German Committee
for Underground Construction
e. V.

Project risk management in underground construction

Heinz Ehrbar

Agenda

1. **Brief introduction**
   Why have we developed the DAUB recommendations?

2. **Content of the DAUB recommendations**

3. **Discussion**

«Firstly, things turn out differently, and secondly, never as you think» (Wilhelm Busch)

2023: 10 weeks standstill Follo Line Tunnel (Norway)

https://www.acciona.com/updates/articles/acciona-successfully-energization-railway-tunnels-follo-line-norway/?_adin=02021864894

2021: Water ingress at the Lötschberg base tunnel (Switzerland)

© Marc Meschenmoser /SRF

2022: Shaft collapse Metro Sao Paolo, line 6

https://www.reuters.com/world/americas/part-sao-paulo-expressway-collapses-near-metro-construction-site-2022-02-01/

2007: Shaft collapse Metro Sao Paolo, line 4

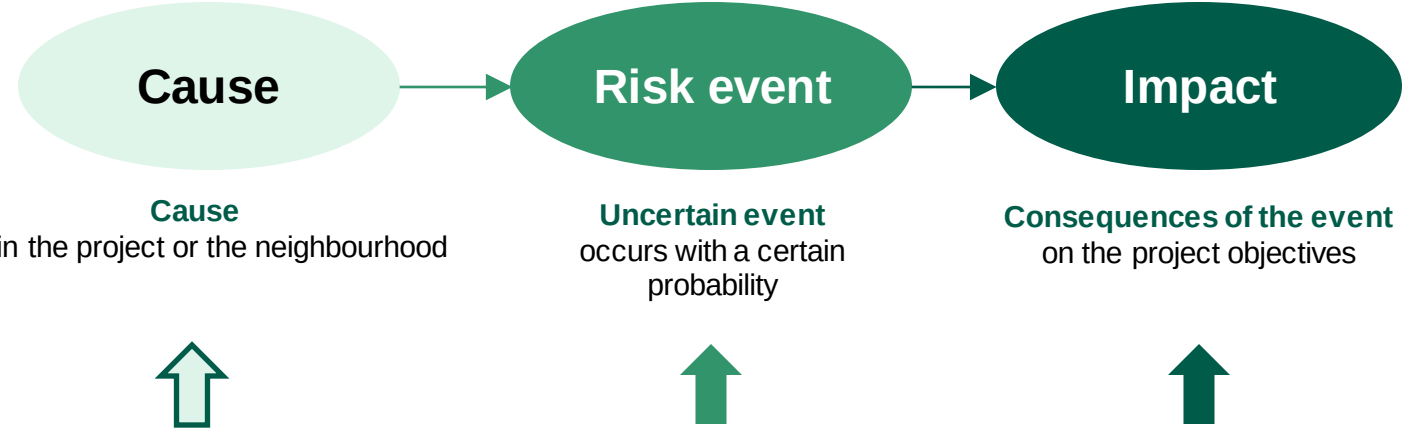
https://newsbulletin247.com/economy/44444.html

Dramatic incidents prevent project success

Consequences

- In some cases, there were **fatalities or serious injuries**
- **Delays in the construction programme**
- **Enormous financial losses**
- **Impairment of third-party property**
- **Reputational damage for construction method(s), contractors, planners and clients**

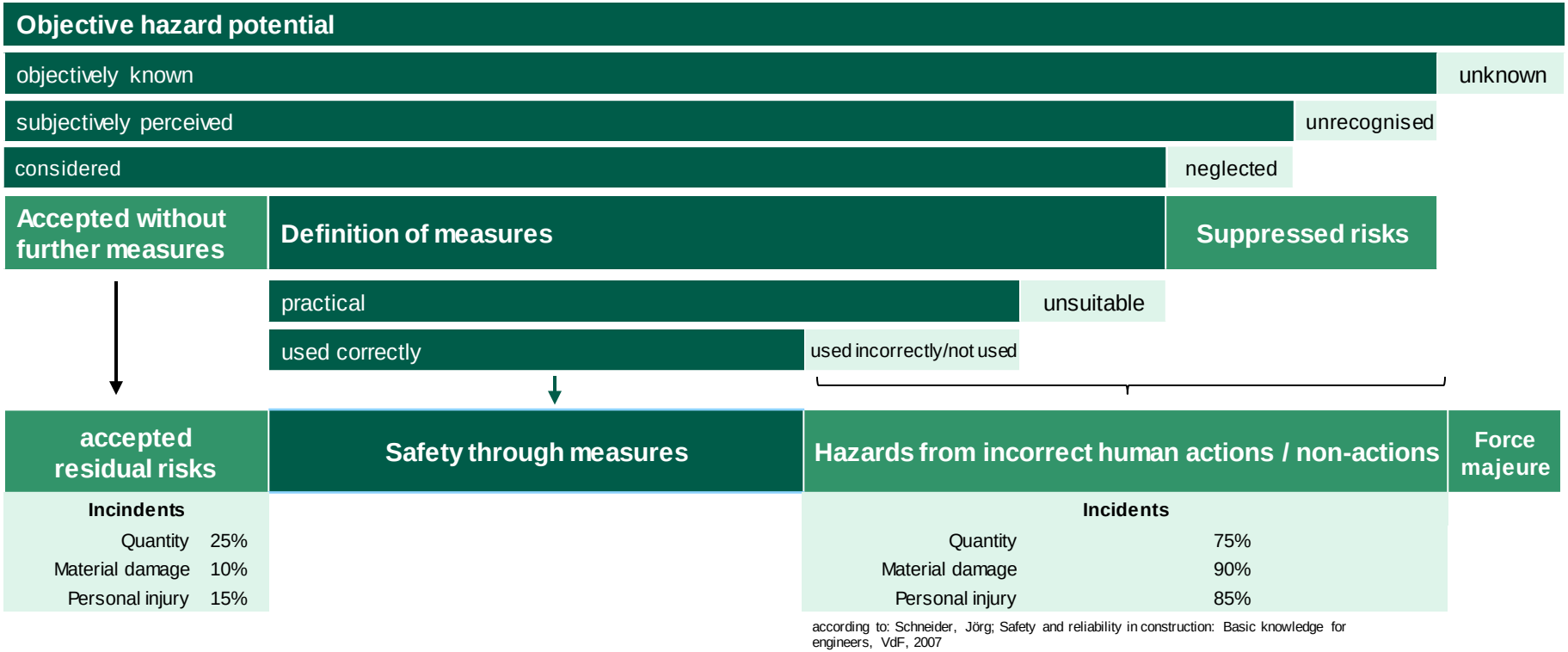
Risk events do not simply occur, they have a cause



Key tasks of project risk management

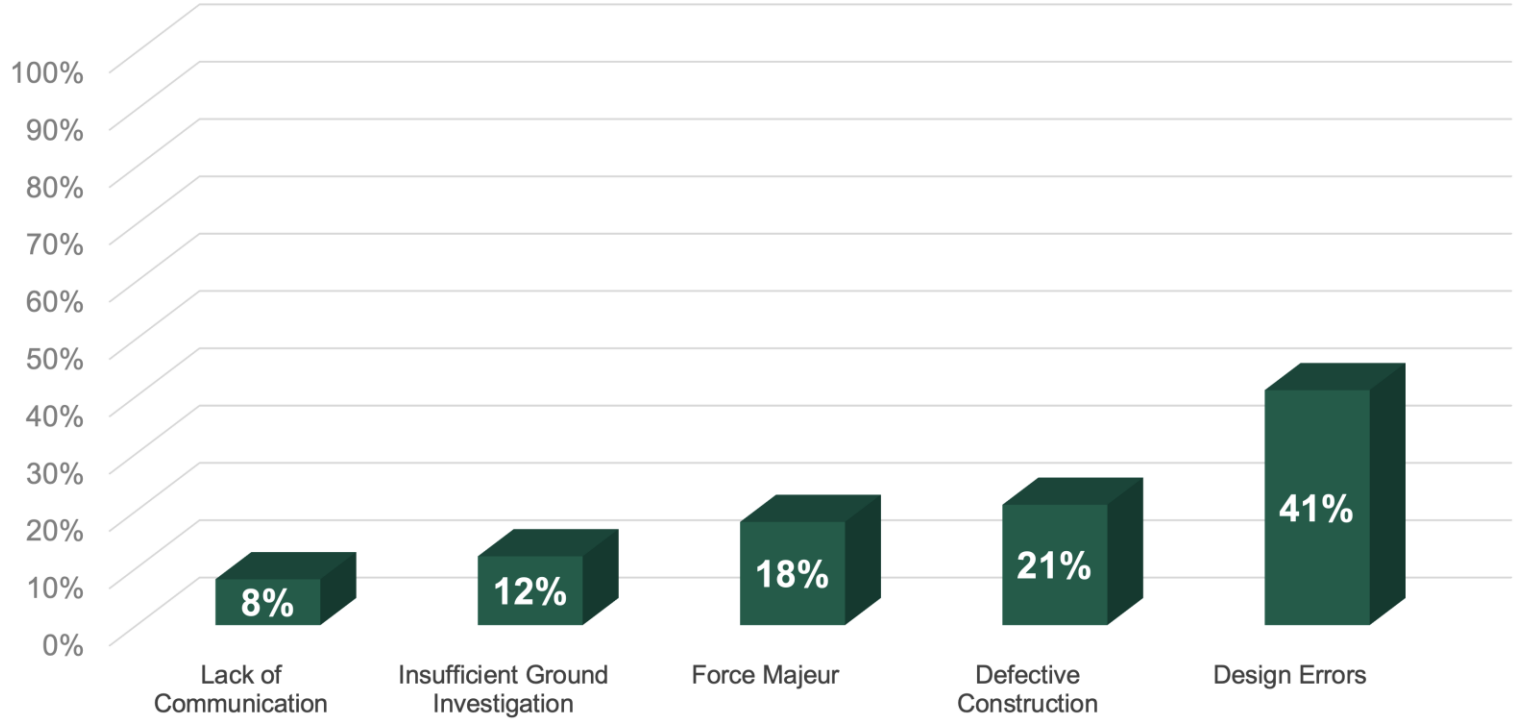
	Causes	Probability of occurrence	Impact
Avoid threats	**Recognise** and **eliminate**	**minimise**	**minimise** and **control**
Utilise opportunities	**Recognise** and **promote**	**maximise**	**optimise** or **maximise**

Human error is the main cause of hazardous incidents



according to: Schneider, Jörg; Safety and reliability in construction: Basic knowledge for engineers, VdF, 2007

IMIA: Tunnel Loss Experience
Causes of Underground Failures



Source: Reiner, Hartmut; Developments in the tunnelling industry following introduction of the tunnelling code of practice, IMIA Annual Conference, Amsterdam, 21. September 2011

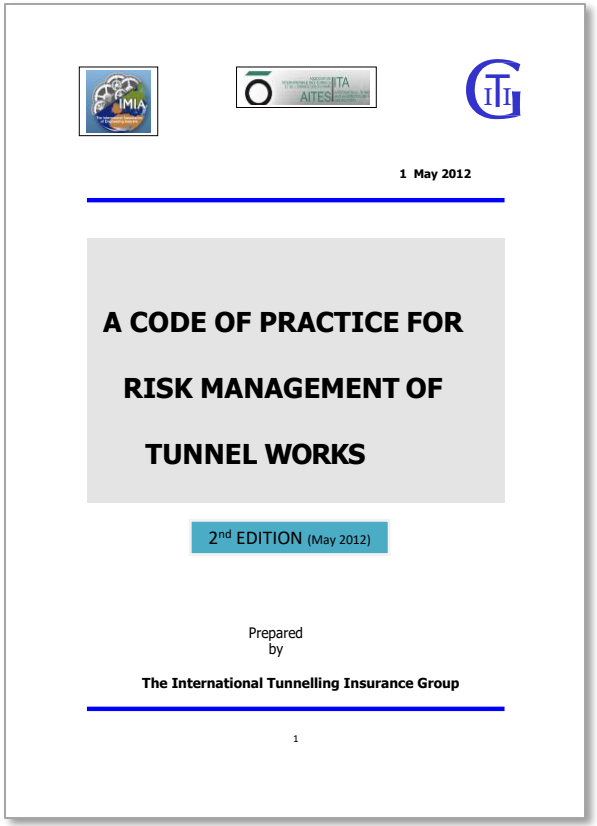
Lack of risk awareness led to serious problems in underground construction (2006 ff.)

1994
2000
2004
2006
2009

"Code of Practice for risk management of tunnel works" (2006,rev.2012):

- Section 1 - Objective of Code
- Section 2 - Compliance
- Section 3 - Introduction
- Section 4 - Risk Management
- Section 5 - Client Role & Responsibilities
- Section 6 - Project Development Stage
- Section 7 - Contract Procurement Stage
- Section 8 - Design Stage
- Section 9 - Construction Stage

https://www.imia.com/wp-content/uploads/2013/05/EP26_2007-German-Version-of-the-Tunnelling-CoP.pdf



1 May 2012

A CODE OF PRACTICE FOR RISK MANAGEMENT OF TUNNEL WORKS

2nd EDITION (May 2012)

Prepared by

The International Tunnelling Insurance Group

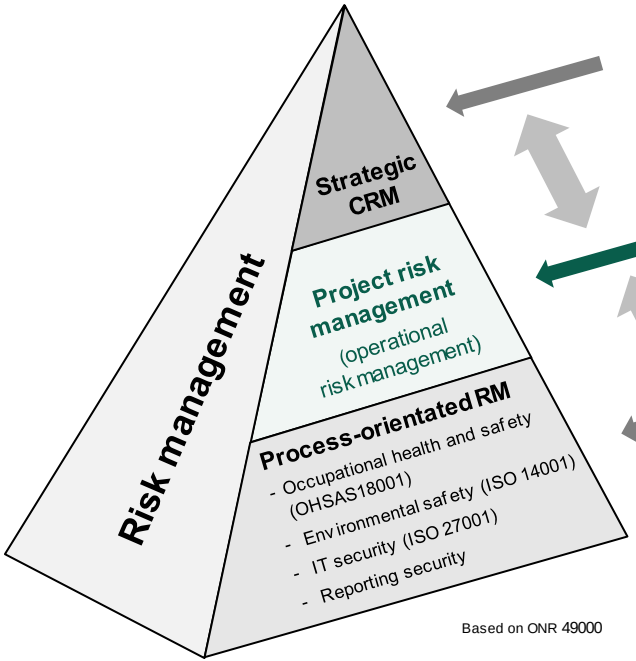
1

Importance of risk management in national design and construction specifications

Mention of the word "risk / risks" in relevant performance models

HOAI Germany	SIA 112 Switzerland
0	3

The hierarchy of risk management



Strategic risk management Company level
(must fulfil the legal requirements)

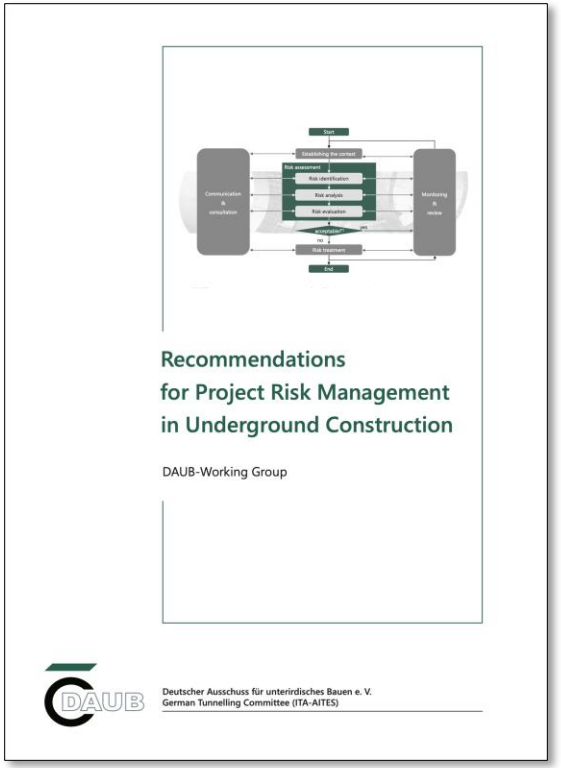
Ensure compatibility through mutual coordination

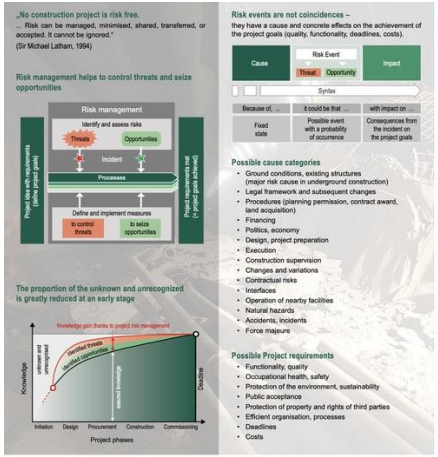
Operational risk management at the project management level
(regulated in the client's QM system)

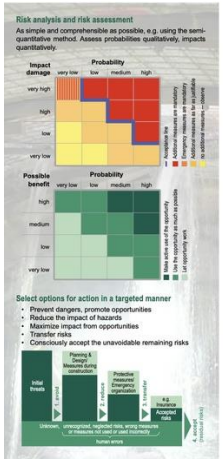
Define harmonised targets and measurement and control parameters

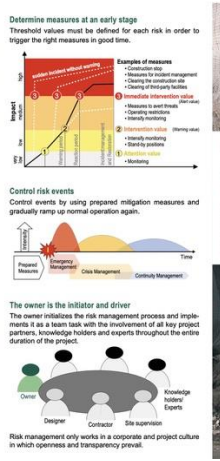
Risk management in the provision of services
(regulated in standards, guidelines, work instructions)

The DAUB recommendations









Objectives and scope of the recommendations

Objectives and target audience

The Recommendations are intended **for every-one involved in the project** (owner, designer, contractor, third party) **for all work phases of a project, to**:

1. demonstrate **the imperative need for phase-specific project risk management,**
2. **clarify their role-specific duties and respon-sibilities** for each project phase, and
3. **introduce common, easy-to-use methods and tools** for project risk management.

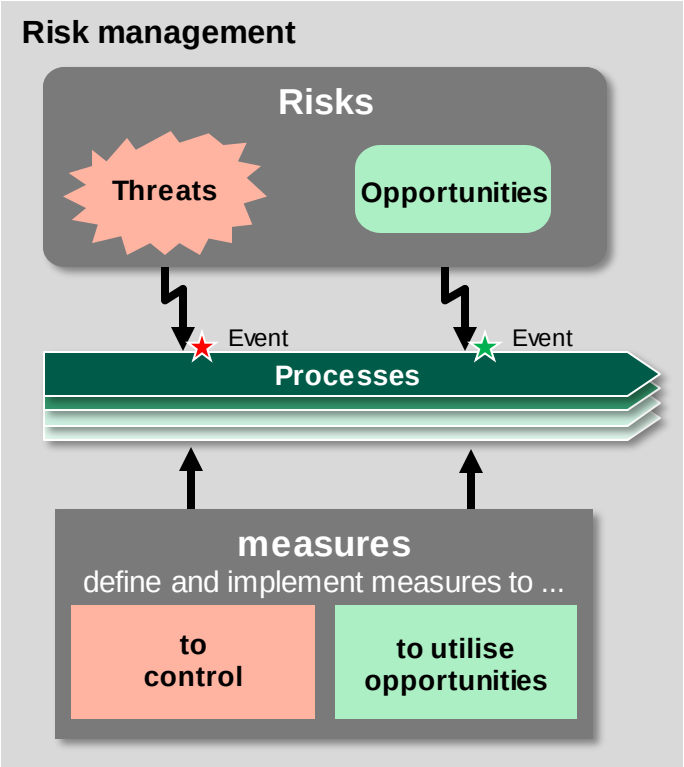
Scope of the recommendations

The Recommendations are applicable:

- **principally, for all construction works,**
- **during all project phases** from basic determination to commissioning,
- **for all trades of the civil works,**
- **for all contract models in construction**.

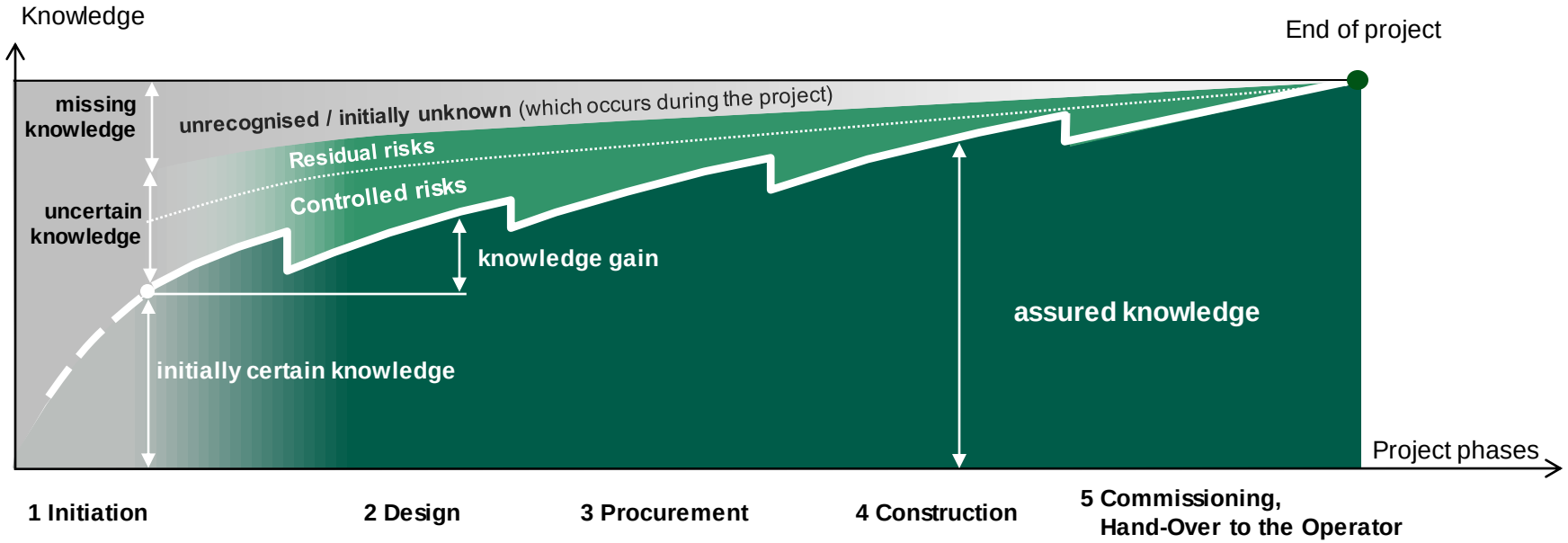
The basic principle of project risk management

Project idea with **requirements**
(formulate project goals)



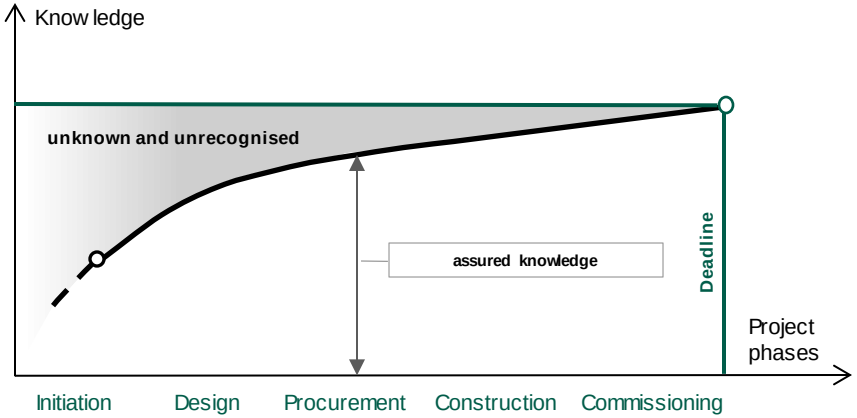
Project requirements fulfilled
(= project objectives achieved)

The curve of knowledge gain

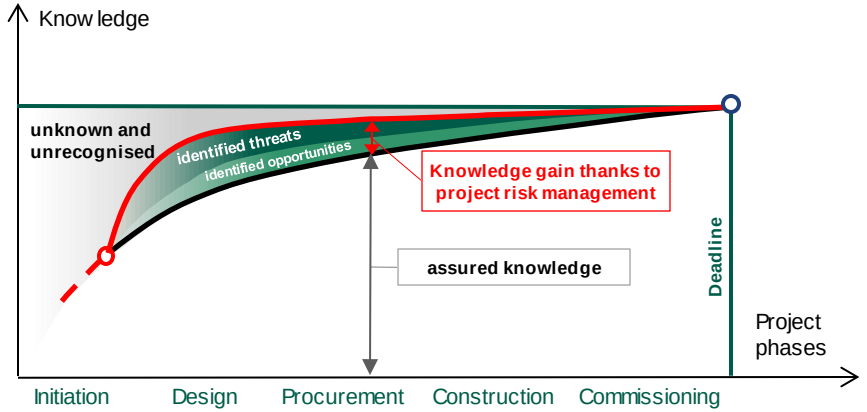


The additional knowledge gained helps to better achieve the project goals

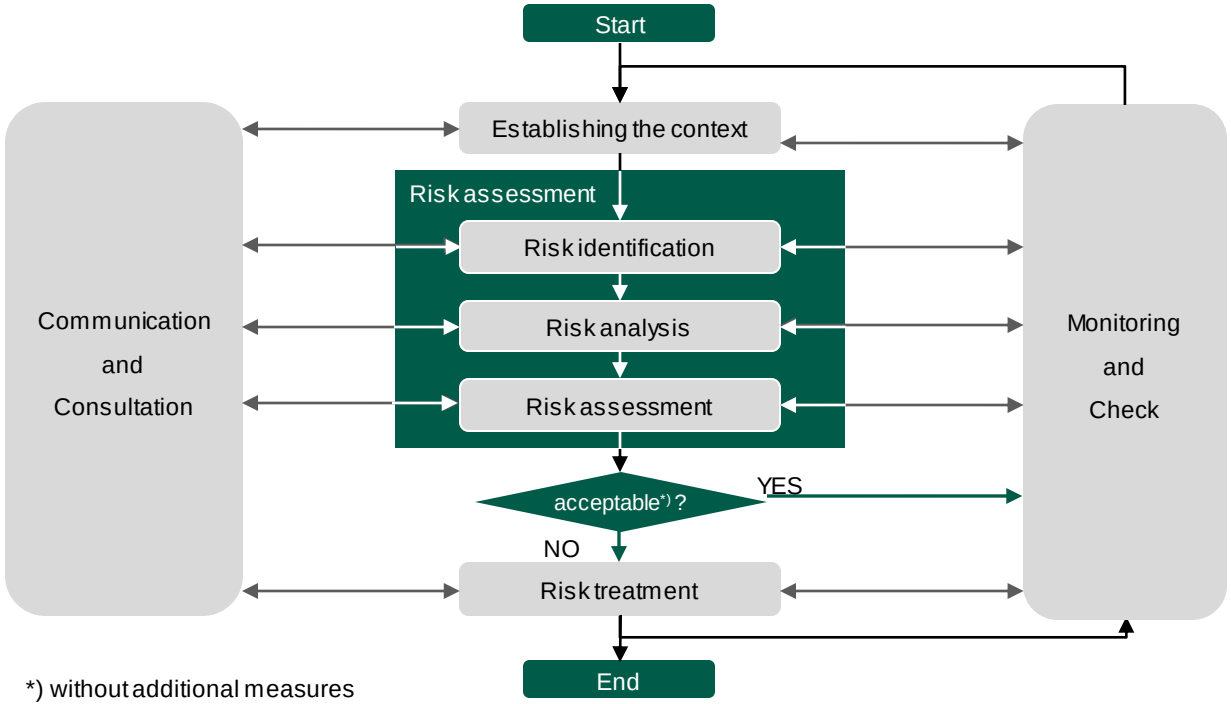
without project risk management



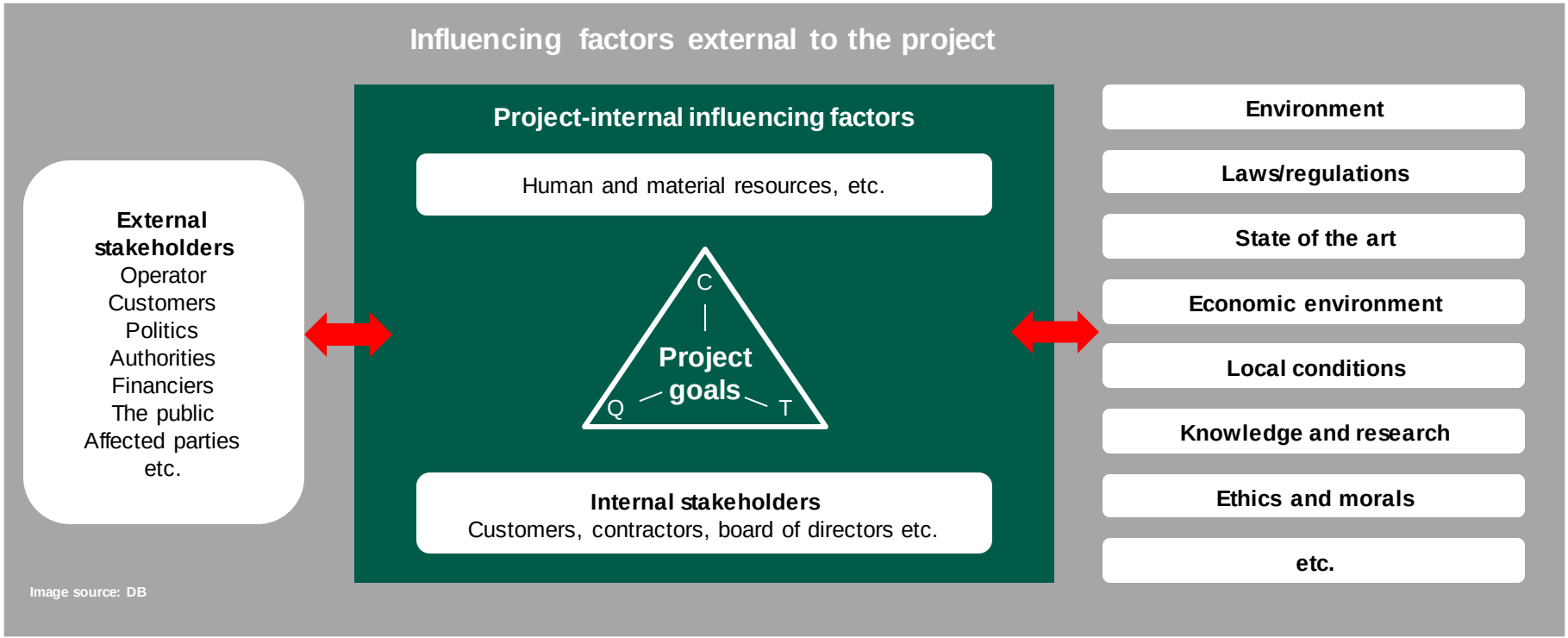
with project risk management



Project risk management methodology; Implementation of the ISO 31000 process



Establishing the project context



Typical cause / impact relationship

Effects of a risk event on

14 cause categories
Ground conditions and existing buildings
Legal basis and any changes
Procedure
Financing
Politics / Economy
Planning / Design
Execution
Building supervision
Order changes
Contractual risks
Interfaces
Operation of nearby plants
Natural hazards/accidents/incidents
Force majeure

11 Project requirements										
Ensure ordered **functionality**	Guarantee agreed **quality**	Ensuring **occupational health and safety**	**Protecting the environment** from damage	Creating public and political **acceptance**	Ensure **compliance with laws / standards** and guidelines	Protection of **infrastructure and third-party rights**	Guarantee of **capacity in the existing network** (operating programme/infrastructure)	Efficient **structural and process organisation**	Meeting the **deadline targets**	Compliance with **cost targets**

Risk identification

Picture: Wikipedia/tamara semina

- Risk workshops (with structured what-if analysis, SWIFT)
- Brainstorming - Brainwriting
- Checklists
- Evaluation of existing risk registers
- Exchange of experience with project organisations with similar tasks
- Obtain expert opinions (Delphi method) / Four-eyes principle
- Interviews
- Literature study / case studies

Risk analysis

Semiquantitative method

Impact I	Probability P: very low	low	medium	high
high	4	8	12	16
medium	3	6	9	12
low	2	4	6	8
very low	1	2	3	4

Quantifying the impact (per objective) in classes

Qualitative assessment of probability in classes

Risk assessment

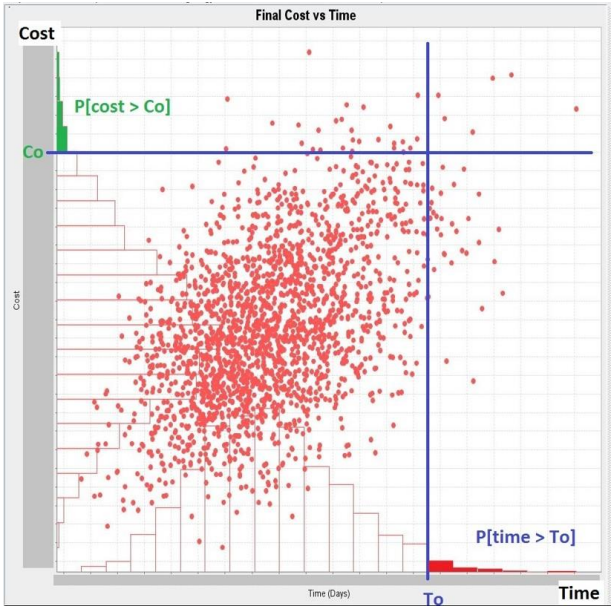
Semiquantitative method

Impact I	Probability P: very low	low	medium	high
high	4	8	12	16
medium	3	6	9	12
low	2	4	6	8
very low	1	2	3	4

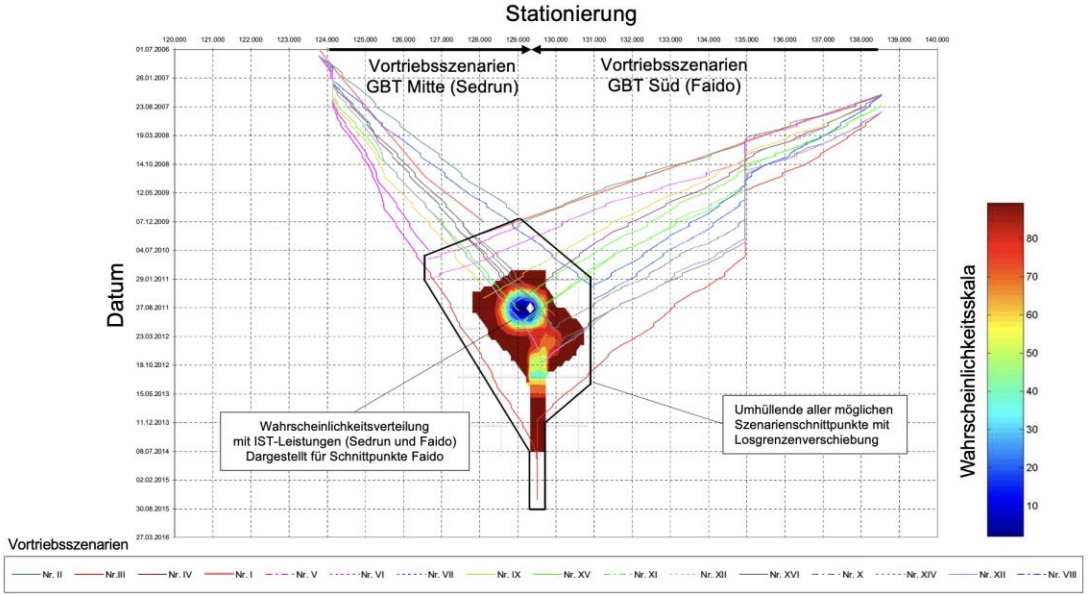
- Additional measures absolutely necessary
- Acceptance line
- Emergency measures absolutely necessary
- Additional measures as far as justifiable
- No additional measures - observe

Risk analysis and risk assessment

Quantitative method (for specific questions)

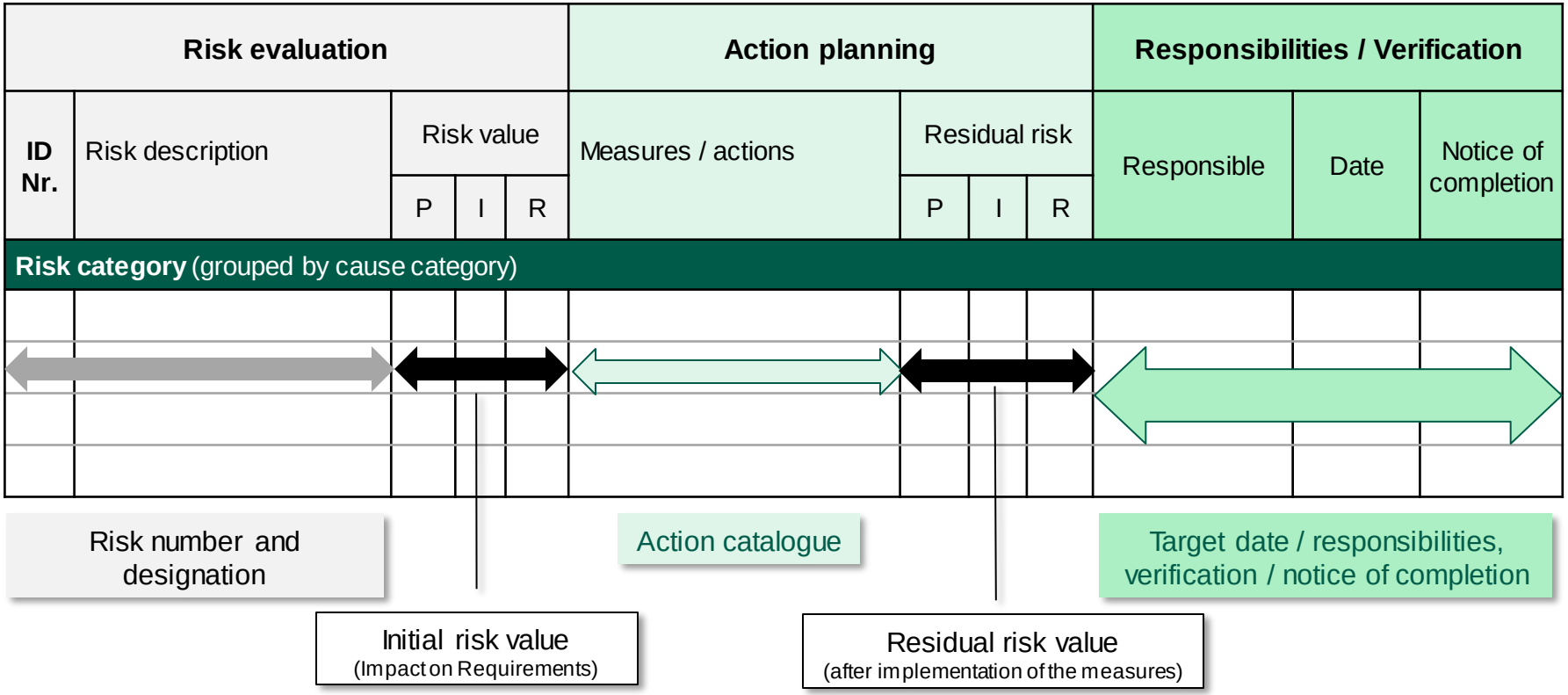


http://www.geomod.ch/geoprest/?DAT_-_Decision_Aids_for_Tunnelling,

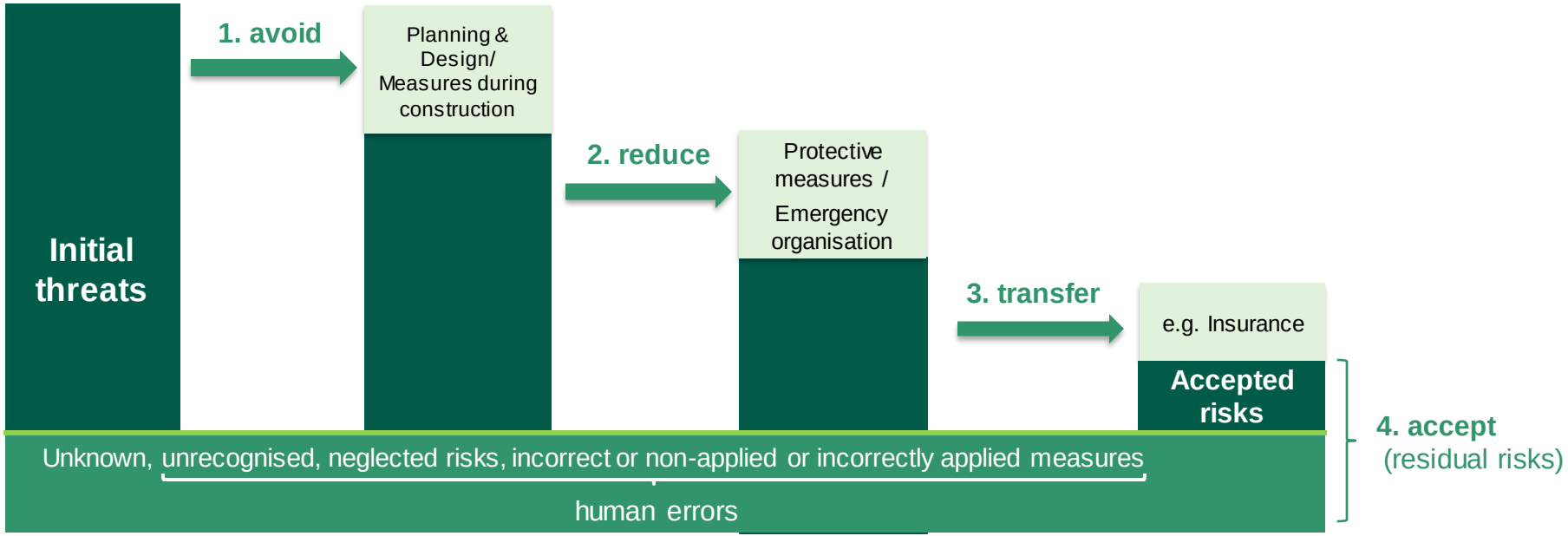


Ehrbar, H., Beeler, P., Neuenschwander, M., Bianchi, (2010, Proceedings ITA World Tunnel Congress, 2010 Vancouver

How to implement?
The risk register as the key management tool



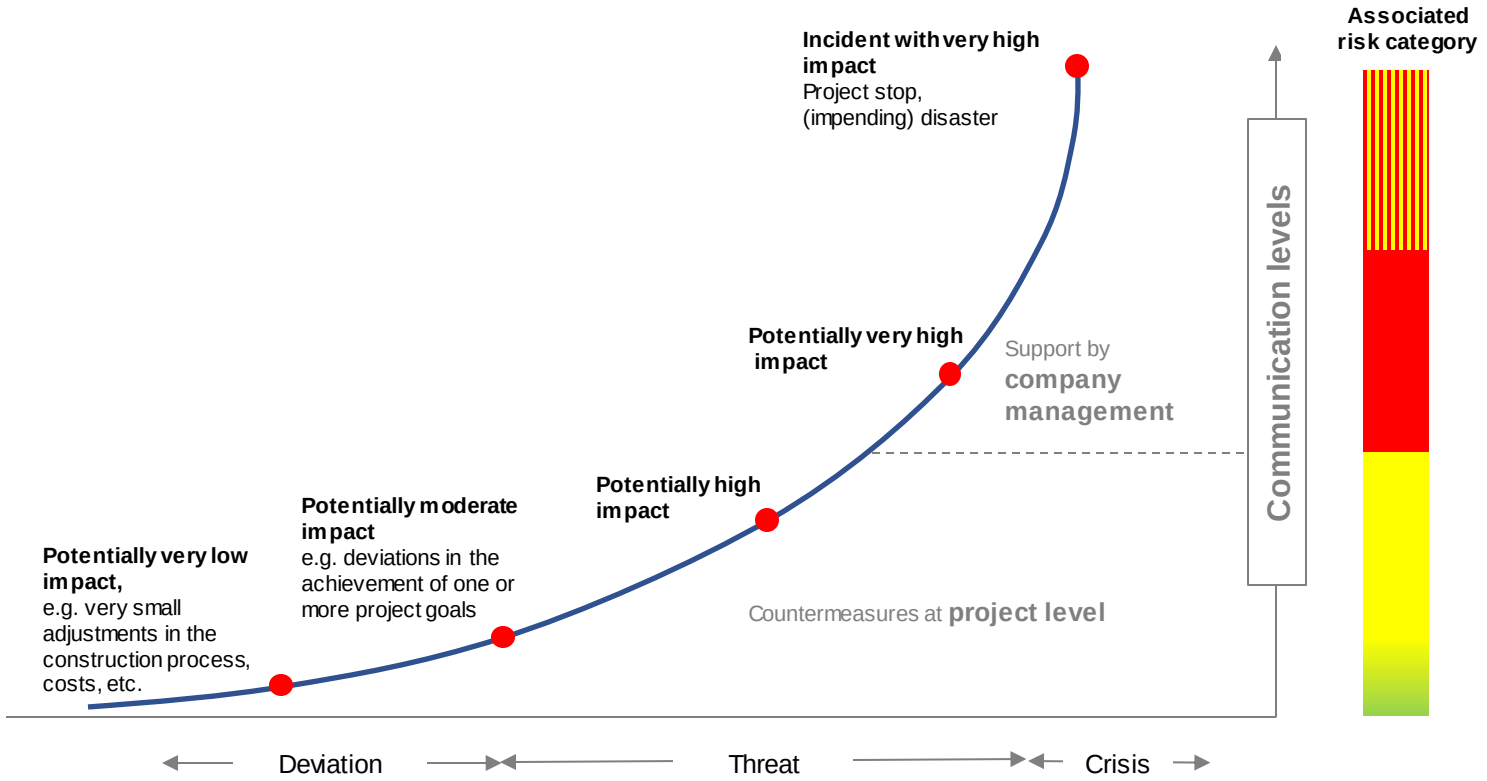
Options for action



Example of mitigation measures for underground construction projects (not exhaustive)

Action type	Action strategy		
	avoid	reduce	transfer
Appropriate Resources	▪ Use of qualified, experienced staff / continuous training ▪ Use of proven device types (state of the art) ▪ Use of new devices	▪ Provision of special teams (e.g. injections, ….) ▪ Provision of (special) devices (e.g. injection devices, pumps, …)	
Material Measures	▪ Optimization of alignment ▪ Careful planning, taking safety and environmental aspects into account ▪ Use of safe, proven construction methods and installations ▪ suitable choice of material	▪ Appropriate site investigations ▪ Optimization of alignment ▪ Systematic exploratory drilling in advance and monitoring during excavation	
Organizational measures	▪ Define a clear risk policy (acceptance lines / alarm values) ▪ Systematic implementation controls Four-eyes principle / Strategic Review Panel ▪ Provision of expert teams	▪ Organization of rescue services ▪ Alliance contract ▪ Provision of expert teams	▪ Contractually agreed risk allocation (e.g. SIA 118/198) ▪ Insurance coverage

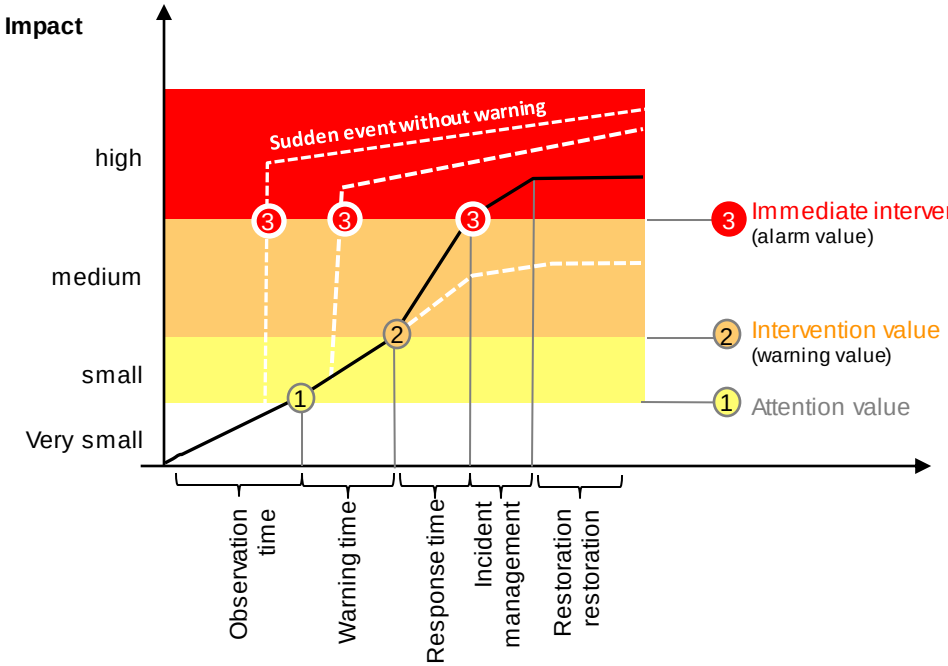
Communication of threats depending on the impact and decision-making level



Risk Communication

Source: SFOT

Each individual hazard must be countered with suitable and measures



3 Immediate intervention value
(alarm value)

2 Intervention value
(warning value)

1 Attention value

Examples of measures

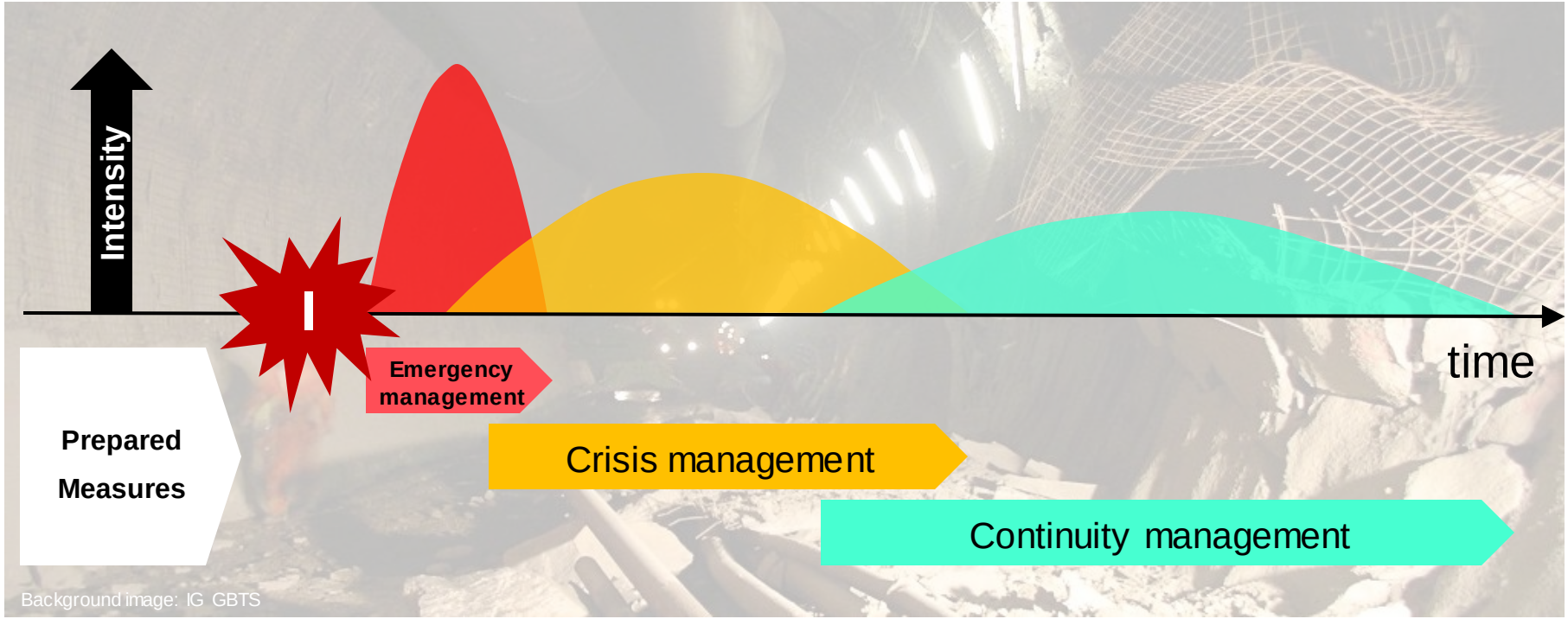
- Stop of construction process
- Measures for incident management
- Clearing the construction site
- Clearing third-party facilities

- Security measures
- Operating restrictions
- Intensify monitoring

- Intensify monitoring
- Picket positions

- observe

Nevertheless, risk events can occur



Communication in the case of incidents

Site

Incident

Minimum content for the initial information

- Where?
- What?
- Who is affected?
- How?
- Why (if possible) ?

Company

Authorities

Board of directors, etc.

Communications Officer

Internal information
External information (media))

«one voice» principle

Executive Management

Information of authorities, board of directors etc. strategic assessment of the situation decision on deployment of a task force

Site

Task Force

- authorized representatives of executive management
- Site management
- Project management / site supervision
- Designer / Specialists
- Experts
- Eventually staff departments such as: communication, legal services, quality management, etc.

Crisis management

Typical ground related hazard scenarios 1/3

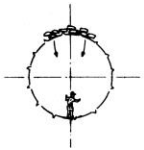
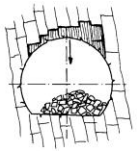
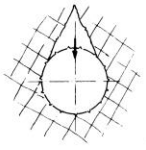
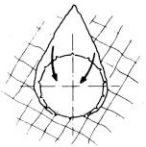
Hazard scenario	conventional	mechanical	Mitigation measures
Rockfall			– Rock cleaning – Head protection at a minimum angle of 180°, immediately after the cavity is opened
Breakdown			– Installation of a sufficiently dimensioned ground support
Downfall			– Installation of a sufficiently dimensioned ground support – if necessary, ground improvement measures

Image source: BLS AT, final report on rock mechanics, excavation, stabilisation, 2009

Typical ground related hazard scenarios 2/3

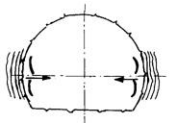
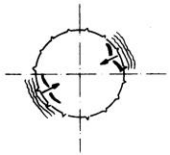
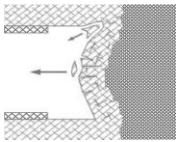
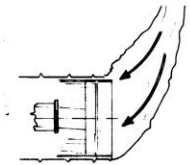
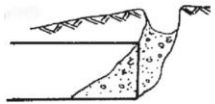
Hazard scenario	conventional	mechanical	Mitigation measures
Stress-induced detachment/ Rock burst			– Waiting time – Customised rock support after each round – Possible expansion holes – Installation of steel ribs – Anchors with high expansion capacity
Unstable tunnel face	 © IG GBTS		– Drainage holes – Support of the tunnel face with long, grouted self-drilling anchors – Selection of a TBM with sufficient face support (in loose material)
Sinkholes		 Kovari/Bosshard: Zimmerberg Tunnel	– Pipe umbrella / large pipe umbrella via TBM tunnelling – Conventional support of the face with long, grouted self-drilling anchors – Selection of a TBM with sufficient face support (in loose material)

Image source in general: BLS AT, final report on rock mechanics, excavation, stabilisation, 2009

Typical ground related hazard scenarios 3/3

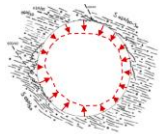
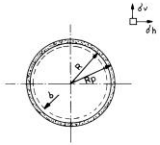
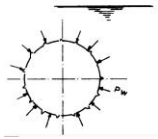
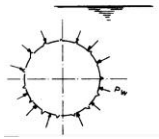
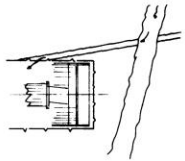
Hazard scenario	conventional	mechanical	Mitigation measures
High deformations / High ground pressures **(Squeezing or swelling rock)**	 © IG GBTS		– Installation of a deformable break-out protection – Additional cut-out for deformations (overcut with TBM) – Reprofiling if necessary
Water pressure (local)			– flow-reducing injections – Ground freezing – Drainage holes
Sudden water ingress at high pressure			– flow-reducing injections – Preliminary drainage holes

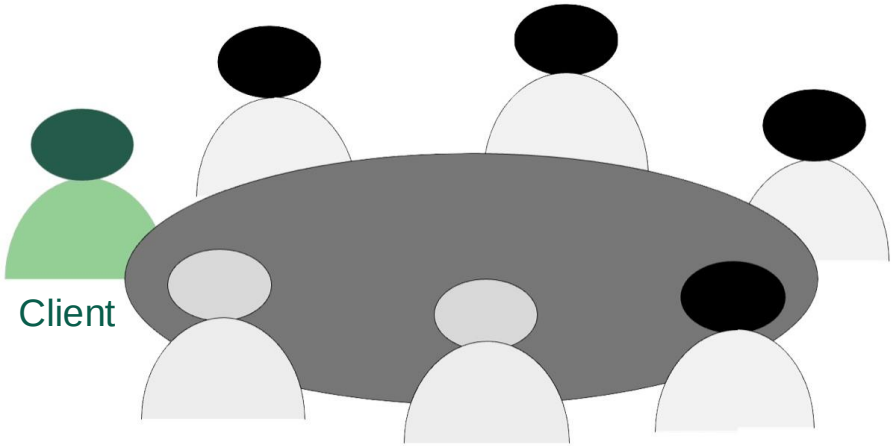
Image source: BLS AT, final report on rock mechanics, excavation, stabilisation, 2009

Who has what responsibility? - Key role of the client

The client is the first to come into contact with the project and must initiate the process.
Project risk management is one of the project manager's management tasks!

Internal participants

- Client (initiator)
- Designer
- Contractor
- Site supervision
- Experts



external participants

- Customer
- Operator
- ev. Authorities
- .....

All internal partners must be integrated and,
if necessary (depending on the context), also external partners to the project.

Phase-related goals of project risk management

Project stages AHO (general process)	Service phases (HOAI) (Design services)	Goals (Design and construction)	Goals Risk management
1. Initiation	0 Analysis of the needs	Needs, goals and framework conditions defined, solution strategy determined	-
	1 Collection of the basics	Clarification of the task (project planning basics/inventory)	Risk management implemented by the owner
2. Design	2 Feasibility design	Proof of the feasibility of the best variant cost estimate	Risk analysis carried out for all variants, risk costs recorded for the first time in the cost estimate
	3 Preliminary design	Project optimized and described ready for implementation, deadlines defined, cost calculation	Detailed risk analysis including planning of measures carried out - risk costs recorded in cost calculation
	4 Technical design	Obtaining of all planning approvals	Acceptance risks eliminated
3. Procurement	5 Detailed design	Definition of the project with construction drawings and workshop drawings	Risk-reducing/opportunity-utilizing measures included in the implementation plan
	6 Procurement	Contract model and risk limitation defined Qualification and award criteria defined	Handover of the findings from the client's risk analysis to the bidders
	7 Contract award	Selection of the contracor taking into account the most advantageous offer	Selection of the contractor, taking into account his contribution to the exploitation of opportunities/threats prevention
4. Construction	8 Object supervision - construction supervision and documentation	Structure realised according to the work contract, in compliance with all project requirements	Implementation of an integral risk management including all parties involved - final evaluation
5. Commissioning	9 Asset managment	Ensure operation Maintain usability and value	Consider operational experience for risk management of future projects

Please support the implementation of project risk management!

«.... so that in future we no longer fall short of what we have achieved but, on the contrary, **that those to come do even better than us!»**

Mr. Sulzer Ziegler, Breakthrough of the Simplon Tunnel, 1905

Many thanks

Picture: IG-GBTS