This difference in newer project has become more as it can be seen between 2015 to 2109 difference is more than any time. This can be related to increased complexity of new projects which reduces the possibility of finding reductions or more accurate estimations for projects which needs to be evaluated.

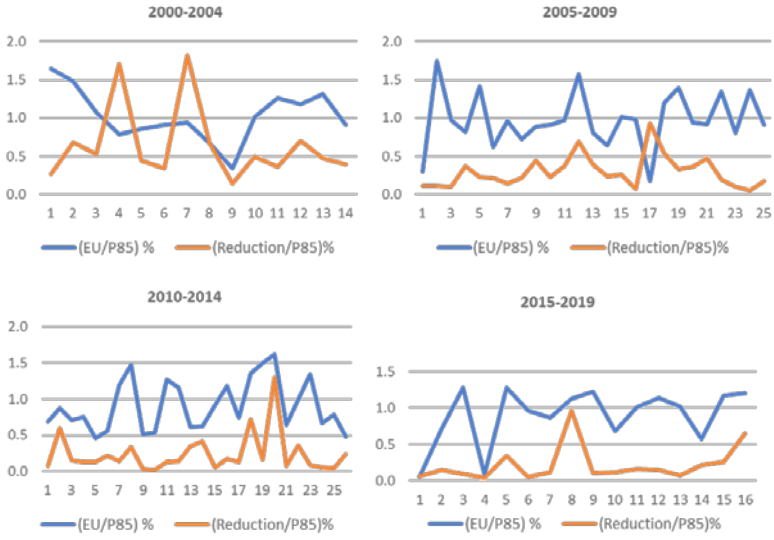

Fig. 3.
The Comparison of (Reduction Value / P85) to (Estimate Uncertainty / P85)

5. Discussion

This section discusses findings in order to answer research questions. The section concludes with findings' potential implications for decision-makers, policymakers, and researchers. This information gives insight to practitioners and managers about the possibility of reduction before the start of the projects and how in the portfolio of the project's reduction value can influence investment decisions in projects.

Paper focused on two main questions to find changes of reductions (RQ1) and relation of uncertainty with reduction (RQ2) in the pre-project phase of road projects. It is noteworthy to mention that this analysis particularly focuses on the expectation and analysis of consultants. Data in this paper have subjectivity of consultants and strength and high experience of them in analysis. This analysis does not give information about other project phases such as design or execution.

5.1. Reduction's Distribution over Different Periods

The first question was answered through finding the quantity of different reduction types in projects. The distribution of reductions in this paper was similar to previous research by Olsson and Magnusen (2007) and Cui and Olsson (2009). Quality had the highest number of reductions in projects and all periods and volume was second. Visual impression and other reductions had lower value in reduction lists.

Reductions could be an opportunity for one project and a risk for another project. For example, removal of the parking place from the road project might be an extra cost for a future project which needs to build it. These reductions always are not satisfactory for users and clients also. For project users who knew the project, these reductions could be unsatisfactory because they see the final project's product. For example, people who have a home near the project in the future might complain about the lack of the place for parking.

We could explain that these reductions have various effects on the owner or contractor, and final user. The research by Olsson shows that project managers oppose reduction lists and in contrast, the agencies and owners support such reductions (Cui and Olsson, 2009). Most reductions in the studied projects are reducing part of work, user-friendliness, quality, or functionality. If the reductions focus on optimization with the application of lean principles, then they will not be at risk for each party besides they could create value for all parties. This could be considered as an acceptable change from the owner and project management perspective.

5.2. Reductions' Dependency on Size of Uncertainties

The Statistical analysis shows that a strong relation exists between the value of the reduction and the size of uncertainty. It was logical that in projects with high level of uncertainty consultants seeks for many possibilities for reductions in order to compensate the effects of future uncertainties. Besides high uncertainty could offer more possibilities for opportunities and risks. High reduction in such case can means as low level of planning and preparation which is not the case in Norwegian road projects with the structured process for quality assurance before project execution

(Welde *et al.,* 2019). According to Olsson & Magnussen (2007) during a project's life cycle with uncertainty decrease, because of receiving more information, the possibility of flexibility decreases due to the high cost of changes. This can be compensated with making less irreversible decisions and having more opportunities with different options.

From another perspective when the projects' complexity or uncertainty increases, the possibility of finding reductions decreases which needs to be evaluated. This trend could be seen in the paper's findings. Findings shows that the proportion of reduction to P85 and estimate uncertainty to P85 in final period is more than previous periods which can be related to high level of complexity or uncertainty in new projects or better uncertainty estimations. The data evaluation in different periods in the paper showed that with the increase of uncertainty in projects the flexibility and reduction opportunities were lower and reduced. In four periods the reduction showed various patterns. This pattern could relate to different strategies which are adopted by owners in each QA schemes period. The proportion of estimate uncertainty to reduction value decreased from the first to fourth periods.

The increase in estimate uncertainty in the third period 2010 - 2014, from the first to the third period, could be related to the inflation rate, project complexity, improved uncertainty identifications, and so on. The reductions have different and irregular patterns. The low reduction values might be related to a high degree of planning in the pre - QA2 phase of the projects, better identification of scope reductions, and increased focus on reductions in previous QA2's or consultants' attitude to predefined reductions.

Figure 4 shows a scatter diagram of projects based on the value of estimate uncertainty and reductions. The red lines in Figure 4, shows the average value for uncertainty and reductions. The value of 4.6 and 15.9 million Krone is considered as an average value for reductions and estimating uncertainty consecutively. High reduction value from one side could be appealing for owners and contractors (Olsson, 2006) and from the other side could be a sign of lack of preparation of pre-project data and scope of the work, which is not favourable. High level of estimate uncertainty if we assume as the negative issue could be unfavourable also. But on the other side, it could be positive which can be a sign of considering different uncertainties. A low level of reduction and estimate uncertainty seems somewhat favourable quadrant because of a low level of uncertainty but low reductions which limits the manoeuvring power of project owners in cost control.

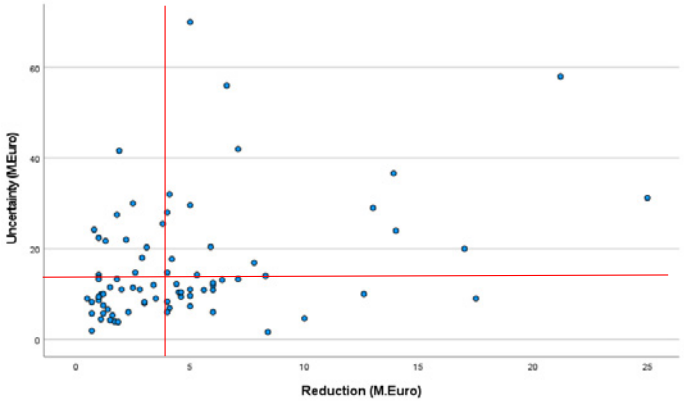

Fig. 4.
Projects Analysis based on Uncertainty and Reductions Value

Although we used the standard deviation of the cost estimate to measure the size of uncertainty, it is important to also evaluate the contingency value of projects. Olsson (2015) indicated that contingency value can be a better measure for evaluating uncertainty in projects, which can be utilized in future studies.

Olsson and Magnusen (2007) pointed out that the number of reductions for quality and volume was similar to our study. This similarity could be originated from similar policies and methods in identifying reductions. Consultants use similar procedures and methods for defining reductions value. There exists no significant improvement in the value of reductions. Shift from reductions to opportunity discovery and value creation could be a better approach. Because in value creation the chance for satisfying stakeholders is more than reduction lists and benefits of them could be the last longing after projects' execution.

5.3. Potential Implication

This research can help decision-makers to design more effective measures and set incentives for identifying reduction values in transport projects. Although reduction value is not desirable in projects, especially for project managers but their value for owners could be appealing. For policymakers helps to adopt effective strategies for keeping the balance of reduction values against estimated uncertainties. For example, defining the limit of reduction for each project against estimated uncertainty could be a suggestion. This could help portfolio managers also to have better insight into the importance of reduction value in the overall level because although the amount of value in one project might not be significant, this amount in the projects' portfolio could be crucial for future investments.

This research also helps the researcher in analysing historical changes in reduction values in Norway over different periods.

Simultaneously, reveals the existing relation of estimate uncertainty and reduction values. But, it does not cover other effective variables on reduction value which is one of this research limitations. The result of this study about the amount of reduction value is not applicable to any other projects such as IT, railway, or defence projects at the national or international level but the research method, statistical analysis of reduction value and estimate uncertainty, and the impact of estimate uncertainty on reduction value as one of the effective variables could be interesting for researchers nationally or internationally.

6. Conclusion

The purpose of this study was to evaluate the pattern of reduction lists in Norwegian road projects. Our analysis works to quantify project flexibility, a topic that is often discussed but lacks quantifiable research. Cost control is an important issue in transport projects, including road projects. *RQ1* focused on determining the categories in reduction lists and each item's quantities from 2000 to 2019. Analysis of pre-project data of 96 road projects was conducted. The results showed that quality/functionality and volume were used most frequently and had the highest value of the reduction lists of all 80 road projects. We also evaluated the changes in reductions during four periods and found a decreasing trend in the number and value of reductions, except in the final period. This analysis showed that the interest toward reductions has not increased during years and stakeholders prefer to use other strategies for cost reduction that reduction of the scope of the project. Although they might change the project's scope in different stages but necessarily focusing on reductions is not interested by parties.

RQ2 attempted to discern the relationship between estimate uncertainty and reductions. The results from statistical analysis showed that the level of estimate uncertainty has a meaningful relation with the level of reductions. However, the coverage of uncertainty by reduction value decreased over four periods. This finding does not prove our first assumption that when a project has more uncertainty, consultants consider more reductions to mitigate and reduce the consequences of uncertainty. Maybe the increase of uncertainty reduces the ability of parties in application of reductions as it is stated and agreed in previous literature by Cui & Olsson (2009). Besides with the complexity increase in projects the possibility of finding reduction could decrease.

This paper mostly focuses on data from consultants' reports and their data analysis in the pre-project phase. Obviously, it will not give full picture insight to the reduction values and their application during projects' life cycle. For decision-makers and portfolio managers could be a good direction of thinking on the amount of reduction value in overall level and their importance for project portfolios. Policymakers could get insight into their decision-making and could choose supportive policies in support of reductions as a cost control tool. For researchers gives a good historical analysis on reduction over 20 years by showing changes.

In the future, the analysis could focus on the projects' execution phase and try to find the correlation with the reductions in different phases. The studies with a focus on the obstacles against operative reductions in the execution phase could be an appealing research topic.

References

Awe, O.A.; Church, E.M. 2020. Project flexibility and creativity: the moderating role of training utility, *Management Decision* 59(9): 2077-2100.

Cantarelli, C.C.; van Wee, B.; Molin, E.J.E.; Flyvbjerg, B. 2012. Different cost performance: Different determinants?. The case of cost overruns in Dutch transport infrastructure projects, *Transport Policy* 22: 88–95.

Charles, S.P.R.; Wanigarathna, N.; Sherratt, F. 2015. Construction project change: Investigating cost and benefits. In *Proceedings of the 31st Annual Association of Researchers in Construction Management Conference, ARCOM 2015*, 833–842.

Chevroulet, T.; Giorgi, L.; Reynaud, C. 2012. A New Paradigm for the Assessment of High Speed Rail Projects and How to Contain Cost Overruns: Lessons from the EVA-TREN Project, *SSRN Electronic Journal*, 15 p. Available from Internet: <https://doi.org/10.2139/ssrn.1910565>.

Cui, Y.; Olsson, N.O.E. 2009. Project flexibility in practice: An empirical study of reduction lists in large governmental projects, *International Journal of Project Management* 27(5): 447–455.

Evans, S.; Bahrami, H. 2020. Super-Flexibility in Practice: Insights from a Crisis, *Global Journal of Flexible Systems Management* 21(3): 207–214.

Flyvbjerg, B.; Skamris Holm, M.K.; Buhl, Sø.L. 2004. What causes cost overrun in transport infrastructure projects?, *Transport Reviews* 24(1): 3–18.

FTA. 2016. Value Engineering on Transit Projects. Available from Internet: <https://www.transit.dot.gov/regulations-and-guidance/value-engineering-ve-transit-projects>.

Gray, D.E. 2014. *Doing Research in the Real World.* SAGE. 26 p.

Günsel, A.; Açikgšz, A.; Tükel, A.; Öğüt, E. 2012. The Role Of Flexibility On Software Development Performance: An Empirical Study On Software Development Teams, *Procedia - Social and Behavioral Sciences* 58: 853–860.

Hillson, D. 2002. Extending the risk process to manage opportunities, *International Journal of Project Management* 20(3): pp. 235–240.

Hillson, D.; Fellow, P.M.I. 2014. How to manage the risks you didn't know you were taking The problem with the typical project risk management approach What is risk ? First principles Different types of 'mattering', *Project Management Institute*, 1–8.

Huchzermeier, A.; Loch, C.H. 2001. Project management under risk: Using the real options approach to evaluate flexibility in R&D, *Management Science* 47(1): 85–101.

Jasiukevicius, L.; Vasiliauskaite, A. 2015. Cost overrun risk assessment in the public investment projects: An empirically-grounded research, *Engineering Economics* 26(3): 245–254.

Johansen, A.; Olsson, N.O.E.; George, J.; Rølstadås, A. 2019. *Practical Risk and Opportunity Management (Chapter), in Book: Project Risk and Opportunity Management*, Routledge. 17 p. Available from Internet: <https://doi.org/10.1201/9780429430589-6>.

Klakegg, O. 2010. *Governance of Major Public Investment Projects In Pursuit of Relevance and Sustainability*, NTNU. Available from Internet: <https://doi.org/ISBN 978-82-471-1986-0>.

Krane, P.H.; Olsson, N.O.E. 2013. Uncertainty management of projects from the owners' perspective, with main focus on managing delivered functionality, *International Journal of Managing Projects in Business* 7(1): 133–143.

Kreiner, K. 1995. In search of relevance: Project management in drifting environments, *Scandinavian Journal of Management* 11(4): 335–346.

Love, P.E.D.; Ahiaga-Dagbui, D.D. 2018. Debunking fake news in a post-truth era: The plausible untruths of cost underestimation in transport infrastructure projects, *Transportation Research Part A: Policy and Practice* 113: 357–368.

Membah, J.; Asa, E. 2015. Estimating cost for transportation tunnel projects: A systematic literature review, *International Journal of Construction Management* 15(3): 196–218.

Odeck, J. 2004. Cost overruns in road construction—what are their sizes and determinants?, *Transport Policy* 11(1): 43–53.

Odeck, J.; Welde, M.; Volden, G.H. 2015. The impact of external quality assurance of costs estimates on cost overruns: Empirical evidence from the norwegian road sector, *European Journal of Transport and Infrastructure Research* 15(3): 286–303.

Olsson, N. 2006. *Project Flexibility in Large Engineering Projects.* Doctoral Thesis. Norwegian University of Science and Technology, Faculty of Engineering Science and Technology, Department of Civil and Transport Engineering. 151 p.

Olsson, N.O.E. 2014. *title in english. [In provide the language: Bruk av kuttlister i store statlige investeringer].* NTNU-rapport. 36 p.

Olsson, N.O.E. 2015. Implementation of Pre-defined Potential Scope Reductions in Projects, *Procedia Computer Science* 64(1877): 387–394.

Olsson, N.O.E.; Hansen, G.K. 2010. Identification of critical factors affecting flexibility in hospital construction projects, *Health Environments Research and Design Journal* 3(2): 30–47.

Olsson, N.O.E.; Magnussen, O.M. 2007. Flexibility at Different Stages in the Life Cycle of Projects: An Empirical Illustration of the 'Freedom to Maneuver', *Project Management Journal* 38(4): 25–32.

Paslawski, J. 2017. Flexible Approach for Construction Process Management under Risk and Uncertainty, *Procedia Engineering* 208: 114–124.

PMBOK. 2013. A Guide to the Project Management Body of Knowledge(PMBOK® Guide). 5th ed.

Samset, K.; Volden, G.H. 2013. Concept No.36 Investing for Impact Lessons with the Norwegian State Project Model and the first investment projects that have been subjected to external quality assurance. Concept rapport. Ex Ante Akademisk forlag. 51 p.

Samset, K.; Volden, G.H. 2016. Front-end definition of projects: Ten paradoxes and some reflections regarding project management and project governance, *International Journal of Project Management* 34(2): 297–313.

Shahu, R.; Pundir, A.K.; Ganapathy, L. 2012. An empirical study on flexibility: A critical success factor of construction projects, *Global Journal of Flexible Systems Management* 13(3): 123–128.

Torp, O.; Magnussen, O.M.; Olsson, N.O.E.; Klakegg, O.J. 2006. Cost uncertainty in large govermental investment projects. Concept Rapport Nr. 15, NTNU. 95 p.

Welde, M.; Odeck, J. 2017. Cost escalations in the front-end of projects–empirical evidence from Norwegian road projects, Transport Reviews 37(5): 612–630.

Welde, M. 2018. In search of success: Ex-post evaluation of a Norwegian motorway project, *Case Studies on Transport Policy* 6(4): 475–482.

Welde, M.; Jørgensen, M.; Larssen, P.F.; Halkjelsvik, T. 2019. Estimating costs in large government investment projects. How good are the estimates and uncertainty analyses in the QA2-reports? No. 59. 96 p.