

# Drainage-Related Risks for Operation and Maintenance of Tunnelling Projects: an Overview

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## Abstract

The importance of drainage-related risks associated with tunnelling projects requires special attention from tunnel operators to analyse and manage the risks. The optimal management of drainage-related risks in tunnelling projects involves multiple objectives such as flood management, maximisation of design capacity of drainage contamination and optimisation of overall drainage system. This paper focuses on identifying the key drainage-related risks that have great potential of occurring in highway tunnelling projects. The outcomes of this research are developed based on findings obtained from extensive literature review and case studies that have been conducted by a few researchers. The identified drainage-related risks will be reviewed in this paper. All these risks can be included as key information when drafting a new risk management plan or to be added into the existing risk management plan in order to enhance the operation and maintenance of tunnelling projects.

**Keywords:** Tunnelling Projects; Drainage-Related Risks; Operation; Maintenance

## 1. Introduction

Tunnels are underground links that can act as railway transportation, highway or expressway transportation and water or power treatment plants with their unique characteristics and potential applications (Fouladgar et al., 2012). Recently, there is an increasing demand in the formation of tunnels, world-wide. For example, Shanghai, one of the major cities of China is having a more advanced and complete transit network now with majority of them are constructed by tunnel structures since year 1995. Globally, the development of tunnel construction has increased rapidly and also very highly demanded as they are forming parts of the complex infrastructure systems, for instance tunnel is forming parts of the Oresund link between Denmark and Sweden (Kauer, 2001).

The optimal management of drainage-related risks in tunnelling projects involves multiple objectives that can be synthesised as storm water control, minimisation of groundwater overflows, maximisation of design capacity of drainage contamination and optimisation of overall drainage system. It is very crucial for tunnel operators to manage the drainage-related risks in tunnelling projects as the tunnel is usually surrounded by complex topography with unknown geological conditions and other factors.

This paper focuses on identifying the key drainage-related risks that have great potential of occurring in highway tunnelling projects. The outcomes of this research are developed based on findings obtained from extensive literature review and case studies that have been conducted by a few researchers. The identified drainage-related risks will be reviewed in this paper. All these risks can be included as key information when drafting a new risk management plan or to be added into the existing risk management plan in order to enhance the operation and maintenance of tunnelling projects.

## 2. General Risks for Tunnelling Projects

Many types of incidents such as landslide, tunnel failure, fire and flooding always occur for tunnelling projects as they always exposed to unknown geological conditions based on the selected locations. As a result, tunnelling projects are experiencing risk in environmental, public, damage to adjacent people and structures and additional cost incurrence (Eskesen et al., 2004).

A few specified risks that often occur in tunnelling projects (Reilly and Brown, 2004):

- Significant increase of cost in terms of support and project
- Potential execution in revenue operations or delay of project
- Inability to acquire predetermined criteria and standards in term of design, maintenance, quality and operational
- Defect with personal damage and potential of death, financial risk and decline in term of reliability or credibility

Risks in tunnelling projects have been divided into three sections as following in some other sources (Jafari and Colleagues, 2006):

- Risk with respect to any types of damage to external parties
- Risk with respect to material damage to device, equipment, machinery and building
- Risk with respect to material damage to property of third parties

There are several categories of risks for tunnelling projects (Yogaranpan, 1996): internal (improper planning and strategic), external (political and economic), natural (storms, floods, earthquakes, and other natural diseases) and human (injury or death):

- Design risk
- Construction risk
- Operation risk

- Maintenance risk
- Political risk

According to Gafari and Aminzadeh (2015), the risks that occurring in tunnelling projects can be defined as unusual problems that cause inaccessibility of geotechnical studies that required in order to predict the factors of many types of accidents that possibly happen at underground areas or spaces. They can be consisted of uncoordinated and geological processes, causes that linked to hydrological conditions of underground, properties and characteristics of geoformations.

There are a number of risks of tunnelling projects including design, geological condition, safety, force majeure and health. For example, the lacking of emergency safe escape accesses is contributing to safety and health issue especially during execution work of tunnels within a limited working area or space. In addition, another safety and health issue is due to insufficient supervision in term of execution works following standard safety regulations or Personal Protective Equipment (PPE) which can bring catastrophic effects. Design risk is defined as the failure to deliver or accommodate the desired service. Besides, the major structure or other types of reinforcement is very important for tunnelling projects in dealing with uncommon geological condition Unpredictable risks events including earthquake occurring at nearby places can contribute to the occurring of risk events such as collapse of a tunnel (Farid and Wong, 2013).

Generally, the risks of tunnelling projects can be divided into external and internal risks that have been extracted from several sources by researchers, as portrayed in Table 1.

**Table 1:** The external and internal sources of tunnelling projects [Source: Gafari and Aminzadeh, 2015; Dekovic and Pili, 2012; Jafari and Colleagues, 2006; Ansari, 2005; Eskesen et al., 2004; Reilly and Brown, 2004; McCabe, 2003; Balol et al., 2003; Edalati and Jialy, 2002; Miller and Lessard, 2001; Yogaranpan, 1996; Touran et al., 1994]

Risks From Internal Sources	Risks From External Sources
1) Time overrun risk	1) Social risk
2) Investment risk	2) Political risk
3) Planning risk	3) Economic risk
4) Management risk	4) Legal risk
5) Planning risk	5) Environmental conditions at the project site
6) Human risk	6) Natural disasters
7) Technical risk	
8) Employer risk	
9) Material/equipment related risk	
10) Financial guarantees	

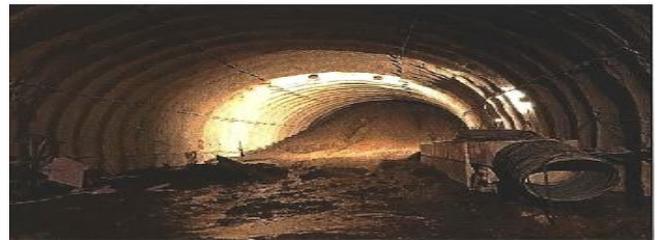
### 3. Major Drainage-Related Risks Occurrences in Tunnelling Projects

The Seikan tunnel (Figure 1) is a 53.85km long railway tunnel in Japan with 23.3km long underwater tunnel portion, embedded underneath the Tsugaru Strait, with an overburden of 100m and 240m below the water surface. A great majority of the tunnel crosses heavily fissured rock (9 large shear zones). The sea and underground water penetrate into these zones and the maximum water pressure is about 25 MPa. Due to inefficient drainage system, 4 large flooding accidents occurred between 1969 and 1976, with severe consequences on tunnel and resulting in 34 casualties. The fourth accident, which took place in May 1979 while driving the service tunnel, was the most severe. The water inflow was of 70m<sup>3</sup>/min under a maximum pressure of 2.8MPa, causing the flooding of 3015m of service tunnel and 1493m of the main tunnel with 120000m<sup>3</sup> of water, in first three days (Hashimoto and Tanabe, 1986).



**Fig. 1:** The flooding accident at Seikan Tunnel in Japan [Source: Hashimoto and Tanabe, 1986]

The Lausanne Metro system is known as one of the urban rail transport system in Lausanne, Switzerland. The operation involves more traditional light rail services and the concept of driverless rapid transit services on a grade-separated route is applied for this rail transport system. During 23 February 2005, a huge amount of soil and water (1400m<sup>3</sup>) entering the tunnel. The St. Laurent's commercial district is experiencing a serious damage afterward. As reported, there is no any contingency plans to manage the drainage-related risk when the incident occurred.



**Fig. 2:** Aspect of the front after collapse (ingress of soil and water), Lausanne, Switzerland [Source: Stallmann, 2005]

A huge financial loss and damage in term of productivity, business and others at Chicago city is due to the tunnel flood incidents. As reported, there are several massive floods have occurred in tunnel system of New York City including Hurricane Sandy. Many workers were affected from the flooding incidents as well.

### 4. Drainage-Related Risks for Operation and Maintenance in Tunnelling Projects

Based on the findings obtained from extensive literature review and several case studies, there were six drainage-related risks been identified. Table 2 indicates the types of drainage-related risk and its descriptions in tunnelling projects.

**Table 2:** Types of drainage-related risk and its description in tunnelling projects

No	Drainage-Related Risk	Risk Descriptions
1	Flooding due to drainage risk	Flooding caused by stream blockage or overflow in drainage system
2	Pavement settlement due to drainage risk	Pavement settlement due to unforeseen stream flow in drainage system
3	Operational delay due to drainage risk	Delay or interruption in term of operation for drainage system
4	Cost overrun in operation due to drainage risk	Proposed operating cost higher than actual operating cost
5	Contingency maintenance works due to drainage risk	Additional maintenance works to be carried out due to unforeseen incidents
6	Cost overrun in maintenance due to drainage risk	Proposed maintenance cost higher than actual maintenance cost

Flooding due to drainage risk can lead to massive obstruction of traffic and damage to tunnel structures, with possible long-term effects. For example, the tunnel structures can be damaged by unknown materials that displaced into the tunnel during the flooding incident. Besides, the pavement settlement due to drainage risk can be crucial too as it usually forms pothole and pitting or scaling on the road surface. The tunnel users may experience risk especially in term of safety during the usage of tunnel. Operational delay due to drainage risk is defined as delay or interruption in term of operation for drainage system. One of the main reasons is

the inconsistencies monitoring of work done in term of operational drainage work. The occurrence of both cost overrun in operation due to drainage risk and cost overrun in maintenance due to drainage risk are very common in tunnelling projects as most of the tunnelling projects experience loss in term of financial as the proposed budget allocation is insufficient to cover the actual cost. Lastly, the contingency maintenance works due to drainage risk involves additional manpower, cost, time or even expertise required to manage the additional maintenance works due to unforeseen incidents. Amongst all the identified risks, the most significant risk is the flooding due to drainage risk due to its catastrophic impacts.

## 5. Conclusion

Managing drainage-related risks in tunnelling projects has been recognized as a very essential process in overall risk management plan. Decisions are made nowadays in increasingly complex environments especially for tunnel. In more and more cases the use of experts in various fields is necessary. To overcome this difficulty, the drainage-related risks for tunnelling projects were identified from extensive literature review and also from several case studies. In order to manage the drainage-related risks of tunnelling projects effectively, the proper operation and maintenance of drainage systems especially in tunnel is very essential in order the systems are functioning to their designed capacity. This will include routine inspection of the systems, and carting out necessary cleaning, repair and desilting works. Tunnel operators should revise maintenance procedures including the frequency of inspection, programs for cleansing, desilting and necessary repair works, and documentation for maintenance records. Routine inspection and preventive maintenance are the best ways to prevent blockages and deterioration of storm water drainage systems, and hence minimize the drainage-related risks in highway tunnelling projects especially in flooding due to drainage risk. The identification and review of all key drainage-related risks is important as all these risks can be included when drafting a new risk management plan or to be added into the existing risk management plan in order to enhance the overall operation and maintenance of tunnelling projects.

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