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# Risk Management During Construction of the Gotthard Base Tunnel

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**ABSTRACT:** A new railway tunnel through the Swiss Alps is currently being constructed which will reach 57 km length and represents the most significant component of the new Alp-crossing railway connection (NEAT). An integral management system was implemented to cover the issues quality management, environmental management and work safety. Risk management is comprehensively being addressed on a strategic and an operative level involving all project partners. It covers the assessment of threats and opportunities including their causes, which have a potential long-term influence on planning and execution of the new connections as a total. As crucial project requirements in the context of operational risk management were identified: functionality, costs, construction scheduling, environmental impact, work safety, and project organization. Finally, the terminology "risk" was extended to include threats *and* opportunities contained in the project.

## 1 GOTTHARD BASE TUNNEL

Since 1996 the longest tunnel of the world is being constructed: The new railway tunnel through the Swiss Alps (Figure 1). The length of the tunnel will reach 57 km and represents the most significant

component of the new Alp-crossing railway connection (NEAT) through the Swiss Alps. On one hand, NEAT will serve the transportation of people, on the other hand, it is a crucial measure in the context of Swiss traffic policy to switch from road to railway for the transportation of goods.

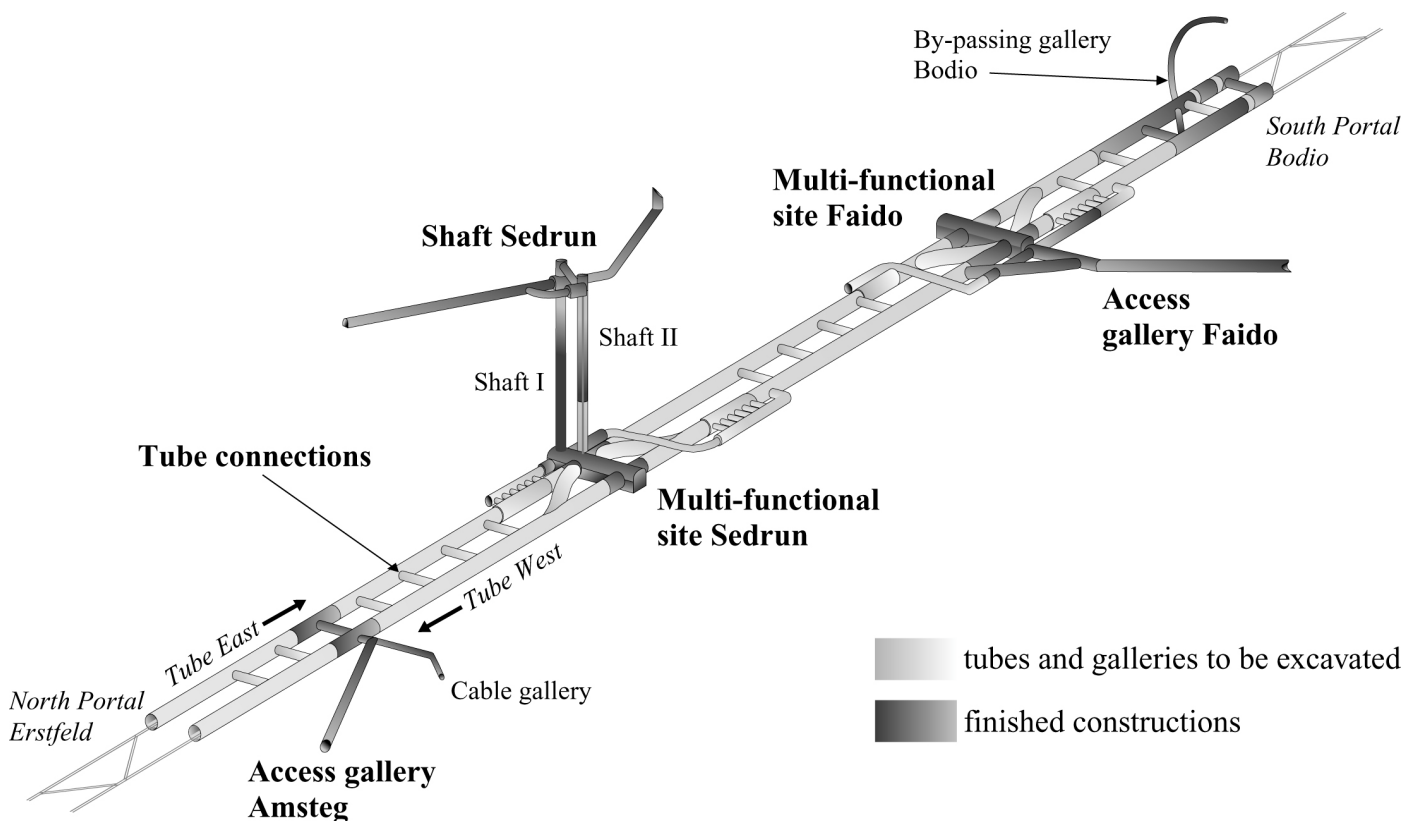


Figure 1: Gotthard Base Tunnel: Length 57 km, status of work progress in spring 2003

With the new Gotthard Base Tunnel the Alps will be crossed at the lowest possible altitude. The vertex lies at an altitude of 550 m above sea level. This is 600 m lower than the original railway line that was constructed in 1882 with a tunnel length of 15 km.

The slopes of the ramps leading to the old tunnel reach 26 ‰, while the base tunnel will only reach 4 or 7 ‰ respectively. Hence, a flat railway line is being realized through the Alps.

Due to safety reasons the base tunnel consists of 2 single-track tubes. At the location of so called "multi-functional sites (MFS)" which are installed at the intermediary construction sites Sedrun and Faido, the trains can change the tube in case of maintenance works. The MFS are located after one third and two thirds of the tunnel length. In addition, the MFS provide the infrastructure for emergency stops with high-performance smoke escape ventilators and the feed of fresh air from outside. Connections between the two tubes are constructed all 325 m.

The tunnel has been designed for passenger trains with a speed of 200-250 km/h and freight trains with 100-160 km/h. The capacity for such mixed traffic amounts to about 300 trains per day in both directions.

During the past seven years the intermediary construction sites Amsteg, Sedrun and Faido, as well as the by-passing gallery close to the portal in Bodio were completed. In this year the actual drilling and excavation of the single-track tubes was started. Based on the current time schedule the tunnel will be put into operation in 2013.

## 2 INTEGRAL MANAGEMENT SYSTEM AT ALPTRANSIT GOTTHARD LTD.

The Swiss Confederation (government) has mandated the public limited company AlpTransit Gotthard (ATG) with the planning and execution of the new railway sections on the Gotthard axis. ATG is a 100% subsidiary of the Swiss Federal Railway.

In the context of its function as project-owner ATG has implemented an integral management system. The system covers the issues quality management, environmental management and work safety.

## 3 RISK MANAGEMENT

The risk management discussed in the present paper forms a component of the quality management. It is established on condition that each involved contractor, planning or engineering consortium has its own company-related quality management (CQM), for instance based on the ISO 9001:2000 standard. The CQM is completed by a project-related quality management (PQM) (Figure 2).

By the enforcement of a systematic PQM it is ensured that:

- interfaces between project partners are defined and secured,
- the risk situation is early recognized, evaluated and appraised,
- determining and crucial project requirements are defined as main quality emphasis.

The quality management and thus also the risk management at ATG are highly valued and therefore in the direct duty of the chairman of the board. With all project partners exist contractual agreements (the QM-agreements) which oblige the contractors to comply with and implement the defined standards.

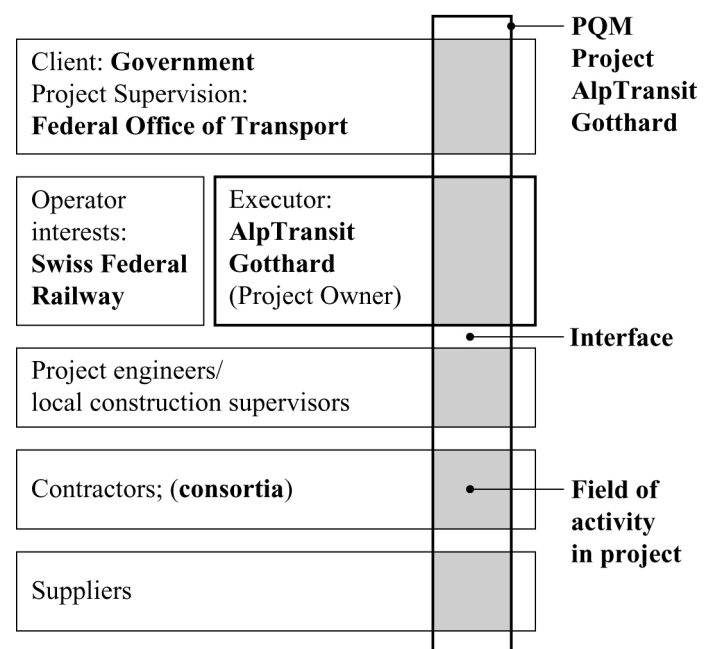


Figure 2: Company-Related and Project-Related Quality Management in the Overall Project AlpTransit Gotthard

The risk management is oriented after the objectives of the corporation ATG, which is given below:

*"All constructions which are part of the Gotthard axis are to be realized according to the quality agreed (with the government), as fast as possible and at minimum cost."*

Aiming at this objective two questions can be formulated with regard to risk management:

- Which factors impair or even prevent the accomplishment of the objective? (Recognize threats, characterize threats, control threats)
- Which factors foster or support the accomplishment of the objective? (Recognizing and making use of opportunities)

Risk management is strictly implemented over all project phases from planning to realization (Figure 3).

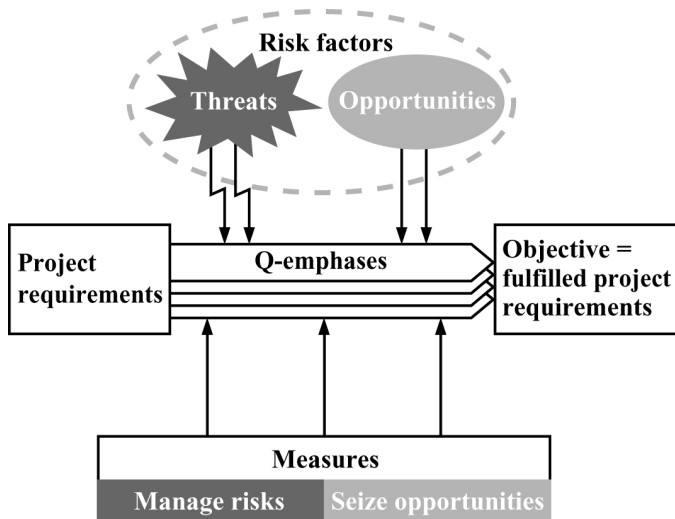


Figure 3: Basic Principles of the Risk Management at ATG

### 3.1 Strategic Risk Management for the Gotthard Axis

Apart from the Gotthard axis, the NEAT consists also of the Zimmerberg Base Tunnel (total length 20 km) and the Ceneri Base Tunnel (15 km) as well as open railway tracks. The total investment amounts to 10 Billion Swiss Francs (~6.7 Billion Euro). The total time period for planning, design and execution covers about 20 years.

On the level of the management board ATG a strategic risk management is pursued. This risk management covers the assessment of threats and opportunities including their causes, which have a potential long-term influence on planning and execution of the new connections as a total.

In the latest project progress report of the management, which is published twice a year and ad-

resses the board of directors of ATG, the supervising authorities and political organizations, the threats and opportunities are listed as shown in Figure 4.

Particularly, the report identifies two "mega"-threats and a "mega"-opportunity, each of them showing a high probability of occurrence and a great extent of impact:

- Threat T1: The financial reserves have been used by the government for so-called purchase order changes, such as to enhance operational safety (e.g. establishment of two single-track tubes for the Ceneri Base Tunnel) or to enable technical quality changes. By the allocation of the reserve funds a financing gap could be created which may have an adverse impact on the realization of the two base tunnels at Zimmerberg and Ceneri, originally planned for 2006.
- Threat T5: If the construction permit for the northernmost section of the Gotthard Base Tunnel including the portal in Erstfeld is not obtained as scheduled by the end of 2003, the deadline for putting into operation the whole base tunnel cannot be met.
- Opportunity O5: The railway lines adjacent to the Gotthard- and Ceneri Base Tunnels have not yet been legally defined, which creates strong political opposition in the regions concerned and influences the construction process of the base tunnels. ATG has recognized the "mega"-opportunity to settle this conflict in a legally binding form under the label NEAT II.

In order to prevent the occurrence of the identified threats and to seize the recognized opportunities, comprehensive measures have been proposed, mainly on a superior management level.

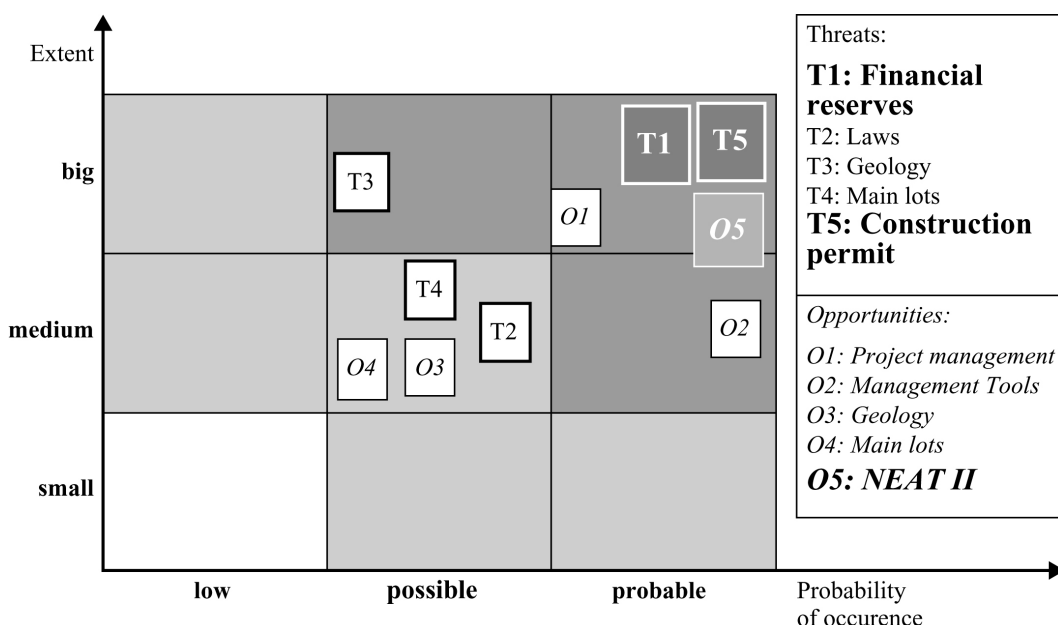


Figure 4: Risk Situation in the Overall Project as of December 31, 2002

No.	Threats	Risk (neg.)			Planned Measures (according contract/project/CQM) > Additional Measures	Residual Risk			Resp.	Date	Monitoring
		P	E	R		P	E	R			
100	Ground Conditions										
110	Geology										
112	Reuse of excavated material worse than predicted										
112a	TZM South	2	2	4	Early initiation of gravel mining in Val da Claus	2	2	4	öBL/OBL	on-going	ArSi Ko Team MBK
112b	GM	2	3	6	Gravel mining in Val da Claus > Possibly: Proposal of quality reduction, AVOR: Adaptation of construction schedule, lot boundaries	2	2	4	öBL/OBL	on-going case-by-case	ArSi Ko Team MBK
113	Mica content in excavated material higher than predicted										
113a	TZM South	3	1	3	Adaptation of treatment technology (mica flotation) > Possibly: Proposal of quality reduction	3	1	3	öBL/PI	on-going case-by-case	Monthly report lot 374
113b	GM	2	2	4	Adaptation of treatment technology (mica flotation) > Possibly: Proposal of quality reduction	2	2	4	öBL/PI	on-going case-by-case	Monthly report lot 374
115	Mine temperature higher than predicted	1	3	3	> Increase cooling performance, possibly reduced working hours	1	2	2	UN öBL	case-by-case	Daily report
120	Disruption zones										
122	Distinctive disruption zone in the Nalps area	2	3	6	Preliminary investigation, injections, long protected explorations > Additional sondage, additional injections	2	2	4	öBL/PI  ATG öBL	2006  2004	  Additional study Instruction öBL

Table 1: Excerpt from the Risk Analysis and Measurement Planning Lot 360 Sedrun

### 3.2 Operative Risk Management for the Construction of the Gotthard Base Tunnel: Risk Analysis and Mitigation Measures

Based on the risk analysis that was carried out by the project-owner at the beginning of construction planning for the Gotthard Base Tunnel, the following crucial project requirements were identified in the context of the operational risk management:

Functionality (safety of load-bearing structures, practical capability), costs (cost minimization, supplementary charges by contractors, etc.), construction scheduling, environmental impact, work safety, and project organization of all involved parties (process management, implementation of contractual agreements, CQM).

The threats and opportunities including their influence on project requirements from the perspective of the project-owner were disclosed and communicated to the contracted project engineers, construction supervisors and construction firms by means of the quality master plan.

Subsequently ATG discussed the risk analyses in detail and elaborated action plans for mitigation measures with the contracted project engineers and construction supervisors. With this procedure ATG aims at defining the major threats and opportunities and pursuing the risk issues in a coordinated, systematic way jointly by all involved parties during project realization.

In the applied methodology for the risk assessment, the risks are quantified as product of occurrence probability and extent of the damage/benefit. Probabilities and damage extents are estimated according to the scale given in Table 1.

Measures with regard to responsibilities, deadlines, reference documents and verification protocols in the context of risk management and realizing opportunities are defined in the master plan.

ATG has developed a three-stage valuation matrix shown in Table 2 which can easily be applied.

	1	2	3
<b>Probability of Occurrence (P)</b>	<b>low</b> (not expected)	<b>possible</b> (cannot be excluded)	<b>probable</b> (occurrence assumed)
<b>Extent of damage/benefit (E)</b>			
<b>Costs</b>	<b>low</b> (below CHF 1 Mio.)	<b>medium</b> (CHF 1 - 10 Mio.)	<b>high</b> (over CHF 10 Mio.)
<b>Schedule</b>	<b>low</b> (below 2 months)	<b>medium</b> (2 - 6 months)	<b>high</b> (over 6 months)

Table 2: Applied Valuation Matrix

The following definitions are being used:

**Risk R** = P x E: Value after implementation of planned measures from the contracts, project and CQM, i.e. remaining risk potential.

**Residual Risk** = P x E: Value after implementation of additional measures.

**Threats:** reduced damage potential (residual damage)

**Opportunities:** seized opportunities (supplementary benefit)

### 3.3 Strategy of Action of ATG

The strategy of action of ATG is based on the following principles, which are visualized in Figure 5:

1. If opportunities or threats reach a risk value of > 6, measures are imperatively taken.

- For all threats with a low probability of occurrence, but a high extent of damage (P=1; E=3; R=3) measures are imperatively taken.
- Opportunities and threats with a risk value of 1 don't require any planning of measures, because the optimum target has already been reached.
- In all other cases measures are considered and implemented where appropriate.

#### 4 CONCLUSIONS

Risk management for the Gotthard Base Tunnel forms a central element in the integral management system of the project-owner AlpTransit Gotthard Ltd. Risk analyses and the planning of mitigation measures are performed for all project phases and construction execution, tailored to the specific level. The more comprehensive these steps are carried out, the smaller is the surprise to be unprepared if an undesired event is encountered. On one hand, risk management as an instrument develops its force by systematic application, on the other hand its significance is enhanced by the implementation not only for the project-owner, but for all involved partners.

Through the comprehensive harmonization of the applied methodology and a common terminology of all subcontractors a sound control of all interfaces was established which also facilitates communication. During application of the comprehensive risk management system it was revealed that the project not only contains threats, but also opportunities which should not be lost. Thus, the terminology "risk" was extended to include threats *and* opportunities.

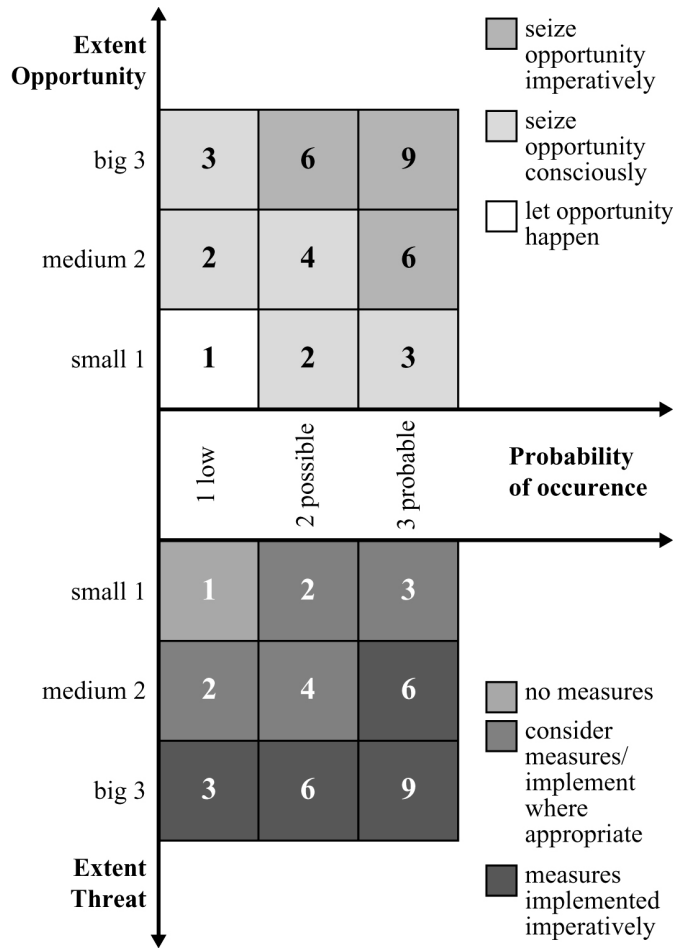


Figure 5: Strategy of Action