ITA WG 2 – Guidelines for Tunnelling Risk Assessment

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**Guidelines for Tunnelling Risk Assessment**

**Risk definitions**

- **Hazard:**
  A situation or condition that has the potential for unwanted consequences:
  - Human injury
  - Damage to property
  - Damage to environment
  - Economic loss
  - Delay to project completion

- **Risk:**
  A combination of the frequency of occurrence of a defined hazard and the consequences of the occurrence
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Hazard and risk

- Identified hazard
  - Frequency / probability
  - Consequences
  - Risk
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Risk management

Planning/policy

System definition

Hazard identification

Frequency analysis

Consequence analysis

Risk

Risk analysis

Risk acceptance criteria

Risk evaluation

Unacceptable

Acceptable

Risk reduction measures

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Risk analysis

- Risk analysis: a structured process which identifies both the probability and extent of adverse consequences arising from a given activity.
- Risk analysis includes identification of hazards and description of risks, i.e. probabilities and consequences (qualitative or quantitative)

Risk acceptance criteria

- Common sense: aim at reducing risk once identified
- More formal criteria:
  - The risk shall be below a certain value
  - Cost benefit type criteria / ALARP (As Low As Reasonable Practicable - Developed in UK and widely used)
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High risk

Unacceptable region

Risk is intolerable and shall be reduced regardless of costs

ALARP region

Risk shall be reduced as long as the costs are reasonable compared with the risk reduction achieved

Broadly acceptable region

No need for considering risk reduction

Negligible risk
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Scope and purpose

• To present a guideline for designers to prepare comprehensive tunnelling risk assessment

• To indicate to owners what is accepted industry practice for construction risk analysis

• Does not include guidelines for contractor's risk management

Abstract

These guidelines, prepared by Working Group 2 (Research) of the International Tunnelling Association, are prepared in order to give guidance to all those who have the job of preparing the overall scheme for the identification and management of risks in tunnelling and underground projects. The guidelines provide owners and consultants with what is modern-day industry practice for risk assessment, and describe the stages of risk management throughout the entire project implementation from concept to start of operation.

Scope and purpose

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ITA/AITES Accredited Material

ITATunnelling for tunneling risk management: International Tunnelling Association, Working Group No. 2

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Guidelines for Tunnelling Risk Assessment

Contents

0. Abstract
1. Introduction and scope
2. Use of risk management
3. Objectives of risk assessment
4. Risk management in early design stages
5. Risk management during tendering and contract negotiation
6. Risk management during construction
7. Typical components of risk management
8. Risk management tools
9. References
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Risk Management Activities, three stages

2. Phase I: Early design stages
3. Phase II: Tendering and contract negotiation
4. Phase III: Construction
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Risk management activity flow
Phase I: Early design stages

OWNER

Establish risk policy

Qualitative risk assessment

Specific (quantitative) risk assessment

Risk register
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Risk management activity flow

Phase II: Tendering and contract negotiation

OWNER

Preparation of tender documents, including:
- Description of significant technical risks
- Technical requirements to mitigate risk
- Description of required risk competence

CONTRACTOR

Preparation of tender, including:
- Proposed risk management system
- Description of experience and competence in risk management
- Identification and description of risks associated with the proposed technical solution
- Identification and description of proposed risk mitigation measures

Selection of contractor, evaluation of:
- Contractor's ability to perform risk management
- Risks involved in contractor's proposed technical solutions

Prepare contract with risk clauses
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Risk management activity flow

Phase III: Construction

OWNER

Supervision and inspection of contractor's risk management

Assessment and mitigation of owner's risk

Approve on contractor's risk mitigation

CONTRACTOR

Establish risk management system

Detailed risk assessment

Propose risk mitigation

Implement risk mitigation
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List of hazards

General hazards:

1. Contractual disputes
2. Insolvency and institutional problems,
3. Authorities interference,
4. Third party interference,
5. Labour disputes

Specific hazards:

6. Accidental occurrences,
7. Unforeseen adverse conditions,
8. Inadequate designs, specifications and programmes,
9. Failure of major equipment, and
10. Substandard, slow or out of tolerance works.
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Construction risk policy

A construction risk policy may indicate:
- scope,
- risk objectives, and
- risk management strategy
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Risk Policy Scope

As an example the scope may include the following risks:

• to the health and safety of workers, including personal injury and, in the extreme, loss of life
• to the health and safety of third party people
• to third party property, specifically normal buildings, cultural heritage buildings and infrastructure
• to the environment including pollution, and damage to flora and fauna
• to the owner in delay to the completion
• to the owner in terms of financial losses
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Risk Management Strategy

The risk strategy should provide:

- a definition of the risk management responsibilities of the various parties involved (different departments within the owner's organisation, consultants, contractors)

- a short description of the activities to be carried out at different stages of the project in order to achieve the objectives

- a definition of methods to be used for follow-up on results obtained through the risk management activities. This could be accomplished by establishing a risk register of some form.
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Qualitative risk assessment

• Hazard identification through brainstorming sessions with risk screening teams.

• Classification of the frequency, consequence and risk levels of the identified hazards.

• Identification of risk reduction measures.

• Documentation of risk management work in risk register.
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Assessment of Scenario Frequencies

Frequency of occurrence in the construction period

<table>
<thead>
<tr>
<th>Descriptive frequency class</th>
<th>Frequency class</th>
<th>Central value</th>
<th>Frequency Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very likely</td>
<td>5</td>
<td>1</td>
<td>&gt; 0.3</td>
</tr>
<tr>
<td>Likely</td>
<td>4</td>
<td>0.1</td>
<td>0.03 – 0.3</td>
</tr>
<tr>
<td>Occasional</td>
<td>3</td>
<td>0.01</td>
<td>0.003 – 0.03</td>
</tr>
<tr>
<td>Unlikely</td>
<td>2</td>
<td>0.001</td>
<td>0.0003 – 0.003</td>
</tr>
<tr>
<td>Very unlikely</td>
<td>1</td>
<td>0.0001</td>
<td>&lt; 0.0003</td>
</tr>
</tbody>
</table>
# Guidelines for Tunnelling Risk Assessment

## Consequence classes

<table>
<thead>
<tr>
<th></th>
<th>Disastrous</th>
<th>Severe</th>
<th>Serious</th>
<th>Considerable</th>
<th>Insignificant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Injury to workers and emergency crew (No. of fatalities / Injuries*)</td>
<td>&gt; 30 F</td>
<td>3&lt;F&lt;30</td>
<td>1-3 F 3-30 I</td>
<td>1-3 SI 3-30 MI</td>
<td>&lt; 3 MI</td>
</tr>
<tr>
<td>Injury to third party persons (No. of fatalities / Injuries*)</td>
<td>&gt; 3 F</td>
<td>1-3 F 3-30 I</td>
<td>1-3 SI 3-30 MI</td>
<td>&lt; 3 MI</td>
<td>-</td>
</tr>
<tr>
<td>Economic loss to third party (mio. Euro)</td>
<td>&gt; 3</td>
<td>0.3 to 3</td>
<td>0.03 to 0.3</td>
<td>0.003 to 0.03</td>
<td>&lt;0.003</td>
</tr>
<tr>
<td>Economic loss to owner (mio. Euro)</td>
<td>&gt; 30</td>
<td>3 to 30</td>
<td>0.3 to 3</td>
<td>0.03 to 0.3</td>
<td>&lt;0.03</td>
</tr>
<tr>
<td>Delay in construction (per hazard)</td>
<td>&gt; 2 years</td>
<td>½-2 years</td>
<td>2-6 months</td>
<td>½-2 months</td>
<td>&lt; 2 weeks</td>
</tr>
<tr>
<td>Harm to the environment</td>
<td>Permanent severe damage</td>
<td>Permanent minor damage</td>
<td>Longterm effects</td>
<td>Impermanent severe damage</td>
<td>Impermanent minor damage</td>
</tr>
</tbody>
</table>

*F=fatality, SI=serious injury, MI=minor injury.
# Guidelines for Tunnelling Risk Assessment

## Hazard Ranking / Risk Classification

<table>
<thead>
<tr>
<th>Risk Matrix</th>
<th>Consequence</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Disastrous</td>
<td>Severe</td>
</tr>
<tr>
<td><strong>Very likely</strong></td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td><strong>Likely</strong></td>
<td>Unacceptable</td>
<td>Unacceptable</td>
</tr>
<tr>
<td><strong>Occasional</strong></td>
<td>Unacceptable</td>
<td>Unwanted</td>
</tr>
<tr>
<td><strong>Unlikely</strong></td>
<td>Unwanted</td>
<td>Unwanted</td>
</tr>
<tr>
<td><strong>Very unlikely</strong></td>
<td>Unwanted</td>
<td>Acceptable</td>
</tr>
</tbody>
</table>
### Guidelines for Tunnelling Risk Assessment

#### Risk Classification

<table>
<thead>
<tr>
<th>Risk Classification</th>
<th>Example of actions to be applied against each class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unacceptable</td>
<td>The risk shall be reduced at least to Unwanted regardless of the costs of risk mitigation</td>
</tr>
<tr>
<td>Unwanted</td>
<td>Risk mitigation measures shall be identified. The measures shall be implemented as long as the costs of the measures are not disproportional with the risk reduction obtained (ALARP principle, as low as reasonably practicable)</td>
</tr>
<tr>
<td>Acceptable</td>
<td>The hazard shall be managed throughout the project. Consideration of risk mitigation is not required</td>
</tr>
<tr>
<td>Negligible</td>
<td>No further consideration of the hazard is needed</td>
</tr>
</tbody>
</table>
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Quantitative risk assessment (example)

• Identify and select risks to be quantified.

• Assign most likely, minimum and maximum figure for each frequency and consequence.

• Calculate the resulting risk estimate as a probability distribution (instead of a single figure) allowing presentation of e.g. 50%, 75% and 95% fractals for the risk.

Quantification is most suitable for estimation of the risk of economic loss to the owner and delay, but may in principle be used for all types of risk.