FUTURE CIRCULAR COLLIDER

WORKSHOP 13. / 14. FEBRUAR 2014, GENEVA

Gotthard Basetunnel

Aspects of Long Tunnels

presented by:

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Introduction

Main Challenges of Long (and Deep) Tunnels

- **Tunnel length leeds to long construction time**
  - Mechanization / automation of procedures, trend to the use of TBM in order to increase performance
  - Intermediate points of attack (if feasible) to cut construction time
- **Geological variety, (high overburden**)
- **Investigations**
  - Not possible / reasonable over the entire length
  - Higher remaining risks compared to other projects
- **Logistics**
  - Long transport distances
  - Access shafts and galleries
- **Muck treatment, material deposits**

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More and More People and Goods Cross the Alps

(Source: GBT, der längste Tunnel der Welt, Die Zukunft beginnt, Hrsg. R.E. Jeker Werd Verlag Zürich, 2002)

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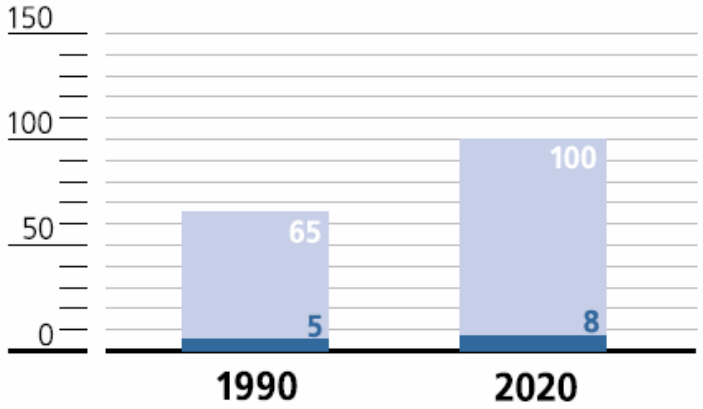
Traffic Crossing the Alps, Estimated Increase between 1991 and 2020

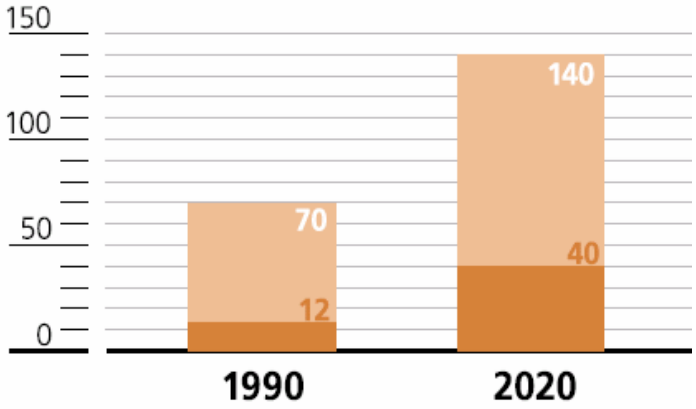
Passengers

Million passenger trips/year



Freight

Million tonnes/year



Traffic through the Alps via Mt. d'Ambin/Fréjus and Brenner (rail + road)

Proportion Gotthard railway

Traffic through the Alps via Mt. d'Ambin/Fréjus and Brenner (rail + road)

Proportion Gotthard railway

(Source: www.alptransit .ch)

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The Modernisation of the Railway Infrastructure Shall Enhance Transferring Traffic from Road to Rail

(Source: www.alptransit .ch)

The political pressure from the EU to have more traffic capacity through the Alps resulted in a political decision in Switzerland that this trafic should be on rails

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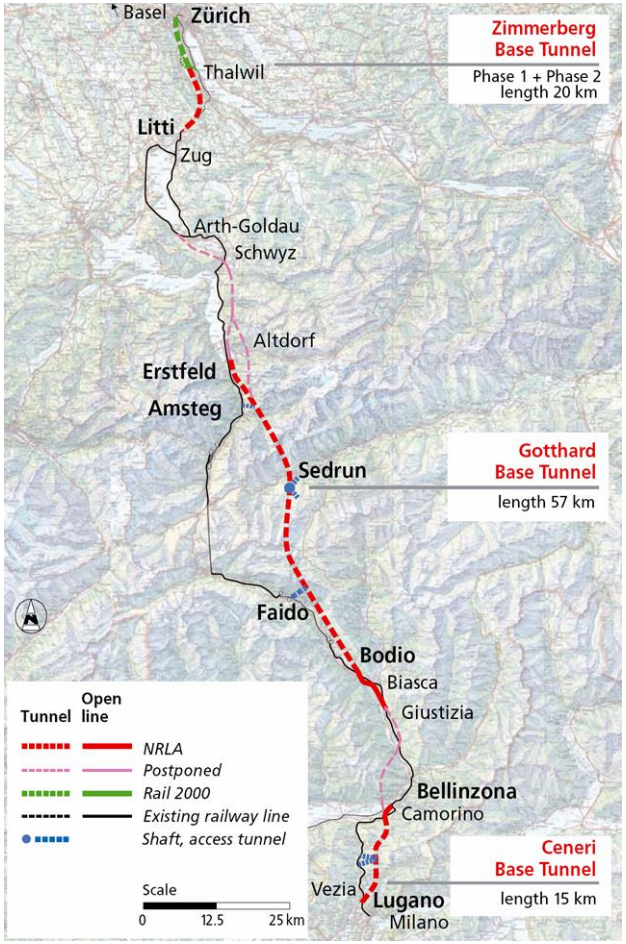
What's the Gotthard Axis?

The Gotthard axis includes the

- Zimmerberg Base Tunnel (works are supended)
- Gotthard Base Tunnel GBT (under construction)
- Ceneri Base Tunnel (under construction)

The new route makes freight transportation more productive and passenger traffic faster



(Source: www.alptransit .ch)

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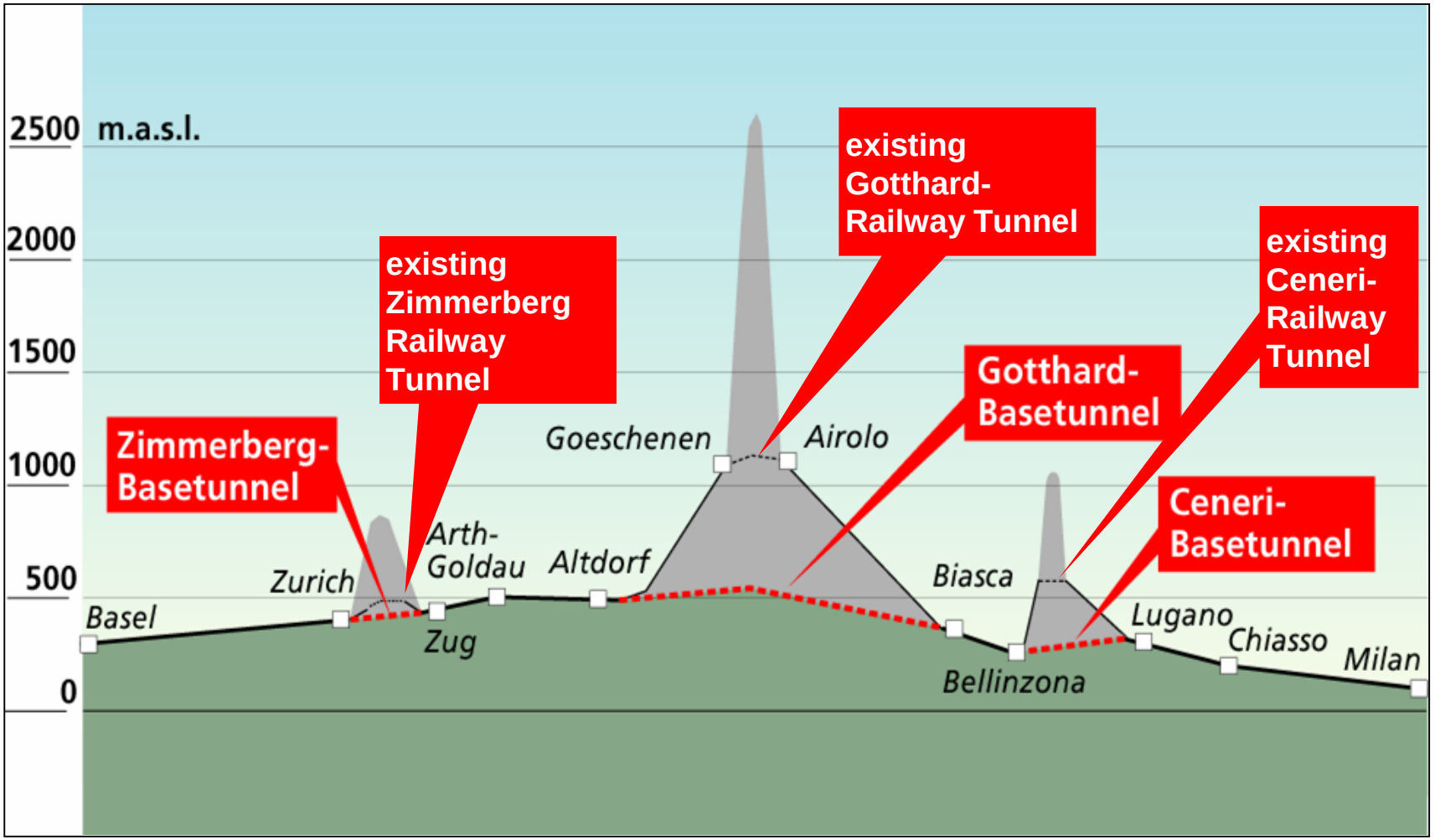
Gotthard Axis, Longitudinal Profile



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Reasons of the Swiss Government for the NEAT

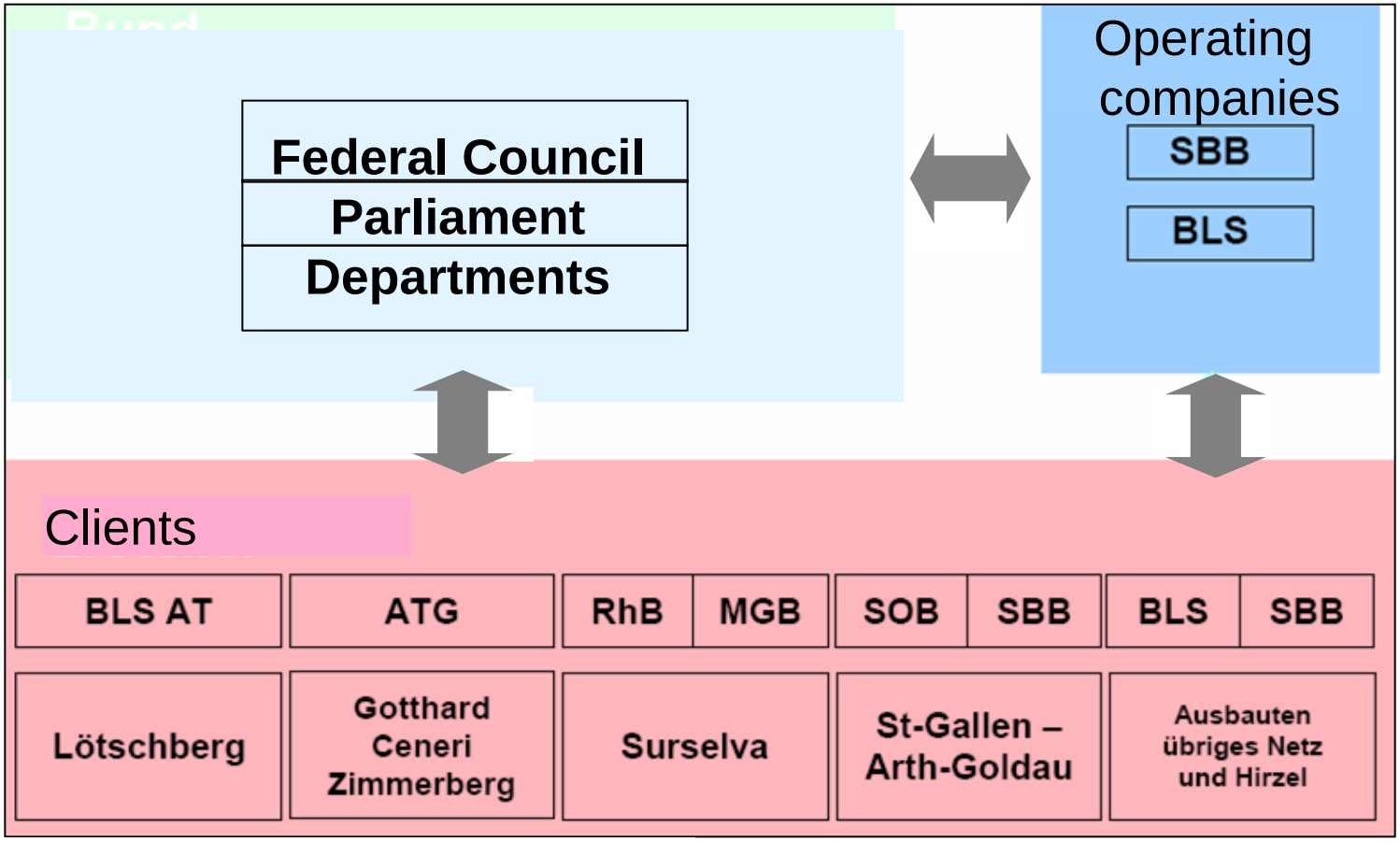
- **Transport political:** transfer long distance traffic from road to rail
- **Environmental:** reduction the number of trucks, protection of the environment
- **National politics:** network instead of only one axis, improved connection between north and south
- **Economical:** connection to Europe‘s high speed rail network
- **European political:** Switzerland strengthens its central role in Europe

Public Votations on the NEAT Project

For the NEAT scheme the Swiss population voted three times:

- on the introducing of a tax on the transportation of heavy goods (freight)
- on the overall financing of the project
- on the technical scheme: network instead of only one axis

Over-all Organisation:
Federal Government, Operating Companies and Clients



(Source: www.alptransit .ch)

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Planning Approvals Procedure

- **publications in official journals**
- **30 days for public consultancy at the local communities**
- **public stake out**

<u>Authorised to raise objections</u>

- **Owners of affected estates**
- **Keepers of respective rights as neighbours**
- **Person who are concerned as leasers or tenants**
- **Communities**

Where <u>to raise objections</u>: only directly at the BAV (Ministry of Transport)

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Permanent Communication: Bodio Visitor Centre

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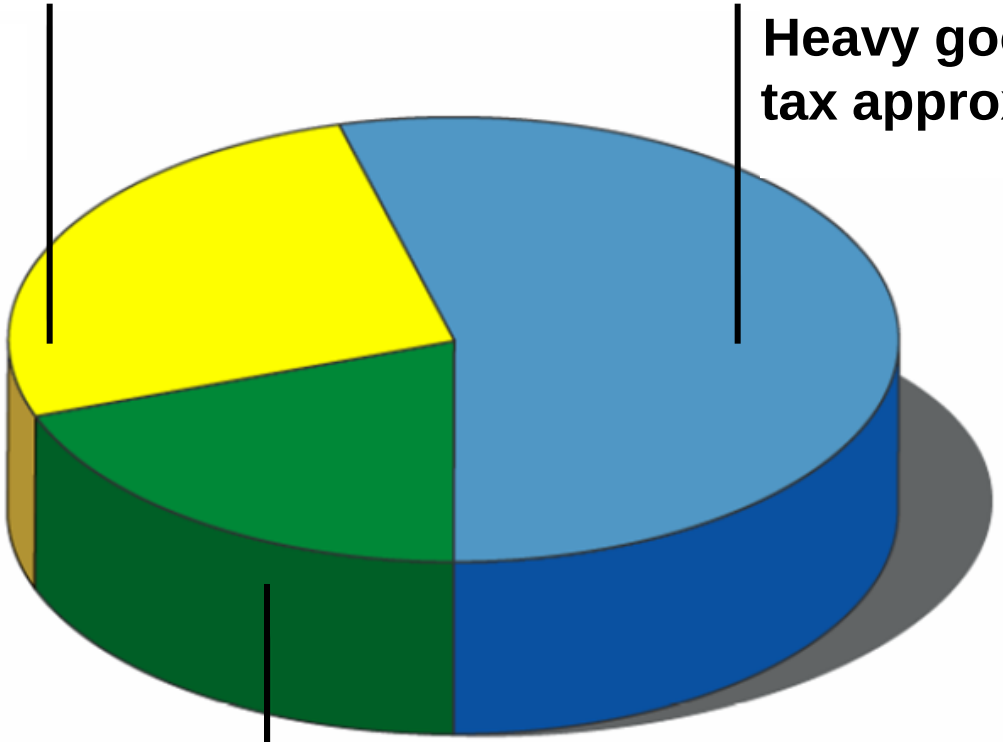
Source of the Capital (30 Billion CHF – for entire NEAT scheme)



(Source: www.alptransit.ch)

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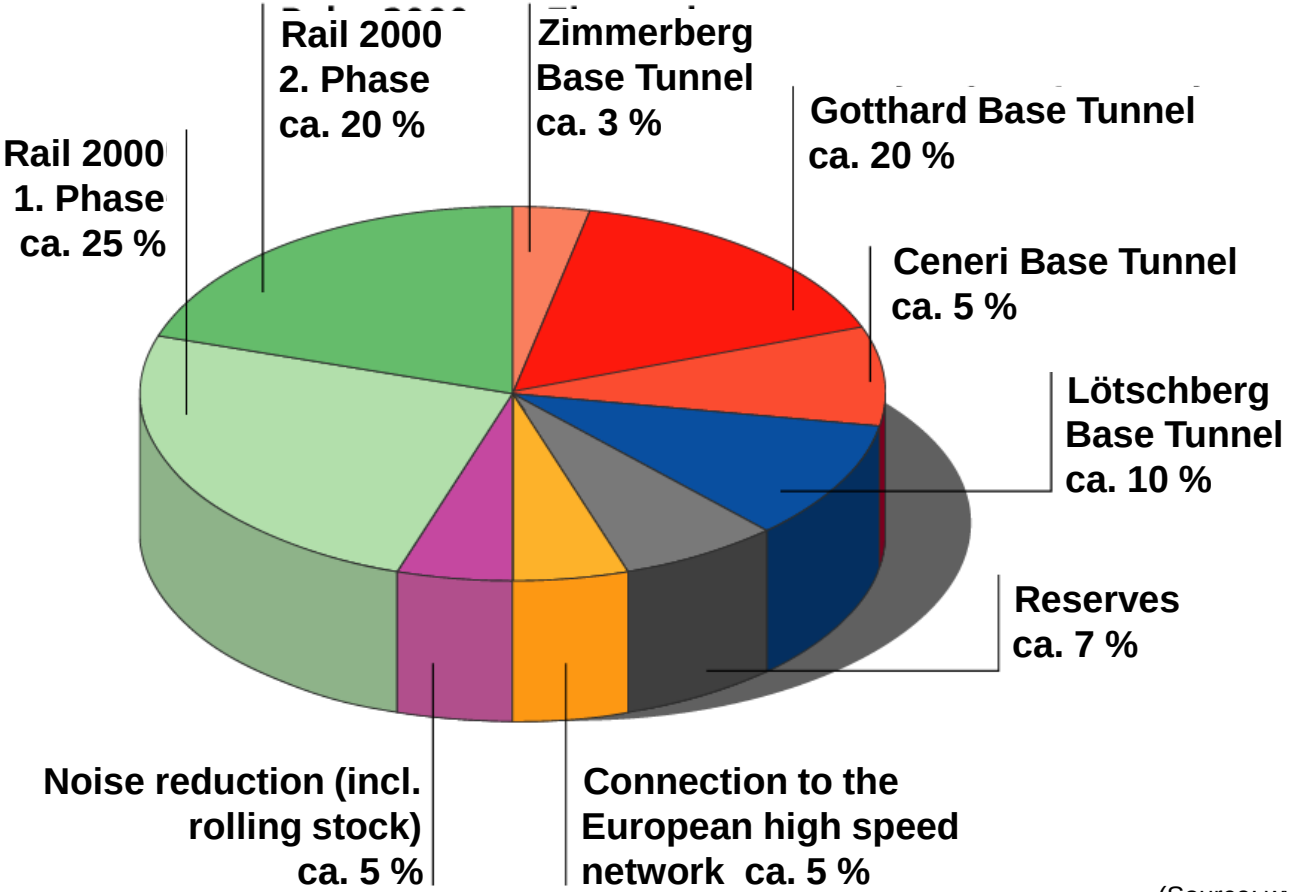
Use of the Capital (30 Billion CHF)



(Source: www.alptransit.ch)

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Credit versus Contract Costs

The NEAT credit:

- **was established at a very early phase and was approved by the government**
- **it was based on a ‚probable' geological situation and has a reserve lump sum for ‚unexpected events and conditions'**

The NEAT costs:

- **the cost is the sum of all contracted works**
- **the cost forecast is constantly (i.e. every 6 months) up-dated according to the progress of the planning and/or the work and compared with the credit.**

The margin between costs and credit was originally + 25%.
The final costs can now be estimated with +-5%.

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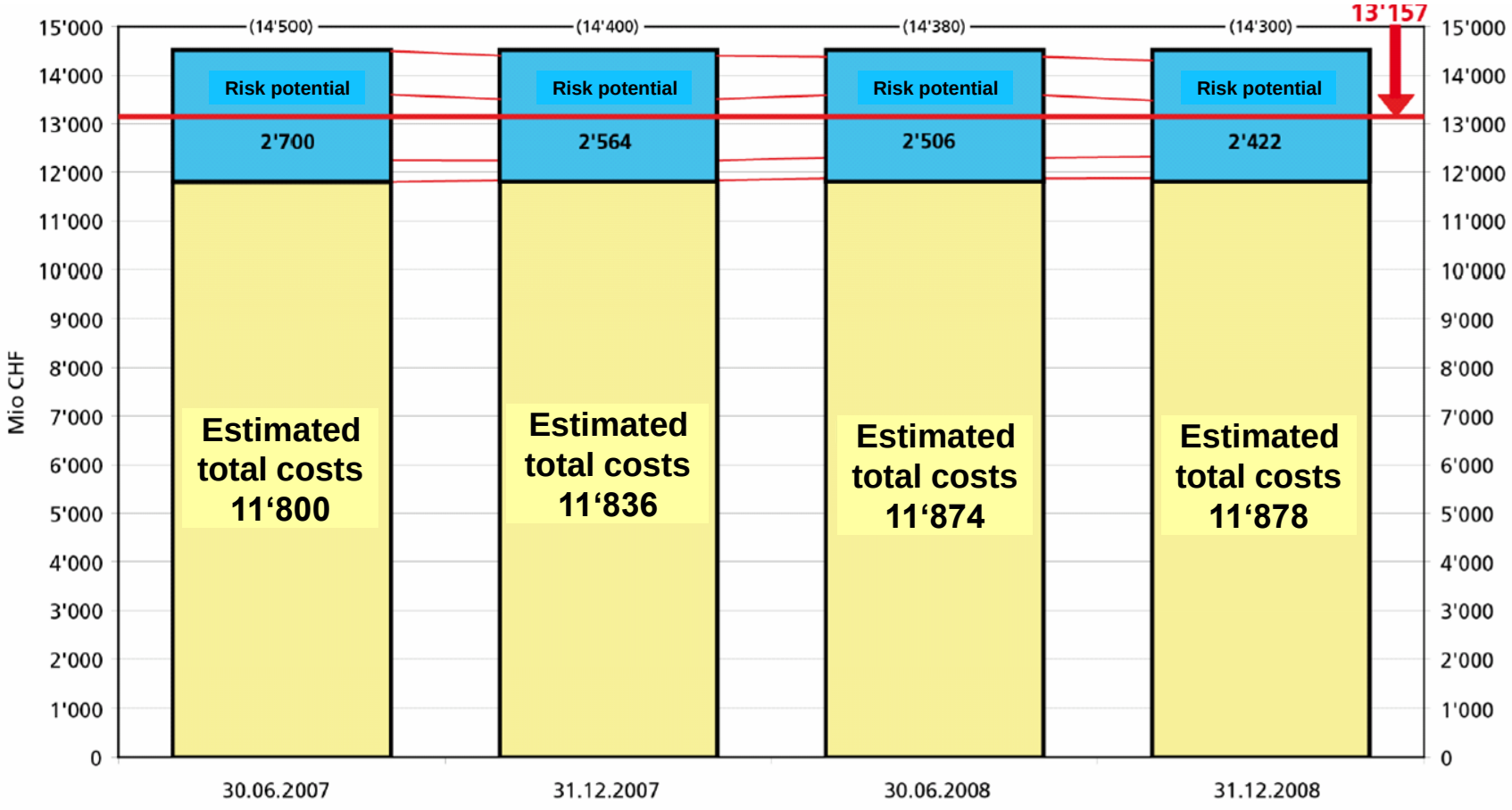
Development of Total Costs and Risk Potential (total axis)



(Source: AlpTransit Gotthard AG)

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Cost Overruns: Magnitude and Reasons

There had been a constant increase in investments and costs for the Gotthard Basetunnel (primilary figures)

Magnitude in total: approx > 3 Mia CHF (ca 40%)

Reasons:

▪ Constracts and construction:	approx	2%
▪ Geology:	approx	18%
▪ Improvements for the public and the environment:	approx	7%
▪ Political delays and financial restrictions:	approx	21%
▪ Safety and state-of-the-art technology:	approx	53%

Quelle: AlpTransit Gotthard AG

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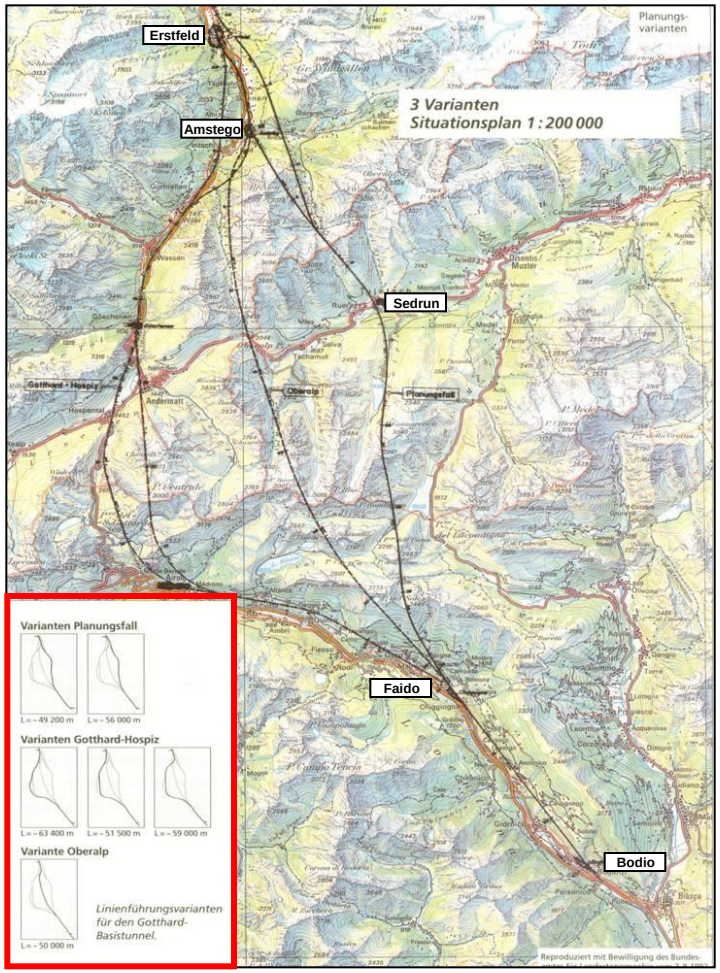
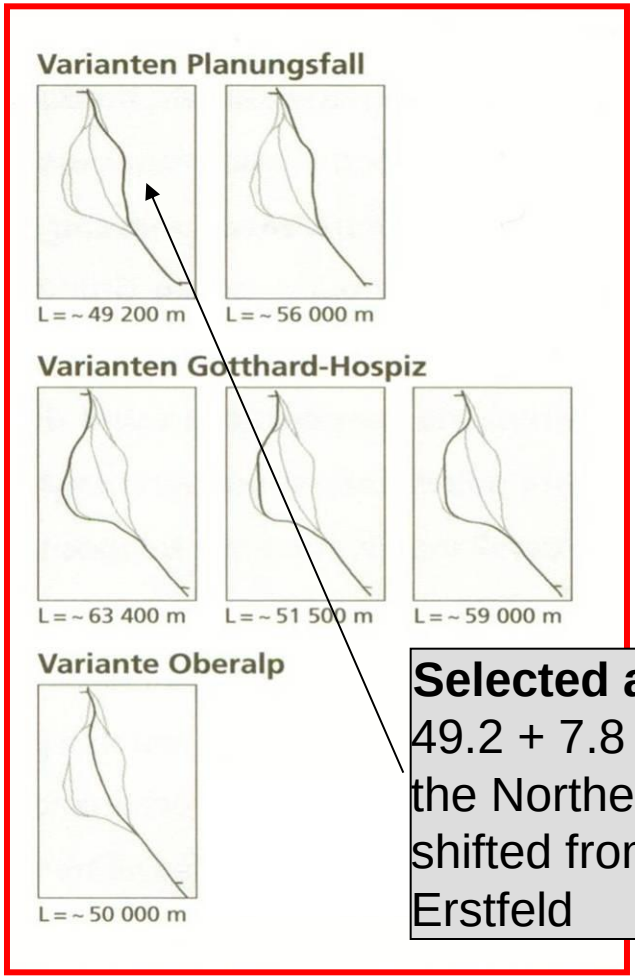
Three Alternatives for the Alignment of the GBT





Selected alternative
49.2 + 7.8 = 57 km
the Northern portal was shifted from Amsteg to Erstfeld

(Source: GBT, der längste Tunnel der Welt, Die Zukunft beginnt, Hrsg. R.E. Jeker Werd Verlag Zürich, 2002)

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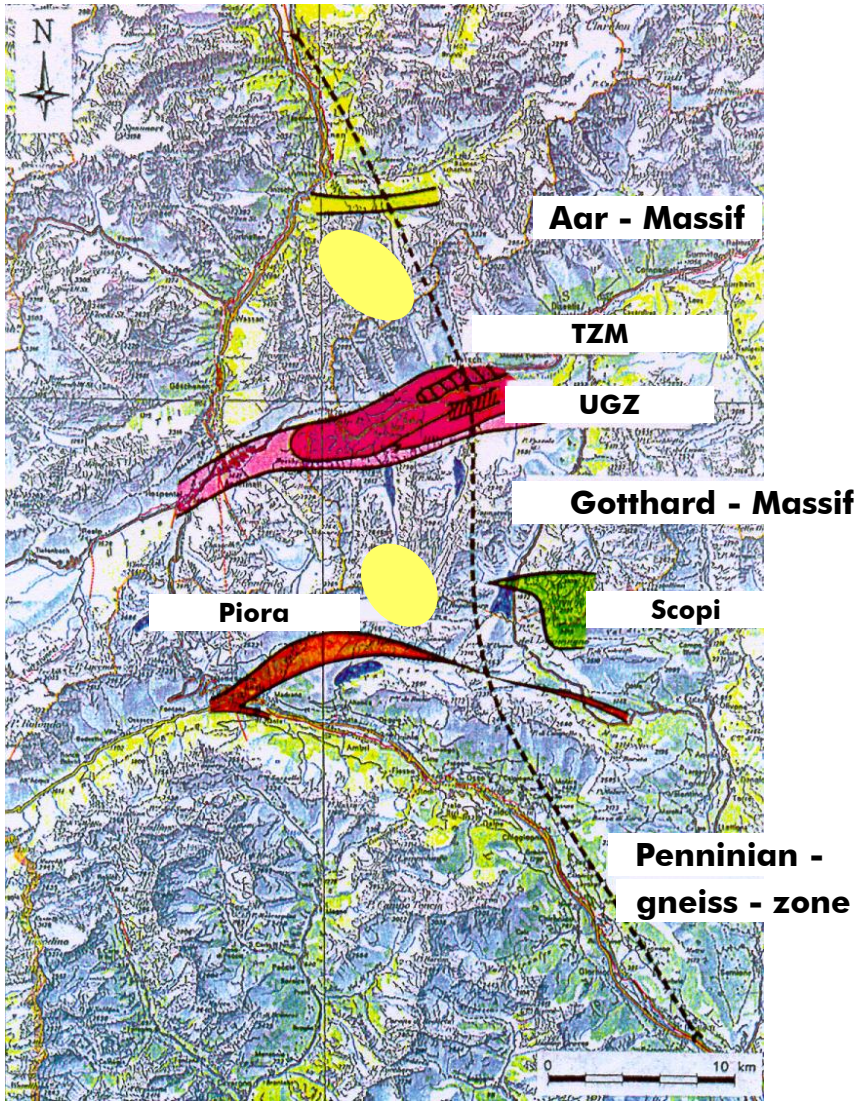
Geological Alignment

- Areas with highest overburden ➔ bypass
- Major fault zones:
- „Tavetsch Intermediate Massif“ ➔ shortest possible crossing
- „Useren Gavera Zone“ (probably aquiferous) ➔ drive on the rise
- „Piora Basin“ ➔ shortest possible crossing, upwards drive
- As large distant to reservoirs and dams possible



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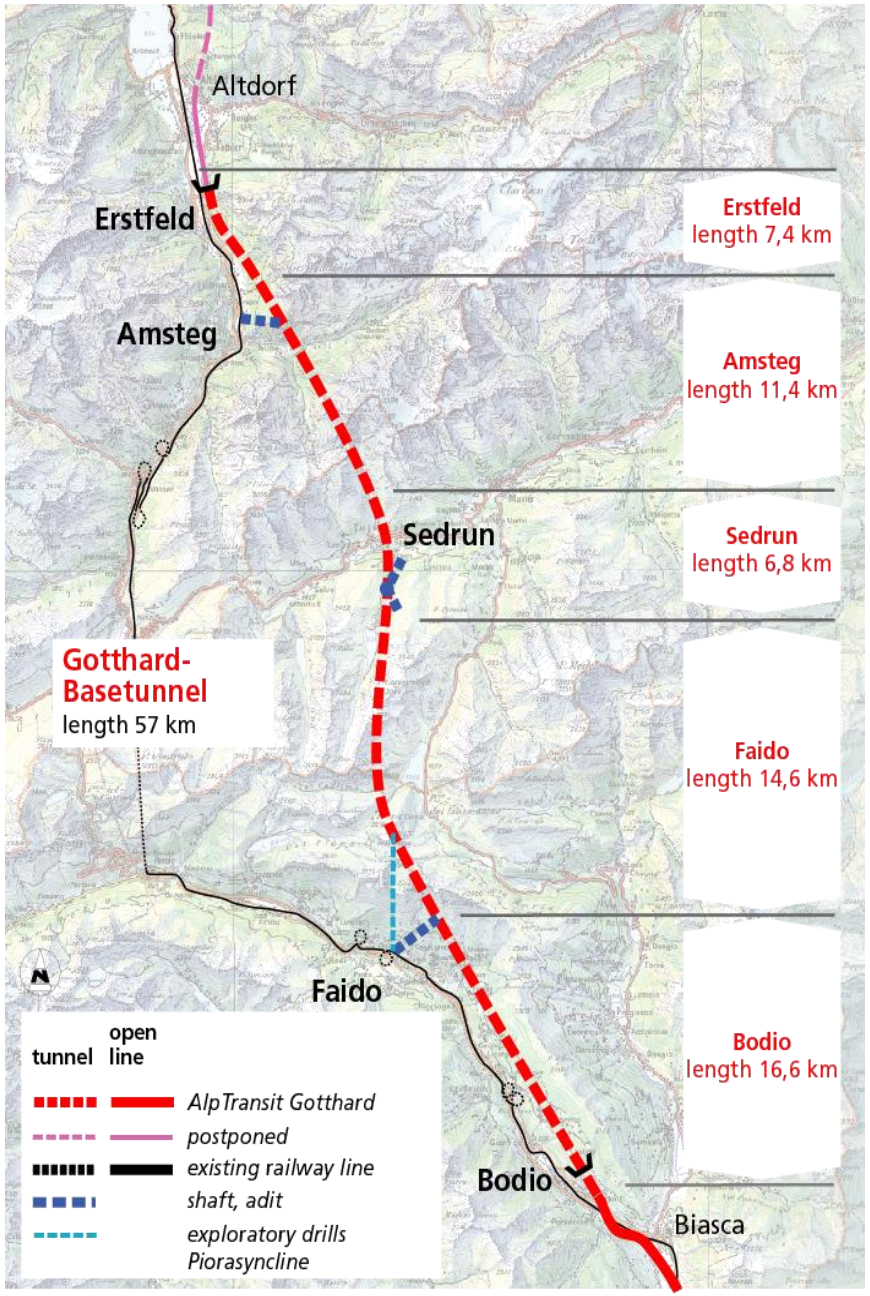
Overview GBT



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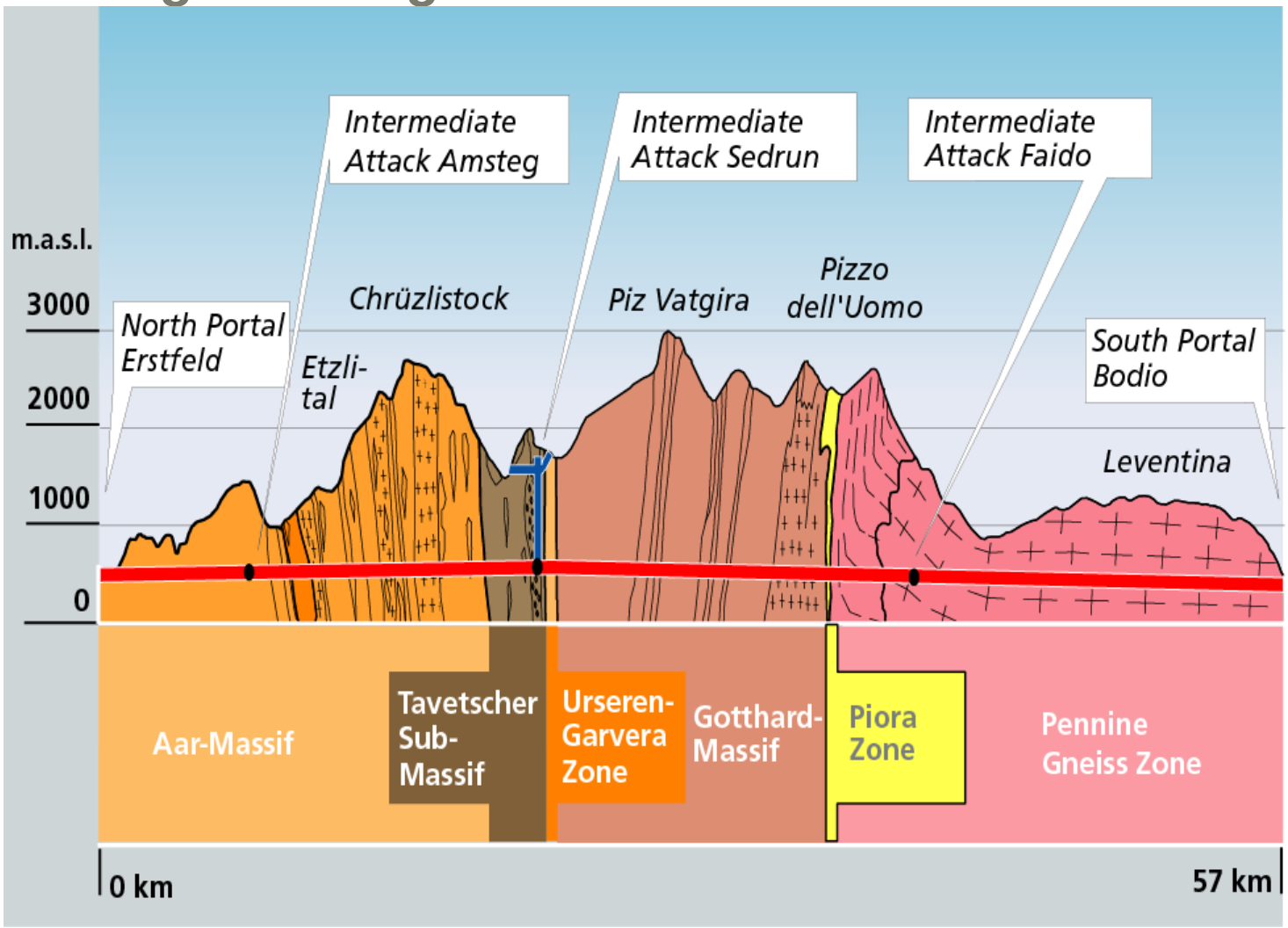
Geological Longitudinal Profile



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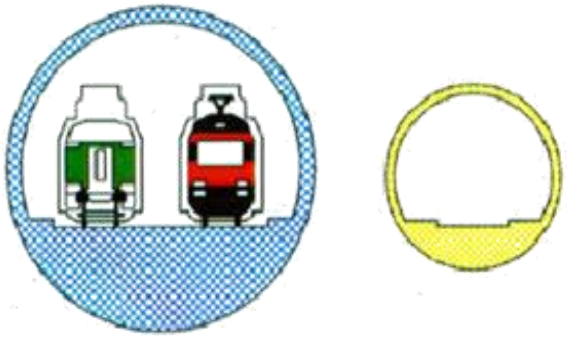
Possible Tunnel Systems of the GBT

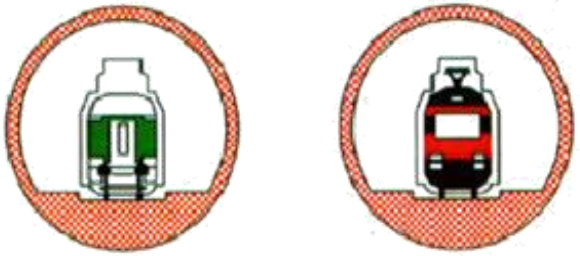
1 double-track tunnel and 1 service tunnel



3 single-track tunnels, of which one used as service tunnel

2 single-track tunnels and 1 service tunnel

2 single-track tunnels constructed to higher standard



: ∅ = 12.3 m : ∅ = 7 m : ∅ = 9.2 m

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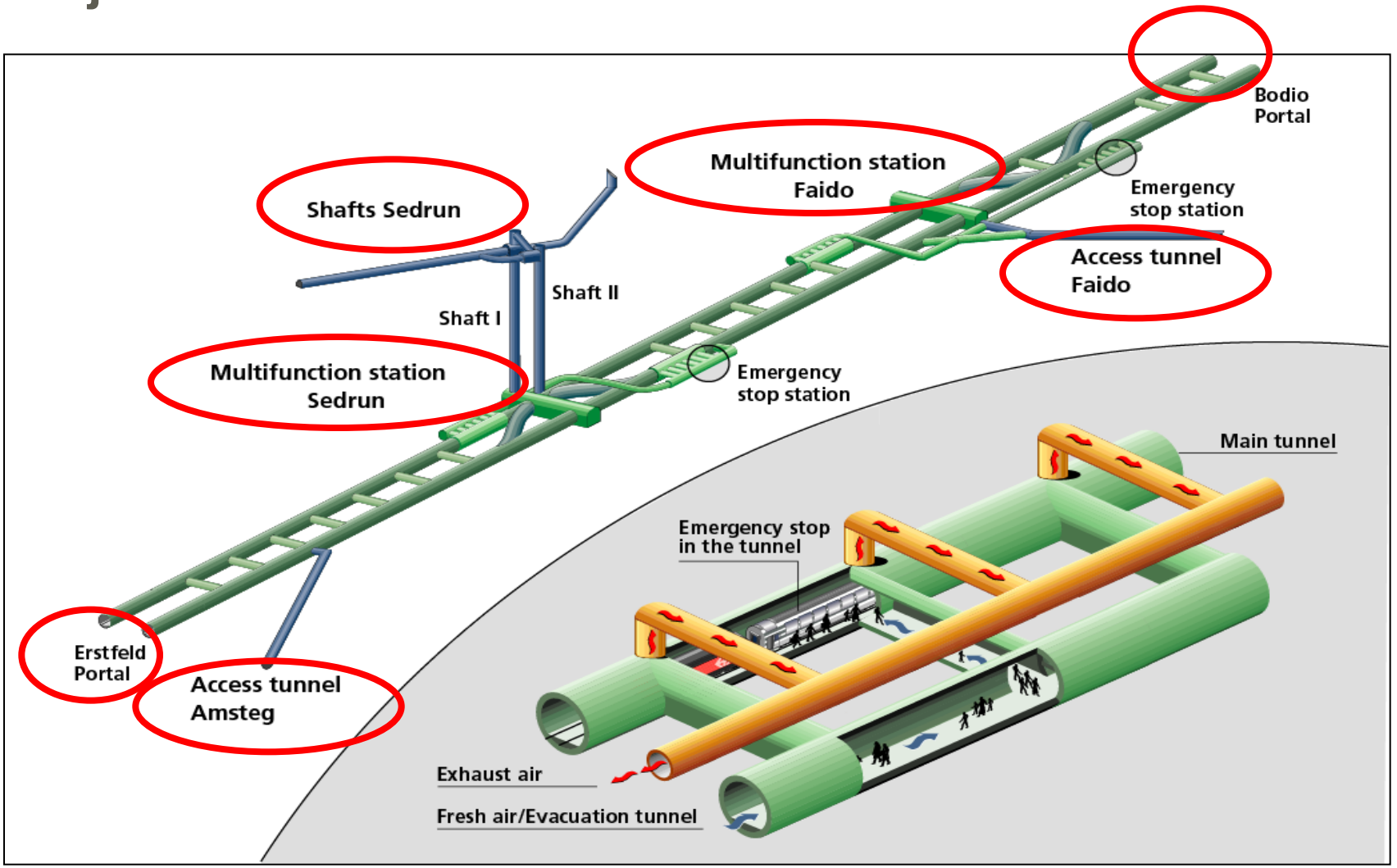
Project



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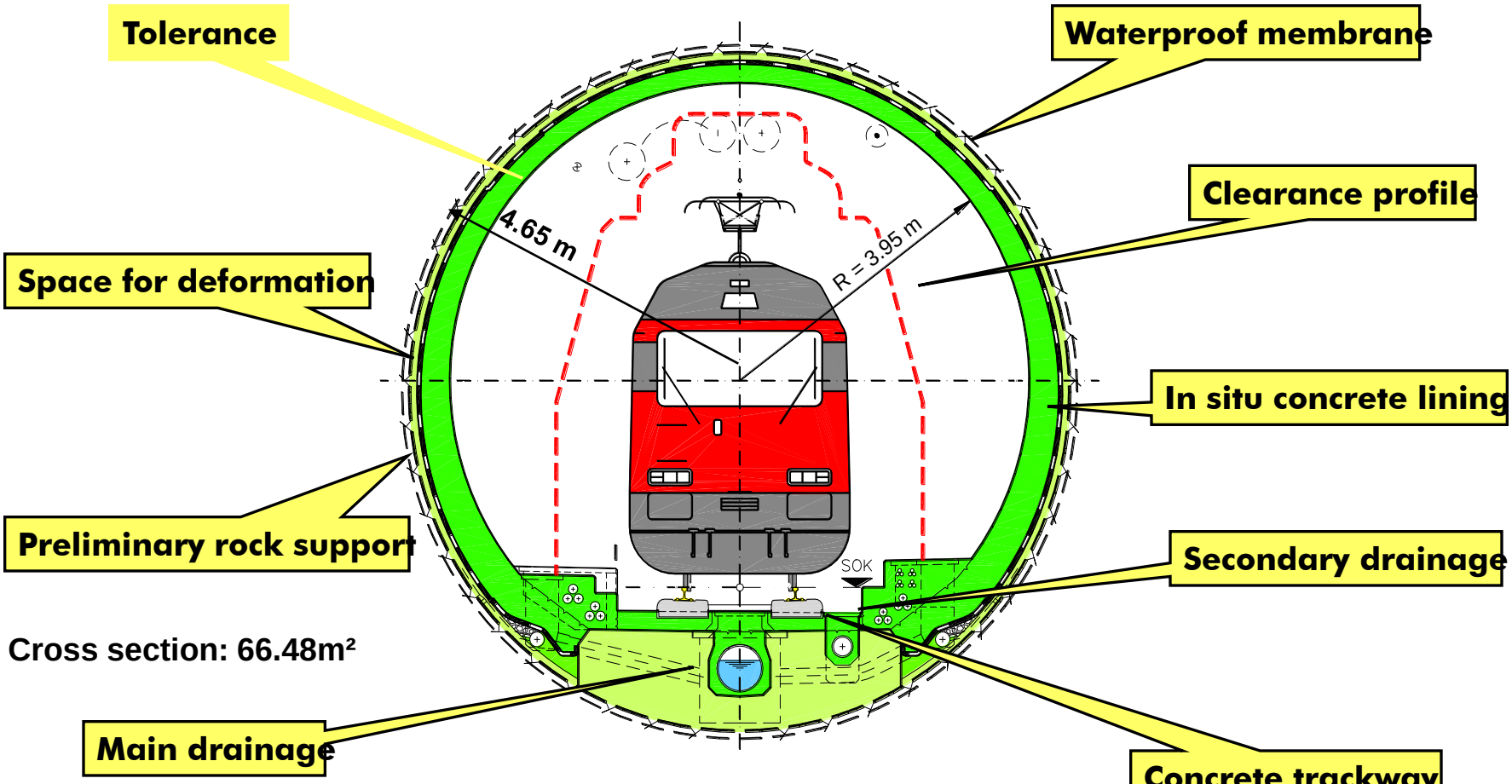
Standard Cross Section TBM Drive



Cross section: 66.48m²

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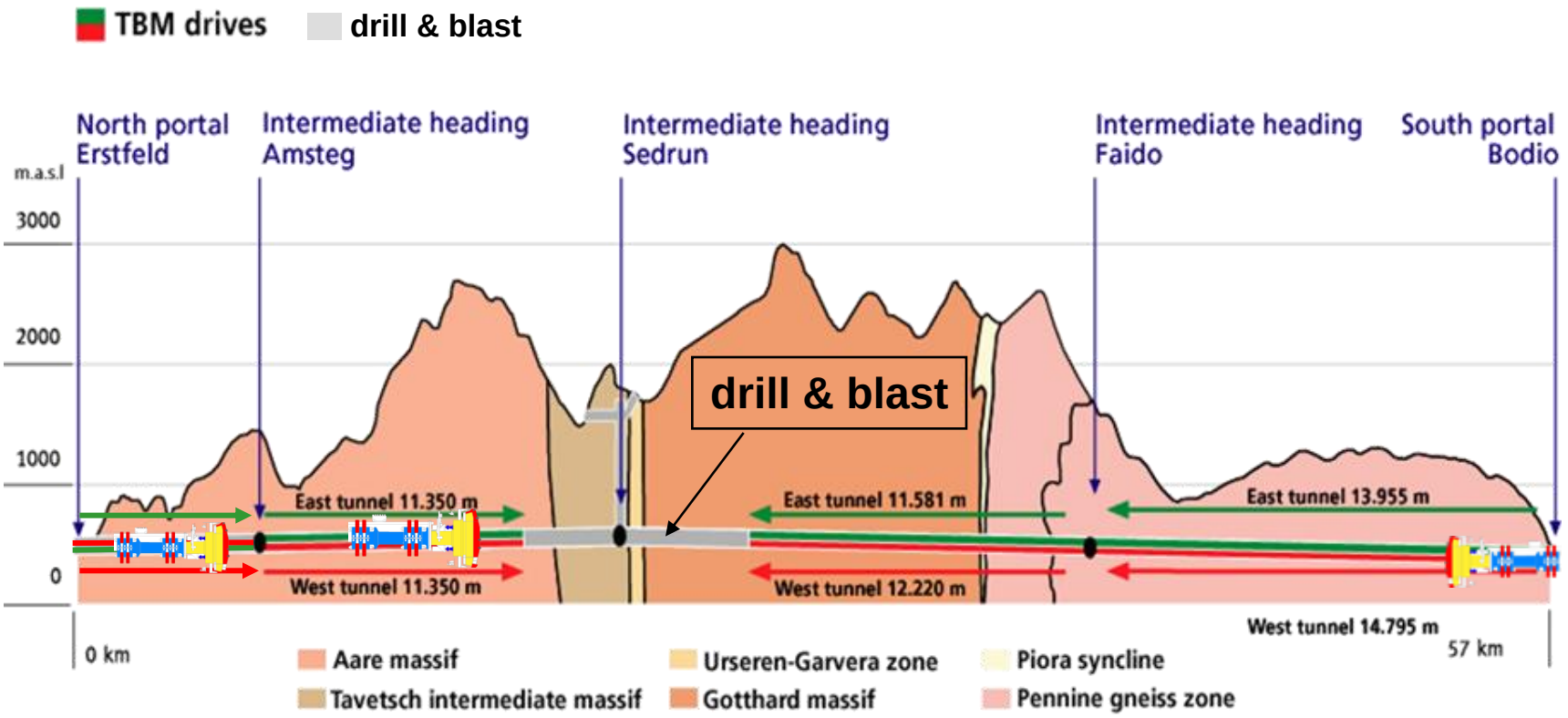
Geology and Heading Sections



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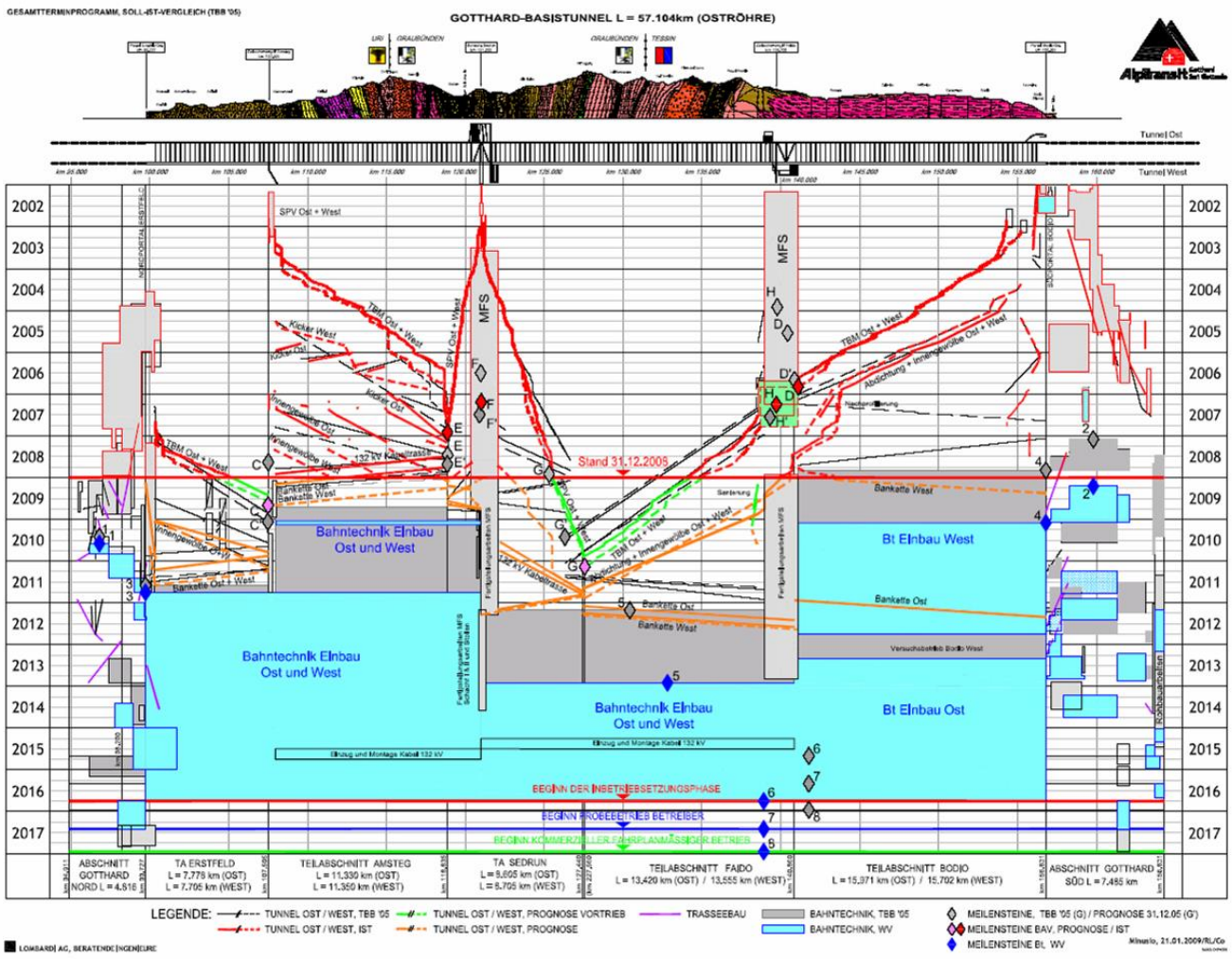
Gotthard Base Tunnel, Schedule



(Source: www.alptransit.ch)

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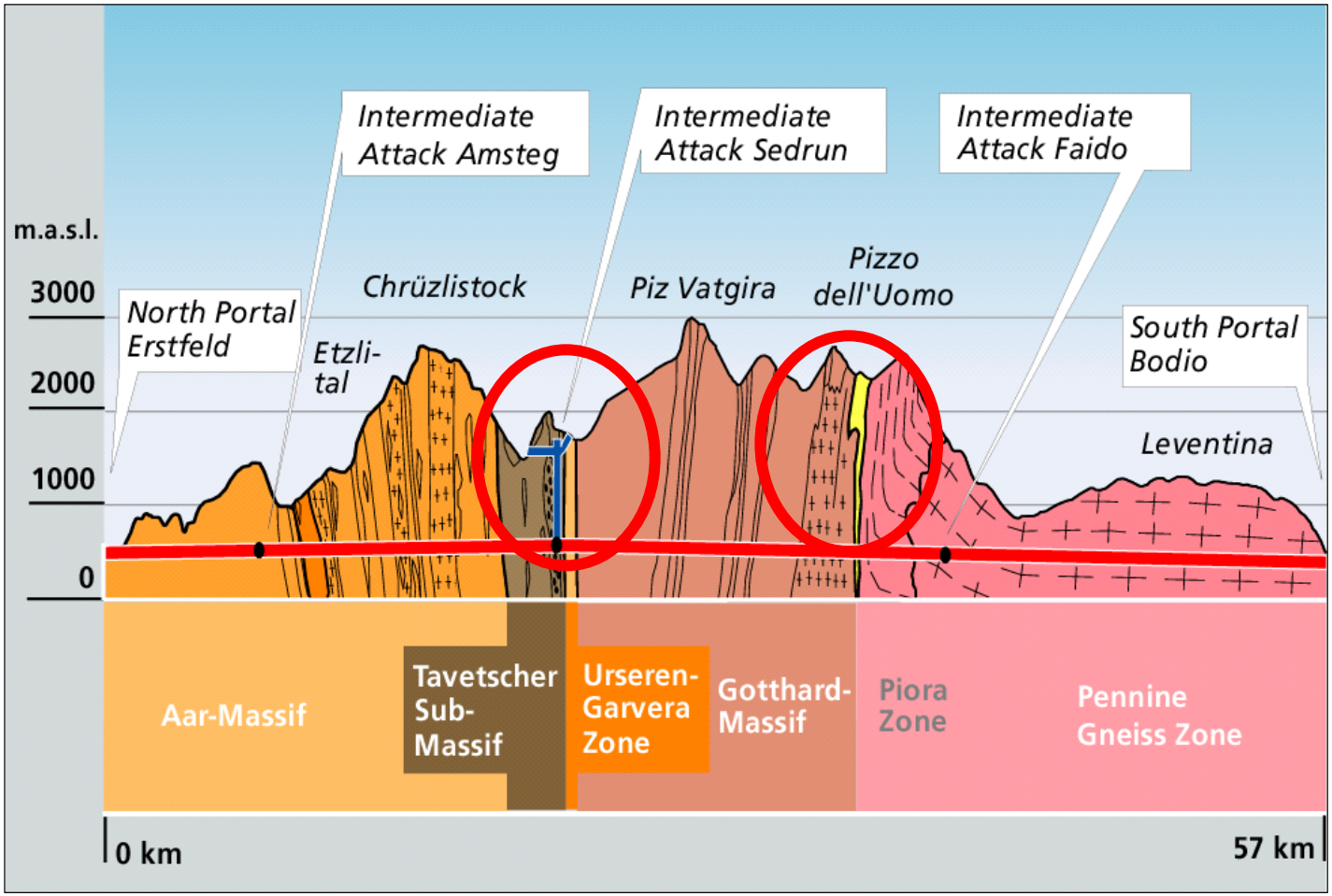
Gotthard Base Tunnel, Geological Longitudinal Profile

Two major geotechnical critical zones



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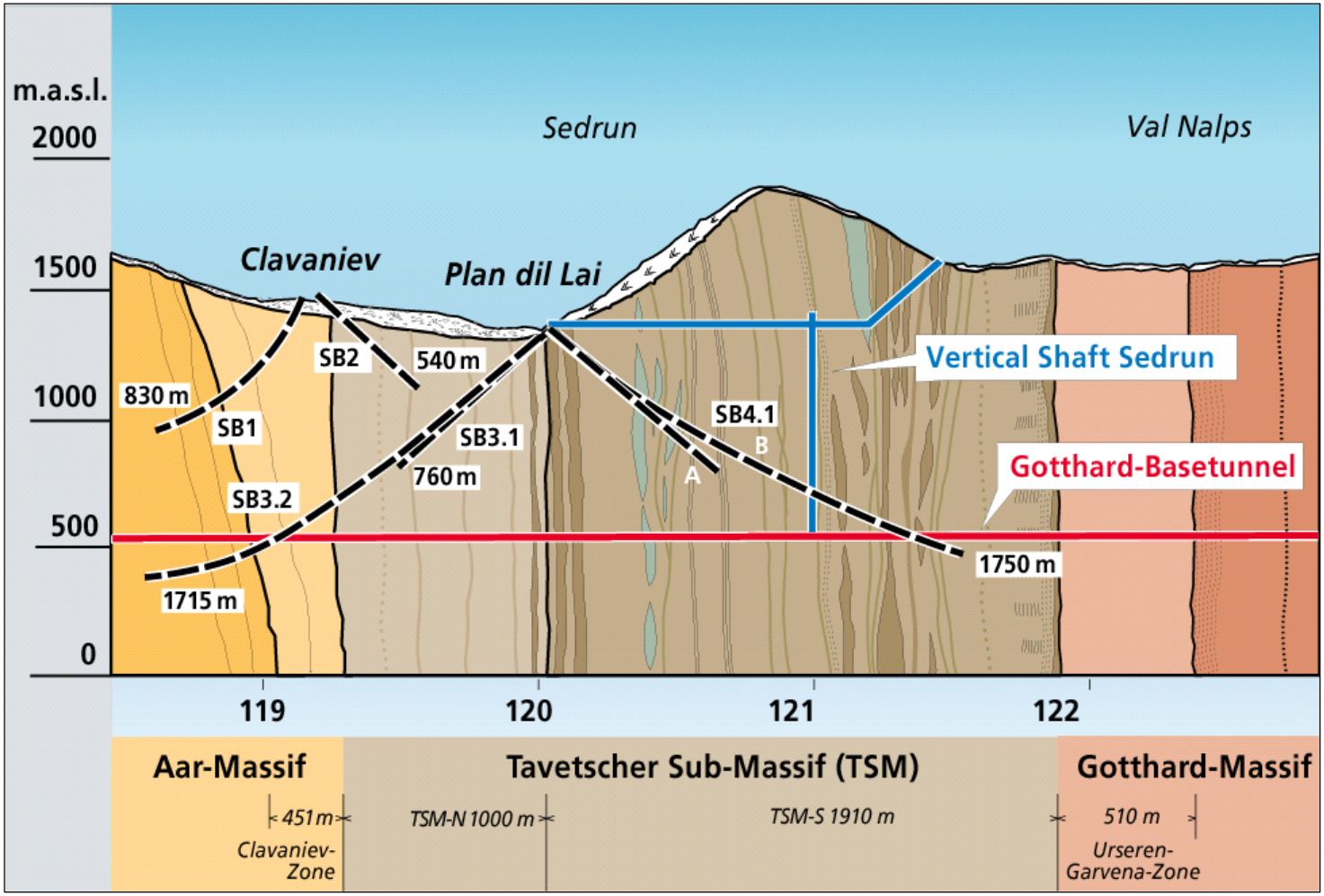
Geological Investigations TZM and UGZ



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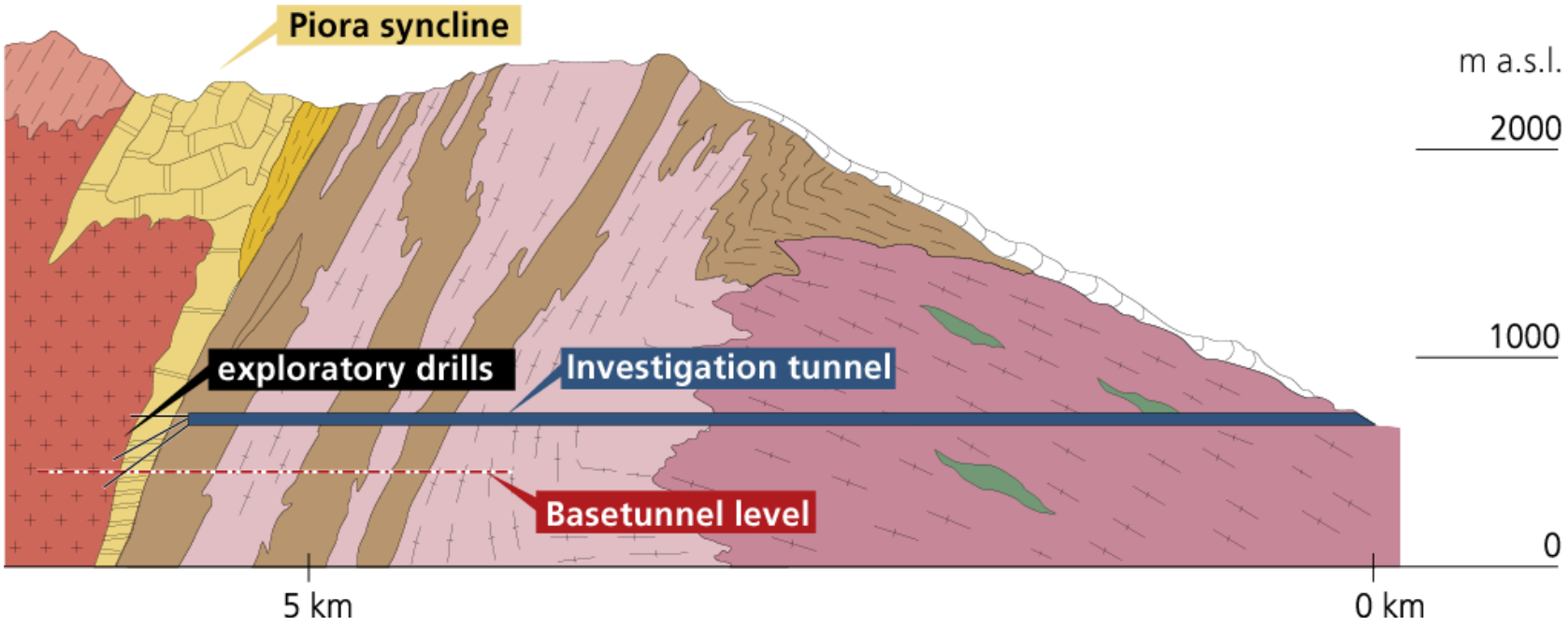
Geological Investigations Piora Bassin



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Exploration Drillings during Excavation

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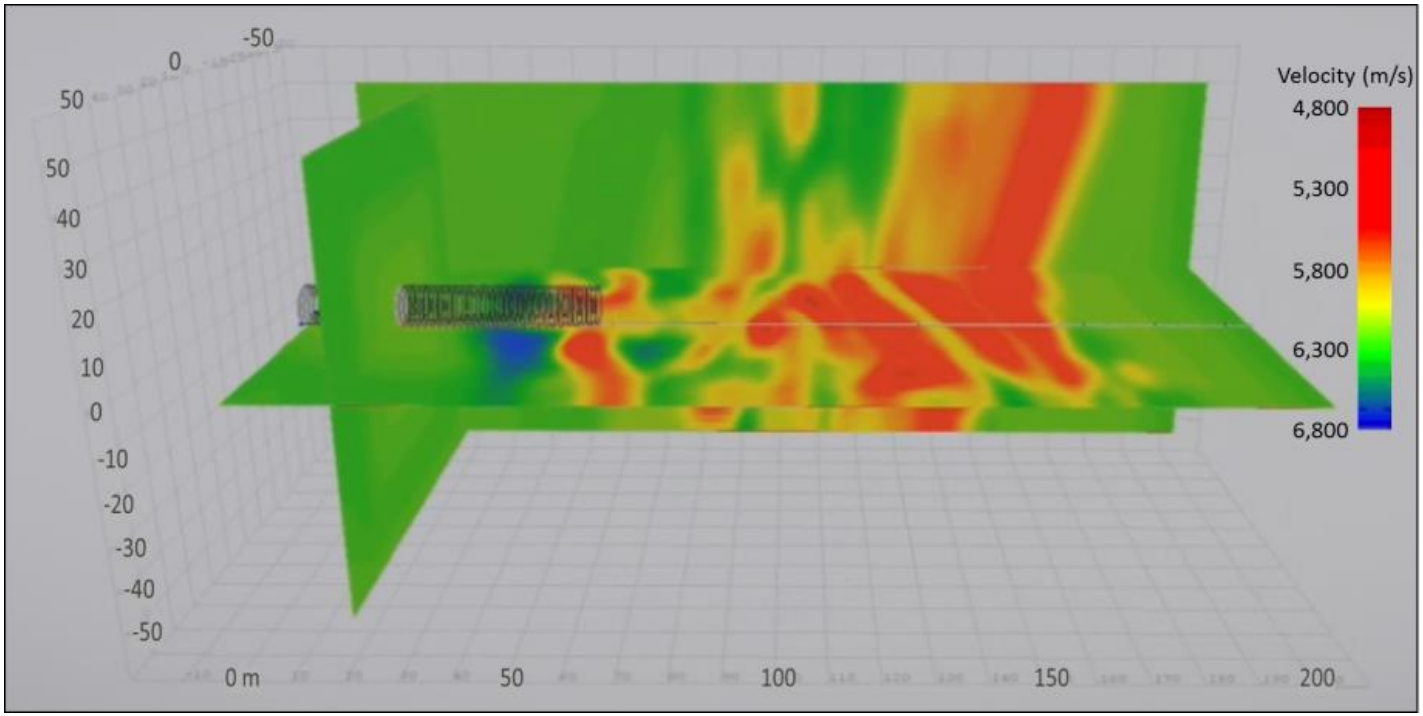
3D Tunnel Seismic Prediction ahead of Tunnel Face

- 1 or more shot lines w/ small explosive charges
- 4 receivers

RCV: 3-component receivers

3D Tunnel Seismic Prediction

3D-seismic velocity distribution ahead of the tunnel face



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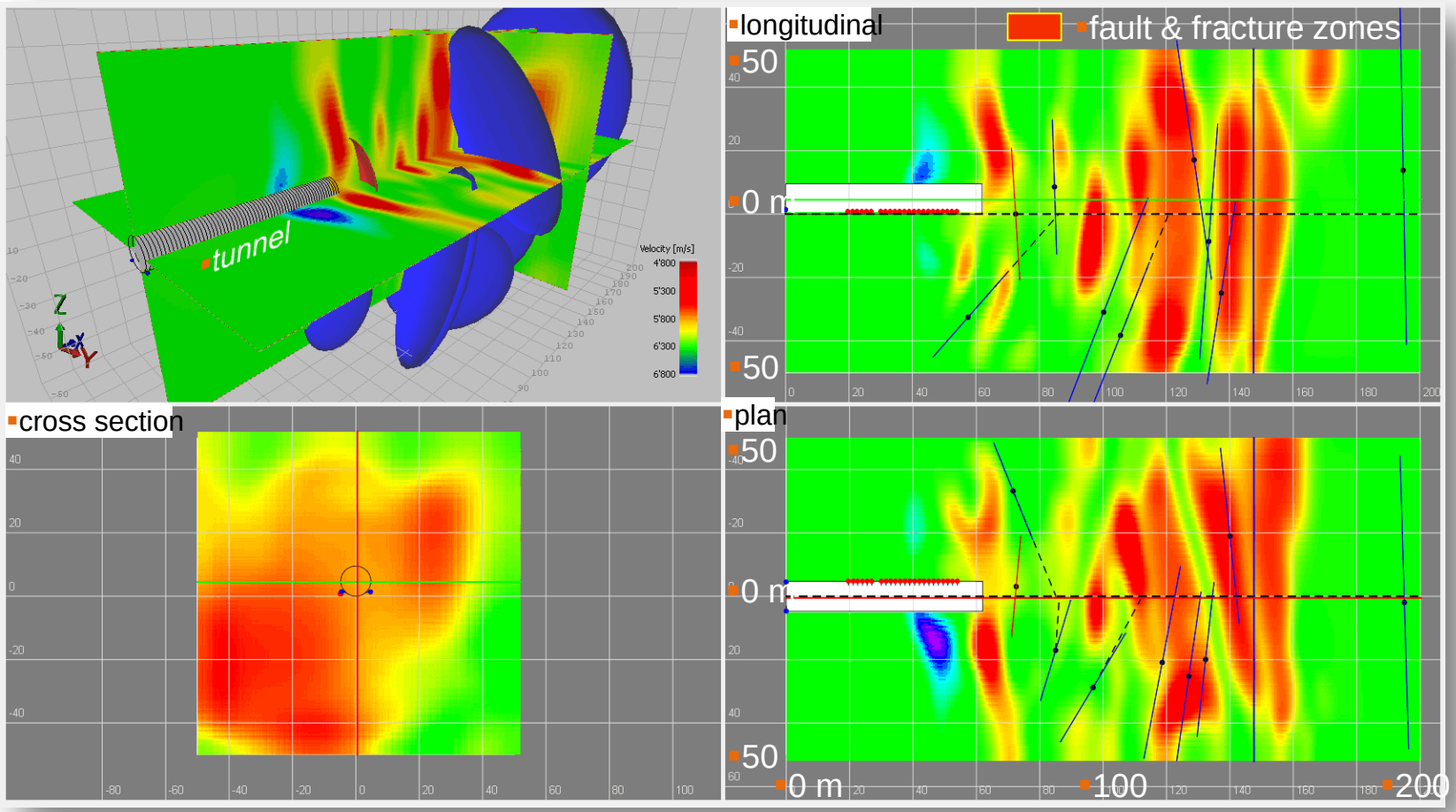
3D Tunnel Seismic Prediction

3D also, under specific conditions, of karst phenomena



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Exploration - Decision Tree

AlpTransit Gotthard San Gottardo

Gotthard-Basistunnel
Los 452/554, Tunnel Faido

Vorauserkundung TBM-Vortrieb
Konzept

Ausführung

Bericht: R175/06.010 J

Amberg Engineering AG, Regensdorf, 22. Mai 2008

Ingenieurgemeinschaft Gotthard - Basistunnel 50d
LOMBARDI AG BERATENDE INGENIEURE · PÖYRY · AMBERG ENGINEERING
c/o Amberg Engineering AG, Trockenloostr. 21, Postfach 27, 8105 Regensdorf-Watt, Tel.Nr.: +41-44-870 91 11; Fax-Nr.: +41-44-870 08 20

6 ABLAUF VORAUSERKUNDUNG TBM FAIDO

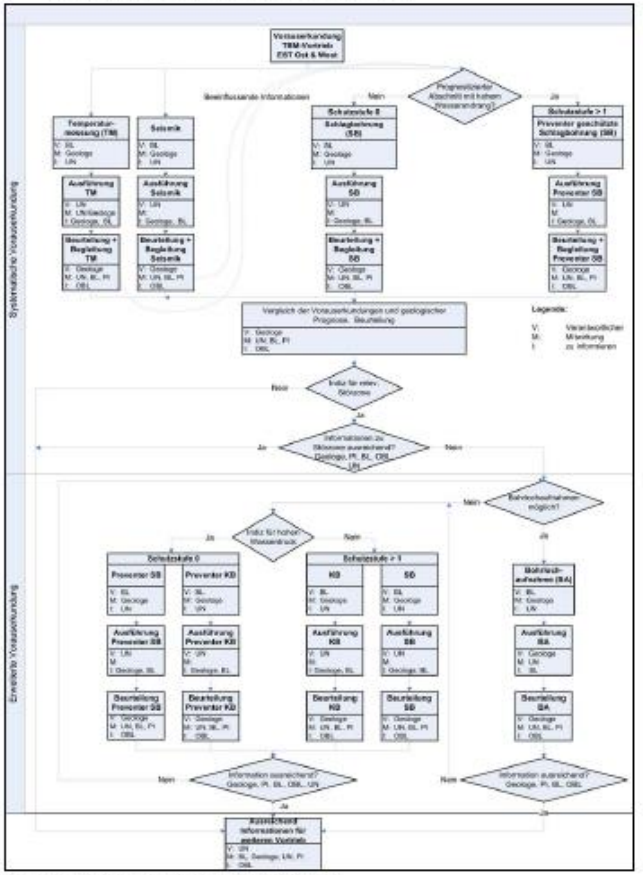


Abbildung 2: Ablaufschema für die Vorauserkundung

Exploration - decision tree

Systematic exploration

- Measure of temperature
- Tunnel Seismic Prediction
- Percussion drillings
- Protected with preventer

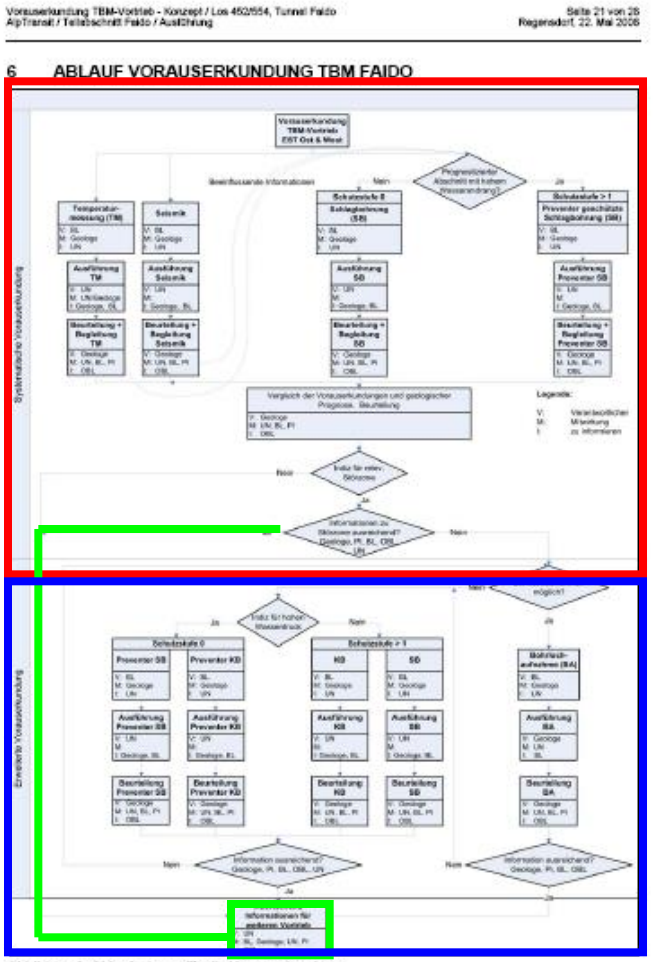
Depending on the results

Vorauserkundung TBM-Vortrieb
Konzept

Ausführung

Additional exploration

- Borlog scanning
- additional percussion drilling
- Core drilling
- Protected with preventer



Preparation for all site characteristics

Geology

Calcula-tions

Adapta-tions

Drawings

Standard excavation

Instruction

Monitoring

Explora-tion

Opera-tions

Action plan 1

Difficult Geology

Action plan 2

Calcula-tions

Drawings

Projects for Fault Zones (Piora)

techn reports

Instruction

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Logistics – Important Support

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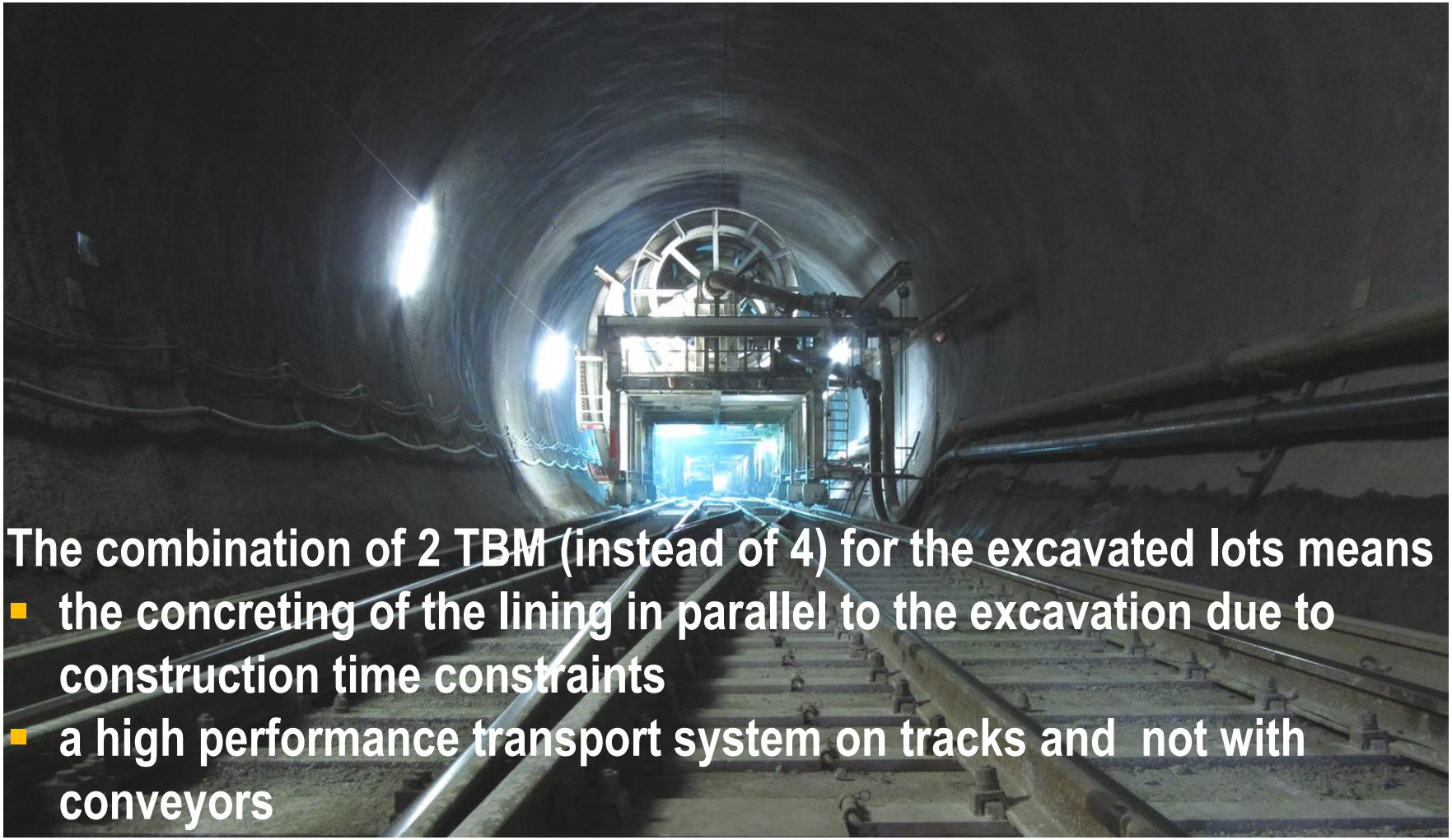
Conditions / bases



The combination of 2 TBM (instead of 4) for the excavated lots means

- the concreting of the lining in parallel to the excavation due to construction time constraints
- a high performance transport system on tracks and not with conveyors

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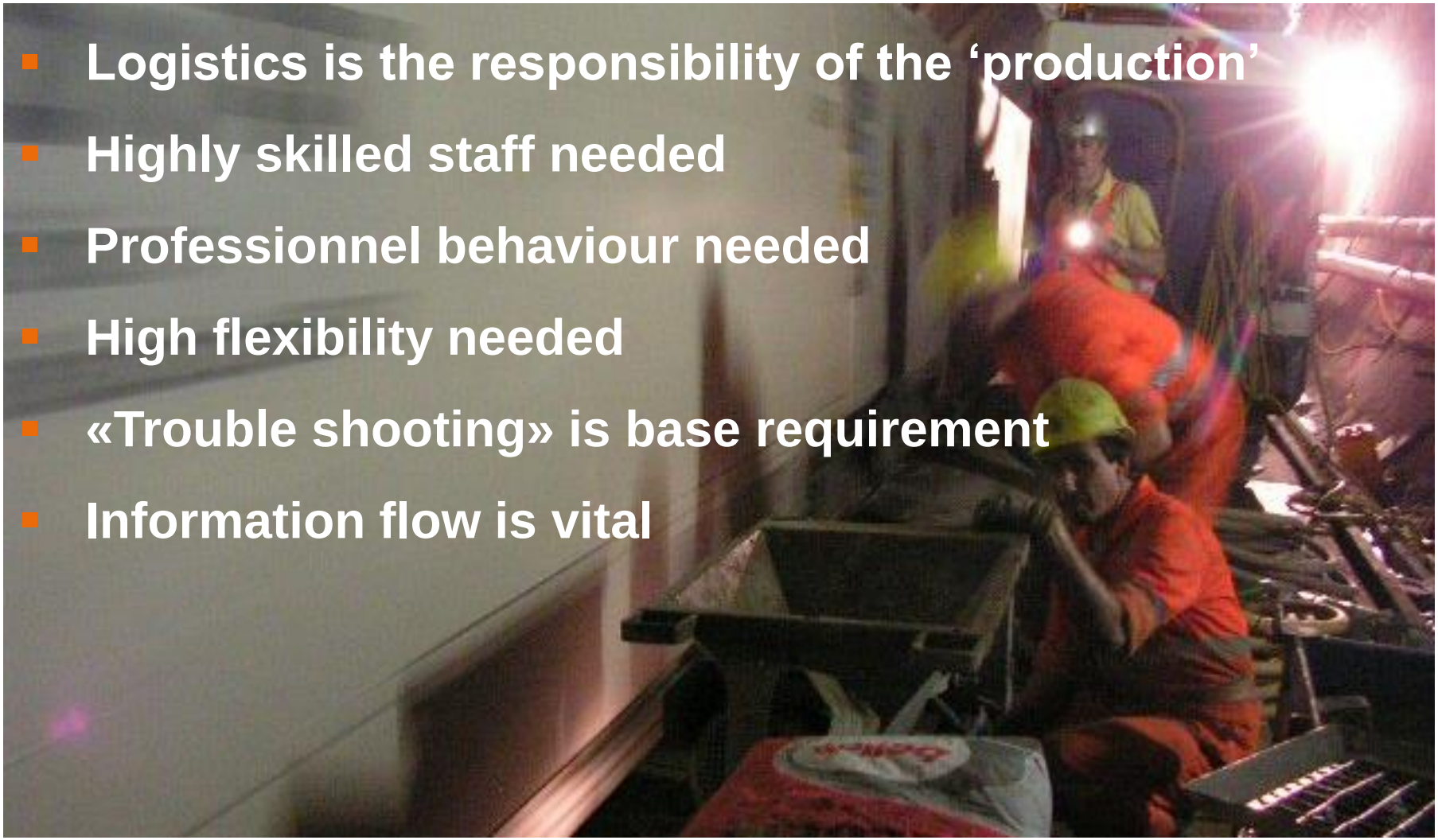
Logistics



- Logistics is the responsibility of the ‘production’
- Highly skilled staff needed
- Professionnel behaviour needed
- High flexibility needed
- «Trouble shooting» is base requirement
- Information flow is vital

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Logistics through Shafts

Definition of a coherent logistic concept serving as base for:

- the necessary hoisting systems in the shaft
- all other elements of the supply chain
- final necessary shaft diameter
- necessary transport handling elements at the shaft foot

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Base for the Shaft Dimensions

Construction period

- Hoisting of muck material
- Supply of support material
- Transport of all further material
- Ventilation (fresh air and exhaust air)
- Hoisting of personell and rescue
- Supply pipelines

Operation period

- Exhaust air shaft
- Fresh air shaft
- Space for hoisting installations
- Cable ducts

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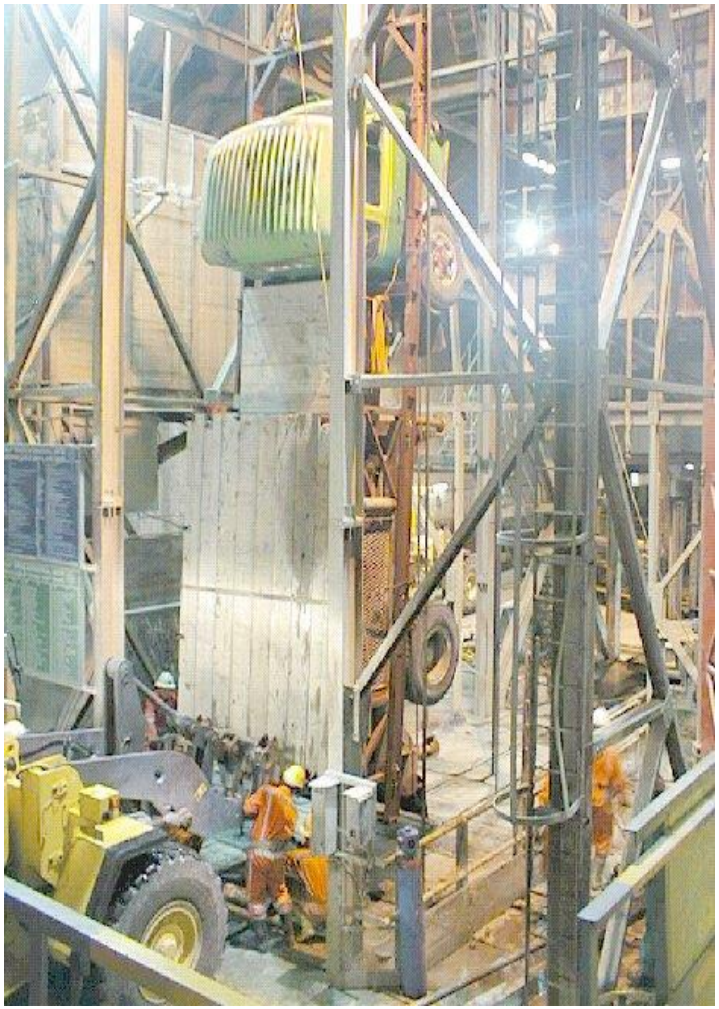
Logistics through Shafts



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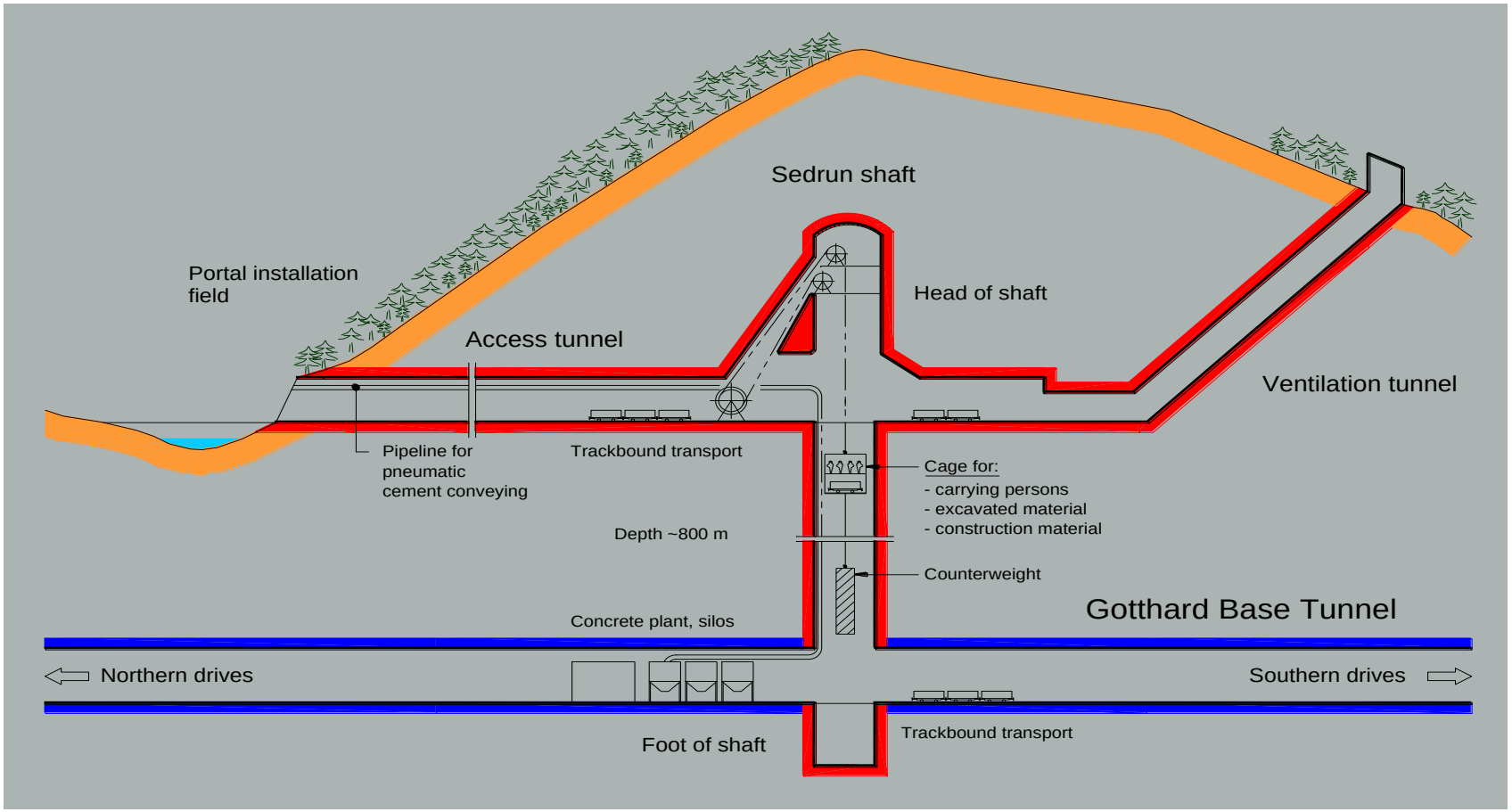
Sedrun Shaft at Gotthard Basetunnel



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Main Characteristics of Sedrun Shaft

- 800 m deep
- Diameter of excavation 8.6 m
- Preliminary support with shotcrete and anchors
- Concrete lining t = 25 cm
- Inner diameter 7.9 m

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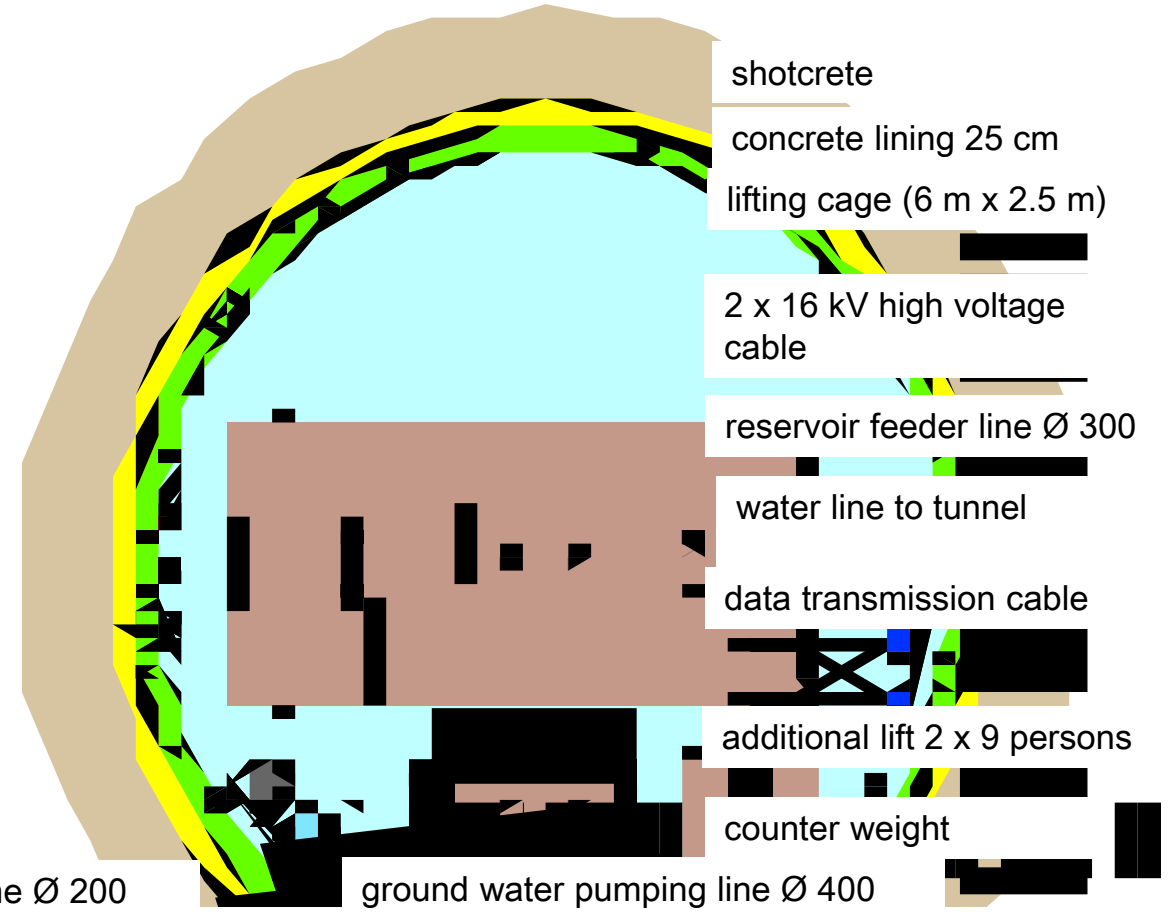
Section of Shaft I Sedrun with Equipment



2 x 16 kV high voltage

data transmission cable

mechanical plumb

compressed air line

ground water line Ø 100

cement pipe Ø 400

ground water pumping line Ø 400

Compressed air line Ø 300

Compressed air line Ø 300

cooling water line Ø 200

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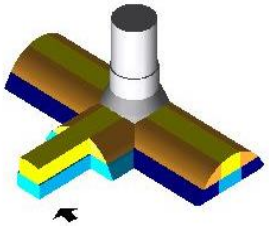
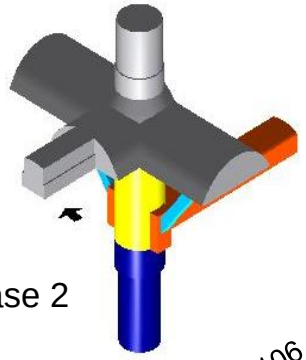
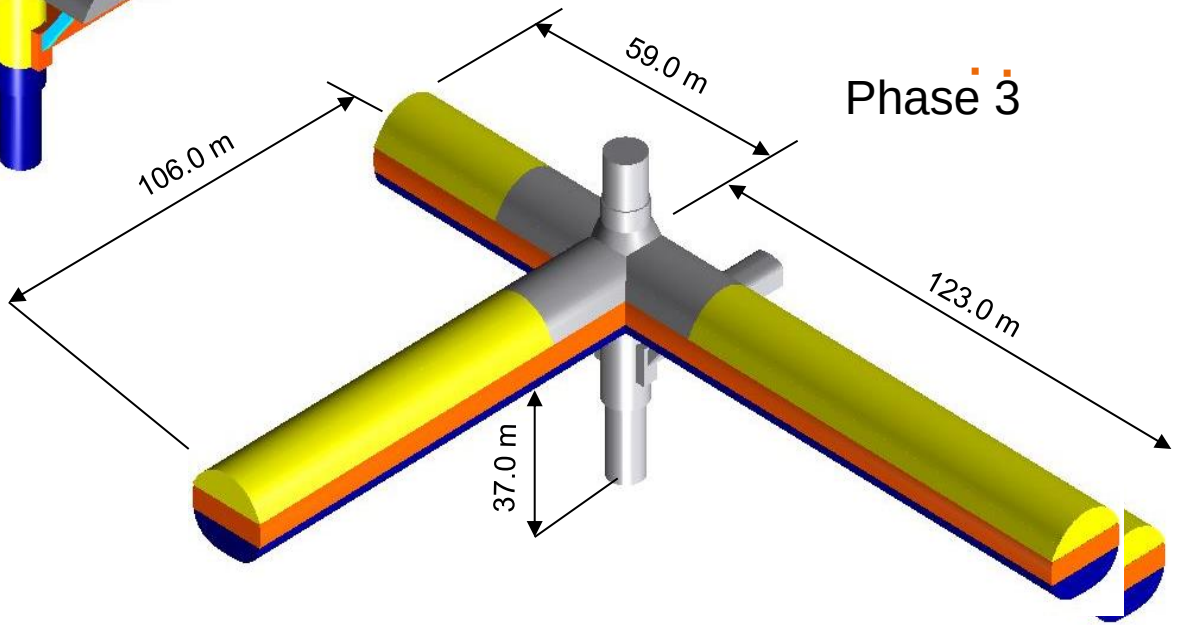
Construction Phases (Excavate the Caverns at Shaft Foot)



Phase 1



Phase 2



Phase 3

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Caverns at Shaft Foot

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Bench Heading in Longitudinal Cavern

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Concrete Production Plant at Shaft Foot

Even large end complex installations can be put at the foot of shafts and run from there

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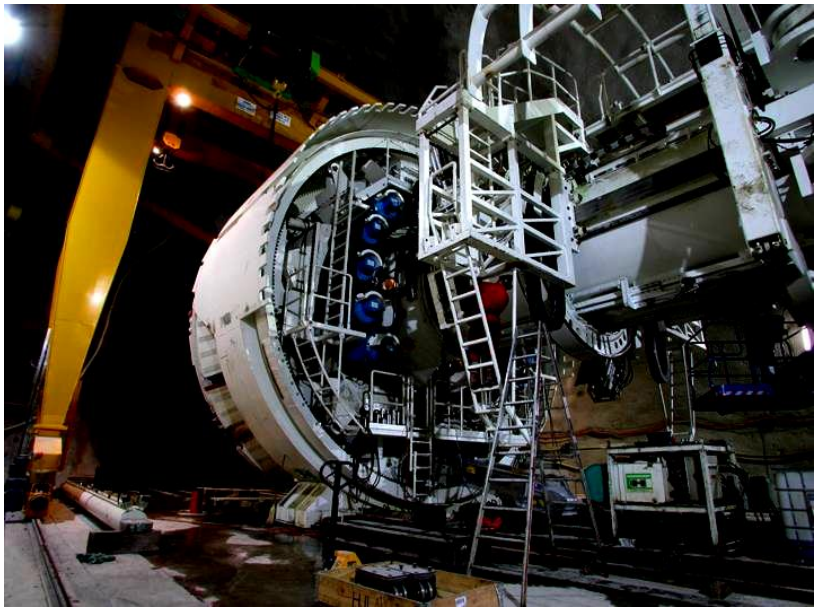
Assembly of TBM Underground
TBM + Back-up Installations = 440 m



TBM can be assembled, transported from one drive to the next and disassembled underground

Source: www.AlpTransit Gotthard.ch

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TBM Transport Underground by Low-Loading Truck

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Dismantling of TBM Underground

(Source: www.Apltransit.ch)

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Dismantling of TBM Underground

Source: AlpTransit Gotthard AG

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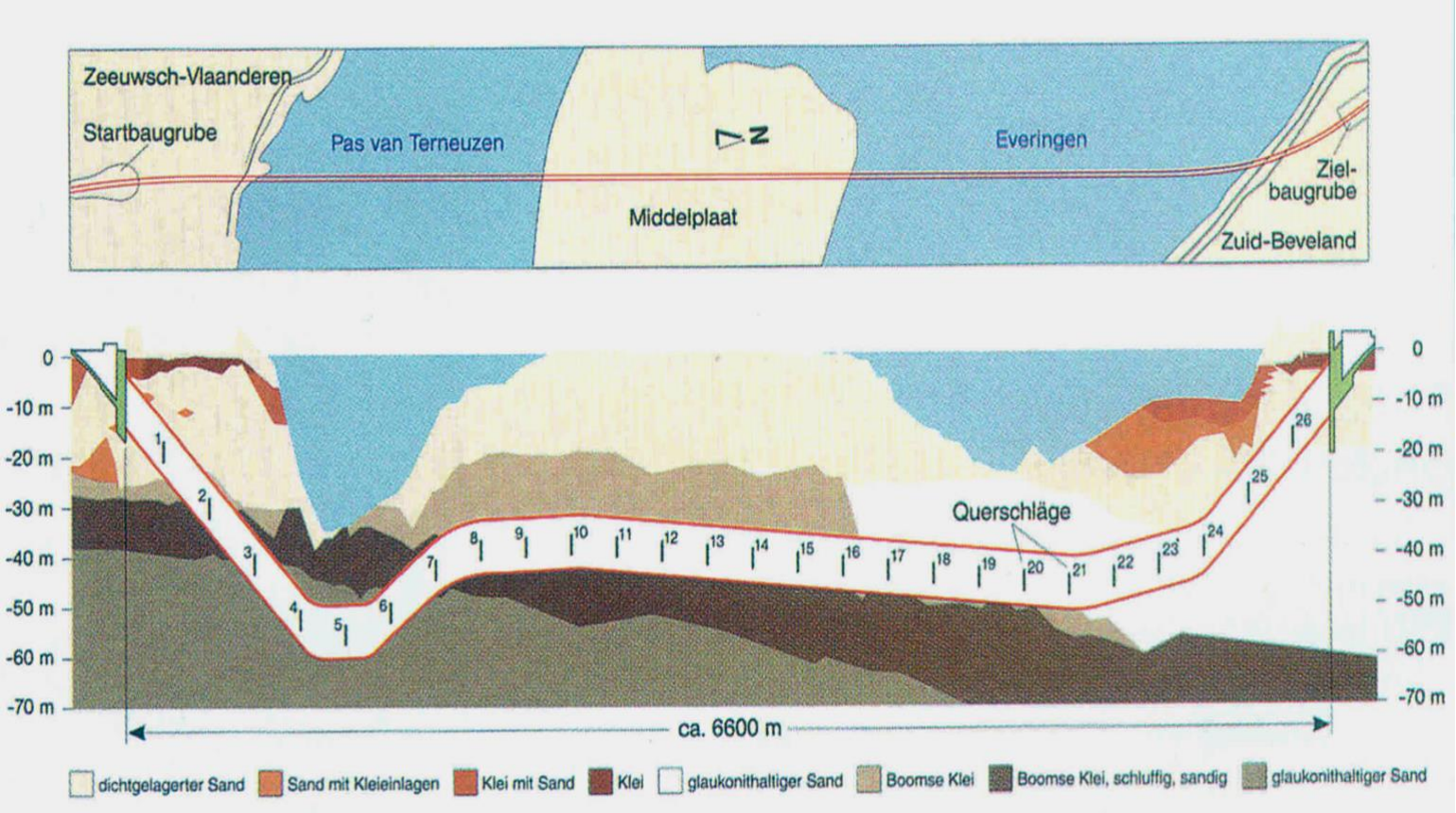
Soft Ground TBM with High Groundwater Pressure



TBM in soil and water pressure up to 10 bars are state of the art (example:Westershelde Tunnel in NL)

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Mixed Use of TBM (Rock and Soil)

Nowadays rock and soil can be excavated with the same TBM, necessary adaptations are made underground (example: Weinberg tunnel Zurich)

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Final Lining

TBM and segmental lining with pre-casted elements results in a watertight final lining

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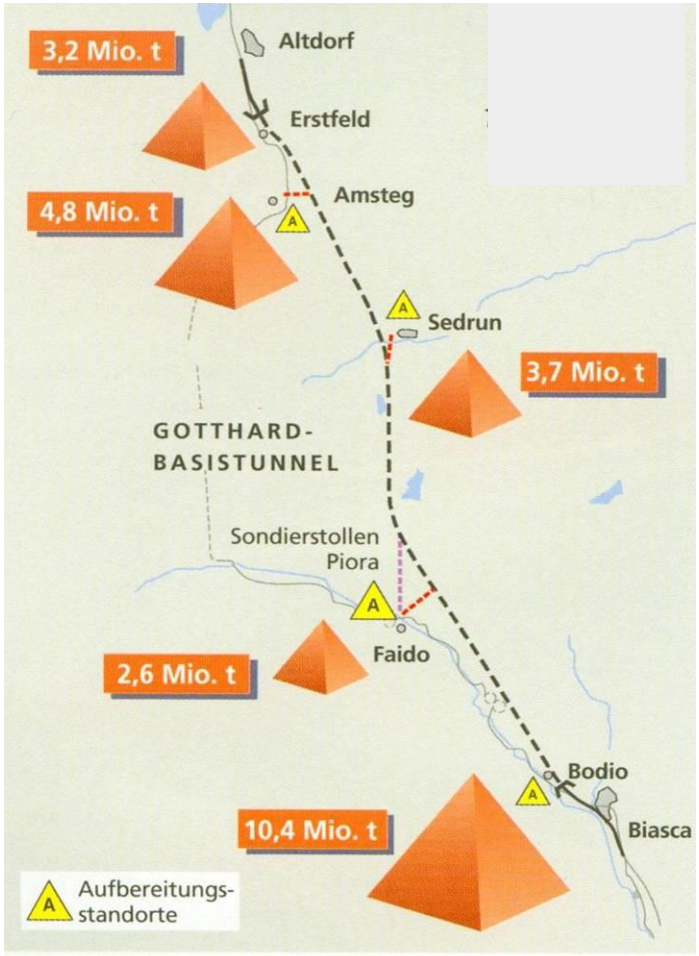
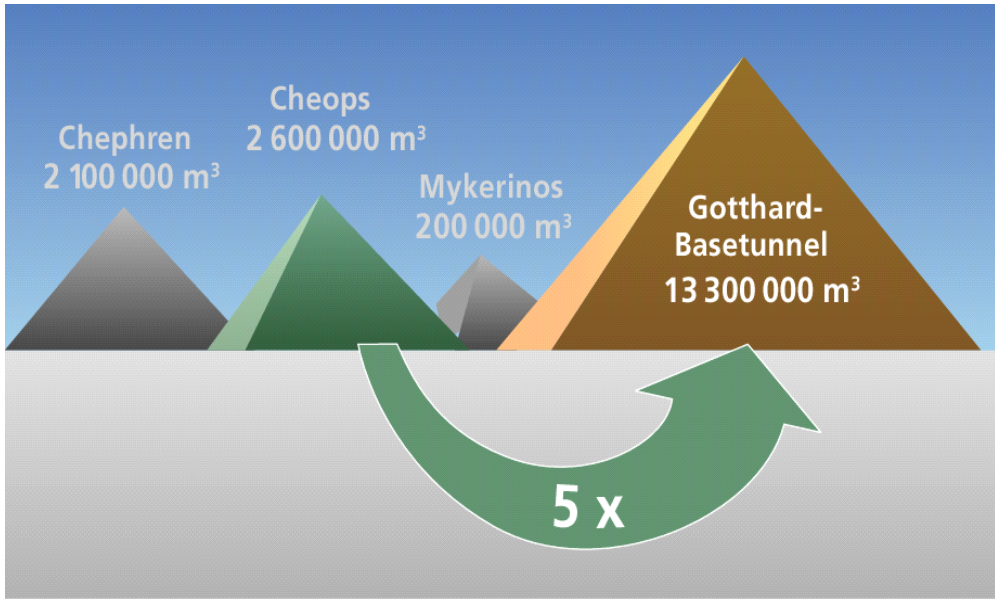
Amounts of Excavated Material





(Source: GBT, der längste Tunnel der Welt, Die Zukunft beginnt, Hrsg. R.E. Jeker Werd Verlag Zürich, 2002)

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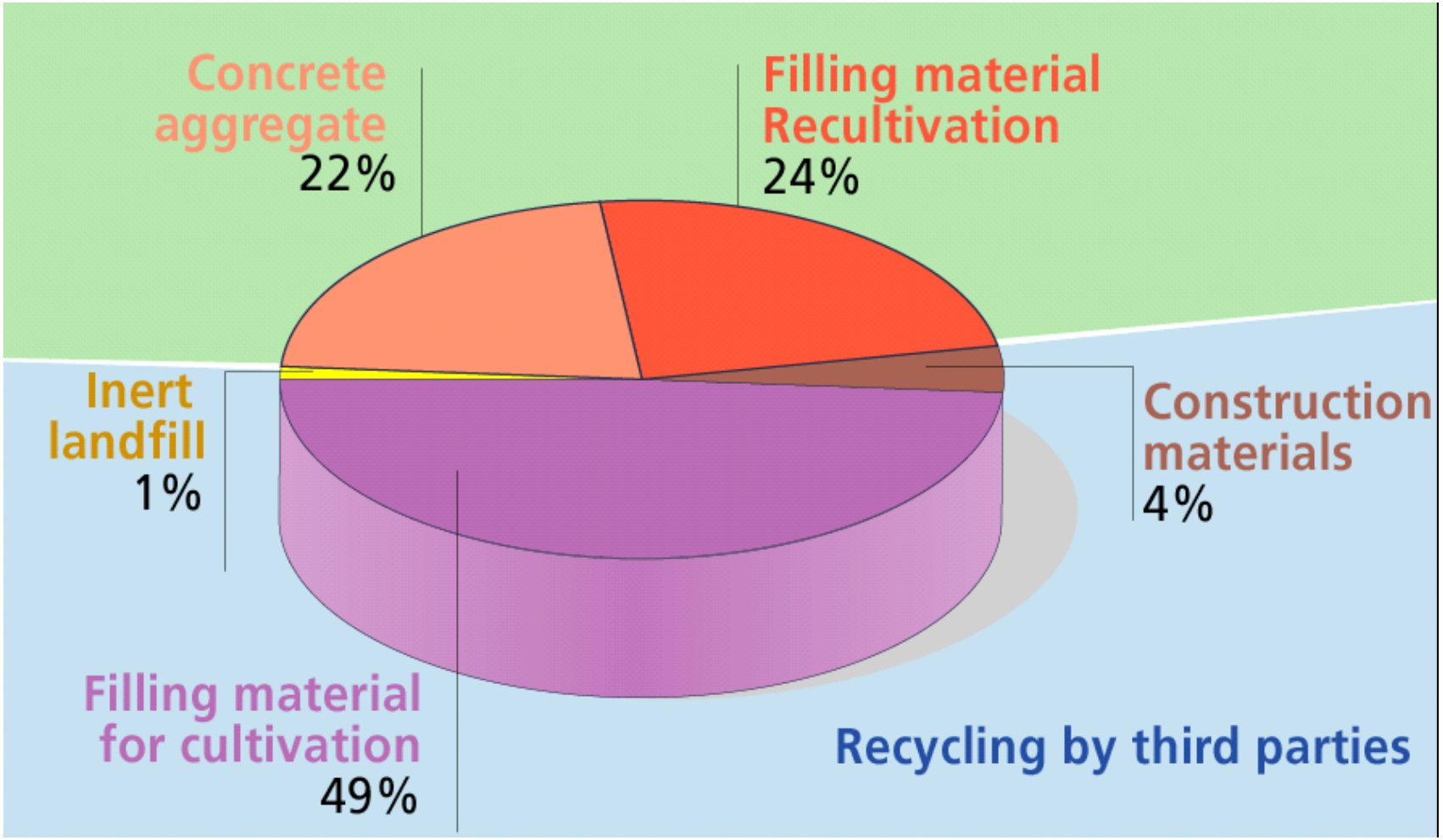
Recycling of Excavated Material



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Muck Treatment Plant on Installation Site Amsteg

(Source: www.Apltransit.ch)

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Faido - Muck Treatment / Concrete Production

- Quelle: AlpTransit Gotthard AG

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Muck Conveyor Belt

Faido - Muck Deposit Cavienca

- Quelle: AlpTransit Gotthard AG

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Bodio – Muck Deposit Buzza di Biasca

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Sedrun - Muck Deposit Val Bugwei

- Quelle: AlpTransit Gotthard AG

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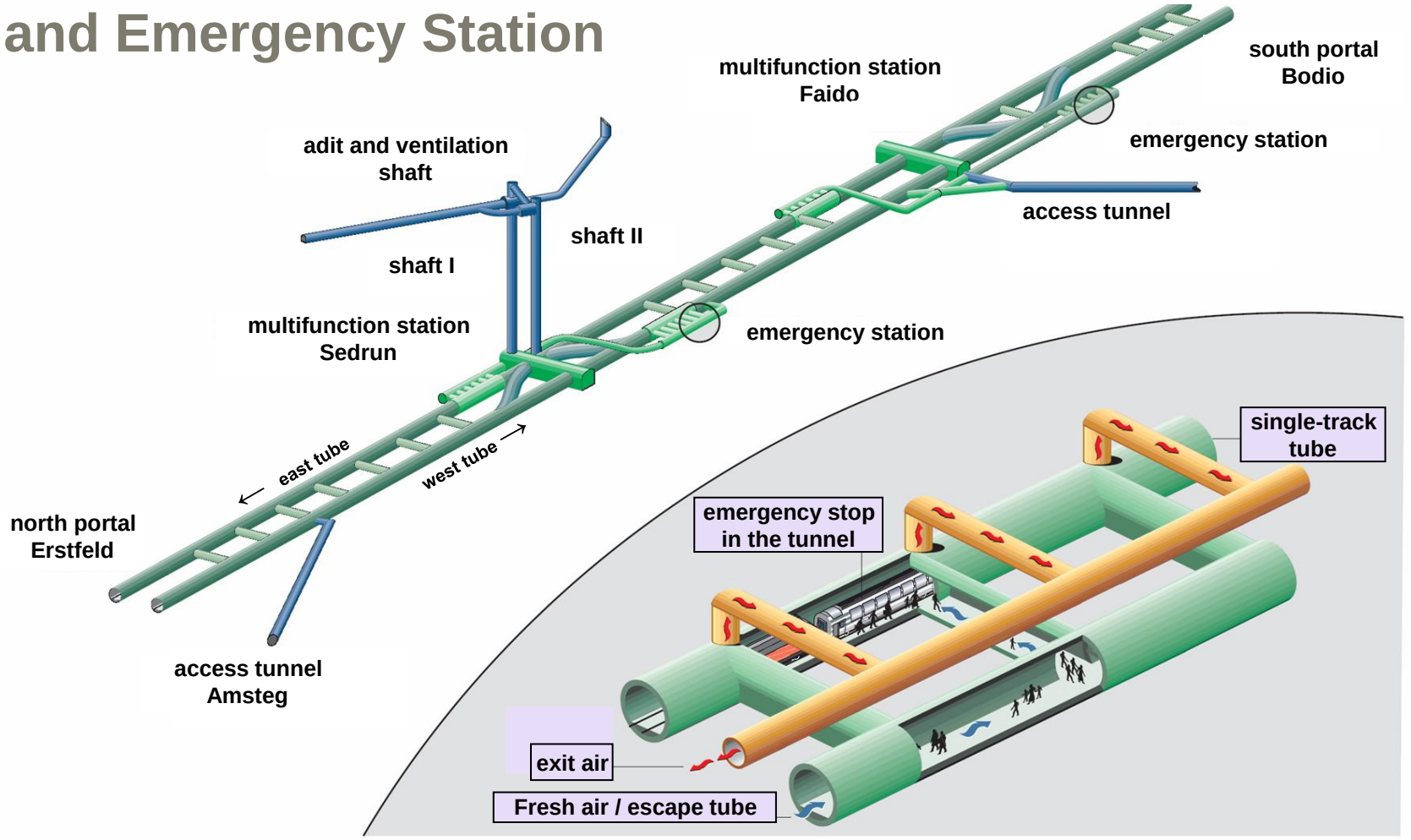
Gotthard Base Tunnel, Tunnel System and Emergency Station



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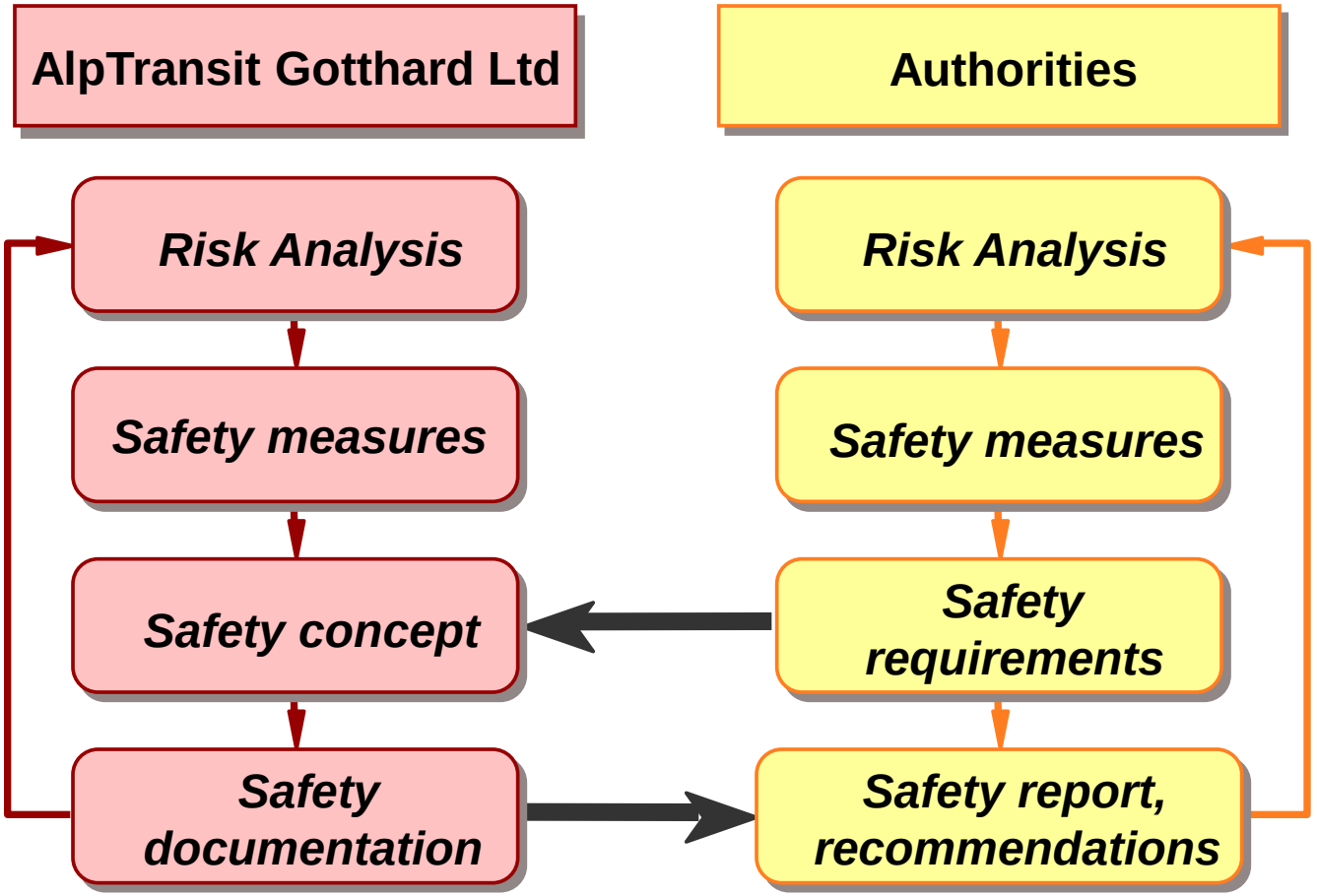
Design and Risk Assessment Process

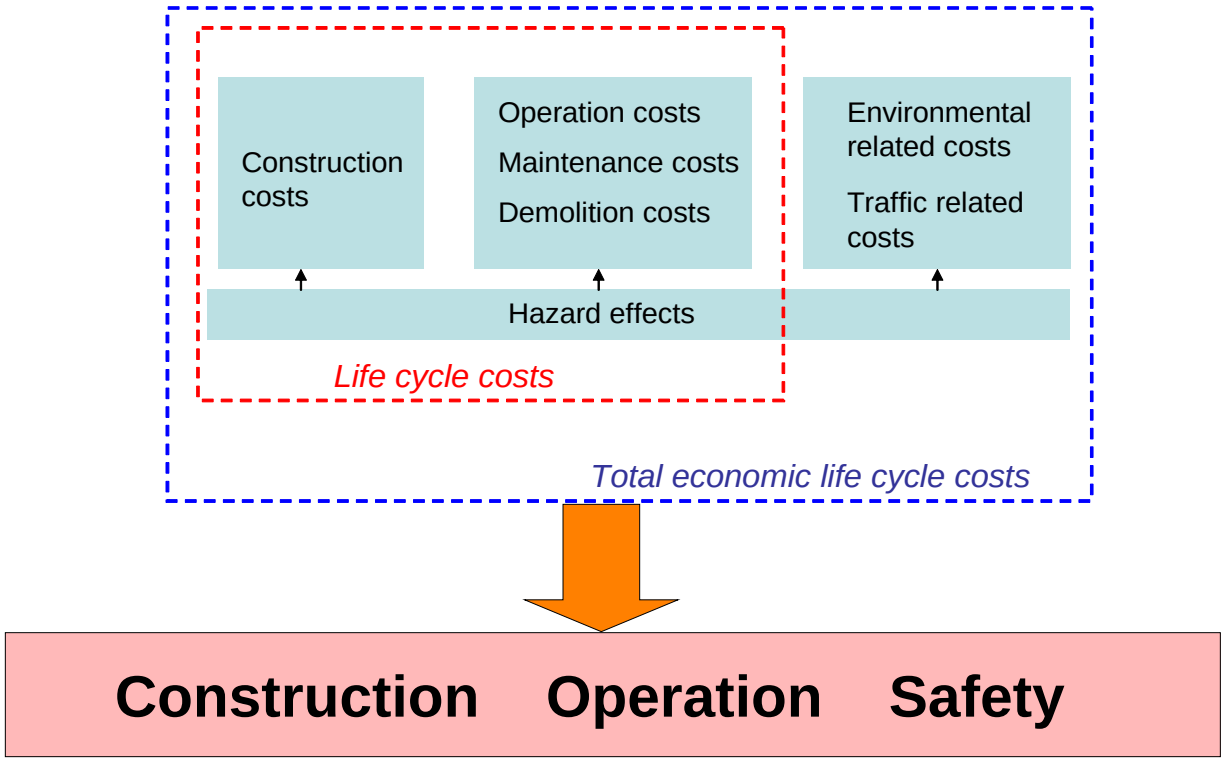
Safety integrated design for the GBT



Best solution = Maximum Total Utility

Aim at the overall best solution:

- Include various aspects (in accordance with the defined objectives and goals)
- Define total utility by weighing of the relevant aspects:



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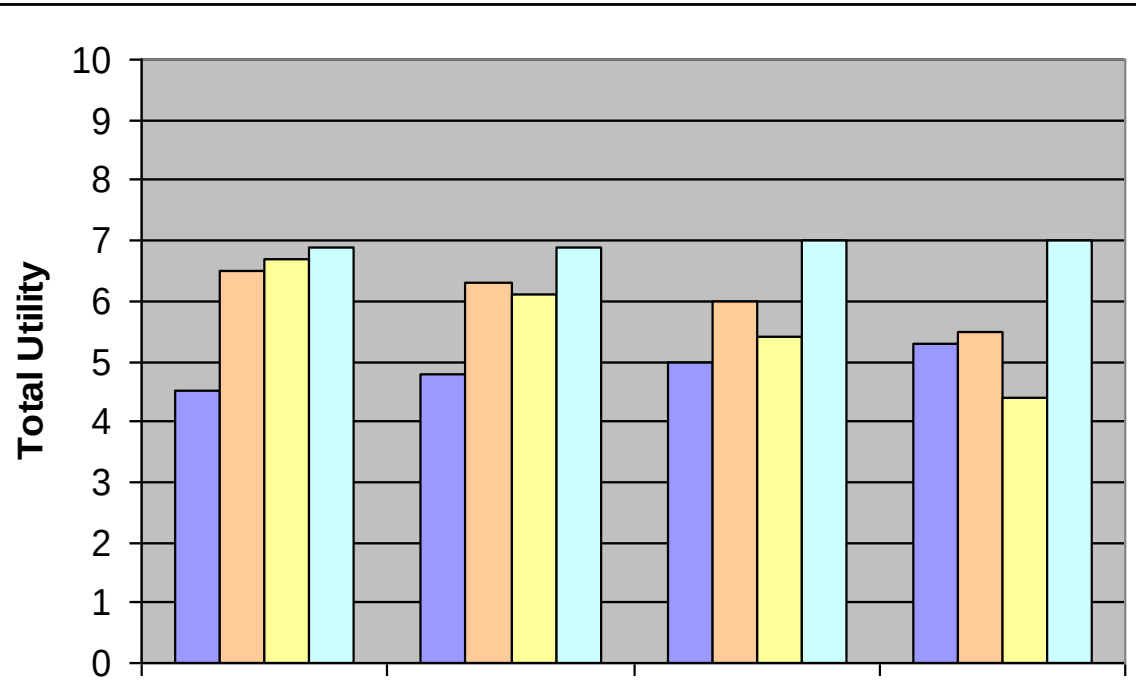
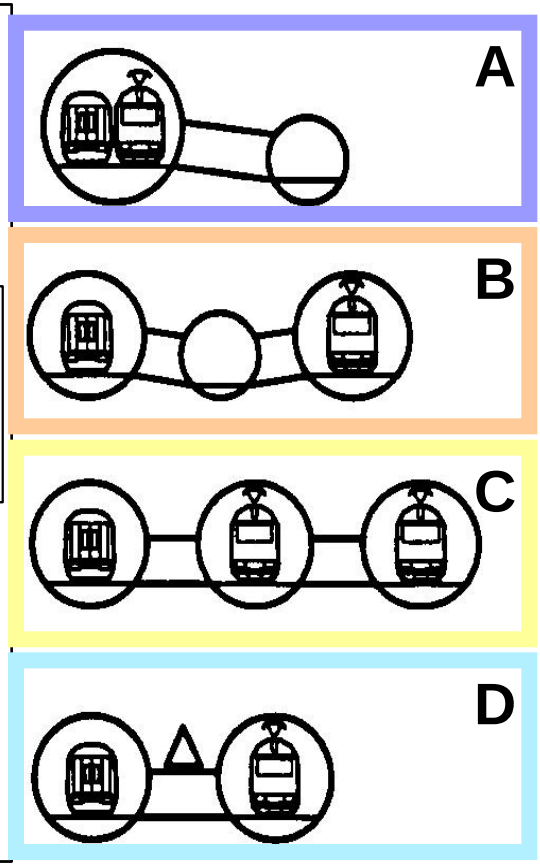
Comparison of Solutions



Construction	0.2	0.333	0.5	0.7
Operation	0.4	0.333	0.25	0.15
Safety	0.4	0.333	0.25	0.15

Weights



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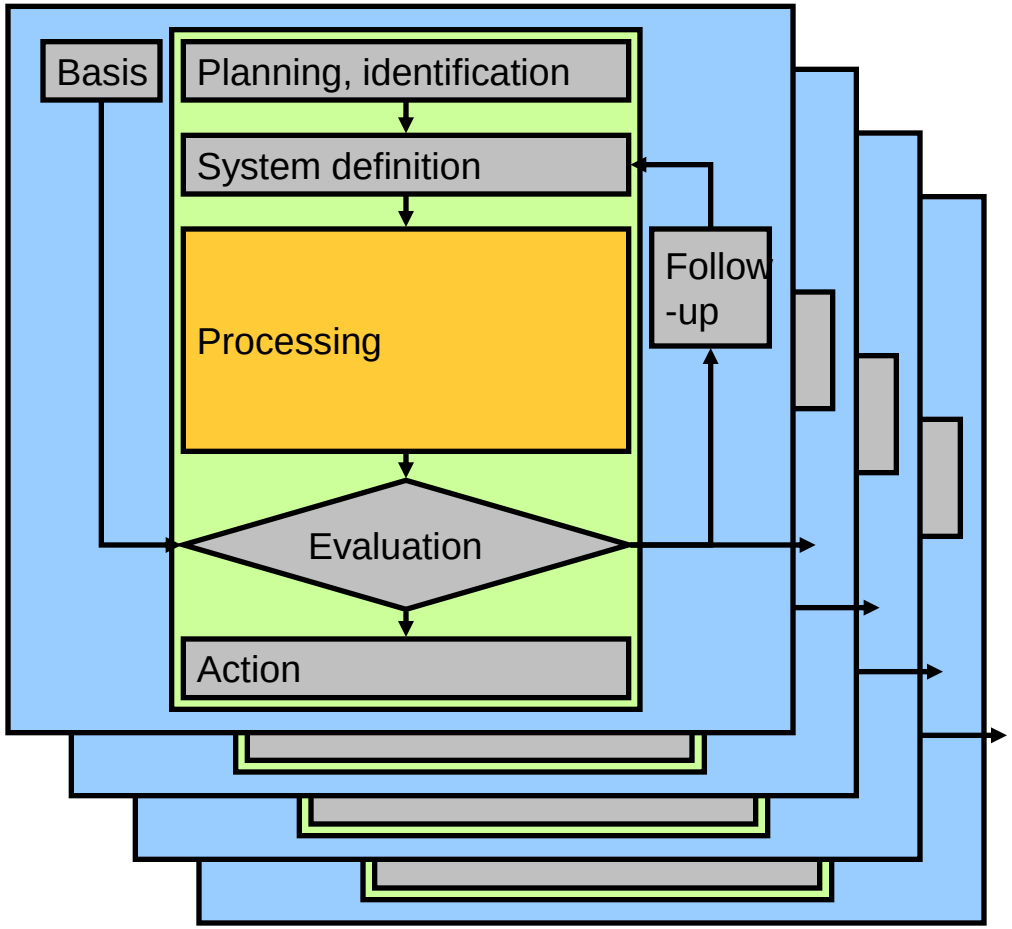
Risk and Safety Assessment



- Stepwise approach adapted to the actual needs
- Hazard identification / analysis
- Safety Review / benchmarking
- Qualitative risk analyses
- Quantitative risk analyses
- Supporting technical investigations and tests (specification of / use of)

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Other Tunnel Types than Railway Tunnels

The integrated design process is dependent on the actual conditions of

- the tunnel
- the traffic and composition
- economy
- Safety and rescue concepts
- operational conditions
- etc.

For another tunnel even of similar length some significant parameters may deviate.

Hereby another concept for the tunnel may prove to be preferable.

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Risk Management in Underground Construction

In the Gotthard Axis the constructional risks and their cost relevance have been evaluated at least every 6 months

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Risk Management

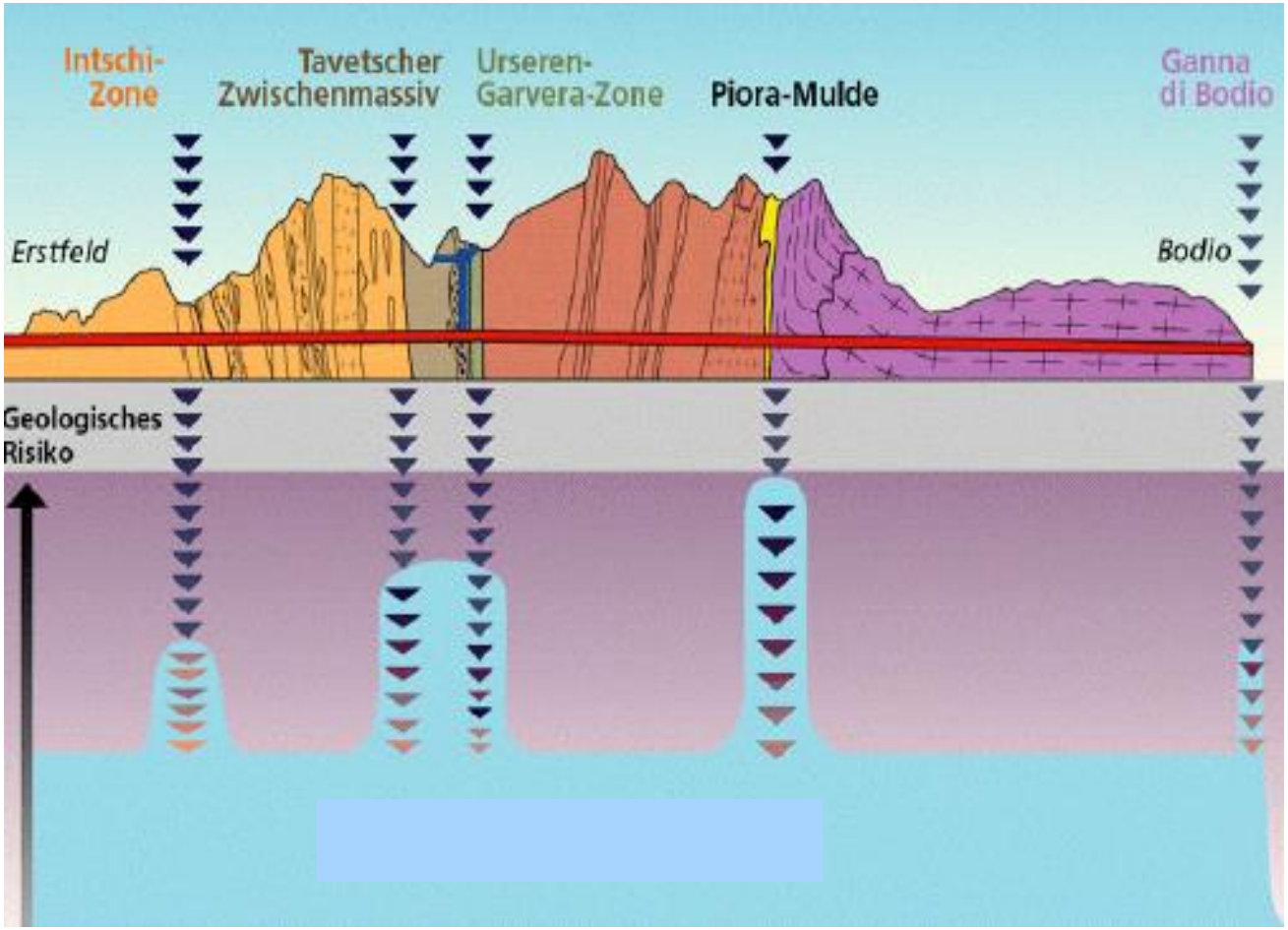
Risk management is the systematic process of identifying, analyzing and responding to project risks.

Risk management is

- **not only a single event**
- **a continuous process during the entire project.**

Therefore the risk control is part of the project life cycle from project initiation to project completion.

Risk Responding, Range of Geological Risks 1992 and Accuracy of Cost Estimation +/- 25%



(Source: Baumgärtner, Büchler, Systematik der Kostenrisiken am Beispiel Gotthard Basistunnel, Kasseler Projekt-management Symposium 2005)

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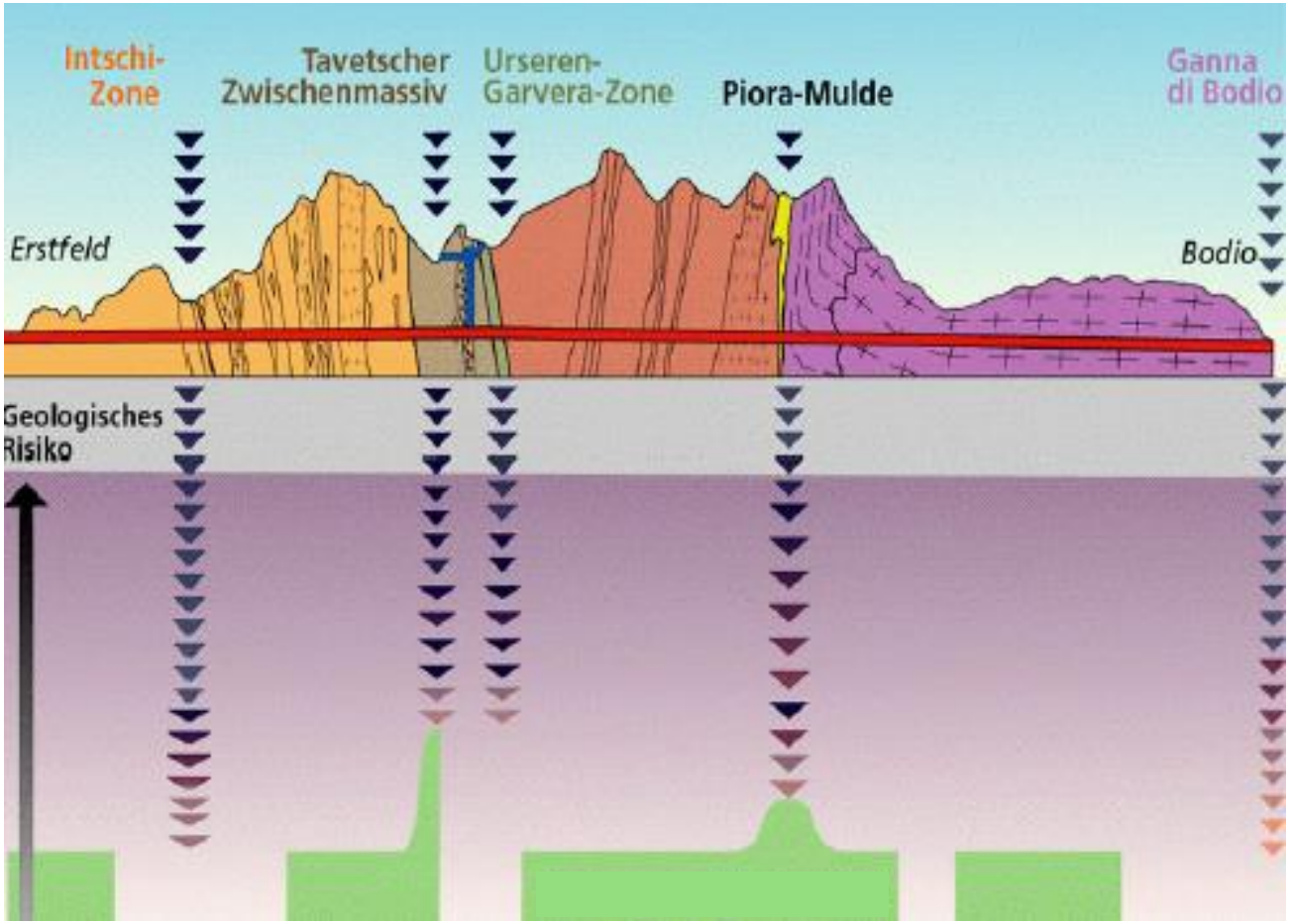
Risk Responding, Range of Geological Risks 2002 and Accuracy of Cost Astimation +/- 10%



(Source: Baumgärtner, Büchler, Systematik der Kostenrisiken am Beispiel Gotthard Basistunnel, Kasseler Projekt-management Symposium 2005)

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FCC and Gotthard Basetunnel

	item	GBT	FCC	c	nc
purpose	use in operation	single track high speed train tunnel	experimental structure		x
geographical and geological conditions	rock conditions	pre alpine and alpine rock formations heavily tectonically deformed with great fault zones (expl. Piora)	mostly flat layers of bedrock few disturbed in contact zones with pre alpine rock and limestone of Jura formations		x
	overburden	up to 2000 m middle hard to hard rock often tectonically deformed metamorphic rock	up to 600 m soft to middle hard rock mostly undisturbed bedrock		x
	core drilling (geol. prospection)	in the high mountains often impossible to find access or place to drill systematically every some 100 m	in FCC area every point of the future construction can be easily reached with a core drill		x
Tunnel climate (temperature and air)	tunnel temperature	rock temperature span lies between some minus degrees (winter time) up to over 40 degrees	more or less constant rock temperature, variations of temperature might influence experiments		x
	air movements	high speed trains are pushing the air through the tunnel when passing	no air movements except turbulences in areas where a machine is producing a lot of heat		x
	fresh air	during operation air has to be changed continuously also to avoid upcoming mist which affects train drivers sight	during maintenance FCC to be ventilated according to number of staff and machines in tunnel, for operation specifications are to be fixed		x
safety	fire-life-safety-system	persons in trains are not trained to behave during any hazard or how to extinguish a fire	staff of CERN will be trained and well instructed about where to go or handle any hazard		x
	evacuation	Up to 1000 persons in one train have to be brought as fast as possible to a save well illuminated and ventilated protected room or trough an escape tunnel to the surface	staff in sectors which can be evacuated can use this way, all others can be brought to safety chambers (also used during construction and accelerator installation) to wait there for being rescued		x

(c = comparable, nc = not comparable)

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FCC and Gotthard Basetunnel

	item	GBT	FCC	c	nc
Realization of FCC	owners organisation (planning/ realization/ starting operation)	complex project with different stages (planning construction, rail engineering and safety/ tendering and realization civil construction / tendering and realization rail engineering / tendering and realization safety / hand over from construction to rail engineering and safety installations, starting operation)	complex project with different stages (planning construction, accelerator and safety / tendering and realization civil construction / tendering and realization accelerator / tendering and realization safety / hand over from construction to accelerator and safety installations, starting operation)	x	
	site logistic	5 big building sites were necessary to realize the whole project, sites also used for rail engineering and safety purposes	4 – 5 big building sites and 4 to 5 middle sized building sites will be necessary to realize the whole project, sites also used for accelerator installation and safety purposes	x	
	aggregate processing of muck and/or disposal	all building sites were equipped with aggregate processing plants to prepare aggregates for the concrete, muck was disposed in landfills and lake Lucerne	Encountered rock is mostly not suited for aggregate processing, muck could be used for landscaping around surface buildings of shaft accesses, rest to be deposed in landfills	x	(x)

(c = comparable, nc = not comparable)

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