Risk Management in Tunneling
– Occupational Safety + Health Plans
for Drill & Blast and Tunnel Boring Machines

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ABSTRACT: Control your critical success factors by applying generally accepted best risk management practices. Establish, implement, update and document a thorough and comprehensive Risk Management System where required by law, project challenges, owner’s specifications and/or where best risk management practices are not available.

1 WHAT CAN A RISK MANAGEMENT SYSTEM DO FOR YOU?

A Risk Management System (RMS) must increase your productivity – from your customer’s perspective as well – or it is useless …

A scientific risk management is a relatively new approach:

- Many managers (of big companies) are talking about it these days.
- Most people remain pretty confused when it comes to day-to-day application.
- Very few people really have personal experience.
- There is an opportunity in combining ongoing US underground activities with previous project risk management experience, providing owners, engineers and contractors with real added value in successfully pursuing their goals.

2 WHEN SHOULD YOU USE A RISK MANAGEMENT SYSTEM?

Where required
- by law
- by project challenges
- by owner’s specifications
- and/or by the absence of best risk management practices

you may choose to control your critical success factors by establishing a thorough and comprehensive RMS.

Examples for requirements:
- US Military Standard 882D requires a RMS of every party within the acquisition process.
- Swiss Law requires all companies operating in a high risk environment (e.g. contractors in the construction industry) to perform a risk assessment.

3 HOW DOES RISK MANAGEMENT WORK?

Control your critical success factors by:
1. Apply generally accepted best risk management practices.
2. Establish a thorough and comprehensive Risk Management System (RMS) where required by law, project challenges, owner’s specifications and/or the absence of best risk management practices.

4 APPLY GENERALLY ACCEPTED BEST RISK MANAGEMENT PRACTICES

Control your critical success factors by establishing a pro-active Quality Assurance/Quality Management System by applying generally accepted best risk management practices.

1. Use an interdisciplinary team.
Tunneling large, sophisticated and very complex projects, in partly still unknown geology and on the background of a highly sensitive environment, has to be well thought through. A well built-up interdisciplinary team is required to deliver best results. Include the owner, the
designer, the construction management, all special sub-consultants etc. as well as representatives of operations and maintenance. Lead the team by an experienced Risk Manager with a substantial background in quality management and safety + health.

2. Leave the ground risk to the owner.

3. Perform a very thorough, very detailed site investigation. Be prepared to invest anything from 1% to a maximum of about 10% (as a general rule) of your Total Cost of Ownership (TCO). Be prepared to core drill at least about 0.6 times the length of your tunnel when trying to avoid dealing with successful contractor’s claims (Waggoner, Daugherty, 1985).

4. Work out a professional Geotechnical Baseline Report (GBR) at least before requesting contractor’s bids. Hand out your GBR to all bidders (Essex, 1997).

5. Plan for contingencies.

6. Establish, run and maintain (before, during and after construction) an adequate control system. Enable real-time on-site interpretation and decision-making.

7. Use a partnering approach.

8. Require Escrow Bid Documents (EBD).

9. Prepare for Alternative Dispute Resolution (ADR). Avoid settling claims before courts as this often proves to be a very expensive process.

10. Emphasize a complete documentation. Keep all available records updated and carefully stored after the project’s completion.

11. Have the contractor to enroll a project-specific Quality Management System (PQM) on site. Fully integrate Safety + Health (OSH) and environmental issues into your PQM.

12. Whenever feasible and practical, test and validate your control of all critical success factors on a small-scale first (e.g. by a pilot tunnel, a test shaft, etc).

5 HOW DOES A RISK MANAGEMENT SYSTEM WORK?

A four-folded approach is recommended by the author (m+m/am):

1. Start with a Preliminary Hazard Analysis (PHA).

2. For hazards with a high potential of harm and where generally accepted best risk management practices are not available (risks in Risk-Zone 1), apply a full and thorough Risk Assessment (RA).

3. Use a Fault Tree Analysis (FTA) to verify your preventive action as an option.

4. Establish, implement, deploy, maintain and document System Safety (SS) for risk mitigation.

Obviously the recommended risk management procedures do not only apply to the construction phases of a project but – sometimes even more important, at least to the owner – to the overall system life expectancy as well.

None of the enlisted procedures are new; some have even more than a fifty-year’s track record. What is really new is the

- combination
- sequence
- and extrapolation from safety + health and machinery safety systems to build up a comprehensive RMS.

6 HOW DOES A PRELIMINARY HAZARD ANALYSIS WORK?

A Preliminary Hazard Analysis acts as a risk-focused filter to allocate your restricted resources (to perform thorough and scientific risk assessments) to the most urgent and important issues.

It regularly follows a three step procedure:

a) Set up a comprehensive hazard inventory (a preliminary, qualitative risk identification)

b) Provide evidence of available best risk management practices

c) Fill in your identified risks in the appropriate Risk-Zone of your hazard portfolio.

You will end up with a fast and easy to understand graphic overview (a risk map).

You may then concentrate your efforts to perform a thorough risk assessment of all risks remaining in Risk-Zone 1.

But before taking off into that timely and costly task make sure that your interdisciplinary team really confirms your hazard portfolio’s allocations.

Figure 1. Example of a Preliminary Hazard Portfolio
**7 HOW DOES A RISK ASSESSMENT WORK?**

A risk assessment matrix, adopted to meet your requirements, let you decide which risks you can (or have to) accept. US Military Standard 882D can deliver a starting point.

**8 HOW DO YOU MITIGATE YOUR RISKS?**

Any underground construction is considered to be a high risk environment. This is for several good reasons:

- Rock/ground always remains unpredictable
- Unforeseen water in big quantities can always be a big, crucial factor anywhere anytime
- Available space is very limited
- Heavy weight, high energy transport activities
- Darkness presumes, light is rare
- High construction noise
- High temperatures, high moisture
- Dealing with explosives, high voltage
- Fresh air is very limited, etc.

In addition, any underground activity normally brings with it

- High public profile, high capital investments
- Work schedules around the clock

All these puzzles bring about owners requests for at least some kind of proven risk management procedures.
10 HOW DO YOU MANAGE SAFETY + HEALTH IN TUNNELING?

Swiss Law requires the implementation of a (Occupational) Safety + Health (OSH) 10 Points System.

Figure 5. Swiss Safety + Health 10 Points System

- Where possible, cross the alpine mountains through the most favorable geology.
- Where possible, cross difficult ground/rock perpendicular to strata as short as possible.
- Build two tunnels.
- Provide cross passages about every 312 m.
- Establish, implement, keep current and document a comprehensive owner’s RMS in all phases of the project.
- Require the consultants, site supervisors and main construction contractors to run their own RMS, keep it updated and document it at least twice a year.

11 WHERE HAS A RISK MANAGEMENT SYSTEM IN TUNNELING ALREADY BEEN USED?

A random selection of several (larger) tunneling projects in Switzerland (CH), in which the author is currently involved, may illustrate the benefits of an RMS approach for controlling the construction processes and their inherent risks.

For further information please feel free to visit the owner’s website [http://www.alptransit.ch](http://www.alptransit.ch) and the author’s website (the author’s contribution to the AUA NAT02 conference)

- [http://www.moergeli.com/dldoc10e.htm](http://www.moergeli.com/dldoc10e.htm)
- [http://www.moergeli.com/dldoc11e.htm](http://www.moergeli.com/dldoc11e.htm)

Thank you.

11.1 AlpTransit, Gotthard Base Tunnel/Switzerland

Early on, the owner took some strategic decisions with regard to risk management:
The contractor contributed by establishing, implementing, periodically updating and documenting a project-specific OSH solution:

- Preliminary Hazard Analysis
- Risk assessments in team workshops
- Implementation of System Safety

Figure 12. Gotthard Base Tunnel: Tunnel Boring Machines (TBM)

Figure 13. Current excavation status at Amsteg

Figure 14. Control Center at the portal

Figure 15. Control Center: Continuous monitoring

11.2 Gotthard Base Tunnel, Lot 252, Tunnel Amsteg/Switzerland

Figure 11. Selected project data Lot 252, Tunnel Amsteg

<table>
<thead>
<tr>
<th>Owner</th>
<th>AlpTransit Gotthard AG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project</td>
<td>Gotthard Base Tunnel</td>
</tr>
<tr>
<td>Location</td>
<td>Amsteg, Canton Uri/Switzerland</td>
</tr>
<tr>
<td>Lot</td>
<td>252, Tunnel Amsteg</td>
</tr>
<tr>
<td>Designer &amp; Client Representative</td>
<td>ING GBTN (Engineering Joint Venture Gotthard North)</td>
</tr>
<tr>
<td>Contractor</td>
<td>Joint venture Amsteg, Lot 252,</td>
</tr>
<tr>
<td></td>
<td>Gotthard Base Tunnel North (AGN)</td>
</tr>
<tr>
<td>Tunnel length</td>
<td>2 tunnels by ca. 11'350 m</td>
</tr>
<tr>
<td>Excavation cross section</td>
<td>Ca. 71 m²</td>
</tr>
<tr>
<td>Construction method</td>
<td>(Drill &amp; Blast +) TBM</td>
</tr>
<tr>
<td>Tunnel construction costs</td>
<td>Ca. CHF 627 M*</td>
</tr>
<tr>
<td></td>
<td>Ca. USD 471 M***</td>
</tr>
<tr>
<td>Project status (11/2003)</td>
<td>TBM operation just started***</td>
</tr>
<tr>
<td>Author’s mandate</td>
<td>Contractor’s support for OSH</td>
</tr>
</tbody>
</table>

* Excl. VAT (Value Added Tax)
** 1 USD (US Dollar) ≈ CHF (Swiss Franc) 1.33 (11/2003)
*** For more information please log on to the owner’s website [http://www.alptransit.ch](http://www.alptransit.ch) and the contractor’s website [http://www.agn-amsteg.ch](http://www.agn-amsteg.ch) - thank you.
**11.3 Engelberg Tunnel/Switzerland**

**Figure 20. Selected project data Engelberg Tunnel**

<table>
<thead>
<tr>
<th><strong>Owner</strong></th>
<th>Luzern Stans Engelbergbahn LSE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Project</strong></td>
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<tr>
<td><strong>Location</strong></td>
<td>Grafenort (near Luzern)/Switzerland</td>
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<td><strong>Lot</strong></td>
<td>North + South</td>
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<td><strong>Designer &amp; Client Representative</strong></td>
<td>Bucher + Dillier Ingenieurunternehmung AG + IG LSE</td>
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<tr>
<td><strong>Contractor</strong></td>
<td>Joint Venture Tunnel Engelberg (ATE)</td>
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<tr>
<td><strong>Tunnel length</strong></td>
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<td><strong>Excavation cross section</strong></td>
<td>Ca. 30 m²</td>
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<tr>
<td><strong>Construction method</strong></td>
<td>Drill &amp; Blast</td>
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<tr>
<td><strong>Tunnel construction costs</strong></td>
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<td></td>
<td>Ca. USD 54 M**</td>
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<td><strong>Construction time frame</strong></td>
<td>05/2001 – ca 12/2005</td>
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<td><strong>Project status (11/2003)</strong></td>
<td>Under Construction***</td>
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<tr>
<td><strong>Author’s mandate</strong></td>
<td>Contractor’s support for OSH</td>
</tr>
</tbody>
</table>

* Excl. VAT
** 1 USD ≈ CHF 1.33 (11/2003)
*** For more information please log on to the owner’s website [http://www.lse-bahn.ch](http://www.lse-bahn.ch) - thank you..

Early on, the owner took some strategic decisions with regard to risk management:
- Systematically probe ahead for gas detection.
- Require the construction contractor to establish, implement, keep current and document an Integral Safety Plan.

The contractor contributed by establishing and implementing an Integral Safety Plan following suva’s (Swiss National Accident Insurance Fund) suggestions. Annual OSH System Checks keep it updated.
So far the contractor dealt successfully with more than his fair share of unexpected ground conditions:

1. **CONCLUSIONS**

   Control your critical success factors by:
   1. Apply generally accepted best risk management practices.
   2. Establish a thorough and comprehensive Risk Management System (RMS) where required by law, project challenges, owner’s specifications and/or where best risk management practices are not available.

   A RMS provides a unique opportunity in combining ongoing US underground activities with previous project experience, providing owners, engineers and contractors with real added value in successfully pursuing their goals:
   - Identify all known hazards graphically on a one-page-sheet early on.
   - Allocate limited resources for Risk Assessments where inevitable (Risk-Zone 1).
   - Mitigate your risks systematically by System Safety.
   - Add value to the owner’s project by minimizing costs, time and third party impacts.
   - Provide evidence of legal compliance.

   To perform an RMS, a four-folded approach is recommended by the author (m+m/am):
   1. Start with a Preliminary Hazard Analysis.
   2. For hazards in Risk-Zone 1, apply a full and thorough Risk Assessment.
   3. As an option verify your planned preventive action by a Fault Tree Analysis.
   4. Establish, implement, deploy, maintain and document System Safety to mitigate your risks.
ACKNOWLEDGMENTS

The author thanks and acknowledges the very competent support and kind provision of plans, schemes and pictures by:

Figure 25. AlpTransit Gotthard AG (ATG)

Figure 26. Arbeitsgemeinschaft AMSTEG, Los 252, Gotthard-Basistunnel Nord (AGN)

Figure 27. Murer/Strabag

Figure 28. Herrenknecht

Figure 29. rowa

Figure 30. Swietelsky

Figure 31. Amberg

Amberg Consulting Engineers

Last but not least, my thanks goes to Mrs. S. Tschupp for her always very competent support in improving my use of the English language.

Without their big help this document would not have been possible.

The biggest thanks goes to all crews on site, safely coping with the unforeseeable as their daily routine. Every day they move into places where no human being has ever been before. Always just one small step for a man, but a giant leap for mankind ...

The author’s apologies go to the readers for any inconvenience dealing with small print, reduced tables and pictures.

An update of the paper can be offered through our presentation at the AUA Conference.

The original paper will be available for download on http://www.moergeli.com/ddocuebersichten.htm after the AUA North American Tunneling 2004 Conference, April 17 – 22, Hyatt Regency Hotel Peachtree Plaza, Atlanta, GA-USA.

REFERENCES

AIB, Amberg Consulting Engineers Ltd. (AIB), Trockenloosstr. 21, CH-8105 Regensdorf-Watt/ Switzerland (http://www.amberg.ch)

AlpTransit Gotthard AG (ATG), Zentralstrasse 5, CH-6003 Luzern/Switzerland (http://www.alptransit.ch)


Herrenknecht AG Tunneling Systems, Schlehenweg 2, D-77963 Schwawau/Germany (http://www.herrenknecht.de)

Lot 252, Gotthard Base Tunnel North (AGN), Grund, CH-6474 Amsteg/Switzerland (Murer AG/Strabag AG) (http://www.agn-amsteg.ch)

Joint venture Tunnel Engelberg (German: ARGE Tunnel Engelberg): (ATE), CH-6388 Grafenort/Switzerland (Achermann AG – Swietelsky Bau Tunnelbau Gesellschaft m.b.H)

Rowa Tunnelling Logistics AG, Leuholz 15, CH-8855 Wangen SZ/Switzerland (http://www.rowa-ag.ch)


Swietelsky Bau Tunnelbau Gesellschaft m.b.H., Eduard-Ast-Str. 1, A-8073 Feldkirchen/Graz (http://www.swietelsky.at)