Chapter

Managing Uncertainty in the Construction Phase of Road Projects

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Abstract

Construction projects are fraught with uncertainties. This chapter's objective is to demonstrate how uncertainty is managed in the construction phase of road projects. Three aspects of uncertainty management in the construction phase are examined: people and organization, management process, and tools and techniques. The specific importance of the construction phase is based on the fast changes and complexity of this phase. A longitudinal study of seven Norwegian road projects is performed. The projects were all large in terms of cost, each with costs of more than $100 million. Researchers evaluated how uncertainty emerged during the construction phase and how major uncertainties were appraised step by step during construction. In addition, this study contributes to a new recognition of important factors, which influences risk and opportunity management in large road projects by introducing a suggested conceptual framework.

Keywords: uncertainty management, risk, construction phase, challenges, enablers

1. Introduction

The topic of this chapter is managing uncertainty in the construction phase of road projects. Road projects are characterized by high complexity and high uncertainty, making the project objectives relatively challenging to achieve. Managers need to know challenges that threaten the foundation for uncertainty management. To improve uncertainty management, we need to understand the main enablers that can improve the uncertainty management process. This will pave the way for better performance of road construction endeavors. To start with, this chapter provides theories that cast light on the nature of uncertainty and the strategies and methodologies used for its management. This chapter aims to provide a suggested conceptual framework to manage uncertainty, thereby enhancing project management's capacity to flourish in the dynamic world of construction projects.

Improved processes and productivity of road projects contribute to reduced construction costs, lower project time, shorter travel times, and higher safety for

travelers and goods. Many stakeholders believe that better roads lead to a firm's productivity and therefore yield economic benefits beyond those perceived by users [1]. The construction phase of road projects embraces different uncertainties, such as soil conditions, weather conditions, and material provision and quality. Furthermore, the choice of delivery models, contracts with contractors, and competency of project team members, as well as the quality of communication among stakeholders and many others, are influencing uncertainty factors.

Numerous studies have been undertaken on construction projects' uncertainty and risk management. Despite the extensive research on the matter, construction projects persist in experiencing both cost and time overruns, as well as underruns [2]. Complexity and ambiguity may be identified as principal factors contributing to the presence of uncertainty. Uncertainty, according to Galbraith [3], originates from a lack of information when a decision has to be taken. He explained that uncertainty hinders the ability of businesses to plan proactively and make sound decisions before project execution. Risks are uncertainties with negative effects on the project's objective. Opportunities are elements with potential for positive outcomes [4]. Uncertainty will relate to different aspects of projects, such as cost, time, quality, reputation, safety, sustainability, and others [5]. Uncertainties can affect different levels of a project: strategic, tactical, and operational levels. Handling uncertainties in a project is done through different types of uncertainty analyses, including managing uncertainty in the project and by uncertainty leadership in the project owner organization [6]. Different frameworks for uncertainty management exist in the literature [7–10]. In summary, uncertainty is managed by seeking to understand up front what we do not know for sure, analyzing its potential consequences, and actively choosing remedies to increase our control over the development.

The construction phase of the projects has not received adequate attention from researchers [11]. However, it is in the early phase and construction phases of the project life cycle that risk management practices are more extensively employed compared with the conceptual or termination phases [12]. Consequently, the analysis of the construction phase, regarding its complexity and demanding nature, becomes crucial.

Effective management of uncertainty in the construction phase poses a perpetual challenge. Understanding what kind of uncertainties matter in the construction phase seen from the owner's or the contractor's side is a challenge in most projects. Finding the risk that matters and estimating the right level of contingency reserves are critical for making the right decisions in the front end and for managing the project through execution. Small reserves could lead to overruns, and large reserves could lead to spending more money and time than necessary, which again is a waste.

In the uncertainty management process, some challenges persist. Knowing these challenges is useful to effectively address them in future projects [13]. Some challenges are related to the uncertainty analysis process, such as the inadequate composition of the uncertainty analysis group, excessive details in cost estimation methods (complexity), failure to recognize opportunities, and underestimated levels of uncertainty in different phases [4]. The aforementioned challenges pertain to the analysis of uncertainties in advance. Despite knowing these challenges, only a limited number of studies have deeply explored practical obstacles in uncertainty analysis and management and proposed effective solutions for them.

A multitude of uncertainty factors affect road projects [14]. Uncertainty management includes different components, such as human and organization, processes and tools, and techniques [8, 15]. Familiarity with the different components and the

challenges in uncertainty management [6] is crucial for managers, engineers, and stakeholders. It equips them with the knowledge and skills necessary to effectively manage uncertainties and contribute to the success of road projects. For better recognition of challenges and to find solutions for overcoming them, understanding the uncertainty management components is important.

Understanding different components of uncertainty management [8] offers insight into uncertainty management practices. It will help project managers with strategies on how to manage uncertainties in the construction phase of the projects. Simultaneously, it will help to identify challenges and enablers for uncertainty management. These components are inseparable from uncertainty management practices because they are interdependent and may influence one another. Not knowing them makes the management process difficult or even impossible.

There are numerous models for uncertainty and risk management [4–7, 16, 17]. The availability of models or tools is not regarded as a significant concern. A variety of models, tools, and techniques to analyze and manage uncertainty in projects are available and working if they are used right. The inadequate consideration given to the process of managing uncertainty throughout the construction phase is of greater concern. The risk management process needs to be improved. One way of doing this is by analyzing how successful projects identify and manage opportunities and risks in the construction phase in practice. This represents a research gap addressed in this chapter.

The purpose of this chapter is to introduce a suggested conceptual framework for uncertainty management in the construction phase of road projects. Increased knowledge about uncertainty factors, uncertainty management enablers and challenges, and uncertainty management components are needed. The questions addressed to answer the purpose are as follows:

Q1: How are uncertainties in the construction phase managed?

Q2: What are the main challenges and enablers in the uncertainty management of road construction projects?

The second section will introduce the basic theories and components of uncertainty management. The third section focuses on the findings from empirical studies, which cover uncertainty management and challenges and enablers in uncertainty management. Section four discusses the findings, and the last section presents the conclusion and way forward.

2. Uncertainty management in large road projects

Uncertainty is an inherent aspect of everyday life, influencing our perception of situations as either opportunities or risks. This perception greatly impacts our understanding of projects and operations, allowing us to take necessary precautions to mitigate risks associated with cost, time, and project quality. Successful projects must carefully consider the interplay between cost, time, and quality, often referred to as the "iron triangle" [18]. Uncertainties stemming from various sources have direct consequences on project cost, time, and quality, influencing decision-making and daily choices. By studying uncertainty management, we not only gain a better understanding of its impact but also acquire valuable insights into how to effectively navigate and manage uncertainties in project environments.

Uncertainty origins and drivers could be categorized into operational, strategic, and contextual risks [19]. Different drivers will occur and vary over a project's

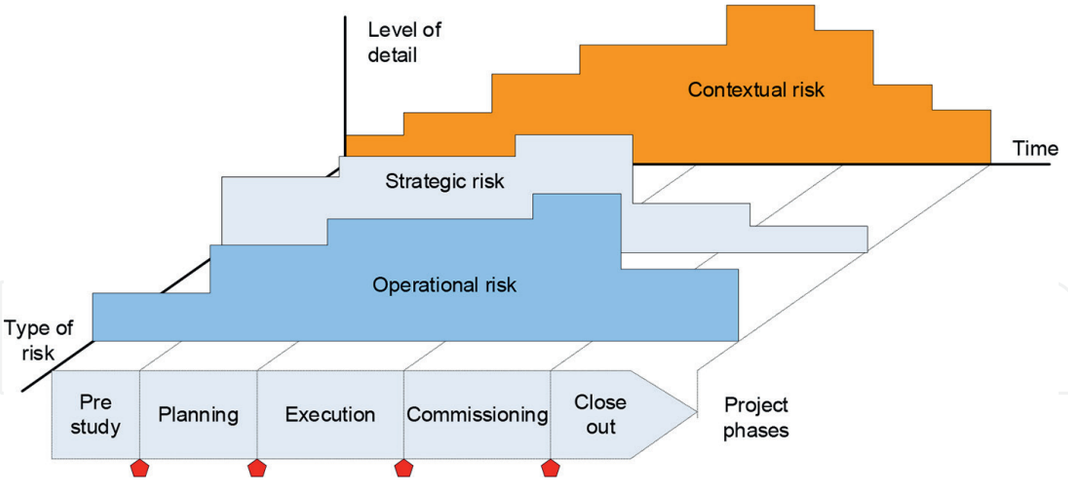

Figure 1.
Operational, strategic, and contextual risk over project phases [19].

construction phase depending on the uncertainty management strategies and the context in which the project is executed [19], as depicted in **Figure 1**. Most of the time, risk management is conducted by project managers in the pre-project and planning phases and is not followed in the construction phase. By getting more information and more analysis, the level of risk is reduced. In the execution phase, all three categories of risk are at high levels, as shown in **Figure 1**. After finishing construction, the level of risk is reduced through commissioning and closeout.

Operational uncertainties related to the project design and construction are managed by the project team. Uncertainties with strategic origins are business-level uncertainties handled by the owner or mother organization and are out of the project manager's control. Uncertainties with contextual origins are conditions external to the project, which may have an impact on its process and results, such as war and events with global effects on the whole supply chain [6] (p. 48) [8] (p. 133). During construction, certain risks may arise, which are difficult to anticipate before project initiation. Lack of competent team members, accidents, unexpected things in ground conditions, or changes in regulations could be some examples of such risks.

To effectively manage uncertainties with different origins, project managers need to have a process supported by suitable tools and expert people. Simister [20] developed a process for uncertainty management based on international standards and guidelines from professional institutions. The process is illustrated in **Figure 2**.

The process of uncertainty management includes identifying, registering, evaluating, and treating uncertainties. The three important components studied in the literature [8] for uncertainty management are as follows:

a. Human and organization

b. The process

c. Tools and techniques

In this section, we explain each of these components separately.

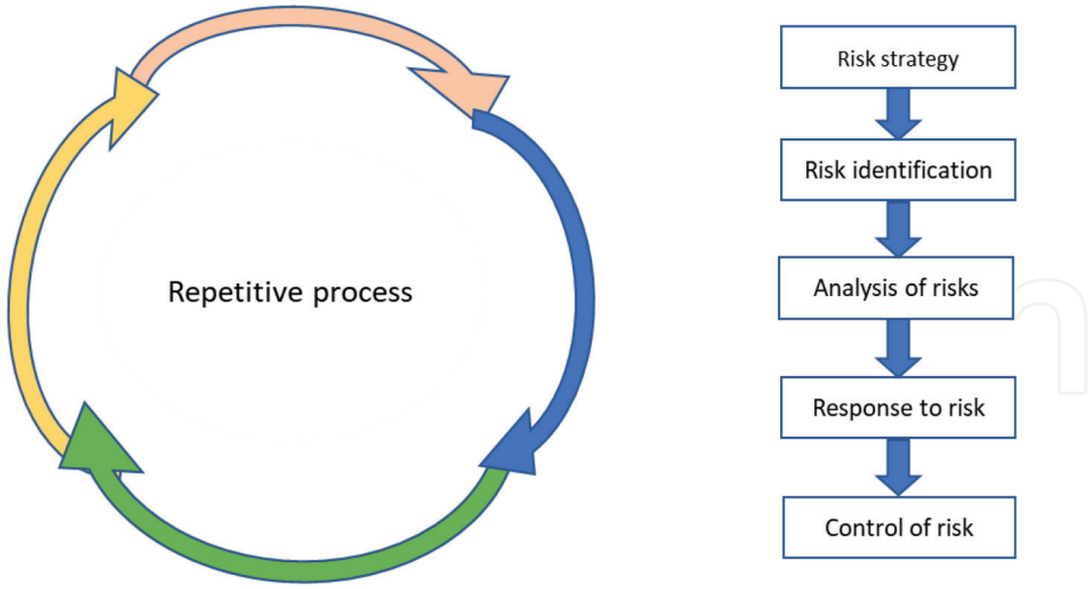

Figure 2.
Process for risk management according to Simister [20].

2.1 Human and organization in uncertainty management

The "human and organization" component incorporates a variety of professions, skills, and roles, including civil engineers, construction employees, project managers, and stakeholders. Effective uncertainty management relies on the critical elements of collaboration, coordination, and the fulfillment of different duties.

Regarding the human and organization component, risk responsibility and ownership have been emphasized as crucial factors [8, 21]. Individuals within project teams need to take ownership of the risk management processes and be accountable for their respective roles. Workforce competency is another key criterion [7, 22]. A team of individuals who possess the necessary competence and skills plays a crucial role in facilitating successful decision-making and problem-solving, particularly when confronted with unknown circumstances. The clear definition of team members' roles [6, 23, 24], effective communication [24, 25], and a supportive organizational culture [26, 27] are additional criteria that contribute to the overall effectiveness of uncertainty management.

2.2 Uncertainty management's process

The process component plays a vital role in uncertainty management, encompassing phases, such as initial planning and risk identification, risk analysis, mitigation strategies, and ongoing monitoring. Each stage of the process is interdependent, ensuring that all uncertainties are effectively addressed and mitigated.

Johansen [28] suggested a 9-step uncertainty management process for identifying, analyzing, and following up project uncertainty as illustrated in **Figure 3**.

Steps 1 and 2 are for preparing the process, Steps 3–7 are for group processes (workshops) for identifying, analyzing, and developing measures for exploiting or controlling the uncertainty, and the final steps, Steps 8–9, are for following up the uncertainty during the project life cycle. Typically, these steps are done in a risk register with a matrix consisting of opportunities and risks with a follow-up function.

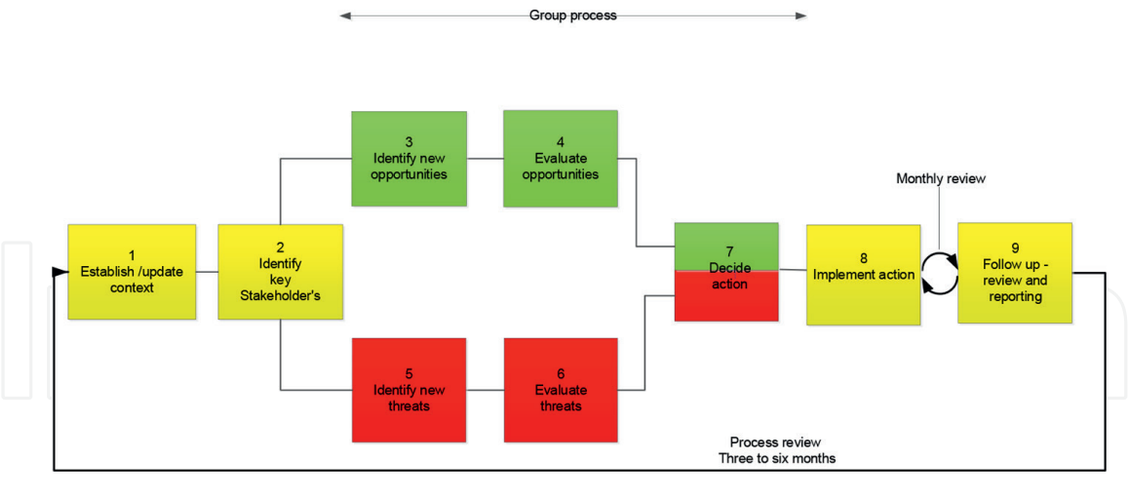

Figure 3.
Practical uncertainty management—9-step framework [28].

Formal and informal meetings have the potential to impact and facilitate the uncertainty management process. Formal meetings are pre-scheduled meetings in which people's role is defined, and project teams with various disciplines gather and conduct an uncertainty analysis session (with an external facilitator) held every month or every 6 months. These formal meetings could be project sessions in which problems and events during projects are discussed, or they could be workshops for identifying uncertainties in the projects. Informal meetings are meetings without pre-plan, such as coffee time, lunchtime meetings, or meetings in the workplace corridors [8, 29].

In the process of managing uncertainty, it is important to identify and plan for harvesting opportunities. Earlier, the focus was only on risks and threats. In recent years, the prevalent trend in risk management has shifted significantly, with a greater emphasis now placed on identifying and capitalizing on opportunities. Standardization contributes to the degree to which uncertainty management is structured and systematically followed, ensuring that all projects adhere to the same set of procedures and guidelines.

Many of these subjects that we mentioned for the uncertainty management process, such as formal or informal meetings, equal consideration for risk and opportunity, and others, originated from organizational culture. Leadership and their support play an important role. In terms of the process component, equal consideration for risk and opportunity has been identified as a crucial criterion [6]. This ensures that potential risks and opportunities are adequately assessed and addressed throughout the project lifecycle. The process should be user-friendly and simple for project teams to implement and use in the daily management of the project. Adequate documentation is essential for effective uncertainty management [7] because it facilitates knowledge sharing and provides a reference for future decision-making. Collaboration and information exchange among project stakeholders also play a vital role in the uncertainty management process [24].

2.3 Tools and techniques in uncertainty management

The "tools and techniques" component involves analytical and visualization methods and techniques for project uncertainty identification, analysis, and management.

Proper utilization of suitable tools and techniques enhances decision-making, communication, and overall project outcomes. The "tools and techniques" component requires careful consideration as well. The complexity or simplicity of the tools and techniques utilized should match the project requirements [21]. Precision is another criterion, with the need to select tools and techniques that provide accurate and reliable results [21]. The capability of visualization and documentation is also important for effective uncertainty management [8, 30].

By incorporating these criteria, stakeholders can establish a comprehensive approach to uncertainty management, ensuring the successful completion of projects while minimizing the impact of uncertainties. The cited references provide further insights into the importance of each component and serve as valuable resources for understanding and implementing effective uncertainty management practices. Additionally, the construction phase of a project is a critical stage wherein project contractors and team members are defined and resources are allocated.

The theoretical foundation presented above makes up a useful base of concepts and principles. To understand the uncertainty management practices and improve their performance in the construction phase, we turn to empirical data from real projects.

3. Empirical findings from the construction phase of road projects

The construction phase in road projects starts when the contractor and team members are in place. Project resources are decided, and a design has been conducted. At this stage, the project environment is dynamic and incorporated with different events and accidents that have the potential to influence the project, which now runs at a high speed.

Here, the empirical study reported is based on longitudinal case studies, including seven road projects in Norway. All seven projects in the study were large in terms of time and money, and they were highly complex projects. All major projects in Norway need to pass the Ministry of Finance's quality assurance (QA) to be approved by their government for financing. Documentation from this QA includes complete uncertainty analysis and is publicly available. All road projects in this study finished their construction phase, and we evaluated them in the year 2022–2023. Case studies include document studies and interviews with experts involved in the uncertainty management of these projects. The interviewees had different roles, such as project manager and project controller. The researchers studied firsthand how uncertainties were managed in the construction phase of the projects. Uncertainties and their management were structured according to three components mentioned. We present the findings in two consecutive sections.

3.1 Identifying uncertainties and managing them

Market, project organization, and project planning were the three major sources of uncertainty in seven studied projects in the construction phase. **Table 1** shows the important uncertainties in the early phase of these seven projects. The data are collected from the project's quality assurance reports or uncertainty cost analysis reports. **Table 1** contains a mixture of uncertainties, which are referred to as "factor uncertainty" that affect all or parts of the project, for example, a market that is unforeseen in relation to the level of detail, the project organization/lack of access

Project	The top 5 uncertainties
1.	• Market • Planning and engineering • Project organization • Rig of contractor for the tunnel • Water and frost protection for tunnel
2.	• Rig, contractor tunnel • Market • Project organization • Construction- Road • Construction- Road - Bridge
3.	• Market • Project organization • Contractor, rig, tunnel • Other project exercises • Unforeseen uncertainty related to the degree of detail
4.	• Market • Unforeseen uncertainty related to the degree of detail • Bracing system in bridge • Project owner cost • Bridge cable
5.	• Market • Land acquisition • Large bridge • Unforeseen uncertainty related to the degree of detail • Engineering
6.	• Project organization and losing competent personnel • Construction execution • Groundwork concerning soil/terrain/masse, measurement certificate • Owner management and framework conditions • Market
7.	• Mass balance • Blasting process • Works on long traffic roads • Geology • Environmental conditions in project (for instance: waterfall, soil, vulnerable species,...)

Table 1.
Top five uncertainties in the early phase of the projects.

to competent workforce, errors in design and poor engineering solutions, nature/weather conditions, unforeseen ground conditions, new standards and norms or laws and regulations, construction time, and geology and geotechnics.

Uncertainties in **Table 1** pertain to cost-related elements such as the rig and tunnel operation, as well as road operations. Additionally, this encompasses unpredictable circumstances characterized by events of low probability with high impact, referred to as "force majeure." In such instances, neither the owner nor the contractor can be held accountable for the occurrence of these conditions. Still, the consequences must be managed.

Market uncertainty often includes several considerations, which means that it can be complicated to assess. One way of looking at that uncertainty is to look at the difference between two different offers as a signal of how much market uncertainty there is in the offers, that is, if the lowest bidder prices the bridge at 950 million and the highest bidder prices the same bridge at 1050 million, the market uncertainty is often seen as 100 million. We believe that this initial assessment is too simple. Many different uncertainties, such as poor ground conditions, insurance requirements, and other factors can cause the latter bidder to assess differently and end up with a higher sum than the first.

Table 2 shows the comparison of uncertainties in the early phase of the seven projects with the construction phase. The uncertainties in the right column are based on interviews with the project owner and project managers from the seven case projects consisting of not only the usual uncertainties, such as the market, but also some more project-specific uncertainties, such as the replacement of bolts on project number 4. It is interesting to observe the difference among uncertainties in the early phase and the construction phase. When construction begins, the essence of uncertainties is different from the early phase. Projects face other unexpected events and uncertainties during the construction phase. In the dynamic and high pace of execution phase, project management must have strategies for tackling uncertainties that are unexpected or not identified in the early phase.

In one of the projects, the project manager emphasized that all team members should have enough competency. However, when observing the contractor's performance across two different teams involved in separate sub-projects, variations became evident. In one project, the contractor demonstrated a highly proficient understanding of the overall scope, resulting in excellent performance. Conversely, in the other project, their lack of competence hindered their ability to deliver a satisfactory outcome.

Creating a conducive working environment and establishing a robust communication platform within a project organization is vital for effective uncertainty management. "*We had good communication with the contractor, which resulted in saving money for both of us (opportunity) and it led to a win-win situation*." This situation was a bonus scheme, which was suggested to the contractor for completing part of the road. This completion of the work led to better and smoother operation and maintenance of the road, which has many benefits for the project owner too. This benefit was estimated to be approximately $1 million.

Another valuable suggestion put forth was the implementation of systematic registering of uncertainties, which involves continuous monitoring of uncertainties and aids in preventing redundant registrations leading to inefficiencies.

Furthermore, road projects should conduct comprehensive feasibility studies and scenario plans to anticipate changes in regulations, funding availability, and market conditions because of strategic uncertainties.

One of the uncertainties that could challenge projects was related to designing irrational procedures for uncertainty management. This weakness reduces our ability to identify uncertainties during the construction phase. If the uncertainties were considered in the planning phase, the result could be much better. For example, in one

Projects	Early phase	Construction phase
1.	• Market • Planning and engineering • Project organization • Rig of contractor for the tunnel • Water and frost protection -tunnel	• Injection • Little rational operation • Changes of requirements • Changes of solutions
2.	• Rig, contractor tunnel • Market • Project organization • Road Construction • Bridge	• Mass balance • Market • Weather condition • Contractor implementation competency • Frost protection
3.	• Market • Project organization • Contractor's rig for tunnel • Other project exercises • Unforeseen uncertainty related to the degree of detail	• Polluted ground • Contractors 'construction's ability • Quantity • Construction time, project organization and planning Construction time, project design
4.	• Market • Degree of detail • Bracing system in bridge • Project owner cost • Bridge cable	• Market • Progress in execution • Weather condition • Key personnel • Replacement of bolts
5.	• Market • Land acquisition • Large bridge • Unforeseen uncertainty related to the degree of the detailed engineering	• Market • Changes of routines • Supervisor and legislation • Construction in a densely populated area • Competency in its organization
6.	• Project organization and losing competent personnel. • Construction execution • Groundwork concerning soil/terrain/ masse, measurement certificate • Owner control and framework conditions • Market	• Total temporary stoppage of the project • Technical complexity in the tunnel • Construction in densely • populated areas • Ground conditions • Foundation of bridge • The technical complexity of Bridge COVID-19
7.	• Mass balance • Blasting process • Works on long traffic roads • Geology • Environmental conditions in the project (for instance: waterfall, soil, vulnerable species, and…)	• Injection • Delivery challenges • COVID-19

Table 2.
Top uncertainties in the early and the construction phase.

of the projects, the project manager said: "*There was little planning and pre-evaluation for tunneling done before the project started, and after beginning construction, unexpected things happened*".

The project manager in one of the projects said: "*Market is one of the important uncertainties, and after contracting to some extent, it is solved. Regulation and changes in them are other uncertainties which affect the project.*" Monitoring market trends regularly and maintaining solid relationships with stakeholders and regulatory bodies are helpful. Lastly, proactive engagement with stakeholders, including local communities and environmental organizations, is essential for contextual uncertainties. By incorporating stakeholders' perspectives, addressing their concerns, and incorporating their feedback into decision-making, road construction projects can reduce conflicts and improve their resilience. Using this comprehensive approach, road projects can effectively manage uncertainties.

3.2 Challenges and enablers toward uncertainty management

In this section, we presented and explored the challenges involved in uncertainty management. Solutions for these challenges can serve as enablers for uncertainty management in the context of road construction projects. The identified challenges are overemphasizing risk over opportunity management, lack of systematic approach in uncertainty management, and shortage of systematic training on uncertainty management.

3.2.1 Emphasizing risk over opportunity

In the process component, studied road projects primarily focus on risk management rather than opportunities. For example, in one of the projects, the number of risks and opportunities found in the risk register had the pattern shown in **Table 3**.

The number of risks presented in **Table 3** surpasses the number of opportunities, highlighting the significant focus on risk management in projects. **Table 4** provides an overview of the total risks and opportunities observed in the construction phase of the seven cases.

Years	Risks	Opportunities	Total
One year before construction	34	2	36
One year after construction	75	3	78
Mid construction phase	64	1	65

Table 3.
Number of identified risks and opportunities in one of the projects.

	Project 1	Project 2	Project 3	Project 4	Project 5	Project 6	Project 7
Risks	52	19	75	23	46	85	—
Opportunities	15	1	3	8	4	15	—

Table 4.
Comparison of project risk versus opportunity focus.

Data for the projects are derived from reports provided at varying intervals, such as monthly, quarterly, biannually, and yearly. Data for project 7 are not available in **Table 4** because of incomplete documentation.

In every study conducted, there was a consistent pattern of risk management taking precedence over managing opportunities. Unfortunately, this tendency persists in six projects. Addressing opportunities becomes increasingly difficult during the implementation phase because plans are decided, and in the middle of construction, identifying opportunities is difficult. The only project in which they exploited opportunities had a different form of contract and procurement strategy. The contract and procurement strategy supported opportunities in this project.

In one of the projects, the project manager mentioned: *"Due to the lack of a culture that promoted the identification of uncertainties and the pursuit of opportunities at a higher organizational level, the project ended up predominantly prioritizing risk management."*

3.2.2 To benefit from the systematic approach

Three projects from the seven in the study have a consistent strategy for managing uncertainty. They engage in a continuous process of collecting information, identifying uncertainties, implementing measures, and monitoring the uncertainties. Additionally, the project's unpredictability is reported monthly.

The case studies demonstrate varying approaches to uncertainty management. While some projects explicitly incorporate the uncertainty register into their uncertainty management practices, other projects update the register minimally after construction commences. According to the project manager's statements in the interview:

> *"I think the value of systematic risk registration is necessary for achieving better and more consistent performance. Fostering transparency and promoting effective communication among all involved parties could improve uncertainty management in projects."*

Moreover, some projects actively pursue opportunities to generate cost savings, whereas others use the register primarily to monitor the early phase identified uncertainties. Overall, each project's uncertainty register identifies more threats than opportunities. Other observed patterns in seven projects were a lack of attention to measures for identified uncertainties and not dedicating sufficient time to develop risk reduction measures. A systematic approach contributes to regularly defining and updating measures during the project's execution phase. Intriguingly, the frequency of uncertainty analysis varied significantly among projects, with some executing it monthly, others three or four times a year, and still others every 6 months. This partly demonstrates a systematic approach to uncertainty management.

Some of the projects experienced challenges in working with the risk registering tool. In some cases, some uncertainties were deleted, which affected the usage of the system for risk registration. There was no regular meeting to follow up on the uncertainty management system. One of the project managers interviewed said: "*To small extent projects logged uncertainties and measures, which they adopt for managing uncertainties. Such logs could be very helpful and could have a learning effect.*"

> *The quote from the owner was: "What has been truly fascinating is that during our prolonged discussions on relationships, they frequently evolved into discussions*

> *about opportunities. This has not only helped us in terms of cost reduction but has also allowed the contractor to mitigate implementation risks and optimize resource utilization, resulting in significant cost savings and greater profitability.*"

3.2.3 Systematic training on uncertainty management

The analysis of seven road construction projects revealed a lack of systematic training for those responsible for managing uncertainty. Numerous respondents mentioned initial difficulties and learning the tools and techniques through trial and error. For instance, a project controller in one of the projects said*: "We had some courses at the beginning of the career for the job position, but we did not have any* training *for uncertainty management, and we learned it during the project.*" Despite confronting numerous uncertainties in their daily work, it remained unclear to what extent they utilized a systematic approach to uncertainty management. This raised the question of why businesses should invest considerable time and resources in uncertainty analysis if the project teams do not directly benefit from it. Some projects were more systematic than others in their approach to uncertainty management. If the frequency of analysis meetings increases and is supported by efficient tools, we anticipate that the outcomes will be more satisfying and in line with expectations. This will come from an increased focus on the right things and the training effect of doing it more often.

4. Discussion

This is not the first study of uncertainty in major Norwegian projects. Market, project organization, and project planning were the three major sources of uncertainty in seven studied projects in the construction phase, aligned with previous studies [14, 31]. As a reference, we note the following results: The most frequent uncertainties in the pre-project phase projects are organizational factors, market conditions, and technical conditions [31]. Project organization, market conditions, project planning and control, and technical conditions are the most frequent uncertainties [14].

Uncertainties arising from market conditions, project organization, and project planning have consistently been recognized as critical factors that can significantly impact project outcomes. Market uncertainties, such as changes in demand, price changes, competition, or economic conditions, pose challenges in predicting project success and may require adaptive strategies. Project organization uncertainties refer to factors related to the structure, roles, and dynamics of the project team, which can influence communication, decision-making, and coordination. Lastly, project planning uncertainties encompass risks associated with project scope, scheduling, resource allocation, and other planning aspects. By acknowledging the importance of these three sources of uncertainty, project managers and stakeholders can proactively identify and address potential challenges, leading to more effective risk management and improved project performance.

All the uncertainties mentioned can be categorized into operational, strategic, and contextual. To proficiently address operational, strategic, and contextual uncertainties, it would be helpful for road projects to embrace a comprehensive and integrated approach. This strategy requires forethought, effective communication, adaptability, and follow-up meetings with the participation of key people in the project team.

Comprehensive risk assessments and review plans should be conducted for operational uncertainties to mitigate potential challenges in day-to-day project activities. This includes conducting site investigations, utilizing reliable apparatus and technology, and communicating with subcontractors and suppliers openly.

Early identification of the mentioned challenges (overemphasizing risk over opportunity management, lack of systematic approach, and shortage of systematic training) in projects contributes to improving the process of uncertainty management, and thus, enhancing cost performance. By implementing effective planning and employing appropriate measures to address risks and capitalize on opportunities, project teams can work toward achieving project objectives more successfully.

In the process component, studied road projects primarily focus on risk management rather than opportunities. This pattern is in line with findings in previous studies [8, 32]. Risks are often more apparent and urgent to address because they are associated with negative outcomes, such as cost overrun and potential loss to the project. Risks are seen as more tangible and predictable, whereas opportunities require an innovative approach to identify them. Road projects also operate within tight budgets and timelines, which prioritize risk mitigation for project success. Opportunities may be perceived as adding complexity or potential delays. However, road projects must recognize and embrace opportunities for innovation and cost savings to achieve improved outcomes. Balancing risk and opportunity management can lead to enhanced stakeholder value and overall project success.

Noticing risks more than opportunities becomes particularly important when a project encounters unforeseen costs and requires cost reductions. While reduction lists and optimizations may assist in lowering expenses, they may not be sufficient to fully offset the costs incurred. In addition, because of the tight schedule and budget, there is often a low flexibility for identifying and spending time exploring opportunities in the execution phase. Failure to recognize and utilize opportunities early in projects can result in significant consequences and expensive changes later in the project's life cycle.

To improve the identification of uncertainties, project teams must recognize the significance of actively pursuing and embracing opportunities throughout the project [6]. This shift in attitude requires nurturing a culture of proactive opportunity identification and evaluation at different levels of the organization. Implementing structured processes and frameworks for opportunity management, promoting collaboration and brainstorming sessions to uncover hidden possibilities, and providing training and guidance on identifying and using opportunities are all contributing to opportunity management [8]. Improving opportunity management and effective risk management projects can maximize their success and efficiency.

The lack of a systematic approach to uncertainty management is another challenge in uncertainty management. One of the main obstacles faced in implementing a systematic approach to uncertainty management relates to the low priority given to uncertainty management processes in projects by top management, resulting in its perceived lack of importance. In some cases, there is a technical challenge wherein existing tools fail to adequately assess the impact of specific risks on project costs when uncertainties are addressed. Understanding this level of influence (uncertainty on costs) could provide valuable insights for project management in monitoring and serve as a valuable learning experience for future endeavors. Furthermore, granting access to tools for all project members enables them to proactively register risks and identify potential opportunities on a daily basis. One of the key takeaways from

a particular project was the integration of uncertainty management into everyday project practices and other related activities.

As the project progresses and new uncertainties emerge, the uncertainty plans and documents should be updated regularly. This ensures that the approach remains effective and pertinent throughout the lifecycle of the project. Feedback from project team members, stakeholders, and relevant industry experts should be incorporated to refine and adapt the plans and risk registers to changing conditions.

A shortage of systematic training was obvious in seven projects. To address the lack of systematic training in uncertainty management, businesses should implement long-term training programs that cover multiple aspects of uncertainty management, foster a culture of continuous learning by encouraging ongoing professional development instead of a one-time event, and provide mentorship and support by connecting experienced professionals with less experienced team members. The focus should also be on having approximately the same goals and philosophies with uncertainty management across the projects so that there is continuity in the uncertainty work.

The level of training should be suitable for each role of the project teams to be effective. An increased focus on the transfer of experience will provide increased competence within the organization and make the project participants better equipped to find and implement the right measures to deal with uncertainties. By investing in these measures, businesses can increase the capabilities of their project teams, improve project outcomes, and boost the effectiveness of uncertainty analysis.

A comprehensive framework for uncertainty management needs three main components, as seen in **Figure 4**. This framework is a suggested conceptual framework that covers and fulfills the challenges and provides solutions (enablers) for uncertainty management.

Figure 4 is a conceptual model for achieving comprehensive uncertainty management, and it presents three components that need to work together. These suggestions depend on project size and complexity. With the increasing complexity and size of the

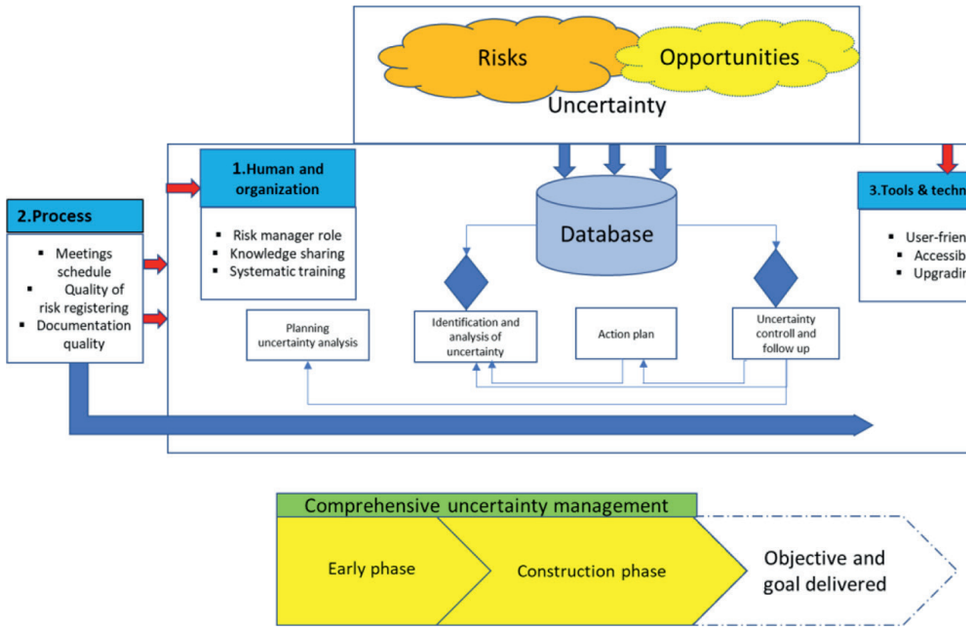

Figure 4.
The conceptual framework for comprehensive uncertainty management.

projects, the suggestions are even more important. In large and complex projects, a comprehensive framework for uncertainty management is recommended. We suggest improvements for all three necessary components of the framework.

The human and organization component covers three suggested improvement areas, such as systematic training, risk manager role, and knowledge sharing. The analysis uncovered a lack of systematic training for uncertainty management within the projects, highlighting the necessity for enhanced training initiatives and knowledge dissemination across the entire project organization. In large and complex projects, having a dedicated role as a risk manager improves coordination and communication in the uncertainty management process. This results in a more effective process. In systematic training, all the people who are involved in the uncertainty management process should have training courses regularly. When tools and processes are updated, they should have new training sessions. Besides, all new staff involved in uncertainty management should have training courses to become familiar with the main concepts of uncertainty management.

In the process components, meeting schedules, quality of risk registering, and documentation quality should be improved. Meeting schedules should include discussions on risks and opportunities. Uncertainty management meetings in projects should mirror the project size. Cost analyses and updating the risk register are typically done every 6 months in large, complex projects, and an update of the analysis of time is recommended to be done at least annually. These updates help leadership at an organizational level have a better understanding of project-level problems and obstacles during the execution process.

Tools and techniques component include a proper cost estimating tool, which is a tool for simulating time uncertainty and risk with an uncertainty/risk matrix. These tools should be an integrated part of the project reporting systems for each large complex project. The tools in use should be checked by experts and improved, if necessary, and it should be ensured that the quality of the reports is high and that the tool is user-friendly. The quality check could be conducted by project managers or personnel with enough experience in technical subjects. Conducting monthly uncertainty management activities allows the project team to consistently and systematically identify and address uncertainties. Although project team members engage in a form of uncertainty management in their daily work, formalizing this process in a systematic manner can further enhance project outcomes. The uncertainty register needs to be updated every year to remain relevant at an operational level. The risk management team needs to have a monthly focus on the top ten risks and opportunities.

5. Conclusions and the way forward

Market conditions, lack of competence in the project organization, and poor project planning are identified as the primary sources of uncertainty during the construction phase of road projects. Consistently, it has been acknowledged that these uncertainties are vital and can have a significant impact on project outcomes. To effectively manage these uncertainties, a comprehensive uncertainty management strategy could be helpful. Strategic uncertainties necessitate feasibility studies and scenario planning, whereas operational uncertainties can be addressed through comprehensive risk assessments and contingency plans. It is possible to manage contextual uncertainties such as market conditions by choosing the right contract strategy, involving stakeholders, and incorporating their perspectives.

The other interesting observation was the differences between uncertainties in the early phase and uncertainties in the construction phase. Most uncertainties in the construction phase were not expected or identified in the early phase. This shows the dynamic and changeable environment for the road projects, the focus opportunities, and the need to continue through the construction phase.

Three main challenges identified in this chapter were as follows: emphasizing risk management over opportunity management, lack of a systematic approach, and systematic training on uncertainty management.

There is strong evidence that many road projects spend most of their focus on risk management as opposed to opportunity management. Improvements can be made by measuring and changing the process, focusing on opportunity before risk. In addition, the design of contract strategies and how to share the risks and opportunities among different parties must be well thought through. Projects can achieve better performance by improving their ability to navigate uncertainty and achieve positive outcomes. Creating a harmonious synergy between a skilled workforce, appropriate tools, and a well-defined process can serve as a solution for achieving improved performance in uncertainty management.

In the future, employing quantitative approaches in uncertainty management research holds significant potential for enhancing uncertainty management practices. Through empirical studies and case studies, valuable insights into different aspects of uncertainty management can be addressed, such as identifying uncertainties, registering them, and implementing effective measures to address them. Additionally, conducting research on uncertainty management across various contract strategies and comparing their performance could yield valuable findings. Such studies can shed light on the risk management effectiveness of different contract types, providing valuable knowledge for future projects.

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Conflict of interest

The authors declare no conflict of interest.

Notes/thanks/other declarations

Place any other declarations, such as “Notes,” “Thanks”, and others before the References section. Assign the appropriate heading. Do NOT put your short biography in this section. It will be removed.

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References

[1] Welde M, Tveter E. The wider local impacts of new roads: A case study of 10 projects. Transport Policy. 2022;**115**(November 2021):164-180. DOI: 10.1016/j.tranpol.2021.11.012

[2] Welde M, Odeck J. Cost escalations in the front-end of projects—Empirical evidence from Norwegian road projects. Transport Reviews. 2017;**37**(5):612-630

[3] Galbraith JR. Organization design: An information processing view. Interfaces. 1974;**4**(3):28-36

[4] Wideman RM. A Guide to Managing Project Risk and Opportunities. Vol. 1. Newton Square, PA: Project Management Institute; 1992

[5] Atkinson R, Crawford L, Ward S. Fundamental uncertainties in projects and the scope of project management. International Journal of Project Management. 2006;**24**(8):687-698

[6] Johansen A, Olsson NOE, George J, Asbjørn R. Project Risk and Opportunity Management. Routledge; 2019. pp. 67-83. DOI: 10.1201/9780429430589-6

[7] Chapman C, Ward S. Project Risk Management: Processes, Techniques and Insights. 2nd ed; 2007. Available from: https://www.amazon.com/Project-Risk-Management-Processes-Techniques/dp/0470853557

[8] Johansen A. Project Uncertainty Management: A New Approach—The "Lost Opportunities" Practical Uncertainty Management Seen from a Project Joint Perspective. Trondheim, Norway: NTNU Doctoral Dissertation; 2015;**6**:1-199

[9] PMBOK. A Guide to the Project Management Body of Knowledge (PMBOK® Guide). Pennsylvania: Project Management Institute. 5th ed. 2013

[10] Hedeman B, Seegers R. Prince2: A Pocket Guide. 1st edition. 2009. Available from: https://www.amazon.com/PRINCE2-2009-Prince2-Hedeman-Seegers/dp/B00CF6CEIS [Accessed 17 September 2023]

[11] Zheng EZH, de Carvalho MM. Managing uncertainty in projects: A review, trends and gaps. Revista de Gestão e Projetos. 2016;7(2):95-109

[12] Zayed T, Amer M, Pan J. Assessing risk and uncertainty inherent in Chinese highway projects using AHP. International Journal of Project Management. 2008;**26**:408-419

[13] Torp O, Klakegg OJ. Challenges in cost estimation under uncertainty—A case study of the decommissioning of Barsebäck nuclear power plant. Administrative Sciences. 2016;**6**(4):14

[14] Shabani R, Torp O, Klakegg OJ, Johansen A. Knowledge about the origins of uncertainties from the pre-project phase of road projects. Infrastructures. 2023;**8**(1):1-16

[15] Shabani R, Malvik TO, Johansen A, Torp O. Dealing with uncertainties in the design phase of road projects. International Journal of Managing Projects in Business. 2022;**16**:27-57

[16] Dikmen I, Birgonul MT, Tah JHM, et al. Web-based risk assessment tool using integrated duration—Cost influence network model. Journal of Construction

Engineering and Management. 2012;**138**(September):1023-1034

[17] Poh YP, Tah JHM. Integrated duration-cost influence network for modelling risk impacts on construction tasks. Construction Management and Economics. 2006;**24**(8):861-868

[18] Pinto JK. Project Management: Achieving Competitive Advantage. 3rd editon ed. Harlow: Pearson; 2013

[19] Rolstadås A, Johansen A. From protective to offensive project management. In: Paper Presented at the PMI Global Congress. Malta—EMEA. May 2008

[20] Simister SJ. Qualitative and quantitative risk management. In: The Wiley Guide to Managing Projects. Hoboken, New Jersey: Wiley & Sons, Inc.; 2004

[21] Klakegg OJ, Torp O, Austeng K. Good and simple—A dilemma in analytical processes? International Journal of Managing Projects in Business. 2010;**3**(3):402-421

[22] Adafin J, Rotimi JOB, Wilkinson S. An evaluation of risk factors impacting project budget performance in New Zealand. Journal of Engineering, Design and Technology. 2021;**19**(1):41-61

[23] Chapman C, Ward S. How to Manage Project Opportunity and Risk. Chichester, GB: John Wiley & Sons Ltd; 2011

[24] Osipova E. Risk Management in Construction Projects: A Comparative Study of the Different Procurement Options in Sweden. Sweden: Luleå University of Technology; 2008. pp. 1-138

[25] Aslam M, Baffoe-Twum E, Saleem F. Design changes in construction projects—Causes and impact on the cost. Civil Engineering Journal. 2019;**5**(7):1647-1655

[26] Karlsen JT. Supportive culture for efficient project uncertainty management. International Journal of Managing Projects in Business. 2011;**4**(2):240-256. DOI: 10.1108/17538371111120225

[27] Rashid A, Boussabiane H. Conceptualizing the influence of personality and cognitive traits on project managers' risk-taking behaviour. In: Wideman RM. A Guide to Managing Project Risk and Opportunities. Vol. 1. Newton Square, PA: Project Management Institute; 1992. DOI: 10.1108/IJMPB-11-2017-0138

[28] Johansen A, Halvorsen SB, Haddadic A, Langlo JA. Uncertainty management—A methodological framework beyond "the six W's.". Procedia—Social and Behavioral Sciences. 2014;**119**:566-575. DOI: 10.1016/j.sbspro.2014.03.063

[29] Krane HP, Langlo JA. Project risk management: Challenges and good practices in active project ownership. In: 24th IPMA World Congress. Istanbul, Turkey. 1-3 Nov 2010. p. 3

[30] Smith NJ, Merna T, Jobling P. Managing Risks in Construction Projects. 2nd ed. Oxford: Blackwell Publishing; 2006

[31] Torp O, Magnussen OM, Olsson N, Klakegg OJ. Kostnadsusikkerhet i store statlige investeringsprosjekter. Concept rapport No. 15. Trondheim, Norway: NTNU; 2006

[32] Hillson D. Effective Opportunity Management for Projects. New York: Marcel Dekker; 2003