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On risk management in large infrastructure projects

Management du risque des grands projets d'infrastructure

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ABSTRACT

Large infrastructure projects are in general unique as the conditions and demands vary from one project to another. Furthermore, these projects are often related to risks of different nature due to high technological level, high environmental, public and political focus, long lead and project times, large and complex organizations, complex contracts etc. This paper aims to give some guidelines how to perform a successful management of risks in a large infrastructure project. The main conclusion is that the key to a successful risk management in a large infrastructure projects is early planning and a strict and continuous execution during the entire life-cycle of the project. Good planning and control of the risks enable an organized, comprehensive and iterative approach for identifying and evaluating the risks and give handling options necessary to optimize the project strategy. The management of risks should be performed as early as possible in the life-cycle of a project in order to ensure that critical risks are incorporated into the project plan and addressed with mitigation actions.

RÉSUMÉ

Les grands projets d'infrastructure sont de manière générale uniques du fait de la variation des conditions et des exigences d'un projet à un autre. De plus, ces projets sont souvent liés à des risques de nature différente, cela en raison du haut niveau technologique considéré, des contraintes écologiques, publiques de même que politiques, ainsi que de la durée étendue de ces projets, de la complexité structurelle des organisations impliquées et des contrats, etc. Cet article a pour but de fournir quelques indications sur la manière de gérer le risque de grands projets infrastructuraux avec succès. La principale conclusion qui s'impose pour une gestion du risque réussie est une planification avancée et une exécution stricte et continue tout au long du projet. Une bonne planification ainsi que la maîtrise des risques offrent une approche organisée, complète et itérative permettant d'identifier et d'évaluer les options de risques et les maniements nécessaires à l'optimisation stratégique du projet. La gestion du risque devrait être exécutée aussitôt que possible durant le cycle de vie d'un projet, cela afin d'assurer que les risques techniques critiques sont abordés avec les actions d'atténuation incorporées dans le plan du projet.

1 INTRODUCTION

Under the last decades there has been a trend that many infrastructure projects have become more expensive than estimated and that the project times have been longer than expected, see e.g. Whyte (1994) and Nylén (1996). The overall quality has also become lower than expected in many cases. Experiences from completed projects show that many problems and shortcomings arise from the design phase and that these are not sufficiently dealt with in the construction stage.

In general, large infrastructure projects are unique as the conditions and demands vary from one project to another. Many infrastructure projects involve works in a geological medium which properties in a large extent is unknown when the works begin and these properties can never be characterized completely. Additionally, these projects are often related to different kinds of risks due to high technological level, high environmental, public and political focus, long lead and project times, large and complex organizations, complex contracts etc. Therefore, many decisions have to be taken under risk or uncertainty. The often very large consequence for a failure in infrastructure projects requires decisions based on high knowledge and competence.

Decisions are normally based on the available information at the time for the decision, which may be very scarce or even inadequate. Limitations in knowledge and competence may create dangerous obstacles to a successful completion of the project in time and cost.

Because of these uncertainties and limitations many authors, e.g. Reilly (1996), Anderson (1997) and Hintze (2001) have proposed a project management with a risk focus for large infrastructure projects. Furthermore, in the light of these uncertainties the need for quality control systems is obvious. From a risk perspective, the quality control is about reducing the risk of an unwanted event. Since almost all large infrastructure projects includes a lot of uncertainties and decision alternatives it is equal important to *"do the things right"* (according to traditional pre defined quality control systems) as *"do the right things"* (Stille et. al., 1998).

The aim of this paper is to discuss the concept of risk and uncertainty in geotechnical engineering and to present a methodology for a successful risk management in large infrastructure projects.

2 THE CONCEPT OF RISK AND UNCERTAINTY IN GEOTECHNICAL ENGINEERING

A stringent system for risk management are particular important in geotechnical projects due to the high degree of uncertainty associated with, for example, the construction material, i.e. the soil or rock. For example, tunnel projects are often related to high risk factors that sometimes can lead to major losses of material, money and even human life. Some factors can lead to total collapse that simply implies the loss of the whole project.

Risks are associated to the lack of knowledge. The knowledge about risks is therefore, in a sense, the knowledge of the unknown. Many researchers have tried to make the concept of risk as objective as possible. Though, on a fundamental level it is basically a value-laden concept since risk often has a negative meaning to most people (Hansson, 2004).

The word *"risk"* is used in many situations and with different meaning to different people. Some of the definitions are:

(i) Risk = an adverse event which may occur.

(ii) Risk = the cause of an adverse event which may occur.

(iii) Risk = the consequence of an adverse event which may occur.

(iv) Risk = the probability of an adverse event which may occur.

(v) Risk = the statistical expectation value of an adverse event which may occur.

The definitions according to (i) and (ii) are particularly used in everyday language and rarely in a technical context. Definitions according to (iii) and (iv) are often used when the size or seriousness of the risk is to be determined. In many situations, e.g. in engineering applications, risks are so strongly associated with probabilities that the word risk is used to represent the probability of an event rather than the event itself.

The fifth definition was developed in risk analysis with the aim of quantifying the total amount of risk associated with a specific event and is often used in technical context, see Hintze (1994) and Hansson (2004). A statistical expectation value is a probability-weighted value which has the benefit of being additive. This definition of risk is often used in risk-benefit analysis in the systematic comparison of risks with benefits. This is also the standard meaning of risk in many branches, e.g. in civil engineering. In its simplest form the expectation value is the product of the probability and consequence of an event. However, this definition of risk is problematic for at least three reasons.

First, neither the probability nor the consequence of an adverse event can be known in advance. Both are distribution functions of random variables which, in civil engineering, seldom can be based statistics. Second, probability weighing is controversial. Events with high consequences and low probability can be perceived completely different from events with moderate probability and consequences, even though the risk is the same. There is a tendency that risks with high consequences and low probability are overestimated. Third, the expectation value approach only assesses risks according to their probability and consequence. For most people, other factors effect their risk perception, e.g. how risks and benefits are distributed or connected and social, political and cultural factors (Hansson, 2004).

Technological risks depend not only on the behaviour of the components in the system, but also on human behaviour. The risk associated with a specific technology can differ considerably between organizations with different attitudes towards risk and safety. In addition, the human behaviour is much more difficult to predict than technological components.

Another issue to be considered is that people make estimates of probabilities. Psychological studies indicate that there is a strong belief in the estimates of probabilities by those who made them, e.g. expert groups. The possibility that the estimates are wrong tends to be neglected. Therefore, it is necessary to make a clear distinction between those probabilities that originate in expert's estimates and those that come from observed events.

3 RISK BASED DECISION-MAKING IN CIVIL ENGINEERING

From a decision-maker's point of view, it is optimal to have quantified risks so that the risks can be compared and prioritised. The critical concern in the quantification of risk is often the determination of probabilities. When there is statistically sufficient experience of an event the determination of the probability can be performed by collecting and analysing that experience. This is the situation, for example, for many electrical components and more standardised projects. For new and untested technologies or technologies used in a new situation this technique is not relevant. This is the situation in most infrastructure projects where the project management have to deal with risks without knowing their probabilities and sometimes not even know what risks they are standing in front of.

Furthermore, not all events have probabilities assigned to them. In decision theory, the terms *"risk"* and *"uncertainty"* are used to distinguish between those who have and those who have not. By a decision *"under risk"* is meant a decision with known or knowable probabilities for different outcomes. In these situations fault and event tress can be used to estimate the probabilities by studying the various chains of events that may lead to failure. By combining the probabilities of various sub events in a chain, the total probability of an event can be estimated. By a decision *"under uncertainty"* is meant one that has to be taken with unknown probabilities or when the probabilities are not meaningful. In these situations traditional methods can not be used but the uncertainties can be handled with conservative assumptions, control and monitoring systems and redundancy.

Though, there are some problems with fault and event trees. First, an event can happen in more ways than we reasonable can imagine. There is no method by which all chains of events that may lead to an accident in a complex technological system can be identified. Another problem is that the total probability can be very difficult to determine even if we know the probability of each individual event due to dependencies between the events. In spite of these difficulties, the construction of fault and event trees can be an efficient way to identify weaknesses in a complex technological system. It is important, though, to keep in mind that an exhaustive list of negative events cannot be obtained, and that therefore the total risk levels cannot by determined in this way (Hansson, 2004).

The knowledge of the risks involved typically increases as the project progresses. This means that different basis for decisions exist at different times. The increased knowledge can be used to reduce the uncertainties and the risks in the project and to reconsider already made decisions and the design, e.g. by the use of Bayesian statistics (see Benjamin & Cornell, 1970, and Ang & Tang, 1984). The increased knowledge is dependent on a continuous free flow of quality-assured information throughout the project organization (Sturk, 1998).

For a successful completion, it is recommended that an infrastructure project to a great extent is executed as an innovation project and not as, traditionally, an implementation project. In an innovation project an important issue is to create opportunities for a learning environment to create appropriate knowledge and experience during the project work. This implies that the knowledge about the risks involved increases during the project. This increased knowledge can be used to reduce the risks, either by reducing the probability or the consequence of an unwanted event. The main differences between an innovation project and an implantation project are presented in table 1.

Table 1: Characteristics of an implementation and an innovation project.

	Implementation project	**Innovation project**
Pre-knowledge	Complete	Incomplete
Project goal	Exogenous the project work	Endogenous the project work
Acquisition of knowledge	During the planning	During the planning and execution
Main result	Final product	Final product, knowledge of the goal and the process to reach the goal
Rationality	Effective project execution	Adequate knowledge for the project

4 RISK MANAGEMENT METHODOLOGY IN LARGE INFRASTRUCTURE PROJECTS

4.1 *General*

Effective risk management requires involvement of the entire project team and also assistant from external experts, knowledgeable in critical risk areas. In addition to technical risks, the risk management process should consider both human elements and organizational issues. Successful risk management projects generally have the following characteristics:

- Experienced and highly skilled personnel.
- Feasible, stable and well understood user requirements.
- A close relationship between all actors involved.
- A planned and structured risk management process.
- A project strategy consistent with risk level and risk handling strategies.
- Continual reassessment of project risks and associated risks.
- Aids to monitor effectiveness of risk handling strategies.
- Formal documentation and communication.

It is important that the risk management process starts at an early stage of a project where the possibilities to influence are high and the used accumulated resources are low. The work carried out in the tender stage must be utilized and updated during the start up and construction stage. The key to successful risk management is early planning and strict execution. Good planning and monitoring enables an organized, comprehensive and iterative approach for identifying and evaluating the risks. This also gives adequate handling options, which are necessary for optimizing the project strategy (see figure 1).

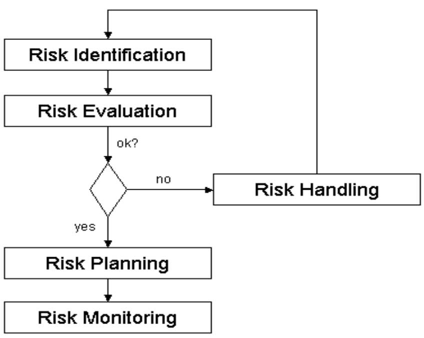

Figure 1. The structure of the risk management process (after Hintze 1994).

To support these efforts, assessments should be performed as early as possible in the life-cycle of the project in order to ensure that critical technical risks are addressed with mitigation actions incorporated in the project plan. As a project progress, new information improves the insight into the risk areas. This allows development of more effective project strategies.

4.2 *Risk Identification*

Risk identification is the process of examining the existence of potential hazards and defining their characteristics. The process begins with defining the project in terms of system analysis, see Carlsson et. al. (2004). It is important to examine and identify project specific potential hazards by reducing them to a level of detail that permits an evaluator to understand the significance of any risk and identify its causes, i.e. the initiating events. This is a practical way of addressing the large and diverse number of potential risks that often occur in infrastructure projects. Evaluators may initially rank events by probability and consequence before beginning to focus the analysis on those most critical to the project.

Although there is a limited amount of information in the early stages of a project this information must be analyzed. Hazards that may have adverse consequences for the outcome of the project must be identified. During decomposition, hazards are identified from experience, brainstorming, experiences from similar projects and guidance included in the project plan.

Critical risks need to be documented. The documentation may include the scenario that causes the risk, planned management controls and actions. It may also contain an initial assessment of the consequences to focus the risk evaluation effort. A risk watch list should be initiated as part of risk identification.

4.3 *Risk Evaluation*

The risk evaluation begins with a detailed study of the critical hazards that have been identified. The objective is to gather enough information about the risks to estimate the probability of occurrence and the consequence on cost, time schedule, quality, environment, safety and health and client satisfaction if the risk occurs.

In practice, the distinction between risk identification and risk evaluation is often unclear because there is some risk evaluation occurring during the identification process. For example, in the process of interviewing an expert it is logical to pursue information on the probability of its occurrence, the consequences, the time associated with the risk (i.e. when it might occur) and possible ways of dealing with it. The latter actions are part of risk evaluation and risk handling, but often begin during risk identification.

Risk evaluation is the problem definition stage of management, which quantifies potential project risks in terms of probability and consequences. The results form the basis for most risk management actions. It is probably the most difficult and time consuming part of the risk management process. Despite its complexity, risk evaluation is one of the most important phases of the risk management process because the standard and quality of the evaluation determine the effectiveness of the risk management.

4.4 *Decisions on accepted risk level*

The decision-making of accepted risk level is a process involving a series of basic steps. It can add value to almost any situation, especially when the possibility for serious or catastrophic outcomes exists. The steps can be used at different levels of detail and with varying degrees of formality, depending on the situation.

The key to a successful process is to complete each step in the most simple and practical way to provide the information the decision-maker needs. The information about the possibility of one or more unwanted outcomes separates risk-based decision-making from more traditional decision-making. Most decisions require information not only about the risk, but also about such things as costs, schedule requirements and public perception. In risk based decision-making all of the identifiable factors that affect a decision must be considered.

In general, it is not possible to decide the acceptable risk level through quantitative risk evaluations all alone. The decision must also be based on social, political and economical judgements. These change with time, which means that the accepted risk levels change with time.

4.5 *Risk Handling*

Risk handling includes specific methods and techniques to deal with known risks and a risk schedule. The schedule identifies who is responsible for the risk area and provides an estimate of the cost associated with the handling of the risks. It also contains planning and execution with the objective of keeping the risks at an acceptable level.

A specific project risk group that assesses risks should begin the process by identifying and evaluating handling approaches and propose these to the project decision makers, who select the appropriate ones for implementation. The risk handling phase must be compatible with the risk plan and any additional guidance that the project plan provides. A critical part is the refinement and selection of the most appropriate handling options.

4.6 *Risk Planning*

Risk planning is the detailed formulation of actions for the management of accepted risks that have been accepted in the decision-making phase. It is the process to:

- Develop and document an organized, comprehensive and interactive risk management strategy throughout the project.
- Determine the methods to be used to execute a risk management strategy.
- Plan for adequate resources in time and space.

Risk planning is an ongoing process throughout the life of the project and includes the description and scheduling of the activities and organization to control, document and communicate risks associated with the project.

4.7 *Risk Monitoring*

The monitoring process systematically traces and evaluates the effectiveness of the risk planning actions against established standards. Monitoring results may also provide a basis for developing additional handling options and identifying new risks. If necessary, the project management should re-examine the risk planning approaches for effectiveness while conducting assessments. As the project progresses, the monitoring process will identify the need for additional risk handling options.

An effective monitoring effort provides information that show if handling actions are not working and which risks are on their way to becoming actual problems. The information should be available in sufficient time for the project management to take corrective action. The performance of the project risk group is crucial to effective risk monitoring. They are the “front line” for obtaining indications that handling efforts are needed and about their desired effects.

5 CONCLUSIONS

The success of risk management is related to when and how it is implemented. A successful risk management should start as soon as possible in the planning process and be carried out efficiently through the entire project. A procedure for quality assessment based on a systematic risk management process is important and shall be focused upon finding important risk factors to follow up under the construction stage.

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