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LESSONS LEARNED FROM

MAJOR ALPINE RAILWAY TUNNELS

A Cross-Project Perspective on Design, Risk, and Collaboration

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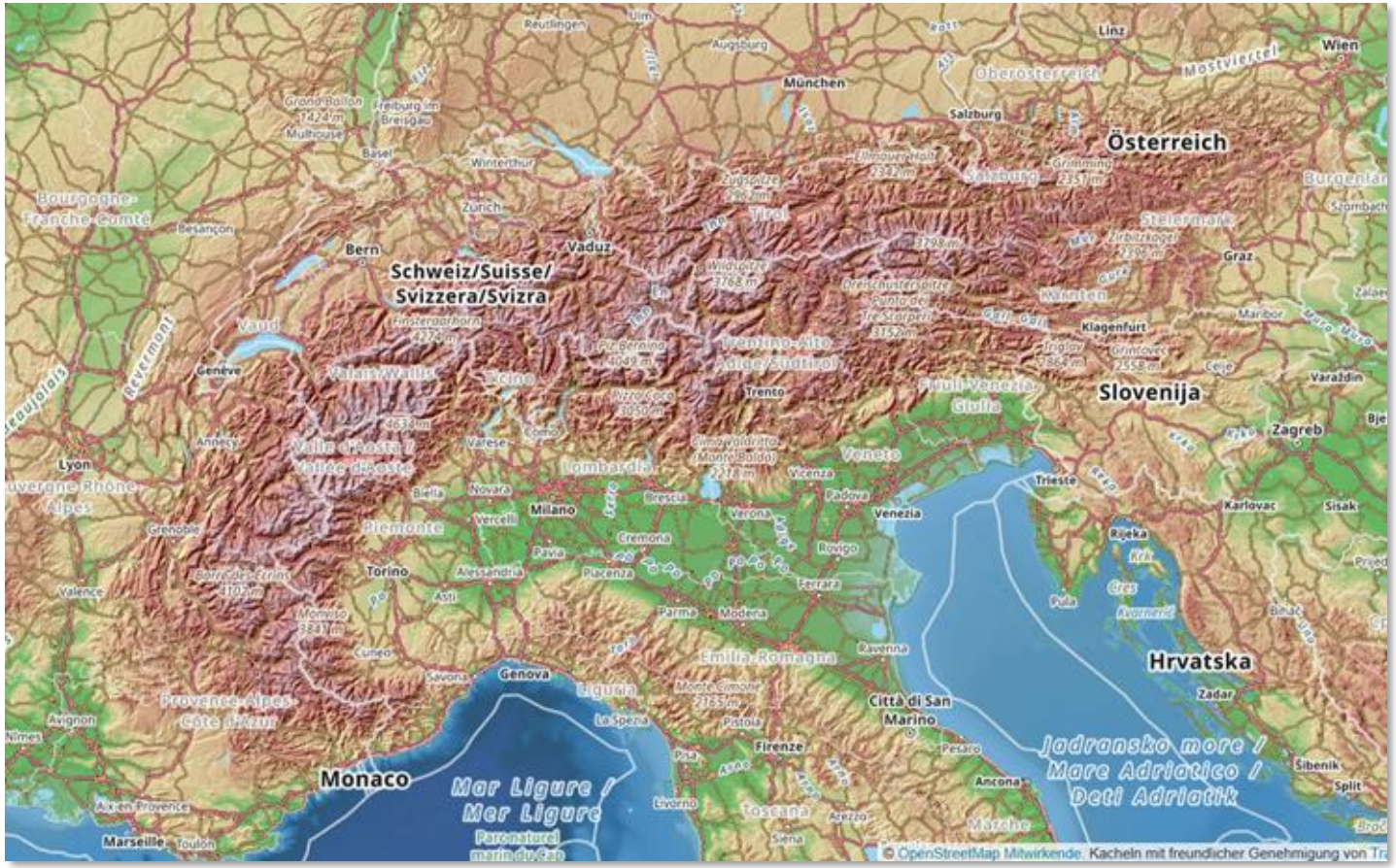
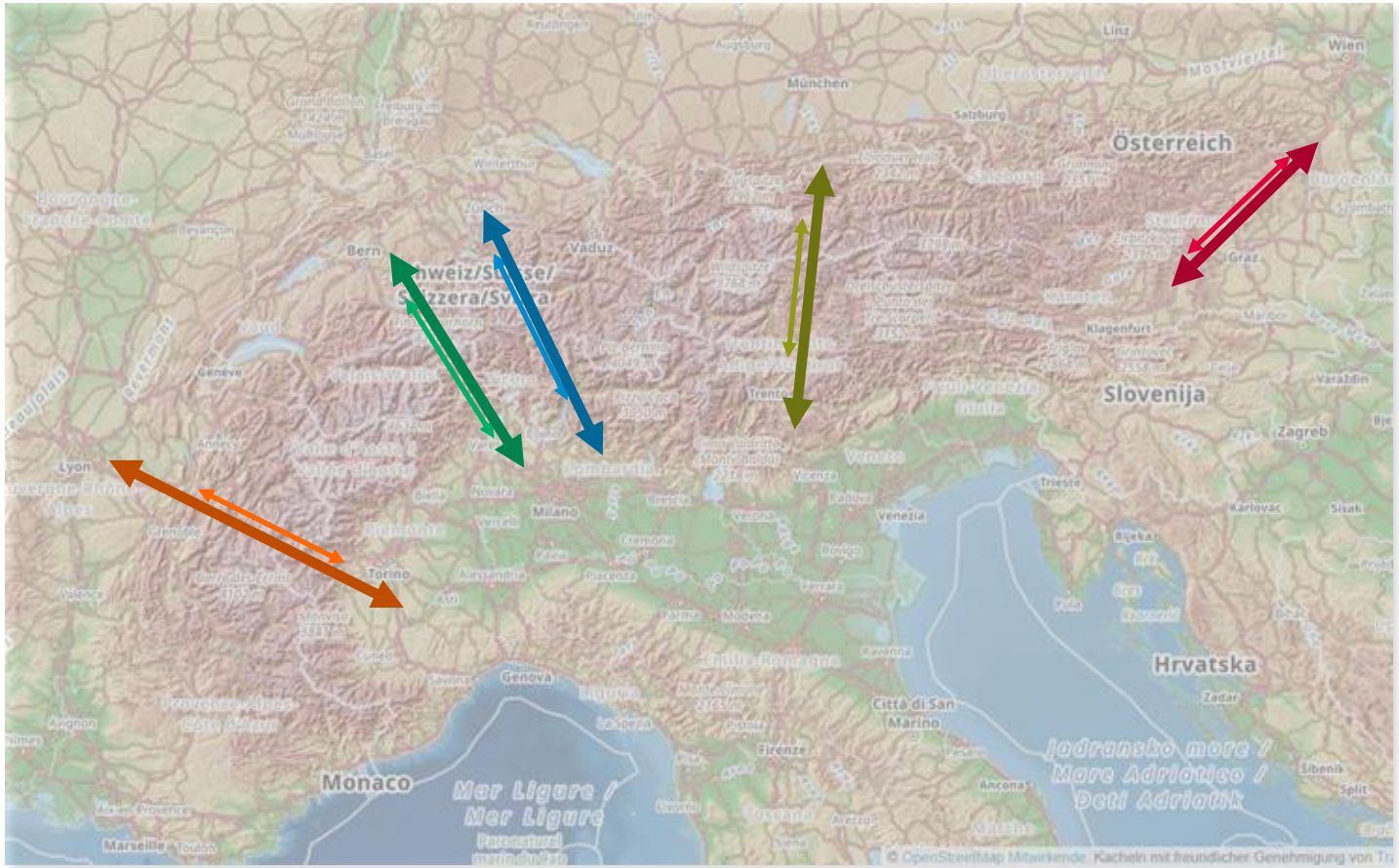
Presentation overview

- Major Alpine Railway Tunnels
- Cross-border collaboration
- Caracteristics of base tunnels
- Dealing with uncertainties
- Flexibility requirements
- Reuse of excavation materials for concrete
- Key lessons learned

Major Alpine Railway Tunnels



Major Alpine Railway Tunnels



Semmering	1.5 km	1854
Brenner		1867
Mont Cenis (Fréjus)	13.7 km	1871
Gotthard	15.0 km	1882
Simplon I	19.8 km	1906
Lötschberg	14.6 km	1913
Simplon II	19.8 km	1921
Lötschberg BT	34.6 km	2007
Gotthard BT	57.1 km	2016
Ceneri BT	15.4 km	2020
Semmering BT	27.3 km	2029
Brenner BT	55.0 km	20??
Lyon-Torino BT	57.5 km	20??

Cross-border collaboration

- **Regulatory alignment** - Harmonising safety standards, approval procedures across borders
- **Contract Structures** - Bilateral treaty frameworks, joint client entities, innovative risk-sharing
- **Cultural & Language** - Communication protocols, multilingual documentation, unified terminology
- **Logistics** - Cross-border supply, workforce mobilisation, emergency coordination across jurisdictions.

Success factors

- Early stakeholder engagement
- Joint technical committees
- Shared dashboards
- Escalation paths predefined
- Cross-team site visits
- Integrated risk registers

Alpine Base Tunnels – flat and low crossings

Base tunnel : «at the base of the mountain»

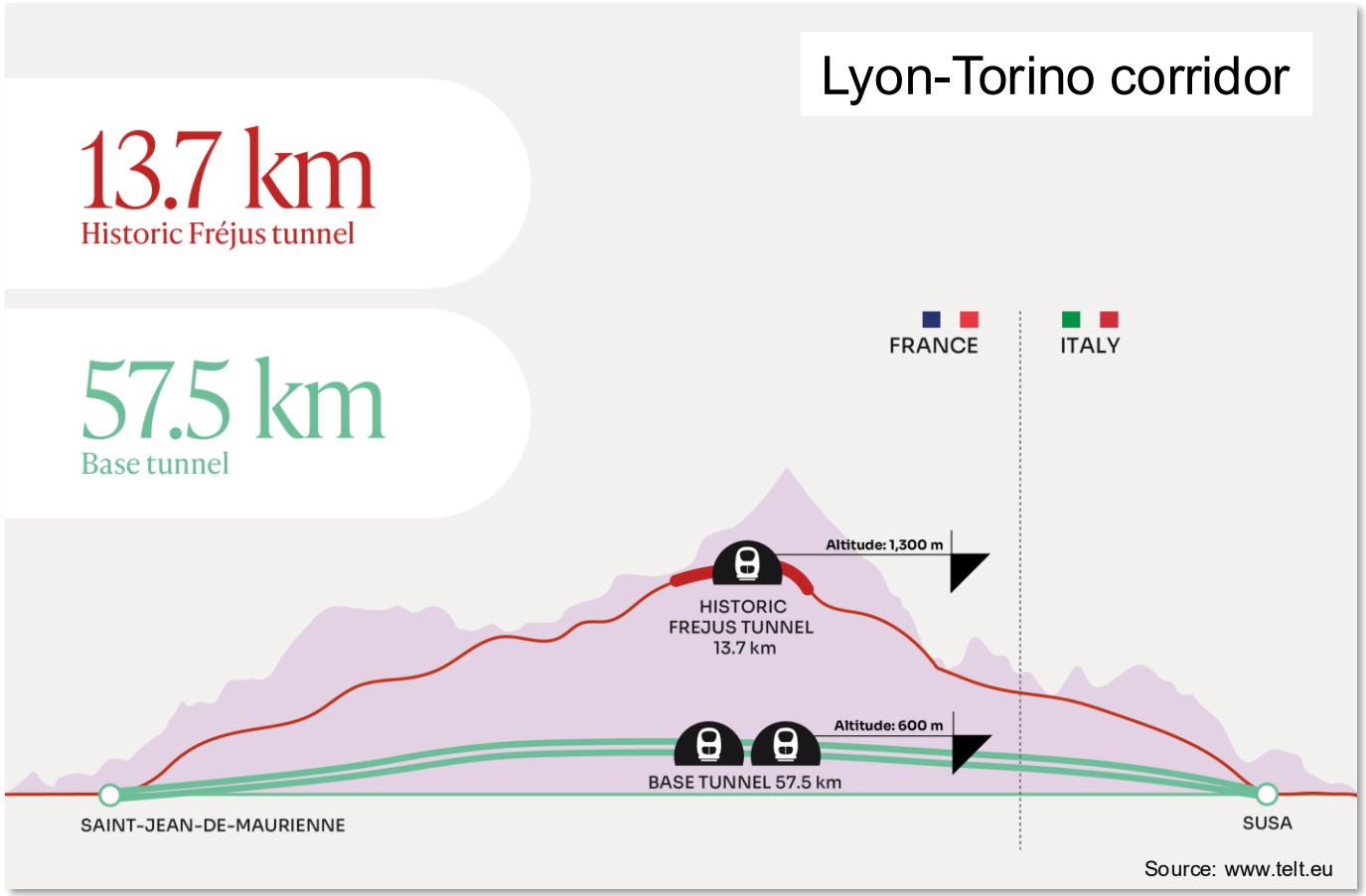
- Flat routes (7 ‰ – 13 ‰)
- Low peak altitude
- Straight alignment

resulting in

- Shorter routes
- Higher train weights
- Higher train speed
- More capacity

compared to historical lines.

Mixed trafic



Alpine Base Tunnels – Special features

Mixed trafic

- Passenger trains: 200 – 250 km/h
- Freight trains: 100 – 120 km/h

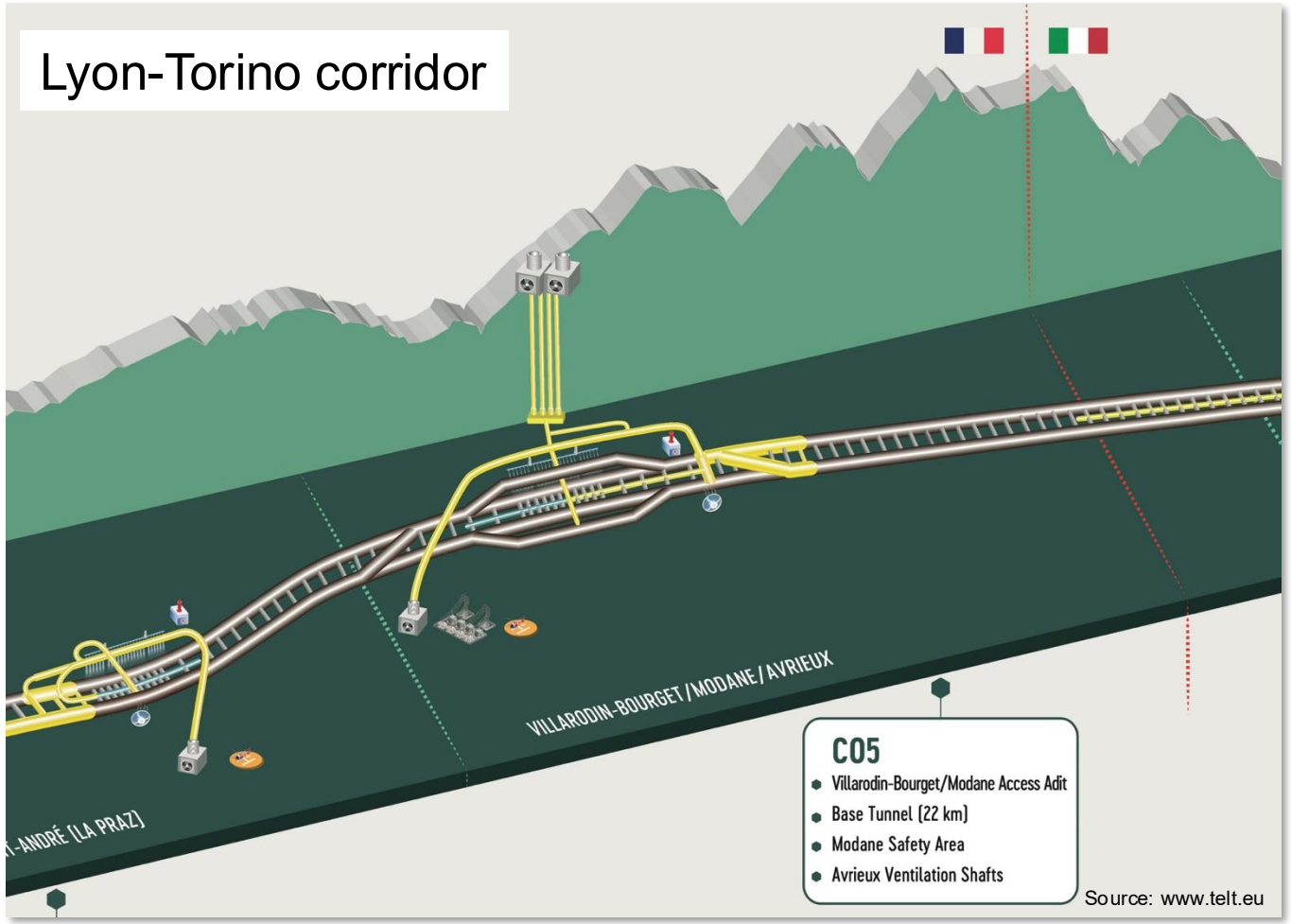
causes a significant drop of capacity on the long streches of a base tunnel

Need for overtaking facilities

- Outside the tunnel
- Inside the tunnel in the case of the Lyon-Torino BT

Emergency stations for evacuation and smoke extraction

Crossover galleries to allow closing of only a part of the system in case of maintainance



Alpine Base Tunnels – Long and deep tunnels

Length: Need for intermediate attack points, resulting in several parallel sites

High overburden (> 2000 m):

- Geotechnical difficulties like tectonic formations, squeezing rock, rockburst
- Hydrogeological challenges
- Rock temperature
  - Construction challenges
  - Maintenance and repair works

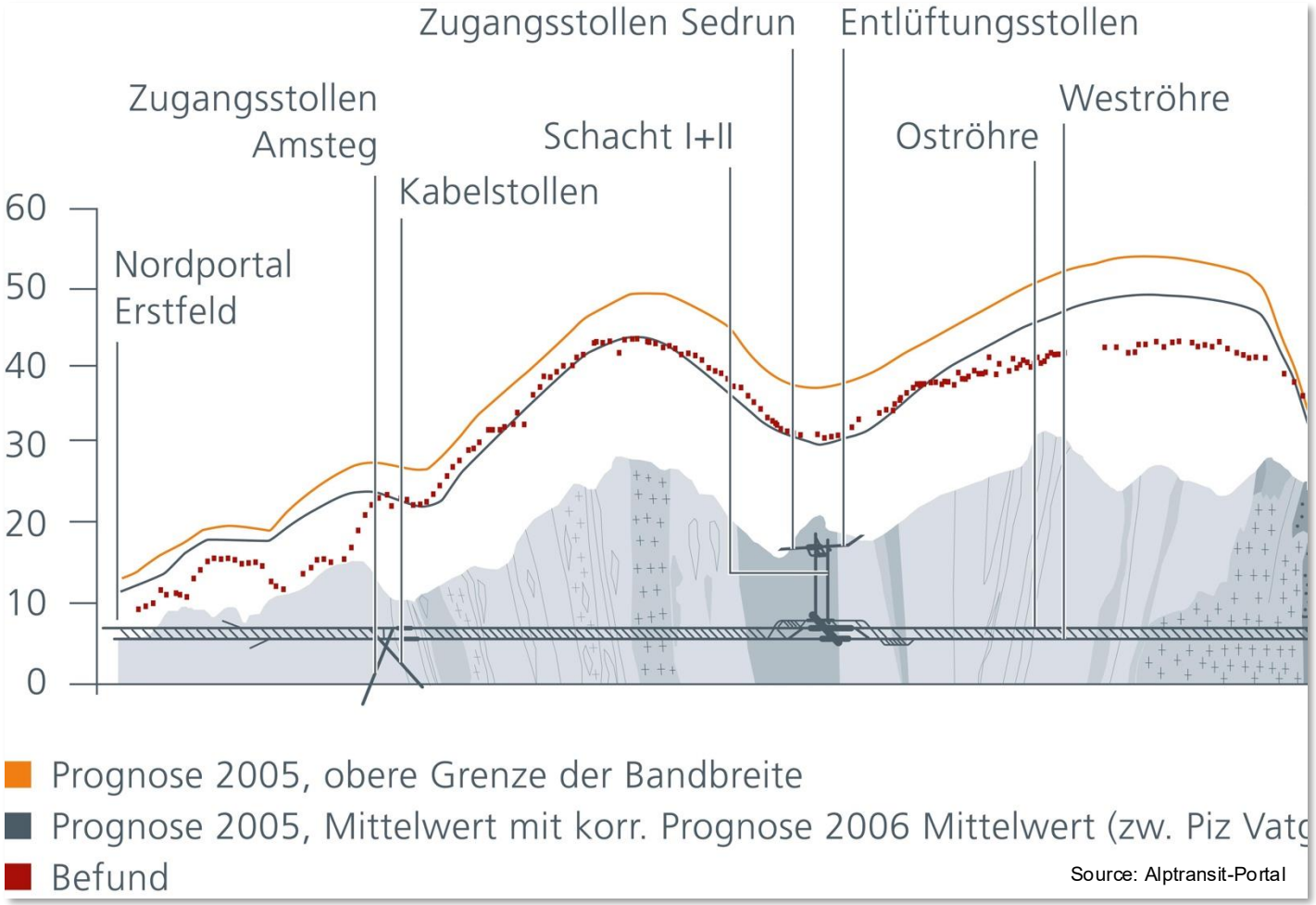
- Limited possibilities for site investigations
- Larger than usual geological / geotechnical uncertainties

Alpine Base Tunnels - Uncertainties

High degree of uncertainties call for improved risk management

- Technical risks and their mitigation (heavy support, injections, pipe umbrellas, partial sections, room for deformation, …)
- Financial risks -> take provisions
- Risks of excavation progress, speed, missed milestones, delay

Influence on construction programme



Source: Alptransit-Portal

Alpine Base Tunnels – Mitigate changes from programme

Construction programmes of base tunnels are highly integrated, with activities on a variety of sites in parallel.

A delay in one operation is likely to have an influence on many other operations on the same project.

Interface risks are client's risks, do not transfer them to contractors.

Mitigation measures:

- Monitor progress and update schedule on a regular basis
- Include contractual provisions for flexibility at the interfaces

Alpine Base Tunnels – Flexibility at interfaces

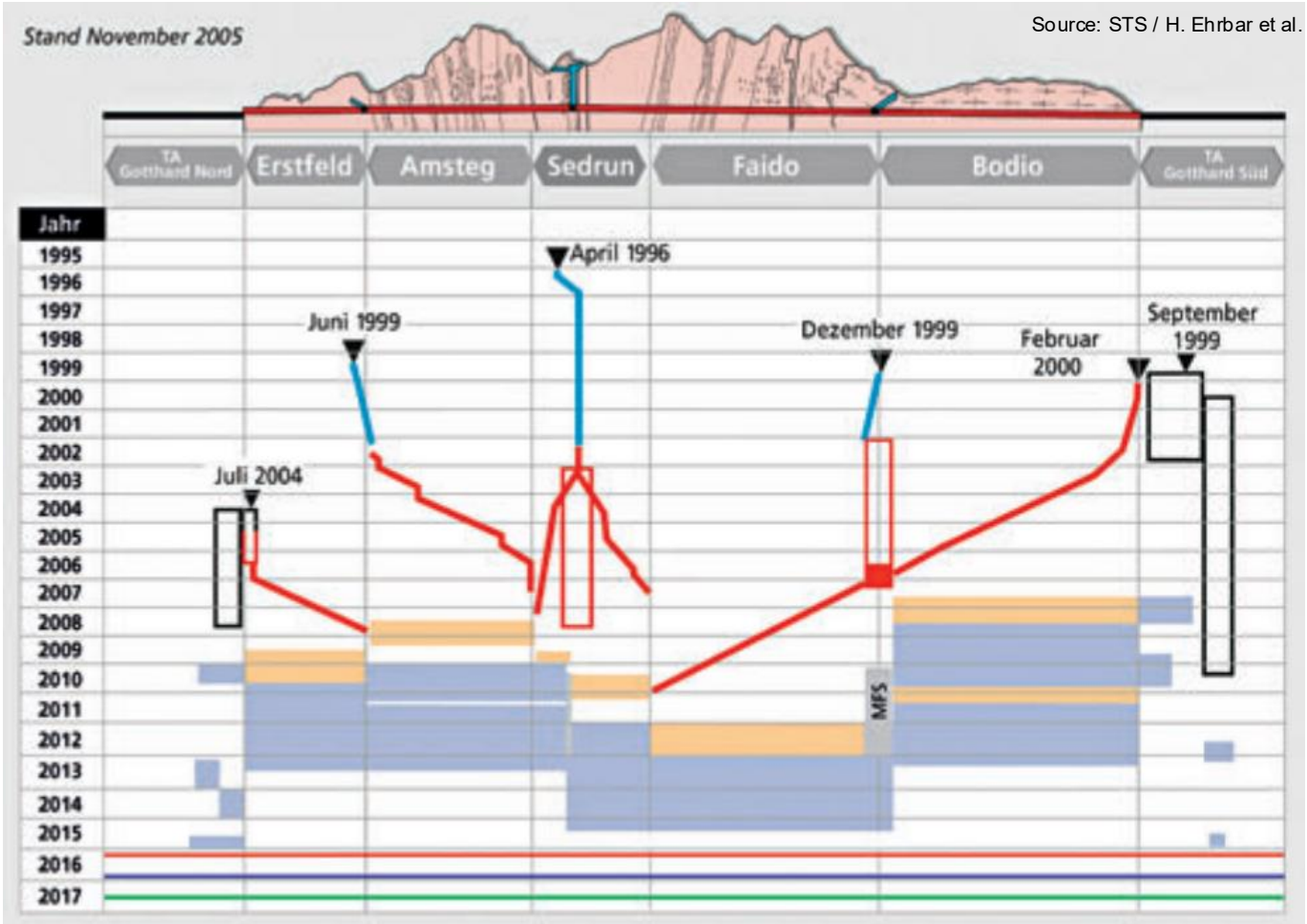
Example 1 :

Two excavation lots heading towards each other, one falling in D&B, one raising with TBM

The 8×0.5 km around the planned breakthrough point are contracted on an optional basis to both lots.

- TBM takes two years of delay
- Difficulties on D&B strech smaller than expected, a year ahead of schedule

Breakthrough point is moved 2 km into the TBM section, winning a year.



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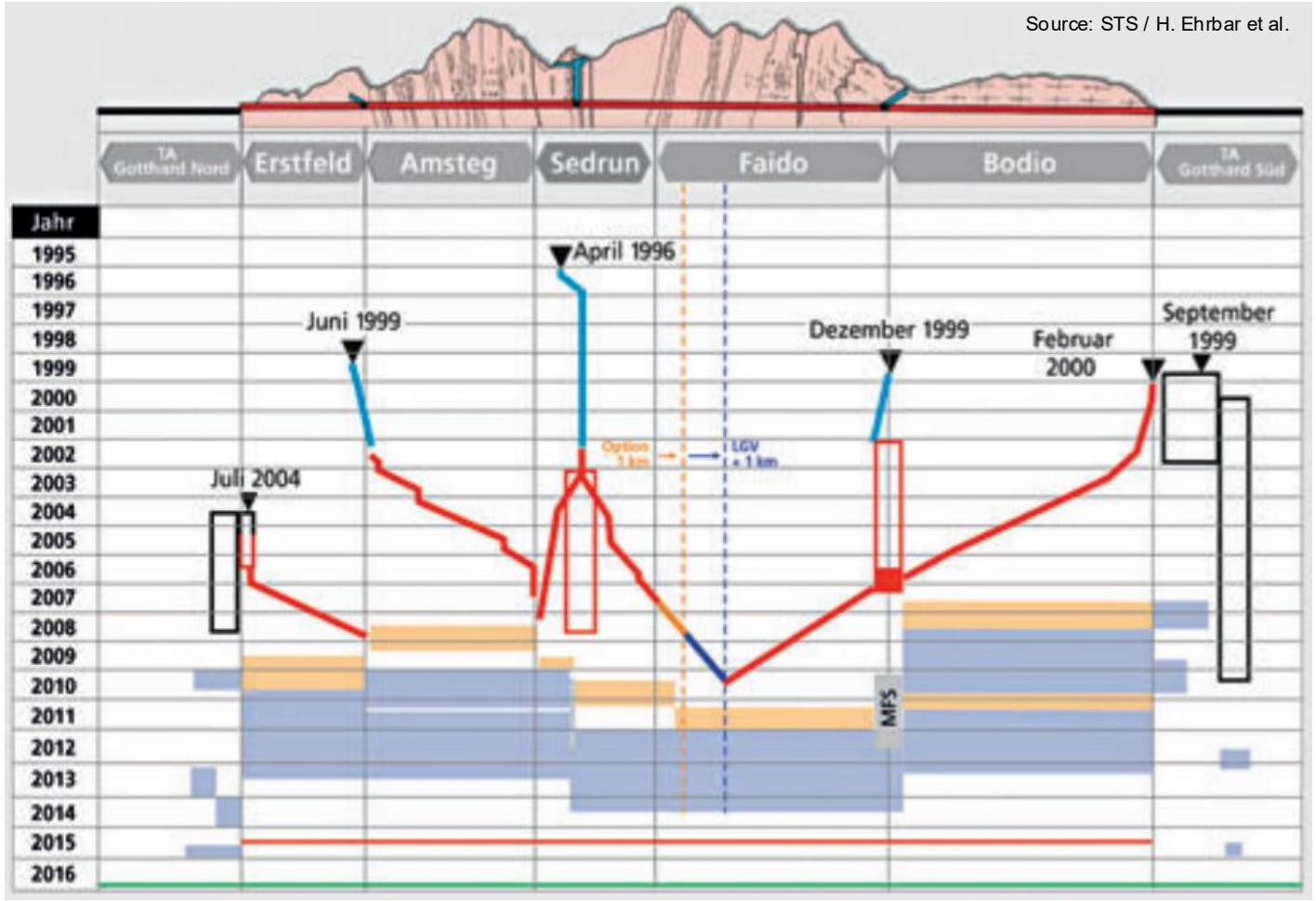
Alpine Base Tunnels – Flexibility at interfaces

Example 2 :

The D&B lot in the previous example excavates also the disassembly chamber for the TBM and installs a crane and other plant.

Another half a year can be saved.

Attention: material flows (excavation, construction) are affected, provide also environmental permits



Alpine Base Tunnels – Flexibility at interfaces

Example 3 :

At the footpoint of an existing access gallery three airshafts (raise-drill) are connected to allow for ventilation of the main tunnel excavation works.

The shaft construction takes a long delay

The excavation works of the tunnel are initiated anyway.

The shaft contractor and the tunnel contractor meet at the footpoint, sharing space and plant, not losing 1.5 years.

Alpine Base Tunnels – Concrete made of excavation materials

Reuse of good quality rock as concrete aggregate is essential.

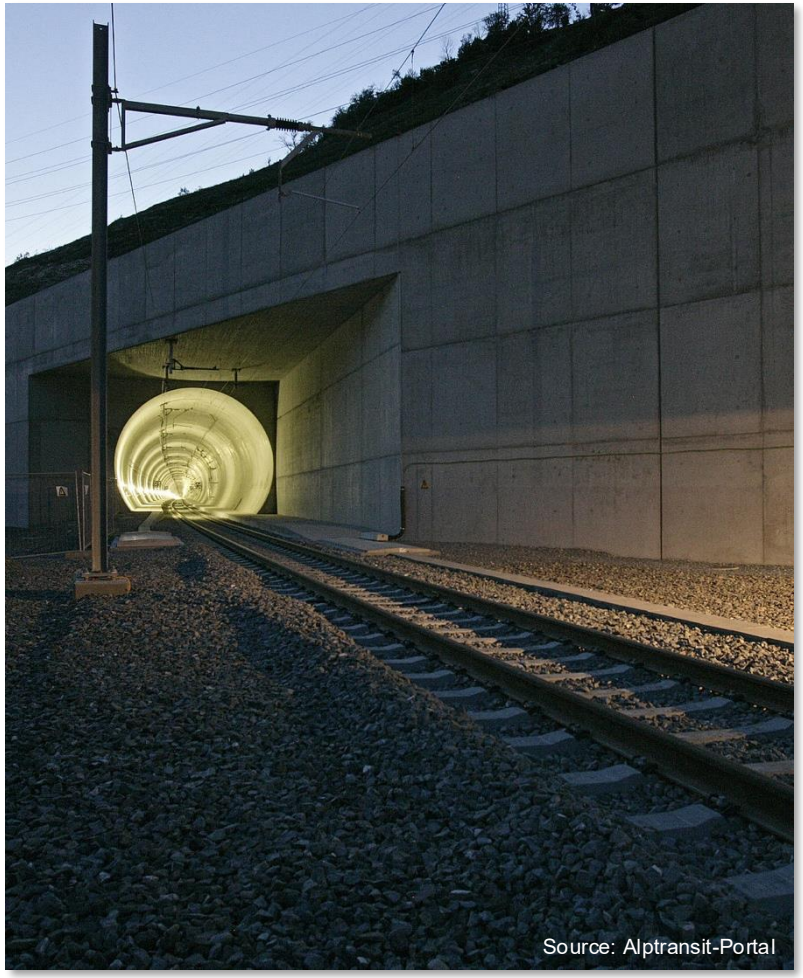
- Reducing transport volumina
- Lesser impact on disposal sites
- Preserving natural resources

Reuse should be planned for at an early stage and made a mandatory requirement in tender documents.

Reuse of excavated rock may conflict with strict requirements regarding concrete quality.

Key lessons learned

- **Invest early in subsurface investigation** Money spent on investigation upfront is almost always cheaper than surprises during construction.
- **Design for uncertainty, not against it** Robust designs build in adaptability so that deviations from expectations can be absorbed without fundamental redesigns or excessive costs.
- **Allocate identified risks early and clearly** Ambiguity in risk ownership is where disputes are born and contingencies are wasted.
- **Culture precedes tooling** No platform or dashboard will fix a team that lacks shared purpose and mutual accountability.
- **Flexibility and trust are stronger than rules and clauses** A lean agreement between parties who genuinely collaborate navigates the unexpected far more effectively than a dense contract.


Source: Alptransit-Portal

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