



## Article

# Sustainable Project Management: Reducing the Risk of Cost Inaccuracy Using a PLS-SEM Approach

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**Abstract:** Determining the factors leading to cost inaccuracy in infrastructure projects relates to sustainability by improving the cost performance of the projects (economic sustainability) and reducing the waste of available resources (environmental sustainability). This study investigates the effects of various factors affecting the cost performance of large-scale road projects in Norway in both the planning and construction phases. To this aim, a quantitative approach using a questionnaire survey was employed to understand the attitude of practitioners towards various factors causing cost increases. An advanced multivariate statistical approach of Partial Least Square Structural Equation Modeling (PLS-SEM) and Relative Importance Index (RII) was utilized to analyze the questionnaire responses. The results of the RII analysis show that local wishes, defective estimations, and long processing times had the most impact on the cost increase during the planning phase. At the same time, scope changes, market conditions, and unforeseen ground conditions were the most influential parameters in the construction phase. Moreover, the results obtained from PLS-SEM reveal that external related factors had the most influence among the other grouped factors (i.e., pre-construction, project management and contractual relationship, contractor's site management, and external) on cost overrun during the construction phase. Increasing the knowledge of these factors will allow for developing relevant project management approaches targeted at improving economic and environmental sustainability within both the planning and construction phases.

**Keywords:** cost overrun; PLS-SEM; project management; sustainability; Norway



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## 1. Introduction

Transportation infrastructure is a key element in the development of countries, and the demand for such infrastructure is increasing, while the economic and material resources available are diminishing. Recently, increased attention has been paid to needs analysis, planning procedures, budget allocation, and the performance of projects to make sure that the right projects are selected for implementation, and that the projects are delivered in a sustainable and efficient way.

### 1.1. Problem Statement

Sustainability continues to attract considerable attention in many domains, including project management. Sustainability stands on the three pillars (i.e., social, environmental, economic) of the well-known “three P” concept (People, Planet, Profit), which are interrelated and affect each other [1]. To relate sustainability to project management, one should consider aspects that can be addressed by sustainability considerations, including human resources management, procurement, communications, and risk management [1]. As sustainability in the field of project management has developed, economic sustainability is now being interpreted as a success factor in projects [1,2].

While economic sustainability is a concern within infrastructure project management, most transportation projects are not monetarily profitable alone, and are often undertaken for additional political and/or social reasons [3]. In addition, many large infrastructure projects around the world are not completed within their cost- or timeframe, further exacerbating cost efficiency problems. The weak cost performance of a project can be considered as a failure in project management, since traditionally project success has been linked to high efficiency in the three main aspects of scope, time, and cost, known as *the golden triangle* [4]. Therefore, determining and eliminating the risk factors that reduce efficiency in any of the mentioned aspects (risk factors) can significantly improve the level of project success [5,6], and thus improve economic sustainability.

### 1.2. Knowledge Gap

The literature in the field of cost overrun/cost performance of infrastructure projects has been primarily focused on the construction phase and on project-specific factors, which can affect the cost performance of the project during the construction phase, including project size, project type (e.g., road, rail, etc.), project completion time length, the geographical area in which project is constructed, etc. [1–5,7–9]. However, while less studied, aspects of the planning phase are also suggested to significantly affect cost inaccuracies in project governance [4]. During the planning phase, many factors can affect the project idea, and the direction in which the project concept evolves. Consequently, initial scope and cost estimations may change and escalate, respectively. Odeck believes cost escalation during the planning phase can be even higher than that of the construction phase [9]. Moreover, factors affecting cost performance during the planning phase may indirectly affect the construction phase. Thus, further research into planning phase factors and their relevance to the overall cost performance of the infrastructure projects contributes to the body of literature on cost efficiency and economic sustainability within project governance.

### 1.3. Research Aim

Cost inaccuracy poses a risk to the sustainable implementation of infrastructure projects. Therefore, determining the parameters affecting cost accuracy will not only improve the cost performance of the project and result in economically sustainable project management, but can also result in the better use of resources and thus further preservation of the environment [1,5,6].

The aim of this paper, therefore, can be expressed in two main research questions:

1. What are the main factors affecting cost inaccuracy during the planning and construction phases?
2. How can different groups of risk factors (constructs) affect cost inaccuracies during the construction phase?

The importance of this study is that the Norwegian Public Roads Administration (NPRA) has reformed and revised the structure of planning and surveillance in the planning process of the large-scale road projects from 2000 in order to curb cost overruns. Hence, this study gives insight into the current challenges in the planning and construction of large-scale road projects, and helps the NPRA to both evaluate the efficiency of the modified program and improve the current system. This is particularly relevant given that recently, the sustainable development of projects has become one of the top goals of the NPRA [7]. The data were gathered via questionnaires, and based on the obtained results, factors in both planning and construction stages were ranked according to their importance. The influential factors in the construction phase were categorized into four main constructs (i.e., external, contractor's site management, pre-planning, and project management and contractual relationship). A full model for cost increase was constructed and empirically validated using the PLS-SEM approach. Studies that have examined the causes of cost increase using the PLS-SEM methodology are scant in the literature. Evaluating these factors can present the current challenges in cost performance evaluation in a larger aggregated picture. It is important to note that this type of study should be done in individual countries, as using

international results may create the risk of fallacies in the interpretation of statistical data. However, the methodology used in this study is still valid for similar studies worldwide, and the results can inform the development of other studies.

#### 1.4. Organization of the Paper

The rest of this paper is organized as follows: Section 2 gives an overview on the concept of cost overrun and the relevant studies; Section 3 describes the methodology of the paper, including the main factors affecting cost increase and overrun in the planning and construction phases, respectively, as well as data collection, and describes the concept and the methods used to analyze and interpret the data; Section 4 presents and synthesizes the results. Section 5 discusses the obtained results, and finally, Section 6 summarizes the study's conclusions within the context of the field.

## 2. Literature Review

The positive difference between actual costs minus estimated costs (in net present value) within the construction phase is called cost overrun. The difference between actual costs and estimated costs can be expressed as a percentage of estimated costs, and is called percentage cost overrun [8–11]. There is a variety of research addressing the issue of cost overruns. Early studies concentrated on the prevalence, magnitude, and percentage of cost overrun [12–15]. Despite differences in their findings, which could be attributed to several factors including geographical area, type of the project, sample size, use of nominal or real prices, methods of calculation, and considering different moments for estimated and actual costs, almost all the studies agree that cost overrun is prevalent, but the magnitude varies from one project to another [8]. Later, studies aimed to focus on the causes and explanations of cost overrun, in addition to the magnitude and the percentage of cost overrun [16–19]. A study within this group by Cantarelli et al. [20] categorized the explanations for cost overrun into four main categories: technical, economical, psychological, and political. Other research has evaluated the causes of/factors affecting cost overrun using questionnaires or surveys. These studies are primarily case-specific/individual, and are limited to a specific country/region [21,22]. However, there is a lack of studies on the identification of root causes of overruns within specific countries. As mentioned, most of the studies have either evaluated cost overrun in large sample sizes around the world, or focused on the magnitude and determinants of cost overrun. Evaluating the causes of cost overrun within specific countries can give a better understanding of the current situation of the project governance and cost performance of the projects. Moreover, since the results of one specific country may not be applicable for other countries, carrying out case study research within specific countries may provide valuable knowledge for organizations responsible for the planning, estimation, and delivery of large projects.

On the other hand, the literature indicates that significant cost increases often occur during the planning phase; thus, to gain a better understanding of a project's cost performance, early planning phases must be taken into consideration [19,20,23]. Cost overrun in the planning phase is commonly considered a "cost increase" or "cost escalation". When the cost estimates are not precise, the wrong project may be decided upon, and later managing the project, especially large-scale projects, will be difficult, likely leading to cost overruns [24]. However, if estimations are accurate and the actual costs are known to the decision-makers, they may choose more profitable projects, modify the current proposal, or invest the budget elsewhere [15]. For instance, Welde and Odeck [23] found that cost estimates used in final investment decisions have gotten more accurate in the past decade in Norway. However, the estimates in the planning stages have been significantly underestimated. They largely suggest that project governance and the role of project ownership should be improved, cost-benefit and ex-post evaluations should be increased, and in general, cost estimations in the planning stages should be further investigated. Therefore, it can be inferred that unlike cost overrun during the construction phase, research on the most important causes of cost increase in the planning phase is scant.

### 3. Methodology

#### 3.1. Identifying the Causes of Cost Overrun in the Construction Phase

Within this study, it was necessary to identify potential causes of both cost increase and cost overrun, to be used within the questionnaire. A comprehensive literature review was carried out to identify the major factors affecting cost overrun during the construction phase. The thirty most common and frequently occurring causes are presented in Table 1. In addition, the two additional factors of project size (budget) and length of the road were added to the initial factors, according to the author's experience and previous studies, resulting in 32 factors considered in the study.

#### 3.2. Identifying the Causes of Cost Increase in the Planning Phase

As there is less existing research on overruns within the planning phase, the identification of potential causes affecting cost increase was carried out through both literature reviews and also two explorative semi-structured interviews with two project teams responsible for implementing two large-scale (budgets more than EUR 75 million) road projects in Norway. The semi-structured interviews identified 18 different causes affecting cost increase during the planning phase, as presented in Table 2. QA1 and QA2 (as seen in the table) indicate two different steps in the Quality Assurance regime introduced and financed by the Ministry of Finance for planning, financing, and implementing large public projects. The main goals of the QA process are to ensure that projects result in more benefits, lower overruns, and improved performance [23].

**Table 1.** Thirty factors affecting cost overrun in the construction phase (from literature review, without two additional complementary parameters).

Factor	Study														
	[25]	[26]	[27]	[28]	[29]	[30]	[31]	[32]	[33]	[34]	[35]	[36]	[37]	[38]	[39]
1- Insufficient site management and inspection	•	•		•				•	•		•	•	•		
2- Forecasting errors (e.g. increasing prices)		•													•
3- Poor project design	•	•		•				•		•		•	•		•
4- Scope changes			•	•	•		•	•	•				•	•	•
5- Labor Unavailability or lack of skilled labor		•	•	•			•		•		•				
6- Improper scheduling	•	•	•	•											
7- Lack of experience (in handling such projects)	•	•	•			•		•		•	•	•	•	•	•
8- Effect of bad weather (climate)	•	•	•	•	•	•			•	•	•	•	•	•	•
9- Unforeseen ground conditions	•							•	•		•				
10- Delay in progress payment by the owner	•	•			•		•	•	•	•	•		•	•	
11- Poor in-site financial control			•									•	•		
12- Low labor productivity		•			•					•	•	•		•	
13- Changes in material types and specifications	•	•				•	•		•	•		•			•
14- Poor project management	•		•	•	•						•		•		
15- Delays in decision-making	•	•				•	•	•	•	•	•	•	•		•
16- Market conditions		•	•		•	•	•	•		•			•	•	•
17- Inefficient use of resources		•		•	•				•			•			
18- Rework due to poor material quality	•		•	•	•	•	•			•	•	•			•
19- Strategic behavior (deliberate behavior)	•	•		•			•		•			•			•
20- Deliberate underestimation of costs	•		•	•				•				•			•
21- Lack of incentives			•				•	•	•					•	
22- Inadequate planning process	•	•	•	•	•		•		•	•	•	•	•		•



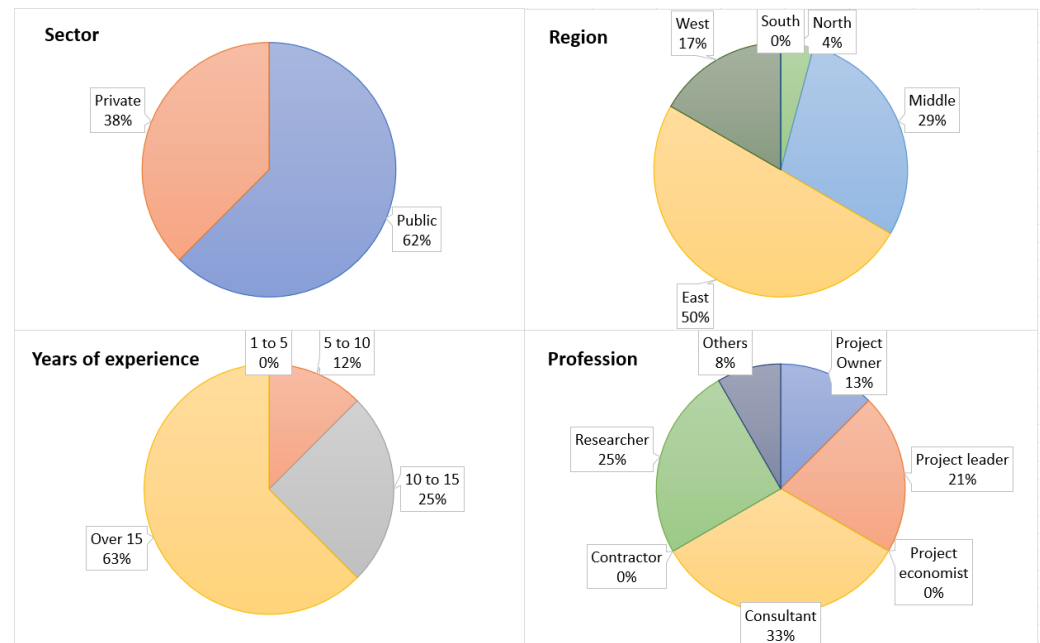
**Table 2.** Factors affecting cost increase in the planning phase.

Num.	Factor
1	Local wishes without cost responsibility
2	Defective estimation
3	Long processing time
4	Those who get the benefit are not the ones who pay
5	Changes in rules and regulations
6	Project optimism
7	Poor project management
8	Lack of follow-up
9	Changes in the society expectations
10	City projects are detailed and costly to estimate
11	Different degrees of maturity before QA1
12	Cost increases from QA1 to QA2 have no consequences
13	Technological development
14	Weak incentives to reduce planning time
15	Little transparency
16	“Value for money” is of little importance
17	Increased funding hides cost growth
18	Changed/different staffing

### 3.3. Data Collection

Questionnaire surveys are among the best means of obtaining information from individuals about themselves or something they belong to or are involved in [40]. In this study, a structured questionnaire survey was utilized for data collection, including three main parts: (1) demographics related to professional experience, (2) defining the importance of factors affecting the cost increase in the planning phase (planning factors (PF)), and (3) defining the importance of factors affecting the cost overrun in the construction phase (construction factors (CF)). The early stages of planning (i.e., the planning phase) include problem determination, recognition of the concept, rough cost estimations, and initial planning until the moment of formal decision-making. The construction phase is from the moment of decision-making and budget allocation until the project is finished and is opened for service. The survey was distributed among owners, contractors, consultants, researchers, and project economists working within the transport infrastructure throughout Norway. Respondents were asked to answer the survey only if they were involved in at least one large-scale road project in their career and were able to consider project-specific factors. A total of 119 surveys were sent by e-mail, and 33 completed survey sets were received back and considered for further analysis, indicating a response rate of 28%.

Figure 1 presents the valid responses according to sector, region, years of experience, and profession. As seen, 62% of the respondents were from the public sector, which owns and maintains the roads in the whole road network in Norway. Half of the respondents are from the East region of the country, which together with the West constitute 67% of the responses. This was expected, since these two regions are densely populated and comprise almost 70% of the population. All the respondents have had more than 5 years' experience, and 63% have more than 15 years. Finally, consultants, researchers, and project leaders were the main three groups of respondents, while no contractors or project economists responded to the survey.



**Figure 1.** Categorization of respondents (N = 33) by sector, region, years of experience, and profession.

### 3.4. Data Analysis

As mentioned before, the survey considers cost increase/overrun factors for both planning and construction phases (18 and 32 factors, respectively), which were collected from a literature review and in-depth interviews. The respondents were asked to give their opinion regarding the impact of each factor on cost increase/overrun by choosing the correspondent number from a five-point Likert scale, where 1 = strongly disagree, 2 = disagree, 3 = neither agree nor disagree, 4 = agree, and 5 = strongly agree (that the factor impacted project increases/overruns).

In order to analyze the data obtained from the received surveys, SPSS version 25.0 was first utilized to process the descriptive statistics and perform a reliability analysis on the collected data, and to examine the internal consistency of the survey (e.g., PFs and CFs). Internal consistency reliability is a means to assess how well a survey is designed and thus measures what is intended. Cronbach's coefficient  $\alpha$ , which is explained below, is one of the most accepted measures for determining the consistency level of the survey [41]. After measuring the consistency of the survey to be acceptable, the Relative Importance Index (RII) was utilized to determine the importance of PFs and CFs in a range of 0.0–1.0, where an RII value closer to 1 indicates higher importance [30]. The RII is calculated as follows:

$$RII = \frac{\sum_{i=1}^5 W_i}{A \times N} \quad (1)$$

where  $W$  is the weight given to each factor by respondents,  $A$  is the highest weight (5), and  $N$  is the total number of respondents.

After this, the construction phase was analyzed in more detail. Construction factors or factors affecting cost increase during the construction phase (CFs) were categorized into four main constructs, including Contractor's Site Management (SM), Pre-construction Phase (PC), External (EX), Project Management and Contractual Relationship (PM), as seen in Table 3. They were then coded for further analysis [41,42]. The main reason for doing so was to evaluate the impact of each group of factors in an aggregated way, which can give a better understanding of the larger issues of cost overrun in the construction phase, thus identifying areas for further study. Categorization of the factors was carried out based on the literature review and the author's knowledge.



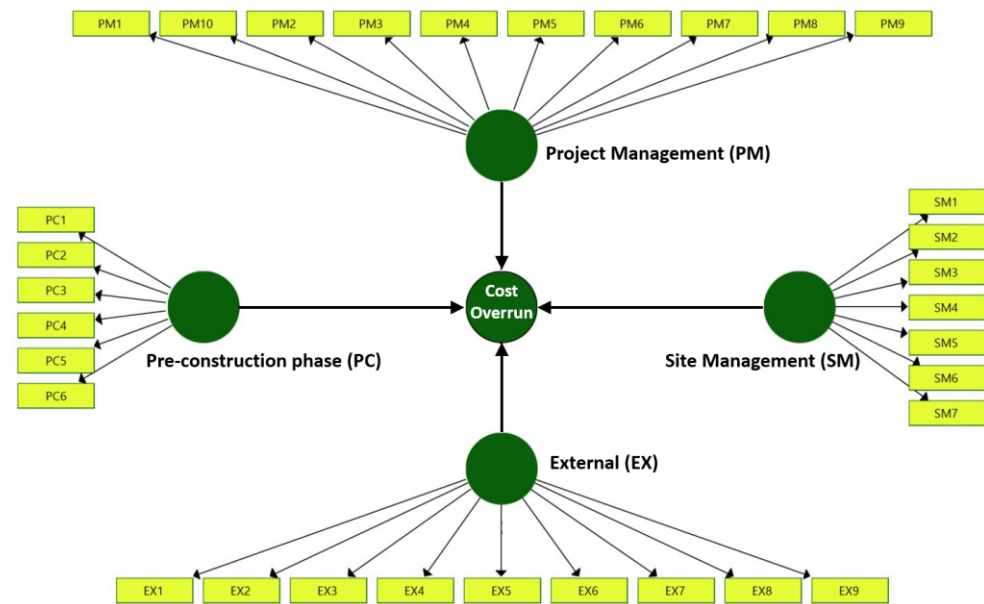
**Table 3.** Causes of cost overrun during the construction phase.

Construct	Abbreviation	Description
External	EX1	Labor unavailability or lack of skilled labor
	EX2	Effect of bad weather (climate)
	EX3	Unforeseen ground conditions
	EX4	Market conditions
	EX5	Lack of resources
	EX6	Monopolization of special equipment
	EX7	Terrain condition
	EX8	Length of the road
	EX9	Project size
Pre-construction Phase	PC1	Forecasting errors (e.g., increasing prices)
	PC2	Delays in decision-making
	PC3	Strategic behavior (deliberate behavior)
	PC4	Deliberate underestimation of costs
	PC5	Inadequate planning process
	PC6	Land and property acquisition challenges
Project Management and Contractual Relationship	PM1	Poor project design
	PM2	Scope changes
	PM3	Improper scheduling
	PM4	Delay in progress payment by the owner
	PM5	Changes in material types and specifications
	PM6	Poor project management
	PM8	Lack of/slow communication between parties
	PM9	Contractual claims (cost or time extension)
	PM10	Conflicts between contractor and the owner
	Contractor's Site Management	SM1
SM2		Lack of experience (in handling such projects)
SM3		Poor on-site financial control
SM4		Low labor productivity
SM5		Inefficient organizational structure
SM6		Inefficient use of resources
SM7		Rework due to poor material quality Lack of incentives

Within the further consideration of the construction phase, Convergent Validity (CV), which is a measure for determining the internal consistency of the CFs' constructs, was determined using Cronbach's coefficient  $\alpha$ , Composite Reliability (CR) scores, and Average Variance Extracted (AVE) [41,43,44]. Cronbach's  $\alpha$  is a reliability measure for the data, and CR is a measure that determines to what extent a construct is measured by its assigned indicators. They both are used to determine the internal consistency of the constructs, and the difference is that Cronbach's  $\alpha$  does not consider factor loading and weighs all the items equally. In contrast, CR considers the item loadings within the theoretical model [41]. It is usually recommended that both Cronbach's  $\alpha$  and CR be higher than 0.7 for a highly internally consistent construct. AVE is another measure for determining internal consistency, which is a measure of the amount of variance that is captured by a construct in relation to the amount of variance due to measurement error. As a rule of thumb, AVE should be higher than 0.5 [41,42,45]. This indicates that the latent variables capture more than 50% of measurement variance.

Structural Equation Modeling (SEM) was first considered to determine the perceived impact of CF constructs on cost overrun [41,46]. Thus, prior to the application of SEM, a theoretical model is required to determine the relationship of the CF constructs to the cost overrun. The theoretical model is presented in Figure 2, showing both the factors and associated constructs. Each factor in each construct is coded and identified as an indicator that relates to the correspondent construct or "latent variable" with an arrow. The direction of the arrow being outwards from the constructs indicates that they are reflective, since a

change in one single indicator (factor) does not affect other indicators, and they (indicators) are highly correlated and essentially interchangeable. At the same time, constructs (latent variables) are essential to cost overrun, since omitting one indicator means omitting one part of the construct, while they are all contributing to cost overrun [47]. This means that the contribution of each of the constructs to the total overrun will be determined, and the reflection (loading) of the four main constructs will be assigned to the corresponding factors. The model presented in Figure 2 measures the direct and indirect relationships between the four constructs and the overall cost overrun.



**Figure 2.** Theoretical model for determining factors affecting cost overrun.

Due to the small sample size and simplicity of the model, the Partial Least Squares method (PLS-SEM) was selected to analyze the data using SmartPLS version 3.0. PLS is a widely used method for estimating path coefficients in structural models, and is becoming significantly popular in management in recent years. Adopting a PLS approach to SEM has been recently recommended, and considered the most suitable method for examining causal relationships in the presence of constructs [41,45]. In addition, it has been demonstrated that SEM has better functionality than other multivariate techniques, including multiple regression, path analysis, and factor analysis [41,45,46]. One of the main advantages of PLS is its modeling ability for latent constructs under conditions of non-normality, and that it is practical for small to medium sample sizes [46,48].

## 4. Results

### 4.1. Ranking of the Factors Affecting Cost Increase in the Planning Phase (PFs)

This section presents the analysis of the results obtained from the respondents' attitudes towards the most influential parameters affecting cost increase in the planning phase. Prior to the RII analysis, reliability analysis was carried out, and Cronbach's  $\alpha$  was determined to be 0.76, indicating acceptable consistency. In addition, the Mahalanobis test identified no potential outliers. Table 4 shows the results obtained from RII analysis, as well as the mean and standard deviation. The factors are ranked according to RII, which gives the same ranking as if sorted by mean. However, RII, which is simply a scaled mean score for an item, is a more precise criterion to evaluate the importance of the factors.

**Table 4.** Ranking of the most important parameters affecting cost increase in the planning phase (PFs).

Rank	Factor	RII	Mean	Std. Deviation
1	Local wishes without cost responsibility	0.818	4.0606	0.7044
2	Defective estimation	0.794	3.9697	1.1035
3	Long processing time	0.727	3.5455	1.1481
4	Those who get the benefit are not the ones who pay	0.709	3.5455	1.0335
4	Changes in rules and regulations	0.709	3.4545	1.0335
5	Project optimism	0.697	3.4242	0.9364
5	Poor project management	0.697	3.4242	1.1734
5	Lack of follow-up	0.697	3.3939	1.1163
6	Changes in the society expectations	0.661	3.2121	1.0828
7	City projects are detailed and costly to estimate	0.655	3.1818	1.2613
8	Different degrees of maturity before projects become the subject of QA1	0.642	3.1515	0.8704
9	Cost increases from QA1 to QA2 have no consequences	0.588	2.9091	0.9139
9	Technological development	0.588	2.8485	1.0642
10	Weak incentives to reduce planning time	0.576	2.8485	0.7124
11	Little transparency	0.558	2.7879	0.8572
12	Socio-economic profitability is of little importance	0.552	2.7576	0.8671
12	Increased funding hides cost growth	0.552	2.6970	0.9838
13	Changed/different staffing	0.473	2.3333	0.8165

The results show that the parameter *local wishes without cost responsibility* was ranked as the most important cost increase factor, with the RII value of 0.818. Next, *defective estimation* and *long processing time* are placed as the second and third, with RII values of 0.794 and 0.727, respectively. These are followed by *those who get the benefit are not the ones who pay* and *changes in rules and regulations* as the fourth most important factors, with an RII value of 0.709.

*Project optimism* together with *poor project management* and *lack of follow-up* were ranked as the fifth factor, with an RII value of 0.697, and *changes in society expectations* was ranked as the sixth factor.

The factors *changed/different staffing*, *increased funding hides cost growth*, *more value for money is of little importance*, and *little transparency* were determined to be the four least influential factors, with the RII values of 0.473, 0.552, 0.552 and 0.558, respectively. This is perhaps reflective of adjustments to quality assurance protocols since ‘increasing the socio-economic profitability’ and ‘increasing transparency’ were among the main objectives of the quality assurance regime in Norway.

#### 4.2. Ranking of the Factors in the Construction Phase (CFs)

Similar to the planning phase, respondents’ attitudes towards the most influential parameters affecting cost overrun in the construction phase were analyzed. Considering the reliability of the factors, Cronbach’s  $\alpha$  was measured to be 0.93. Data were assessed for multivariate outliers using a Mahalanobis Distance Test, and no multivariate outliers were identified [49]. The results of RII analysis for the CFs are presented in Table 5. *Scope changes* was determined to be the most important factor affecting cost overrun during the construction phase, with an RII value of 0.842. The value of RII for *market conditions* was calculated to be 0.818, as the second most important factor, followed by *unforeseen ground conditions* with an RII value of 0.806.

On the contrary, *delay in progress payment by the owner*, *deliberate underestimation of costs*, and *monopolization of special equipment* were listed as the least influential factors on cost overrun, with RII values of 0.412, 0.442, and 0.455 respectively.

**Table 5.** Ranking of the most important parameters affecting cost overrun in the construction phase (CFs).

Rank	Factor	Description	RII	Mean	Std. Deviation
1	PM2	Scope changes	0.842	4.212	0.820
2	EX4	Market conditions	0.818	4.091	1.011
3	EX3	Unforeseen ground conditions	0.806	4.030	0.847
4	PM10	Conflicts between contractor and the owner	0.752	3.758	0.751
5	PC1	Forecasting errors (e.g., increasing prices)	0.739	3.697	0.810
6	PM9	Contractual claims (cost or time extension)	0.697	3.485	0.939
7	PC2	Delays in decision-making	0.691	3.455	0.938
7	PC5	Inadequate planning process	0.691	3.455	0.971
8	SM1	Insufficient site management and inspection	0.648	3.242	0.969
8	EX9	Project size	0.648	3.242	1.032
9	PM3	Improper scheduling	0.636	3.182	0.882
10	PM6	Poor project management	0.624	2.758	0.663
10	PM8	Lack of/slow communication between parties	0.624	3.121	0.960
10	EX7	Terrain condition	0.624	3.121	0.960
11	SM2	Lack of experience (in handling such projects)	0.600	3.000	0.559
12	EX8	Length of the road	0.588	2.939	1.171
13	SM7	Lack of incentives	0.582	2.909	0.843
13	PC6	Land and property acquisition challenges	0.582	2.909	0.980
14	SM5	Inefficient organizational structure	0.570	2.848	0.870
15	SM6	Rework due to poor material quality	0.558	2.788	0.992
16	PM1	Poor project design	0.552	2.758	0.663
16	PM5	Changes in materials types and specifications	0.552	2.758	1.119
17	EX2	Effect of bad weather (climate)	0.527	2.636	1.113
18	EX1	Labor unavailability or lack of skilled labor	0.521	2.606	0.704
19	SM3	Poor on-site financial control	0.515	2.576	0.936
19	EX5	Lack of resources	0.515	2.576	1.062
20	SM5	Inefficient use of resources	0.503	2.515	0.870
21	PC3	Strategic behavior (deliberate behavior)	0.497	2.485	1.004
22	SM4	Low labor productivity	0.485	2.424	1.062
23	EX6	Monopolization of special equipment	0.455	2.273	1.008
24	PC4	Deliberate underestimation of costs	0.442	2.212	1.193
25	PM4	Delay in progress payment by the owner	0.412	2.061	0.827

#### 4.3. Structural Relationship Model for CF Constructs

The theoretical model (SEM-based), which was developed to determine the relevance of each of the main constructs (categorized CFs) to cost overrun, and the results are presented in this section. As stated before, the CFs were categorized into four main constructs:

(i) *External*—factors that are not under full control of project organization, such as the effect of bad weather and market conditions;

(ii) *Pre-construction*—factors mainly related to the planning or, more generally speaking, pre-construction phase, but their impact is revealed in the construction phase and affects the project's cost performance;

(iii) *Project Management and Contractual Relationship*—human-related factors that can barricade the smooth and stable process of the project;

(iiii) *Contractor's Site Management*—challenges related to financing, scheduling, supervising, or the problems derived from changing requirements.

The above-mentioned constructs were modeled in SmartPLS, and their relationship with cost overrun was measured. First, the internal consistency reliability of the model was tested by measuring Cronbach's alpha and Composite Reliability (CR). In addition, the convergent validity of the model was tested through assessing factor loadings and Average Variance Extracted (AVE). Item loadings for all the 32 factors are presented in Table 6. The minimum values of item loading range between 0.5 and 0.7. A value of 0.6 was used as the threshold, and only EX4, SM2, and SM7 had loading factors lower than 0.6 (0.583, 0.469,

and 0.353, respectively) [41,45,48]. EX4 was kept since the loading factor was very close to 0.6, and SM7, with the lowest loading factor, was deleted from further analysis. In the second round, it was observed that the deletion of SM7 resulted in a negligible increase in SM2's loading factor. However, as this was still below the threshold, SM2 was also removed from further analysis.

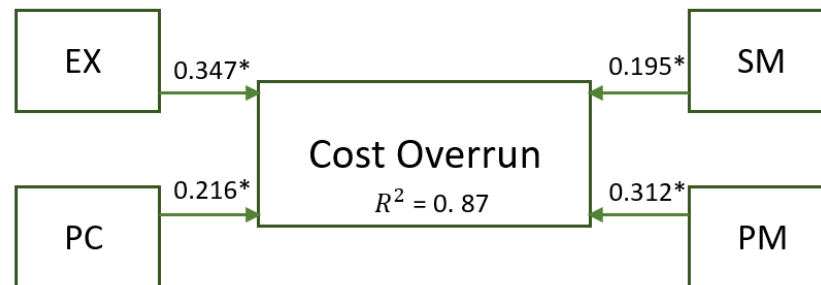
**Table 6.** Reliability and convergent validity of the constructs.

Factor	Iteration 1				Iteration 2				Iteration 3			
	Loading	Alpha	CR	AVE	Loading	Alpha	CR	AVE	Loading	Alpha	CR	AVE
EX1	0.735	0.785	0.834	0.581	0.735	0.785	0.834	0.581	0.735	0.785	0.834	0.581
EX2	0.83				0.83				0.83			
EX3	0.802				0.802				0.802			
EX4	0.583				0.583				0.583			
EX5	0.688				0.688				0.688			
EX6	0.774				0.774				0.774			
EX7	0.787				0.787				0.787			
EX8	0.726				0.726				0.726			
EX9	0.866				0.866				0.866			
PC1	0.877	0.82	0.87	0.729	0.877	0.82	0.87	0.729	0.877	0.82	0.87	0.729
PC2	0.751				0.751				0.751			
PC3	0.763				0.763				0.763			
PC4	0.697				0.697				0.697			
PC5	0.781				0.781				0.781			
PC6	0.726				0.726				0.726			
PM1	0.725	0.784	0.839	0.556	0.725	0.784	0.839	0.556	0.725	0.784	0.839	0.556
PM10	0.679				0.679				0.679			
PM2	0.694				0.694				0.694			
PM3	0.791				0.791				0.791			
PM4	0.811				0.811				0.811			
PM5	0.808				0.808				0.808			
PM6	0.826				0.826				0.826			
PM7	0.788				0.788				0.788			
PM8	0.762				0.762				0.762			
PM9	0.732				0.732				0.732			
SM1	0.813	0.671	0.794	0.452	0.804	0.728	0.812	0.502	0.826	0.742	0.828	0.568
SM2	0.469				0.493				Omitted			
SM3	0.874				0.896				0.869			
SM4	0.755				0.791				0.784			
SM5	0.727				0.786				0.831			
SM6	0.722				0.757				0.845			
SM7	0.353				Omitted				Omitted			

Regarding Table 6, it can be observed that all AVE values, which are used to measure the common variance in a given construct, are higher than the recommended value of 0.5, ranging from 0.556 to 0.729 [48]. Moreover, CR values, which describe the degree to which the construct factors indicate the latent construct, were observed to be higher than the recommended value of 0.7 [46,48]. Thereafter, discriminant validity was checked, and the AVE value of each construct was found to be larger than its corresponding correlation coefficients [46,50].

The structural relationship model determines the direct and indirect relationships of each construct to cost overrun using regression coefficients  $R^2$  and  $\beta$ , as presented in Figure 3. Moreover, the bootstrap procedure examined the significance of  $\beta$  values in indirect relationships among the constructs. However, due to the simplicity of the model used in this study and given that the constructs are directly related to the overall cost overrun, only direct relationships were measured in the model fit [41,46]. According to previous studies [45,46,48], the path relationships are assumed to be significant at

10%, 5%, and 1% significance levels, while the  $t$ -values are higher than 1.65, 1.96, and 2.57, respectively. In particular, the percentage of model variance extraction is shown by  $R^2$ , while path coefficients ( $\beta$ ) indicate the strength of the relationships between the constructs [41,45]. This means that the values of path coefficients shown in Figure 3 indicate the impact of each construct on cost overrun.



\*Critical  $t$ -value: 2.58 ( $P < 0.01$ )

**Figure 3.** Results of the structural model.

As shown in Figure 3,  $R^2$  is determined to be 0.87—higher than 0.26, which Cohen [51] believes indicates substantial explaining power. Regarding the path coefficients, it can be observed that all the constructs positively affected cost overrun, but they share different variance values. For instance, the construct EX has  $\beta = 0.347$ , which means this construct significantly affects cost overrun compared to the others by explaining 34.7% of the variance in cost overrun. Second, PM shares 31.2% of the variance ( $\beta = 0.312$ ) with respect to cost overrun. The value of  $\beta$  was observed to be 0.216 and 0.195 for PC and SM constructs, respectively.

## 5. Discussion

This section discusses the results presented in the previous section, mainly the ranking of the most important factors affecting the cost inaccuracy in the planning and construction phases, and elaborates on the results obtained from PLS-SEM.

### 5.1. Factors Affecting Cost Increase in the Planning Phase (PFs)

*Local wishes without cost responsibility* was ranked as the most important factor, with an RII value of 0.818. A good example of this type of factor is the case of St Olav's Hospital in Trondheim, Norway (while not a transport project, this is still a state-funded project). The initiators and eventual owners of the project at the county level assumed that the state government would take responsibility for funding, and the cost increases would not stop the project based on previous state-funded hospital projects. However, within a few years, costs were increased from NOK 1 billion to NOK 12 billion, and if the state government had not curbed the cost increase through extensive hospital reform measures, the cost increases could have been much more [4,52]. Liabilities and incentives for cost control should be introduced at the early stages of planning to avoid cost escalations. The public sector relies on transparency in order to strengthen accountability. Therefore, government-funded projects should be selected based on high-quality information about the needs, benefits, costs, and risks.

Considering the factors of *local wishes without cost responsibility* (first), *defective estimation* (second), *those who get the benefit are not the ones who pay* (fourth), together with *project optimism* (fifth), it can be inferred that generally, inaccurate estimations in the phase of planning, together with local wishes and lack of responsibility, are the main reasons for cost increases in the planning phase. Sometimes, local promoters deliberately provide low-cost estimates to make it easier to gain acceptance for the project. Estimations are normally unrealistic, and on the contrary, benefits for the users and society are overestimated. As a result of underestimating the costs and overestimating the benefits, the chance of the project



being accepted increases, and the project initiatives, which might have been reasonable and beneficial in the first place, grow in costs and become over-dimensioned, due to the requirements additionally introduced after the initial approval of the project. In contrast, if the actual costs are presented, the project may be rejected at the early stages [52,53].

These results agree with previous studies, which state that politicians play a role in the planning process. Road administrations in some regions are more politicized than others, which can also result in misleading cost information being given to Parliament, which eventually leads to cost increase. In addition, competition exists between different parties in some regions to keep their policies at the forefront [23]. As another example, Volden [53] evaluated nine large-scale projects' planning stages, and found that substantial resources were spent just on lobbying.

The fifth-place ranking belonged to *project optimism*, together with *poor project management* and *lack of follow-up*, with an RII value of 0.697. Although these three parameters are still among the most important in the respondents' opinions, project handling in the planning phase in Norway has been significantly improved since the quality assurance regime was introduced in 2000 and expanded in 2005. This implies that both the economic appraisals and cost estimates of large government projects must be scrutinized by external consultants before projects are allowed to proceed to the next planning phase [54]. This governance regime ensures that plans and estimates are subjected to an outside view, which may reduce the risk of over-optimism and strategic behavior.

Project planning in Norway is an open and communicative process that requires that all stakeholders must be consulted. Local authorities must grant planning permission before the government can approve a final budget. This increases the risk of both a misalignment of incentives and that the process may take longer than planned. As time passes, the expectations of society increase, and our acceptance of adverse environmental and social effects decreases. In addition to the fact that it may stretch the planning phase out, it may cause unwanted cost increases [55].

### 5.2. Factors Affecting Cost Overrun in the Construction Phase (CFs)

Ranked first in this study, *changes in the scope* of the projects has been listed among the main reasons for cost overrun indicated within the literature. Ascher [56] found that about 40–90% of the total cost overrun can be explained by three factors alone: scope change, impact of inflation, and delay. In a more recent study done by Lee in 2008, the author concluded that changes in scope, delays during construction, unreasonable estimations, and adjustments of project costs are the main reasons of cost overrun [57].

One of the main reasons that *market conditions* is ranked second is that Norway has experienced three different periods of high market volatility since 2000 (i.e., inflation, and as a result increases in materials prices, in 2004–2005; the world crisis in 2008–2009, and the oil price drop in 2015–2016). Norway's economy is highly dependent on the oil market, and fluctuations in the price of oil can result in an unstable and volatile market. This has also been investigated by Dahl et al. [58], who found a clear relationship between the increase in oil prices and cost overruns.

*Unforeseen ground conditions* was observed to be the third most important factor, and has been among the most important factors in the literature, but its importance is even higher in Norway. Fjord and mountain landscapes in the western and eastern regions, and to a lesser extent the central region, make the topography of Norway challenging for infrastructure construction. Most of the population is located in areas with large marine deposits, making road construction vulnerable to quick clay and unstable geological conditions. Therefore, it can be deduced that the first three factors should be considered as serious uncertainties in the early planning phases, which may lead to unwanted time or cost overruns.

In the opinion of Norwegian experts, *conflicts between contractor and the owner* was ranked as fourth, with an RII value of 0.752. Generally, Norwegian work culture is egalitarian and independent, meaning that people are given enough freedom to work in the areas of their responsibility. The system is also based on trust, and people usually prefer

not to be told in detail how to do their job. However, conflicts and disputes in the construction industry in Norway have been increasing in recent years. According to a study carried out by Sabri et al. [59], tender specification and contract understanding, final settlement payment, low-priced contracts, and changes in the project were the most influencing parameters resulting in conflicts and disputes. Among them, tender specifications and contract understanding were the most influential causes of conflicts in Norway, followed by disagreements on final settlements, usually issued by the public owner. They recommend introducing a clear dispute management pattern for investments in large-scale Norwegian infrastructure projects [59].

*Forecasting errors* is another factor, similar to market conditions, that should be considered in uncertainty analysis from the early planning phases. This is a factor that stems from underestimation during the planning phase, affecting the cost overrun in the construction phase. In such a case, the government has two options: either finance the project for the additional requested budget, or stop the project. However, if the estimations were more precise, the government could make another decision, such as project modification. Increasing transparency and logging all project cost estimations from the early stages of planning could be a solution for increasing the precision of the estimation and reducing the risk of forecasting errors. Nevertheless, the analysis methods in this study could not measure these effects, which could be a potential area for further research.

*Project size* and *length of the road* were evaluated in this study, and were ranked as eighth and twelfth. Previous studies showed that project size, which is defined according to the budget allocated for the project, might have an impact on the magnitude of cost overrun, as the larger the project, the higher amount of cost overrun. However, the findings are inconclusive, but it can be regarded as an important parameter according to the obtained results.

*Delay in progress payment by the owner*, *deliberate underestimation of costs*, and *monopolization of special equipment* were listed as the least influential factors on cost overrun. It was expected that monopolization of equipment can be more influential in developing countries, in countries with lower GDP, or in places where the management and governance of the public projects is not transparent, and there might be a risk of corruption. *Deliberate underestimation of costs* and *strategic behavior (deliberate behavior)* were also among the lower-ranked factors. This indicates that in contrast to some of the available research, including that by Cantarelli et al. [20], who categorized them as economical explanations for cost overrun, these factors do not play an important role in Norway.

### 5.3. CF Constructs

Concerning the SEM analysis and model result in Figure 3, and with regard to the second research question, it can be inferred that external factors have the largest impact on cost overrun within this study. As previously stated, external factors are not entirely under the control of humans, such as the effect of bad weather or market conditions. However, it is possible to consider uncertainties that originate from external factors in the planning process. As of now, cost estimations, particular to Norway, are calculated based on stochastic (probability-based) estimations in the early planning phases. Carrying out stochastic estimations, either through mathematical analytical methods or simulation tools, results in a cumulative probability distribution of investment costs. The estimation process produces a tornado diagram that ranks different uncertainties according to their impact on total costs, which can then result in further oversight during the construction phase.

The *project management and contractual relationship* construct was determined to be the second most important group of factors affecting cost overrun. As mentioned previously and discussed in Section 5.2, this construct primarily includes human-related factors that can directly affect smooth and stable project governance. Risk factors in this construct mostly originate from tender specification and contract misunderstanding, improper scheduling/delayed final settlement/payment, low-priced contracts, and changes in the project's scope. For example, *conflicts between contractor and the owner* and *contractual claims*



(*cost or time extension*) were ranked as fourth and sixth among the CFs, respectively. Therefore, improving and better clarifying tender specifications and contract understanding may reduce conflicts and disputes, which have been recently increasing in Norway.

Site management factors have the least impact on cost overrun. This means that contractors are performing justifiably in Norway, according to the respondents, who notably did not include contractors themselves.

According to the model results, pre-construction factors have the second lowest impact on cost overrun. These are factors that reveal themselves during the construction phase, but stem from the planning phase. Considering the previous rankings (in Table 5), some of the factors, including *forecasting errors* (e.g., *increasing prices*), *delays in decision-making*, and *inadequate planning process*, rank rather highly (fifth, seventh and seventh, respectively). While others, specifically *strategic behavior* (*deliberate behavior*) and *deliberate underestimation of costs*, are listed among the least important factors. Thus, there is not necessarily a consistent trend among the factors within this construct, and the low-ranking factors can reduce the overall impact of the construct as a whole.

## 6. Conclusions

Cost performance, specifically cost overrun, is an important topic within transportation economy and project management. It is essential to realize what factors affect cost overrun during both construction and planning phases. Determining these factors will not only improve the cost performance and improve the success level of the project, but also helps to manage and ensure the proper use of resources.

Considering sustainability, the main focus of this study was on the economic aspect of sustainability, focusing on risk factors that can affect the cost performance of large-scale road projects in order to curb cost overrun risks. Thus, increased knowledge of factors affecting cost performance is important to attain economically sustainable project management. Moreover, it can also result in the better use of resources, and thus the further preservation of the environment.

This study investigated the most important factors affecting cost overrun in the planning and construction phases using data from Norway. Using data from one country, where projects are planned and implemented in a consistent manner, ensures a more robust assessment of causes than studies based on data collected from different countries and from different time periods. This paper enhances the past research by introducing a new set of factors that may occur during the planning phase and affect the final cost performance of the project, as well as the most influential factors in the construction phase affecting cost overrun in Norway. Projects go through different stages in their development and delivery, and the causes of cost increase and overrun may differ as time proceeds. To identify root causes, studies should therefore distinguish between projects' front-end and delivery. To this aim, a questionnaire survey was distributed to various relevant people who have been involved in at least in one large-scale road project in Norway. The main findings of the study can be summarized as follows:

- *Local wishes without cost responsibility, defective estimation, long processing time, those who benefit are not the ones who pay, and changes in rules and regulations* are the main factors that can result in cost overrun in the planning phase. This suggests that from a political perspective, there may be arguments for better aligning the interests of project owners and local stakeholders, for example, through a mechanism for mandatory local contribution. Furthermore, despite progress in improving the quality of project front-end management over the last two decades, there is still potential for improving efficiency by improving cost estimation methodologies that better capture the risks in the early stages of appraisal and planning. Likewise, *changed/different staffing, increased funding hides cost growth, and socio-economic profitability is of little importance* are among the least influential factors, indicating that the planning process in some of the regions might be politicized. In addition, long processing time should be considered as a

serious uncertainty even in the planning phase, which may result in an increase in cost estimations;

- *Scope changes, market conditions, and unforeseen ground conditions* are the most influential factors on cost overrun in the construction phase, according to the experts' opinions in Norway. This is in agreement with previous studies, as these three factors have been among the most critical uncertainties in large infrastructure projects worldwide. In addition, within the construction phase, *delay in progress payment by the owner, deliberate underestimation of costs, and monopolization of special equipment* are the factors with the least influence on cost overrun;
- Factors affecting cost overrun during the construction phase were categorized into four main constructs—external, contractor's site management, pre-planning, and project management and contractual relationship were modeled in SmartPLS version 3.0 to determine and compare their impact on cost overrun. External factors—generally uncertain factors with less human controllability—had the greatest impact on cost overrun. This indicates that although cost estimations in Norway are based on stochastic estimations, there is still room for improvement. However, according to the respondents, planning phase factors did not strongly affect cost overrun during construction despite the suggestions in the previous literature.

The results of this study create knowledge on risk factors that can affect cost inaccuracy in both the planning and construction phases, and the relationships between them. Investigating such factors in the planning phase and their impact on the construction phase and overall cost overrun has not been considered in the literature yet. This research also highlights that studies of cost overrun address economic sustainability within project management.

Finally, it should be mentioned that this study also has limitations. First, the results of this study are not directly applicable to other countries, and similar studies should be carried out in individual countries. However, the methodology used in this study can be utilized for other similar studies. Second, the small sample size was the limitation of this study, which made the use of SEM challenging. However, the PLS-based method was used in this study, which is recommended in the literature for small sample sizes. In addition, with a bigger sample size, it could have been possible to cover more attitudes (e.g., contractors) in the research, and reduce the risk of biased answers. This could be suggested for further research, together with an assessment of the planning phase as a highly relevant parameter that can influence the cost performance of the project.

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