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Knowledge about the Origins of Uncertainties from the Pre-Project Phase of Road Projects

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Abstract: To succeed with projects, we need to understand and manage uncertainty. Uncertainties impact a project's cost, time, and quality performance. The project's front end is challenging for decision makers due to the high level of uncertainty. This paper identifies the most common uncertainties and their origin in the pre-project phase of large road projects. It also analyses the changes in these factors over 20 years. Document studies collected information about uncertainty factors identified in the early phase of 90 large road projects. The research strategy was explanatory, and data were collected from quality assurance reports from a population of large Norwegian road projects. The project cost varies between USD 30 million and over USD 2 billion. Then, 15-factor groups were established for categorising uncertainties. This study shows a rise in uncertainty factors with operational origins and a decrease in uncertainty factors with strategic and contextual origins over the last 20 years. Identifying and understanding common uncertainties and their origins provides policymakers, practitioners, and researchers with useful insights for policy revision and investment decision making and facilitates a proper focus regarding uncertainty analyses in the front end of road projects.

Keywords: pre-project; uncertainty; operational uncertainty; strategic uncertainty; contextual uncertainty

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1. Introduction: Uncertainty in Projects

Uncertainty is a fact of life. It is present in most decisions and people's understanding of the world, their plans, and projects. The investor typically makes business opportunity decisions. In the case of investment projects, this tends to be the project owner. Thus, identifying and analysing uncertainties in the projects' front end would be particularly interesting to owners. Project owners, promoters, investors, and financiers need to know what uncertainties related to cost, time and scope they will face when making investment decisions [1]. This paper takes the owner's perspective and defines uncertainty analyses and management as one of the essential aspects of project governance.

Uncertainty can influence project outcomes in terms of time, cost, and quality [2], meaning that it can significantly affect project success. More importantly, the effects of uncertainty are not limited to short-term objectives but can also affect strategic objectives. Uncertainty is a significant concern when deciding which project to invest in and what concept to develop [3,4]. Accordingly, uncertainty management is a vital component of project management.

Project managers are responsible for a project's success. As such, uncertainty management transcends uncertainty in decision making but also includes variability in the state of things, variation in processes, and limited rationality in human behaviour. Managing uncertainty is undoubtedly a key competence for project managers [5].

To manage uncertainty, it is essential to trace its origins, understand its possible consequences, and predict how uncertain events may unfold [6]. The identification of uncertainties is a starting point. The consequences of uncertainty can be upside (opportunities) and downside (threats). Johansen [1] argues that uncertainty management becomes more vital in low-budget projects with tight schedules. Presumably, uncertainty management becomes more critical as the scope and complexity increase. Several authors [1,6] have highlighted that an increased focus on uncertainty management has been a significant development area in projects over the last decades.

Major public investment projects in Norway are quality assured in the front end by external consultants, analysing cost and time uncertainty. This is part of a standard governance procedure for all large public investment projects. It includes an uncertainty analysis of the project cost as an input to the Norwegian Parliament's decision making [7–9]. The quality assurance (QA) of external consultants is carried out before the budget's approval and the project's execution.

Uncertainty factors could be assessed from operational, strategic, and contextual perspectives. Operational uncertainties relate to the project and are managed by the project team. Strategic uncertainties are those on the business level that are beyond the project manager's control and may instead fall under the remit of the project owner. Contextual uncertainties refer to conditions outside of the project that could affect its process and results [1] (p. 133) [5] (p. 45).

This paper aims to develop knowledge about uncertainty factors in road projects and their origin. While there is extensive literature on uncertainty analysis and management [1,10–13], analyses on the type and quantity of different categories of uncertainty factors in road projects are somewhat lacking [14]. In pre-project phases, when detailed project information is scarce, the project uncertainty factors are more generic than specific. Therefore, investigating historical data could benefit new projects [15].

Furthermore, this study is intended to help project owners make better decisions about projects and increase the likelihood of selecting the right project concepts and executing them successfully. One of the key strategies to achieve this aim is to improve our knowledge of project uncertainties. This involves understanding the uncertainty nature, its root causes, its effects on project processes, and its consequences. Due to the sheer scale of this issue, the scope was narrowed to answer the following research questions (***RQ***):

RQ1: *What uncertainties appear most often in the pre-project phases of road projects?*

RQ2: *What are the dominating origins of uncertainties in the pre-project phases of road projects?*

RQ3: *What changes in uncertainty origins can be observed between 2000 and 2019 in pre-project documents?*

The research questions will be answered by studying the results from the uncertainty analysis of 90 quality assurance reports prepared by external consultants. The remainder of the paper is structured as follows. Section 2 provides theories relating to uncertainty and the projects' front ends. Section 3 details the research design and methodology. Section 4 presents the findings, which are then discussed in Section 5. Section 6 provides the conclusion and possibilities for future research.

2. Uncertainty: From Definition to Classification

This section introduces the theoretical framework for the research. The section presents the definition of uncertainty and its theories relating to construction projects.

2.1. Definition and Understanding of Uncertainty

The concept of analysing uncertainty was first introduced in the mid-1950s with the program evaluation and review technique (PERT) to estimate a project's time [16]. With uncertainty as the overarching term, Galbraith argued that uncertainty chiefly concerns a lack of information [17]. Different authors recognise uncertainty in construction projects [11,14].

Recent studies have combined historical knowledge with AI-based approaches to learn from the risk and uncertainty domain [15,18]. For instance, Erfani et al. [15] used a data-driven model with Natural Language Processing (NLP) and deep learning to measure the similarity of risk registers, which belong to experts in major transportation projects. In other research by Jallan and Ashuri [18], they developed a structured method using text mining and NLP capabilities to draw out information from "textual disclosures". In addition to historical data, using expert opinions is another way to improve the performance of risks and uncertainty management in road construction projects [19,20].

There are two uncertainty types related to projects' cost estimates: estimate and single event uncertainty [14]. Estimate uncertainty, also known as variability, occurs because an estimate is a probabilistic assessment of a future condition. For example, someone is going to build a bridge but does not know the cost. These uncertainties relate to quantities, rates, and unit prices, and they focus on components of base estimates [14,21]. Single-event uncertainty relates to the probability and consequences of a possible event [9]. For example, the contractor goes bankrupt during the bridge construction. If so, this will impact both the schedule and project costs, but if not, no consequences will appear.

The three categories of risks are: operational, strategic, and contextual [9,12]. Operational risks are uncertainties under the control of project managers, such as technical issues, the use of resources, efficiency, timeliness, project organisation, and process control [9]. Strategic risks are uncertainties under project owners' control (but not project managers'). These risks' examples include starting or ending projects, scope approval and major scope changes, contract choice and project execution strategies, and project objectives' changes [9]. Contextual uncertainty involves external causes that affect the project during the planning and execution. Project managers or owners have little to no control over this uncertainty type. Examples include law and market conditions, national culture, geopolitics (e.g., new parliamentary rules more or less in favour of roadbuilding), environmental policies, and general technological development [9].

Rolstadås et al. [12] argued that the most dominating forms of uncertainty change over a project's life cycle. Contextual, strategic, and operational risks can fluctuate over a project's phases. They explained that pre-study analyses do not necessarily represent the "full picture" of manageable uncertainty. In the short-term, operational uncertainties are dominant, whereas contextual uncertainties have the major manageable uncertainty shared by the project owners in the long term. Strategic uncertainties show an increasing trend over time. Johansen et al. [9] argued that uncertainty analysis is usually executed during the pre-study or planning phase, but, often, it is not followed up particularly well in the projects' later phases. The majority of uncertainty analysis is directed towards managing operational risk. Contextual and strategic risks are often neglected and managed poorly.

2.2. Digging Deeper: What Are the Sources of Uncertainty in the Front End?

Uncertainty can be classified in different ways [9,11,22,23]. De Myer et al. [11] presented the four types of uncertainty: variations, foreseen, unforeseen, and chaos. Variation is different changes that affect the performance or outcome of activities. Foreseen uncertainty is events that might affect an activity's performance or the project objective. Unforeseen uncertainty or "unknown unknown" is not identifiable in ordinary project planning but can positively or negatively affect performance. Chaos is uncertainty that relates to projects with an uncertain basic plan, and projects that are in this state often end up in a totally different solution than originally intended. Austeng et al. [5] stated that managing uncertainties requires one to understand the drivers behind them, allowing for a more comprehensive understanding of uncertainties. Therefore, recognising projects' uncertainties is essential.

Torp et al. [14] (p. 38) developed 15-factor groups for categorising uncertainty drivers. Factor groups are "groups of issues which identify uncertainties with similar cause and effect" [6,14] and facilitate classification and analysis. These factor groups included market, organisation, project planning and control, cost elements/technical condition, contract strategy/purchase, project leadership, scope management, client involvement, transfer to operation, framework condition, currency, interfaces, stakeholders/surroundings, nature, and health, environment, and safety (HES).

Torp et al. [14] based their factor groups on a literature review and empirical findings from different projects. Torp et al. [14] showed that, in 56 projects, organisation, technical condition, and the market had a high number of uncertainty factors. Of the 56 projects examined, 22 were road projects. They identified 66 uncertainty factors from these road projects, the top 3 factors for each project. Torp and Klakegg [24], focusing on decommissioning a nuclear power plant, identified 12 project uncertainty factor groups based on structured brainstorming. These factors groups were described and assessed regarding their influence on the project's cost [6]. There could be many uncertainties or events that can affect a project's performance or objectives. Uncertainty analysis seeks to identify these uncertainties to counter them most effectively. Using data analysis, one can determine the most important uncertainty factors and those that are most likely to impact the cost of road projects.

2.3. Uncertainty Categories for Factor Groups

The factor groups in Table 1 have been taken from previous research by Torp et al. [14] and Torp et al. [24]. Categorising the factor groups allowed us to more deeply understand the existing uncertainties in the pre-project phases of the examined road projects. The dominant sources of each uncertainty factor can be identified by determining its factor group. Each factor group is categorised into operational, strategic, or contextual uncertainty. Moreover, the table's factor group categorisation is based on the project owners' perspective.

Table 1. Uncertainty categories for factor groups adopted from Torp et al. [14,24].

Factor Groups	Description of the Factor Group	Uncertainty Categories
Project planning and control	Qualities include structure, systems, and routines such as cost, schedule and quality control, project planning and control systems, and change control. Project managers always conduct the monitoring of time and cost.	Operational
Health, environment, and safety	Occupational accidents, safety in project environment.	Operational
Technical Issues	Technical challenges due to large and complex project components (i.e., large bridges, tunnels) and their cost variations. Additionally, technological development and technical solutions.	Operational
Interfaces	The interface between projects and project elements. Interfaces between different contractors and subcontractors, as well as between executives, should be clarified and established early on.	Operational
Leadership and project culture	Leadership, motivation, and communication in project-based organisations.	Operational
Project organisation	Aspects such as quality and skills in the project organisation. Capacity, competence, continuity, and quality of resources in the project organisation. Involvement of construction managers in construction design phases. Structure, responsibility, roles, etc. are also found in this factor group.	Operational
Transfer to operation	Challenges related to testing and implementing the project results and preparing for operations and maintenance.	Operational
Contract strategy	Overall contract strategies such as contracting processes, contract models, and compensation formats. Contract strategy covers milestones for completing elements, incentive use, and risk sharing among contract parties.	Strategic
Client involvement	Aspects such as client demands, execution strategy, and client involvement during the project processes.	Strategic
Framework conditions	Changes are implemented by the project owner, especially related to financing, resource allocations, necessary permissions, and changed framework conditions and premises.	Strategic
Scope management	Includes design development and development and changes of project scope.	Strategic
Market conditions	Includes commercial aspects such as competition and market conditions and development.	Contextual
Stakeholders and media	Collaboration with stakeholders/surroundings, including road users and neighbours.	Contextual
Nature	Geotechnical and geological problems, weather conditions, wind, flooding.	Contextual
Currency	Changes in currency affect the project.	Contextual

Here are some examples to illustrate the categorisation of factors: health, environment, and safety is uncertainty related to occupational accidents, which relates to the project team's operation inside the projects. Therefore, it is an operational uncertainty and is associated with the condition of the project. Contract strategy is strategic and encompasses aspects such as contracting procurement procedures, contract models, and compensation formats decided by the project owner. The contract strategy is strategic uncertainty because the project owner could determine it, and it is not under the project manager's authority. Contextual uncertainties are outside the control of the project manager and project owner. They are related to the project's environment.

The factor group "market", as a contextual uncertainty, covers price changes, inflation, new suppliers, and new products. This group consist of elements that can partly be understood as contextual from the project owner's side, such as "price changes and inflation", but it can also be argued from the project management perspective that "new suppliers and new products" can be considered relatively operational and therefore belongs to the factor group "operational" uncertainty. We made the factor groups categorisation in Table 1 from the project owner's perspective.

3. Method and Research Design

The first part of the methodology covers the research strategy. The second part of the methodology details the paper's document study and data structure. Once done, the following part focuses on the six-step data analysis process. The fourth part explains the validity and reliability of the research, and the final part concludes with research limitations.

3.1. Research Strategy

The research is explanatory, takes descriptive information into account [25], and follows a long period of data development related to the quality assurance scheme for large public projects. A sample of 90 large Norwegian infrastructure road projects from 2000 to 2019 have been investigated. These projects were subjected to external quality assurance. QA is conducted as part of a national governmental scheme aiming to secure the cost for large public projects before budget approval in the Parliament and the final decision to execute the project. External consultants analyse the costs and uncertainties related to costs and report their findings to the Finance Ministry. QA consultants conduct independent uncertainty analysis on projects from the owner's perspective. All consultants follow similar structures and methods for analysis, as described by Lichtenberg [26], which is similar to what has been reported in some detail by Torp and Klakegg [24]. Typically, five to seven consultancy companies have a framework agreement with the Ministry of Finance to carry out this type of Quality Assurance. The agreements last for 2 years, with the option of a 2-year extension. Some consultants have been in the game for years, while some new ones have arrived. Each quality assurance is a separate contract involving consultants and people from the project owner's ministry, the agency, and the project. Therefore, a possible copy–paste from previous quality assurance reports would easily be uncovered.

3.2. Document Study and Data Structure

This study used a structured document study of QA reports from 90 large public road projects in Norway. The projects' size varied between USD 30 million and USD 2 billion. Output data were analysed from the consultants' uncertainty analysis.

The "top lists" of uncertainties [14,24] from the consultant's analyses were used for collecting input data on uncertainties. The uncertainty data of reports can be categorised as qualitative. These data were sorted based on priority according to their contribution to total variability in costs. Each of the 90 projects had a similar list.

3.3. Data Analysis

The authors used a six-step process to analyse the data from 90 projects (see Figure 1). The process was conducted by the authors. Steps 1–2, collecting uncertainties and labelling uncertainties to factors, were carried out in a workshop. Steps 2 and 3 answered the first research question, steps 4 and 5 answered the second, and step 6 answered the third. The data evaluation of steps 1–2, 4, and 6 was qualitative, whereas that of steps 3 and 5 was quantitative (see Figure 1).

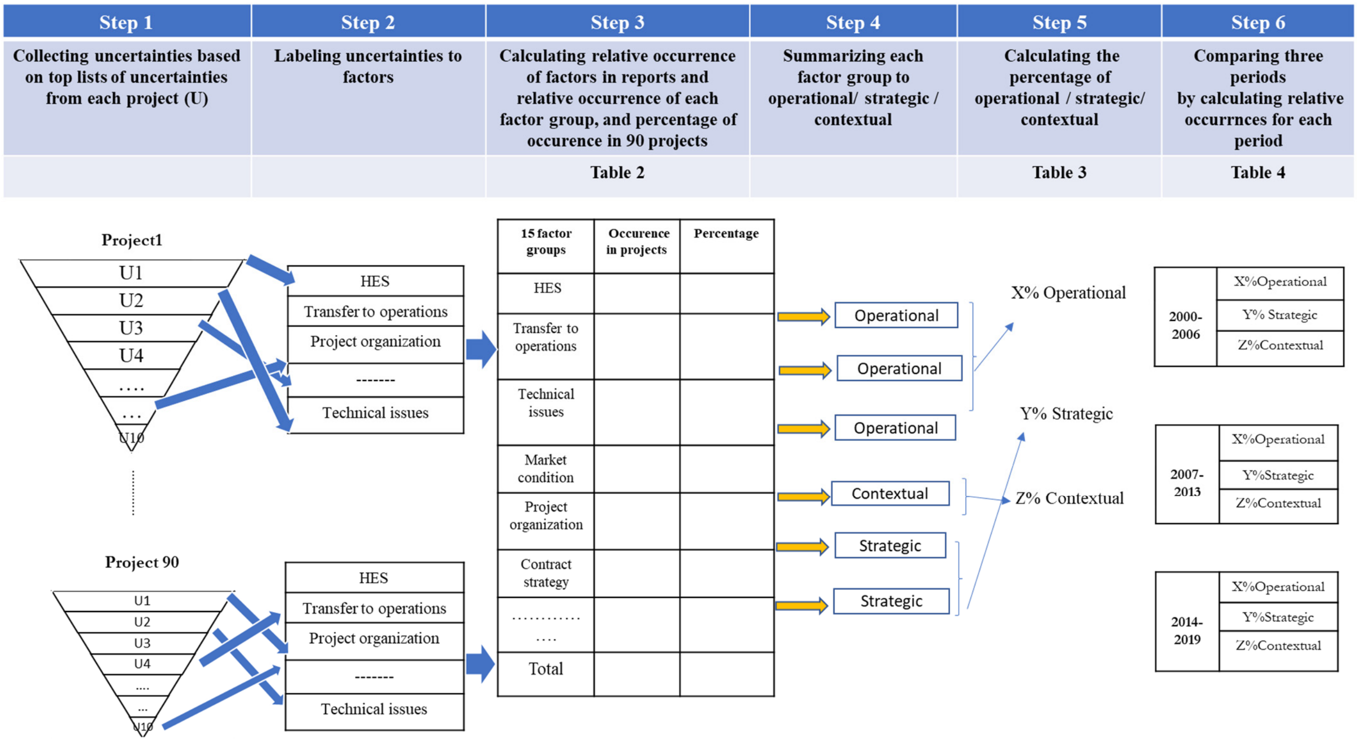

Figure 1. Six steps for the analysis of data from 90 road projects.

For the data collection, projects' uncertainty data provided in documents by consultants were used. The authors had no role in cases that were analysed. The data were imported from a large database and categorised by authors into different factor groups, based on categories described in Table 1. As depicted in Figure 1, step 1 involved listing all top ten uncertainties based on each project's uncertainty profile, which was transferred to an Excel sheet with 939 rows for uncertainty factors. Next, these uncertainties were labelled into determined factor groups in step 2. For example, of the first project's top uncertainties, three were related to technical conditions, two were related to market conditions, one was related to nature, and so on. Different factors concerning market conditions, such as price changes, market development, and inflation, were gathered under the label of "market conditions". This process was performed for all 939 uncertainty factors documented in the QA reports. In step 3, the relative occurrence of these factors was calculated. This analysis shows how frequently these factor groups occurred within the projects. We sought to determine the occurrence of factors in projects to answer the second research question in the next steps. Therefore, their emergence in 90 projects was calculated. For example, it was found that market conditions have emerged on the top list of 88 projects out of 90 projects, and these data are used to calculate the percentage of occurrences. In the fourth step, each factor was classified into one operational, strategic, and contextual category. The fifth step calculated the share of operational, strategic, and contextual uncertainties. Step six involved comparing and calculating the relative occurrence of operational, strategic, and contextual uncertainty over three separate periods, namely, 2000–2006, 2007–2013, and 2014–2019.

3.4. Validity and Reliability of this Research

The data source prepared by consultants for this research was highly consistent. All projects were analysed by independent, expert consultants who were under scrutiny and worked by the same overall procedures and methodology. Over the years, consultant companies have changed, and a responsible agency evaluates their competency before their selection. This issue helps avoid cognitive, optimism, and overconfidence bias, which might happen if specific consultants were responsible for analysis for years. People from the agency and the project organisation are also involved in the analysis, but the overall structure and procedure of analysis were stable.

In many cases, multiple consultants evaluate and prepare a common report. The original data source and validity are high [7]. Over the years, the consultant QA process led to a better and trusted cost performance of large investment projects in Norway [27].

The authors of this paper analysed the documents, and the data were extracted and systemised in an Excel sheet to identify the descriptive statistics. The process reflected the acknowledgement that real-world complexity creates uncertainty in facts and interpretation, and we needed to increase its clarity through simplification. External consultants conducted uncertainty analysis, thereby adding distance between the researchers and objective facts. Through the six-steps analysis process, the authors changed the complicatedness to a simple representation of the major driving forces of uncertainty. The robustness of the process and the careful interpretations imbued the analysis with a clear and robust structure, although it did affect the precision of answers.

However, it should be noted that analysing uncertainty will never reveal specific answers due to its nature. Qualitative analysis is open for interpretation and intrinsically prone to subjectivity. For example, the positions of different uncertainties in the factor groups were partly subjective, and scholars might have different perceptions of where each should have been listed. The authors used group discussions to balance subjectivity in the analysis. Despite possible errors, by having 90 projects in the sample, the total results will indicate the most dominant uncertainties in road projects.

The validity and reliability of the research process is strengthened by the many years of experience held by the paper's co-authors. Three have conducted over 20 years of research and methodology implementations for uncertainty analyses. This could also represent a tendency to defend the methodology developed during the study period. However, being aware of this source of error, we hold that this is, in fact, a strength of our analysis.

The data source was a relatively big sample of large Norwegian road projects, which are not representative of all road projects but cover this category of projects well. It cannot be assumed that the results represent other project types, the private sector, or other countries. However, as the literature tells us, the main challenges are the same across major transport infrastructure projects all over the globe, so the results should still be interesting to international readers.

4. Findings

This section presents observations from the uncertainty analyses conducted at the front end of the 90 road projects according to the developed factor groups by Torp et al. [14], which are described in Table 1. Section 4.1 outlines the most common uncertainties (RQ1) and their origin, i.e., if they are operational, strategic, or contextual (RQ2). Section 4.2 compares three periods to determine whether there has been a change in focus and uncertainty types over time (RQ3).

4.1. Most Common Uncertainties in the Front End of Road Projects and their Origins

The most common uncertainty in the 90 road projects is shown in Table 2. The first column addresses uncertainty factors. The second column depicts the sources of uncertainty, which can be operational, strategic, or contextual. Column three shows the occurrence of uncertainty factors in the consultants' reports. Column four represents the relative occurrence derived from the preceding column division to the total occurrence of that column. Column five displays the frequency of occurrence of a factor in projects. The previous column, which shows the proportion of occurrence in 90 projects, was used to determine the final column.

Table 2. Most common uncertainties in 90 road projects ranked by the number of occurrences.

Factors	Uncertainty Categories	Occurrence of Uncertainty Factors in Consultant Reports	Relative Occurrence to Total Occurrence	Occurrences of Each Factor Group in Projects	Percentage of Occurrences in 90 Projects
Market conditions	Contextual	127	13. 5%	87	97%
Project planning and control	Operational	219	23.3%	84	93%
Technical issues	Operational	270	28. 8%	82	91%
Project organisation	Operational	80	8.5%	74	82%
Nature	Contextual	78	8.3%	62	69%
Contract strategy	Strategic	43	4.6%	37	41%
Framework conditions	Strategic	35	3.7%	29	32%
Scope management	Strategic	34	3.6%	29	32%
Stakeholders and media	Strategic	25	2.7%	20	22%
Health, environment, and safety	Operational	13	1.4%	11	12%
Interfaces	Operational	11	1.2%	10	11%
Transfer to operation	Operational	2	0.2%	2	2%
Client involvement	Strategic	2	0.2%	2	2%
Leadership and project culture	Operational	0	0	0	0
Currency	Contextual	0	0	0	0
		Total = 939		Total = 90	

Based on consultants' reports, the occurrence of uncertainty factors is presented in column three. Some projects have more than one factor for each factor group. For example, consultants registered four market-related factors for project one, whereas no market factors were registered in project two. Alternatively, consultants registered three project planning and control factors for one project, but no project planning and control factors were registered for another. A total of 127 out of the 939 factors fell into the market conditions category and were classified as contextual uncertainty. Column 4 shows this as 13.5% (127/939) of the total uncertainty factors. This information only shows these factors' quantity and not how many projects these factors emerged in or their consequences on the projects.

To answer the RQ2—to know the dominating origins of uncertainties, it is necessary to know how often each factor occurs in projects, as depicted in column five. Of the 90 road projects, 87 had uncertainty related to the market conditions as one of the top uncertainties. A total of 84 had project planning and control on the top list. Each factor is counted in a project only once for each factor group. Currency and leadership and culture did not occur in this dataset. In Norway, the Ministry of Finance has decided that currency changes and variations are normally managed by the government and will be compensated to project owners. Leadership and culture may have been considered in the project organisation factor group. Therefore, the consultants registered no uncertainty for them in the pre-project phase. Alternatively, these factors were not included in any top lists. However, they have been retained in Table 2 due to these factor groups having originated from the empirical results reported by Torp et al. [14,24]. These factor groups might be important in other types of the projects.

Table 2 shows that market conditions, project planning and control, and technical issues most often occurred in the pre-project dataset of this paper, as compared to Torp et al.'s [14] previous study. In a typical project, one could expect with a probability of 97% that market conditions would be one of the top uncertainty factors. This factor is related to commercial aspects, such as competition, market conditions, and market development. Project organisation (74 out of 90) and nature (62 out of 90) were also highly frequent in the paper's dataset. Contract strategy, framework conditions, scope management, and stakeholders and media were all often perceived as uncertainty sources. HES and interfaces occasionally appear on the top list. Transfer to operation and client involvement seldom occurred.

Table 3 sums up the relative occurrence of operational, strategic, and contextual uncertainties: 63.4%, 14.8%, and 21.8%, respectively. This shows the relative occurrence of the factor group. Then, the same analysis was conducted on the factor level and checked how many project uncertainty factors occur. This allowed us to calculate the percentage of operational, strategic, and contextual uncertainties (see Table 3).

Table 3. Comparing origins of uncertainty based on a single-factor level and a factor group level.

Uncertainty Origins	Single Factors	Factor Groups
Operational	63.4%	49.7%
Strategic	14.8%	22.2%
Contextual	21.8%	28.1%

Column 2 shows that, in a single project, there is a 63.4% probability that uncertainty has an operational origin, a 14.8% probability that it has a strategic origin, and a 21.8% probability that it has a contextual origin from uncertainty factors. Column 3 shows the statistical probability of operational, strategic, and contextual uncertainties from specific factor groups. For example, based on a single project, one could expect a 21.8% contextual uncertainty based on a single factor. In contrast, 28.1% of the uncertainty factors would have a contextual origin for a typical project. To exemplify the difference in calculations, project one has three market-related factors, and all were counted in column 2. In column 3, the one-factor group was counted.

In both columns, operational uncertainty had the highest occurrence in the pre-project data. Both columns indicate that consultants identified a high number of specific factors with operational origins, and when combined in groups with similar origins and consequences, operational uncertainty was dominant. This indicates the importance of uncertainty factors with operational origins. Similarly, strategic uncertainties were perceived as less frequent and therefore less important. This may be reasonable given the owners' perspectives of these uncertainty analyses. It is not unreasonable to think the analysis looks primarily for sources of uncertainty outside the owners' area of responsibility. In terms of frequency and importance, contextual uncertainty lies between the two other categories.

4.2. Comparison of the Three Study Periods

This section compares how the identified uncertainties at a single-factor level changed over three periods for the 90 projects (see Table 4). These comparisons show the changes in consultants' perspectives and analyses over three periods. The first period was similar to Torp et al.'s [14] study from 2000 to 2006. This was the initial period of the Norwegian QA scheme, with a high focus on cost and uncertainty. The second period, 2007–2013, involved a focus shift from the cost to the intended effect in the QA scheme. In the third period, 2014–2019, the QA scheme was established and became stable. The frequency of occurrences clarified the number of uncertainty factors registered by consultants in each period. For instance, project planning and control occurred 43 times out of a total of 269 occurrences of factors in 25 projects during the first period. This resulted in 16% of total relative occurrences.

Table 4. Comparison of "Top uncertainties" in three periods of study (N = 90).

Factors	Uncertainty Categories	Number of Occurrences of Uncertainties in Projects			Relative Occurrence to Total Occurrence			Changes over Time	
		1st 2000–2006 n = 25	2nd 2007–2013 n = 38	3rd 2014–2019 n = 27	2000–2006	2007–2013	2014–2019	1st to 2nd	2nd to 3rd 2nd to 3rd
Project planning & control	Operational	43	107	69	16%	26.3%	26.2%	+10.3 ▲	−0.1 ▼
Technical issues	Operational	86	102	82	32%	25.1%	31.2%	−6.9 ▼	+6.1 ▲
Market conditions	Contextual	34	62	31	12.6%	15.2%	11.8%	+2.6 ▲	−3.4 ▼
Nature	Contextual	24	37	17	9%	9.1%	6.5%	+0.1 ▲	−2.6 ▼
Contract strategy	Strategic	12	14	17	4.4%	3.4%	6.5%	−1 ▼	+3.1 ▲
Interfaces	Operational	2	6	3	0.7%	1.5%	1.1%	+0.8 ▲	−0.4 ▼
Transfer to operation	Operational	0	0	2	0	0	0.8%	-------	+0.8 ▲
Project organisation	Operational	25	32	23	9.3%	7.9%	8.7%	−1.4 ▼	+0.8 ▲
Leadership & project culture	Strategic	0	0	0	0	0	0	---------	
Currency	Contextual	0	0	0	0	0	0	----------	
Framework conditions	Strategic	16	15	4	6%	3.7%	1.5%	−2.3 ▼	−2.2 ▼
Stakeholders & media	Strategic	10	10	5	3.7%	2.4%	1.9%	−1.3 ▼	−0.5 ▼
Health, environment, and safety	Operational	3	7	3	1.1%	1.7%	1.1%	+0.6 ▲	−0.6 ▼
Scope management	Strategic	12	15	7	4.5%	3.7%	2.7%	−0.8 ▼	−1 ▼
Client involvement	Strategic	2	0	0	0.7%	0	0	+0.70 ▼	-----
	Total number	269	407	263	100%	100%	100%	00	00

Project planning and control had an approximate increase of 10% from the first to the second period and showed no significant change from the second to the third (0.1%). In contrast, technical conditions reduced by 6.9% from the first to the second period but increased by almost 6% from the second to the third. Contextual uncertainties (except for the unchanging currency) increased from the first to the second period but decreased from the second to the third. This decrease in contextual uncertainties is an interesting finding which requires further evaluation. Only strategic uncertainties decreased in both periods, except for contract strategies, which increased from the second to the third. During this period of time, contract strategies and, more specifically, Early Contractor Involvement have gained more focus.

Table 4's comparison of uncertainty factors at the single-factor level reveals that factors with operational origins expanded from 59.1% (sum of operational uncertainties is highlighted in the year 2002–2006, 16% + 32% + 0.7% + 9.3% + 1.1% = 59.1%) in the first period to 62.5% in the second period and reached 69.1% in the third period. In contrast, uncertainty factors with strategic origins decreased from 19.3% in the first period to 13.2% in the second and 12.6% in the third. Uncertainty factors with contextual origins increased between the first and second periods but reduced in the third. From the first to the second period, uncertainty factors with operational origins from increased the first period, but uncertainties with strategic and contextual origins decreased. In the last period, an increasing share of operational uncertainty was concurrent with a reduction in strategic ones. These percentages express the relative weight of the different origins in the period.

5. Discussion

This section discusses the findings to answer the research questions. The section concludes with the findings' potential implications for policymakers, practitioners and researchers.

5.1. Frequently Occurring Uncertainties

Some uncertainties were perceived to occur often, others rarely. The analyses identified different sources of uncertainties addressed by RQ1 and RQ2. The factor groups technical issues, project planning and control, and market conditions were the three uncertainties most frequently occurring in this dataset. Generally, one could observe that these issues are always present in any project. Their absence in the top uncertainties of some projects does not mean that consultants neglected them but rather that they were not always considered to be among the most important uncertainties.

Technical issues are related to uncertainty in terms of cost variation, complexity, technology development, and technical conditions, which is high in the pre-project phase. Because many decisions are not made yet in this phase, the complexity of these projects is typically high, and there exists high uncertainty. For example, technical difficulties of operations are types of these uncertainties. Project planning and control showed a high number of occurrences, which might be related to the undefined processes and schedules and the high uncertainty of controls and systems planning at this phase. High uncertainty from market conditions must be expected, since tendering has yet to begin at this phase. Competition levels, price changes, economic changes, and new competitors are all related to the market. Owners do not know how the contractors will respond to a project's contracts.

In total, factors with strategic and contextual origins showed a low occurrence compared to factors with operational origins. The results were in line with previous research [14,24], showing operational uncertainties' dominance. It can be interpreted that this indicated uncertainty analyses' tendency to focus on issues that the project organisation is responsible for. Operational uncertainties are specific, interesting, and close to the participants, thereby facilitating the identification of many different single factors. Thus, the analysis may overstate the total uncertainty (see Table 3). It is plausible that the real level of operational uncertainty is close to that calculated from factor groups.

Based on their occurrences and share in 90 projects, contextual uncertainty accounted for 21.8% of total uncertainty. From this result, one can assume that either the analysis does not focus on contextual uncertainties or there are fewer contextual uncertainties than operational ones. On the one hand, Norway is known as a stable context for projects, which could mean that this figure may be lower than that in other countries. On the other hand, according to Johansen et al. [9], contextual risks and opportunities are often virtually ignored. Another potential reason for a low level of contextual uncertainties is that, as Samset [3] explained, these uncertainties become more apparent in the execution phase. Part of contextual uncertainties, such as accidents or market variations, is more in the realm of unforeseen uncertainties—according to De Meyer et al. [11]—and they are hard to predict in the front-end phase. Therefore, they could be less presented in front-end analyses. It is also plausible that judgment bias is an essential explanation for failing to see unwanted future development outside one's control.

Strategic uncertainties have an even lower share of total uncertainty (14.8%). A possible explanation is that analysis from the owner's perspective is inclined to favour the strategies and decisions of owners as an uncertainty source. However, that would be a judgment bias. An alternative explanation may be that the Norwegian political system and the QA scheme are rigid and sufficiently established to reduce strategic uncertainties to the low level indicated in this analysis. Alternatively, a combination of the two explanations could also be possible.

Examining the judgment bias explanation, low levels of strategic uncertainty at the front end of road projects may have different reasons. Strategic uncertainties, such as major scope changes, are difficult to predict at this phase. Cost estimation focuses on the cost of the current solution, whereas uncertainty analysis is supposed to challenge the premises and assumptions the solution is based on. Uncertainty analyses still tend to set the scope as a basic premise [9]. This results in reporting and documenting low levels of uncertainty for scope management. Scope changes can increase the project's preliminary cost [27–29]. Several authors [1,29] have identified scope changes after the financing decision as the main reasons behind cost overrun.

An alternative way to consider this as strategic uncertainty is to examine this low assessment as reducing the risk of the project's financing rejection [30]. The low focus on strategic uncertainties could be related to the overconfidence in project owners' abilities to manage uncertainties, the stability of governance systems, and adequate responsiveness toward industry changes. Similarly, high levels of contextual uncertainties could threaten the projects' success.

Given the discussion above about the origins of uncertainty, one could attempt the same on a more detailed level using the results on a single-factor level. As indicated in Table 3 and the logic of the analyses, the result factor groups' analysis is more stable than the analysis for identified factors. It gives a more realistic view of the origins of uncertainty than single factors. As single factors are highly situational and vary significantly across the different analyses, we chose not to further this line of enquiry.

5.2. Changes in Identified Uncertainties over Different Periods

Table 4's analysis shows the growth of uncertainty factors with operational origins and the decrease in strategic and contextual ones during the three study periods. Project planning and control as a factor group with operational origins showed the highest increase over the two periods. At first sight, this result was somewhat unexpected. The QA scheme resulted in significant professionalisation [31], although this may be more recognisable on a strategic level. There is an increasing level of project size and complexity during this period. Finally, there have been severe changes in context—for example, the financial crisis of 2008, which has led to a greater focus on contextual changes.

The results can be related to improvements in the knowledge or experience of evaluators and their concerns over schedules, cost estimations, methods, and other related factors. This would explain the greater focus on operational uncertainties. Technical issues were reduced in the first period, which could be due to a change in focus from the first to the second period. Using their experiences from the first period, consultants might have sought to reduce overfocusing on technical issues. Uncertainty in technical issues rose again from the second to the third period, which could be explained by increasing complexity.

Except for contract strategy, strategic uncertainties were reduced over all periods. This may partly be explained by the effect of the QA scheme [7], which systematically strengthened the governance system. The contract strategy increased by approximately 3% between 2014 and 2019. This pattern may reflect growing concerns about contract strategy and its significance to project success. New relational-based contract strategies have received more attention over the period covered by this analysis, and the changes from the competition- to collaboration-based contracts may be a reason for and consequence of this observation. Introducing new contract forms increases uncertainty until the experience is transformed into learning. However, increased collaboration likely resulted from increasing complexity and dynamics, meaning that this may be multi-directional. Scope management and stakeholders and media, as two strategic uncertainties, were also reduced in two periods. In total, uncertainty factors with strategic origins decreased from the first to the third period. As indicated above, there are reasons to believe these were increasingly underestimated as greater confidence was placed in owners' ability to manage projects successfully.

The most challenging change to explain is the reduction in the contextual uncertainty presented in the reports. Several developments during the period seem to indicate that the world and society have faced both temporary shocks, such as the 2008 financial crisis (which affected Norway significantly less than other countries but was still a significant source of uncertainty and risk), and long-term developments, such as new digital technology and the integration of administrative and technical systems occurring both in society and the project environment. Even nature has proven to be increasingly challenging in light of climate change. Market uncertainties were the most frequently cited, but the allocated effect seems to have been diminishing. This may hold the key to the total effect since it could be the most important factor group in this category. Market uncertainty was heavily focused on in the study period. This could have been influenced by increased knowledge and the authorities' efforts to increase competition by inviting international suppliers to compete. There is reason to believe that the total effect of contextual uncertainty is underestimated. Therefore, this should be addressed by policymakers and the consultants who perform these analyses.

5.3. Potential Implication

The results reported here can help policymakers design more effective requirements for uncertainty analysis and management systems. As a component of governance systems, uncertainty management supports effective policies and overall societal decisions and allows consultants and project stakeholders to address the appropriate uncertainty factors. It may help project owners in their decision-making processes, estimations, and evaluations and generally strengthen project governance through an increased awareness of the relative importance of uncertainties with different origins. For example, information about the origins of single uncertainty factors could direct them to set more controlling policies and inspections for cost- and time-related project issues. An increase in operational uncertainties could be improved by engaging contractors early in the process of uncertainty management and pre-evaluations. This will help them become familiar with project sites and understand the technical difficulties of the projects earlier. This study can contribute to practitioners' development of more robust management tactics. From the owner's side, knowledge about which uncertainties to focus on in the front end is especially useful. Knowing which uncertainties are most important and which strategic, operational, and contextual uncertainty factor categories are the most influential for project management is helpful. They would thus be able to adopt suitable strategies for each uncertainty and more effectively cooperate in contracts.

The result of this study is helpful for researchers focusing on the projects' early phases. Indeed, the six-step process can be applied to other studies. It could be applied to other types of projects. It shows how to define and categorise factors and the path for identifying uncertainties with high occurrences. It is suggested that it would also be an ideal starting point for future research into the sources and consequences of uncertainty in the projects' later phases.

5.4. Limitations of the Study

This study used a sample of 90 large road projects in a population of the same in Norway. The top list of uncertainties for each project represents a significant share of uncertainties but not the total. More positively, it is noteworthy that all consultant reports and project uncertainty analyses followed the same process and structure. The results are well documented in the reports. It would be an idea to improve the quality of data sources by interviewing specific project consultants. Unfortunately, many consultants involved in the analyses are unavailable, and access to them is difficult. However, the analyses are well documented, and they are also reviewed by people in the ministry and in the agency.

Besides, enough literature supports the validity of data prepared by consultants over the years [7,27].

The study focuses on secondary data (i.e., reports conducted by consultants on behalf of the Ministry of Finance). This study is limited to the front-end phase and the discussion of uncertainty factors from the uncertainty analyses in the front end of road projects. This means that the consultants are fairly "subjective" in their understanding of uncertainty factors present in road projects and consequences involving possible cost, time, and scope.

6. Conclusions—And Suggestions for Further Research

The paper's purpose was to develop knowledge about uncertainties through the pre-project data of road projects. This is done by addressing three research questions

RQ1: What uncertainties appear most often in the pre-project data of road projects? The uncertainty analysis reports show that market conditions, project planning and control, and technical issues had the highest occurrences.

RQ2: What are the dominating origins of uncertainties in the pre-project phases of road projects? Uncertainties with the operational origin, such as project organisation, technical issues, HES, project planning and control, interfaces, and transfer to operations, most frequently occurred and account for almost 50% of the total. Uncertainties with strategic and contextual origins accounted for approximately 30% and 20%, respectively.

RQ3: What changes in dominating uncertainty origin can be observed from 2000 to 2019 in pre-project documents? It is answered by comparing three periods (2000–2006, 2007–2013, and 2014–2019). Operational uncertainties grew from the first to the third period. Strategic uncertainties fell from the first to the third period (except for contract strategy). The total uncertainty of both strategic and contextual origins decreased over the three periods. This result was analysed against the backdrop of several known societal developments and provided critical comments on several aspects. In particular, it is suggested that the analyses systematically pay insufficient attention to strategic issues due to the pre-defined owners' perspective. There is a widespread belief that total uncertainty is routinely underestimated.

Data of this paper was sourced from the structured analyses of consultants conducted for 20 years on large Norwegian public projects. However, as with any study could suffer from subjective judgment. We sought to offset this through group discussions and the participation of highly experienced co-authors. It cannot be expected (and is not suggested) that the results represent all project types, including those in the private sector or other countries. However, the main challenges faced by major infrastructure projects are the same regardless of country. Therefore, the results could be interesting to international readers. The data thus cannot answer directly to "what was the effect on the cost, time or scope?" Or "which of the uncertainty factors seem to be under- or overestimated in terms of effects for road projects?"

This data does not reveal the complete picture of every type and importance of uncertainty within road projects. Instead, it shows the experts' perspective toward uncertainties and is more akin to a rear-view mirror which shows a part of the path. Future research should complement these findings by analysing data from different project phases. Uncertainty types that could be identified and managed in the subsequent phases of road projects should be investigated with a more case-oriented approach. Data from ongoing or finished projects could be a point of analysis and comparison with the data of this paper to determine which uncertainties most influence these projects. The analysis does not cover the period of the COVID-19 pandemic, meaning that it would be interesting to follow up this study with additional analysis to document the pandemic's effect on the perceived uncertainty in public investment projects.

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