Logistics Aspects of Long and Deep Tunnels

ITA Working Group 17
Long Tunnels at Great Depth

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1 >> INTRODUCTION

Long and deep tunnels allow humanity to overcome natural obstacles, thus allowing efficient and environmentally friendly transportation of goods, resources, and people. As highlighted in the previous Reports from Working Group 17 (thereafter referred as "WG17"), large underground projects, such as **long and deep tunnels**, are **unique in terms of complexities and uncertainties** and often face **enormous challenges,** among which **logistic aspects.**

Effective management of key logistical aspects of long and deep tunnels is essential for the success of the project; it impacts, among others, safety, performance (and so construction time and costs), environment and acceptance. As the saying goes, management of logistics is **« the art of never stopping a construction site, it is like an umbilical cord »**. Logistics has to ensure that the right material, in the right condition, at the right time, at the right place, is available to the right person. Therefore, understanding the logistical constraints and **anticipating the contractors' needs is crucial** to create the best possible working environment and a solid construction contract.

The importance of this topic, combined with the lack of literature dedicated to the specific logistic aspects of long and deep tunnels, has led WG17 to focus on developing a **recommendation to guide Owners and Designers in understanding the impact and complexity of the logistics of these extraordinary projects.** The aim is that those reading the guidelines will be able to **address key aspects in the early design phase.** The recommendation summarizes the experience of Owners, Designers and Contractors from worldwide projects, and is based upon the experience of the WG17 members on projects excavated at great depth.

The first part of the guideline presents **the key logistical aspects that should be anticipated prior to the construction.**

The second part of the guideline deals with **the main challenges related to the logistical aspects during the construction** and provides some guidelines how to deal with them.

In order to facilitate the appropriation of the readers, we have introduced at the end of each sub-thematic, **key logistics guidelines synthesizing** the essential aspects to consider with regard to the conception and construction. All these points are summarized in a dedicated table in Appendix 1.

To support the recommendations proposed in this document, WG 17 compiled **an international database to highlight different Owner's point of view regarding logistical aspects** (presented in Appendix 2). This database was collected by conducting interviews with specific project owners worldwide (Argentina, Austria, Chile, France, Japan, Italy, Nepal, Norway, Slovenia, Spain, South Korea, Sweden, Switzerland) and WG17 warmly thanks the actors who contributed to this collection of information and agreed to share their experience.

WG17 paid particular attention to the consistency with existing ITA Guidelines. For the convenience of ITA members, we have created a table corresponding to topics partially covered by other Reports, but from a general tunnel construction perspective and not with specific focus on . Indeed, we recall that the objective of this report is to adapt these topics to long and deep tunnels, which issues are beyond the ones of regular tunnels.

		GENERAL IMPLEMENTATION ABOUT LOGISTICS	VENTILATION	SAFETY	ENVIRONMENTAL ASPECTS & SUSTAINABILITY	ACCESSES	REUSE OF MATERIALS / SPOIL MANAGEMENT
ITA Report N°.03	"Environmental and sustainable development reasons for going underground», Working Group No. 15, January 2010.				✓		
ITA Report No.08	«Guidance on the safe use of temporary ventilation ducting in tunnels», Working Group No. 5, 2011.		✓	✓			
ITA Report No.12	«Adits for long and deep tunnels », Working Group No. 17, April 2013.	✓		✓		✓	
ITA Report No.14	«Guidelines For the Provision of Refuge Chambers In Tunnels Under Construction", Working Group No. 5, 2018.			✓			
ITA Report No.17	«Recommendations on the development process for Mined tunnels », Working Group No. 14 and 19, April 2016.	✓					✓
ITA Report No.21	«Handling, Treatment and Disposal of Tunnel Spoil Materials », Working Group No. 14 and 15, April 2019.				✓		✓
ITA Report No.26	«Tunnel spoil handling, treatment and disposal options from a global perspective», Working Group No. 14, May 2022.				✓		✓

2 >> KEY LOGISTICAL ASPECTS TO MANAGE BEFORE CONSTRUCTION

INTRODUCTION

The design and construction of long and deep tunnels often face enormous challenges, including logistic aspects, which **require solutions way beyond the strategies** generally adopted for underground structures:

- Excavation generates **large amount of spoil,** which need either to be treated and re-used, or to be transported and dumped;
- Construction of the tunnel requires a **continuous and large supply of materials** (rock support, segments, inner lining concrete including reinforcement, tools and spare parts, waterproofing, temporary and permanent utilities, internal structures). This continuous flow of materials often requires the construction of **dedicated roads and the creation of intermediate access shafts or adits.**
- **Hundreds of employees and workers** needs to be transported, housed and brought to the various workstations, often in harsh climatic conditions (cold/heat/rain);
- **Safety requirements** related to the length of the tunnel and the difficult accessibility, may necessitate the construction of escape routes (labour regulations and occupational health and safety regulations of the respective project countries must be complied with and harmonised with the project-specific boundary conditions).

This chapter is dedicated to all aspects that should be anticipated (mainly by Owners and Designers) before the start of any construction work. Typical aspects to be considered for long and deep tunnels may include:

- Acceptance: extended construction time and its impact on the local community, highlighting the benefit and sustainability of solutions;
- Authorization and Environmental aspects;
- Identification of final disposal sites;
- Accesses: traffic generated, remote project areas, intermediate accesses, dedicated underground structures;
- Supplies: Extraordinary power and water requirements, sophisticated transportation, continuous and large supply of materials, ventilation and cooling systems underground;
- Location of camps for contractors, designers and owners;
- Anticipation and possible synergy with the operational phase from a sustainable perspective;
- Provisions for Health and Safety during construction phase.

It is important to remark that those aspects are often strictly related to the construction method (conventional excavation vs. TBM).

2.1 ACCEPTANCE OF THE PROJECT BY THE LOCAL COMMUNITY

Long and deep tunnel projects may suffer from a low acceptance of the population due to the **major impacts they cause during the construction phase.** Long and deep tunnels are major projects which, due to their long construction time (usually several years) have a significant impact on the surrounding regions.

- The traffic induced by the construction has a significant impact on the capacity of the existing routes or railway systems;
- In remote areas, new access routes, often a challenge in itself, need to be built to create the necessary logistic capacity;
- Spoil disposal may change the shape of the corresponding area by creating new landscape;
- Site requirements often lead to the installation of new power lines and water transfer systems;
- All these works, including access sites, job site installation and other large plants needed during construction may require land expropriation, at least during time of construction;
- Hydropower schemes usually lead to an important loss of land, requiring compensation strategies.

Local project acceptance strategies need to be considered as an integral part of the design and construction phases of major projects such as infrastructure tunnels or hydropower schemes. Experience shows that the most successful way to build a long and deep tunnel is to proceed with a multidisciplinary team including professionals who can support the Owner in managing the communication and entering in a continuous dialog with the local population before, during and after the construction phase. Mass communication techniques can be used strategically, especially to avoid the perception of a division between technicians and experts, who draw up the perfect project on paper on the one hand, and a community, which has its own very clear concept of the common good, on the other. It will be also important to follow these aspects during the operational phase. Communication, both internally and externally, is one of the most important tools needed during all the phases of the performance of a project. A tailormade communication strategy, taking all the stakeholders into account, should be established at an early stage of the project.

In setting up a process of creating awareness (first) and consensus (subsequently), it is important to start by defining the main logistics needs of the construction works, and to successively map all the involved areas and their stakeholders. This will reduce the risk of the project being perceived as self-referential and "imposed from above". Early information about the lack and need for certain infrastructure in the affected project area can therefore lead to sustainable solutions way beyond the construction phase.

Figure 1 : Brenner Base Tunnel Information center throughout the project's life (courtesy BBT).

It is also important to highlight the positive impact of these projects on the local population, even during the construction phase. The **added values during the construction phase** could be important especially in rural and remote areas, thus raising the quality of life in the area:

- Generation of work opportunities in the tunnel, and for all business related to it, including education, education and qualification;
- Opportunity boosts providing services to local businesses such as restaurants, accommodation and gastronomy (restaurants), catering and cleaning services, etc.
- Creation of new or extended public services such as schools and day care centres, wastewater treatment plants, installation or rehabilitation of public utilities, etc. (power, water, communication)
- Renovation or construction of roads and railway connections

During the operational phase, compared to conventional transportation such as surface roads, the impact of long and deep tunnels on the environment is usually far less:

- Localized only in the vicinity of the portals and safety and ventilation shafts (i.e. visual impact and noise only in the portal areas);
- Once in operation, tunnels bring significant advantages to local populations, whether the purpose is noise reduction, reduction of travel time, etc.
- Sustainability is maintained also during the operational phase of the project, as permanent buildings, infrastructure and, if possible, short travelled excavated material can be used after the construction period has ended. In addition to that, water collected from the tunnel can be seen as an opportunity, e.g. as geothermal energy source;
- There can be long lasting effects such as higher educational levels, better quality of water, power and communication lines, improved traffic connections, and preparations for future utilization of areas filled up with excavated material from the tunnel production;
- However, sufficient attention must be paid to the effects of the end of a large infrastructure project, where, for example, capacities built up during the construction phase by local shareholders have to be realigned.

Commonly elaborated solutions depending on the local situation should be identified in order to find the best possible compromise between construction and local needs over the short and long term. As suggested by Mario Virano, General Director of the railway project between France and Italy, Tunnel Euralpin Lyon Turin (TELT) "a megaproject is done because it creates *added value, and the worst unsustainability of an infrastructure is the decline of relations and the local area; therefore, in the design of megaprojects the challenge is to generate value and combat the decline of the local areas"* [1].

Finally, during the realization of the work, it is beneficial to consider the following aspects:

- The construction sites constitute the most immediate information tool regarding the work, the technologies applied, the safeguards adopted to protect the environment, and so on. All the work areas (offices, workshops, installations, machinery, etc.) can be physically used to explain the work, its history and context, as well as current and future changes;
- At a local level, the presence of the site produces changes that must be included in the relations with citizens. Content regarding acquired data and monitoring processes concerning health, circulation of dust and CO_2 production must be periodically disseminated, with the aim of responding to any fears;
- Progress in the management of positive effects must also be communicated and an integrated communication plan can be envisaged, using a temporary or permanent info center, public meetings at various levels, open door days, and relations with the press. To improve transparency, some project display on internet the environmental KPIs.

KEYS LOGISTICS GUIDELINES TO ANTICIPATE

- Local project **acceptance strategies** need to be considered as an **integral part of the design and construction phases,** since acceptance is a continuous process of awareness building and subsequent consensus building.
- Find the best possible compromise between construction and local needs over the short and long term.
- The need for certain infrastructure in the project area may lead to **sustainable solutions well beyond the construction phase.**
- **A tailored communication strategy,** taking into account all stakeholders, should be established from the beginning of the project, and during the construction phase, always remembering that the **construction sites are the showcase of the project.**

2.2 AUTHORIZATIONS AND ENVIRONMENTAL ASPECTS

The knowledge and the successive management of the environmental aspects and restrictions related to the construction of major infrastructure play a fundamental role in the definition and design of the project and, in particular, to its logistics.

The early definition of the logistical needs is absolutely crucial for anticipating the relevant authorization processes, thus avoiding delays or construction interruption of the major construction works. It is **recommended that the Owner obtains all major authorizations and permits** for the project from the responsible institutions and authorities (as e.g., the land ownership) from the earliest possible time, depending on the time to produce necessary documents for the approval process, and on the process itself.

In order to achieve this goal, **preliminary logistics principles should be developed and defined during the early design phase,** with particular attention to the fact that the impacts of these requirements are often **underestimated.**

In the case of long and deep tunnels, and from the Owner point of view, there are a few main concerns:

- Identification of **surface areas** required to properly carry out the works as detailed in chapters § 2.4 to §2.6;
- Identification of **sustainable processes using the waste hierarchy** (as shown in Figure 2): such as the re-use of the excavated material for aggregate production for concrete, road and rail dam construction, noise barriers, backfill of old mining pits or as a basement for future development of the area. Due to environmental regulations, a **plan for the reuse of excavated materials** *(Tunnel Spoil Management Plan)* is today mandatory, especially for long tunnels that produce a large amount of spoil, as recommended by ITA Report NO.21 [5] (AITES WG 14 and WG 15, 2019);

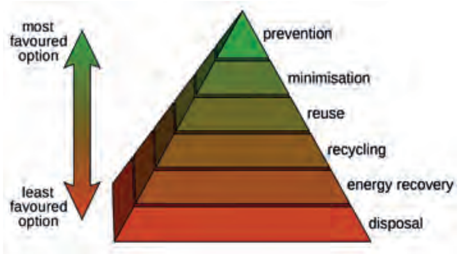


Figure 2 : Waste hierarchy.

- Identification of **temporary and final spoil** disposal areas for non-reusable spoil (cf. §3.2. Muck management and reuse of materials) that require environmental compatibility authorizations.

The environmental impact of a major construction work, such as a long and deep tunnel, plays a role that is certainly relevant to both its technical and functional aspects. A good quality project allows the integration of the construction in the landscape and reduces the irreversible environmental damages to the acceptable minimum by defining the appropriated mitigation measures.

Regarding the interaction between the underground works and the environment, the ITA Report N°.3 from WG 15 [3] recommends considering the following key topics at the design stage:

- The management and organization of the job sites;
- Architectural and landscaping considerations;
- Water and air issues, ground contamination, the impact of noise, dust, light and vibrations on the population living near the tunnel entrance;
- The natural biotypes (flora and fauna) and a correct natural resources management.

Examples of temporary environmental impacts that mostly can be influenced by the choice of the logistic solutions are:

- Impact of the spoil transportation, from the tunnel entrance to the intermediate and then to the final storage area (landfill for instance), depending on the means of transportation (trucks, rail, ship, conveyor belts);
- Impact of the construction in terms of the emissions (dust, noise and vibrations);
- Impact of drainage and pollution of the underground and surface water.

KEYS LOGISTICS GUIDELINES TO ANTICIPATE

- It is recommended that the **Owner obtains all major authorizations and permits** for the project from the responsible institutions and authorities (as e.g., the land ownership) **from the earliest possible time,** before starting construction.
- A It is recommended that the owner carries out a survey of all necessary permits based on a conservative design of the project (as a general rule, is recommended to ask for a wider scope than strictly required, thus avoiding to be constrained in the later project stages), considering both construction and service stage.

2.3 IDENTIFICATION OF FINAL DISPOSAL SITE FOR SPOIL

Long tunnels generate a huge amount of spoil or mud. The soil is classified into reusable materials or waste (see also Section §3.2 Muck management and reuse of materials for more details).

The disposal of spoil (temporary or final) may require land acquisition and environmental approval. Additionally, the transportation of the spoil also to the disposal sites, may also require temporary land acquisition and also has an impact on the environment (traffic, noise, …). Therefore, the selection of the disposal sites location and size requires a comprehensive and timely (all related planning and approval procedures should be completed prior to the start of tunnel construction) evaluation of those aspects.

KEYS LOGISTICS GUIDELINES TO ANTICIPATE

- Long and deep tunnel excavation generates **large amount of spoil,** which need either to be treated and re-used, or to be transported and dumped;
- Determination of the **size and location of the final disposal site** should be incorporated into the project **design phase;**
- Related planning and approval procedures is preferable to be completed prior to the start of tunnel construction.

2.4 ACCESSES

2.4.1 Traffic outside the working site

Large construction sites such as deep and long tunnels involve a complex supply flow of personnel, machinery and construction materials. Muck transport adds to the amount of transports; the flow is directed to the construction site (personnel, installations, machines, construction materials) as well as from the construction site (typically excavated material, sludge, wastewater).

Due to the relevance of the logistical flow, a careful study of the logistics needs is required from the early stages of the project. The result of the study defines the location of the most relevant sites in which to stage logistical elements, and consequently, the infrastructure needs in order to link these areas . The feasibility of logistical accesses to the construction sites is also relevant for the definition of the tunnel alignment and the position of intermediate adits. As deep and long tunnels are generally located in mountain areas where flat surfaces are scarce. It may be possible to split the required surfaces into several zones.

Typical examples are:

- New train switches and railway lines, as shown in Figure 3;
- New roads (e.g., new access or exits to existing highways), as shown in Figure 4;
- Cable cars;
- Waterways (rivers, lakes, seas).
- Separate tunnels for transport of excavated material to permanent deposit areas or for re-loading to other kind of transport outside the “muck-transport tunnel”
- Air transport by planes and helicopters

The resulting costs, which at first glance may appear very high, may be acceptable and beneficial for large projects, as they are small compared to the infrastructure costs, and in particular, to the advantages resulting from a robust construction site accessibility. The selection of the most suitable infrastructure needs not only a careful evaluation of the required capacity but also the consideration of environmental and social aspects. As a matter of fact, the traffic outside the working sites is often one of the main causes of non-acceptance of the project. The construction site is perceived, for example in the case of transport on the road, as a source of additional traffic jams, dust, noise and air pollution. Those aspects are relevant because the related restrictions may cause the slow-down of construction activities (e.g., traffic limitations during night time). For this reason, clear requirements have to be set from the Owners in terms of allowed infrastructure type.

The timely identification of the most suitable infrastructure type is also crucial for the on-time start of the main construction activities. This is related to the construction of the infrastructure itself as well as its approval process. For these reasons it is preferable to tender and execute critical access and site infrastructures prior to the main construction works. This may also include awarding contracts for separate lots parallel to the main construction lots, such as material handling.

Figure 3 : New Rail Switch, Sigirino, Ceneri Base Tunnel.

Figure 4 : New Access Road to Highway, Sigirino, Ceneri Base Tunnel.

KEYS LOGISTICS GUIDELINES TO ANTICIPATE

- The **traffic generated** by the construction of a long and deep tunnels is an **enormous, continuous logistical flow.** So the determination of **most suitable infrastructure** (roads, railroad , waterways …) in order to link the areas and manage this traffic flow **should be incorporated into the project design phase.**
- It is preferable to tender and execute critical access and site infrastructures prior to the main construction works.

2.4.2 Accessibility of remote area

The geographical location of the project may have a strong impact on the logistics of tunnels. Due to the nature of long and deep tunnels, often through mountainous regions, portals and, if any, adits, are often located in remote areas, characterized by absent or difficult accessibility. The latter requires the construction of roads or other transportation way as illustrated in Figure 5 to Figure 8, with examples in Switzerland, China and India.

When planning those aspects and the related logistics, it is also important to consider the severe weather conditions often characterizing those areas:

- extremely cold temperatures which may lead to seasonal closures of the site;
- extreme snowfall which can cause blocked access roads or avalanches;
- extreme hot temperatures which may lead to daily interruptions;
- extreme altitude with related health issues;
- extreme rainfall (monsoons) causing flooding.

Figure 5 : Emosson Portal, Nant de Drance, Switzerland, summer 2009 (Marti Tunnel Ltd).

Figure 6 : Road conditions on the Rohtang access route (May, 2015) [15].

Figure 7 : Cable car for the Linthal Project, Switzerland, 2015 (Marti Tunnel Ltd).

Figure 8 : Site installations and conveyors belt solutions at Jinping Hydropower Project, China (Marti Technik Ltd).

KEYS LOGISTICS GUIDELINES TO ANTICIPATE

- Due to the nature of long and deep tunnels, often through mountainous regions, **portals are often located in remote areas,** characterized by absent or difficult accessibility => requires the construction of dedicated roads or other transportation way;
- The severe **weather conditions** that often characterize these regions (snow and extreme cold) further increase the complexity of access;
- Climatic conditions can have an impact on the time frame available for the construction works during the year and should be considered in the project time-frame.

2.4.3 Excavation of intermediate access / adits

2.4.3.1 Main objectives during different project phases

The reduction of the construction time or the advance exploration of the geology at tunnel level often requires the excavation of intermediate access points, called adits, as detailed in the ITA Report N12 from WG17 [4] : *"An adit starts at a place on the surface of the work site and leads to the main structure. Generally one or several caverns or galleries are set aside for site logistics and/or for the operation of the main structure. An adit can be different type, such as inclined gallery, shaft, transverse gallery and parallel heading, which shall be chosen considering the terrain, geology as well as the purpose of the adit."*

The main functions of the adits can be summarized as follows:

- geological survey gallery (exploratory tunnel) used to improve the geological knowledge of the tunnel alignment *during the design stage* (at tunnel scale). The acquired geological knowledge serves to stabilise the design of an underground structure. Moreover, extensive geological surveying can be done from these galleries to better define the expected geological behaviour;
- access point to build the main tunnel, and serve as **logistics access,** to make it possible to excavate the main tunnel from several advancing faces *during construction;*
- accesses for maintenance, ventilation, rescue teams, and evacuation escape routes *during construction and operation.*

In the example of the Brenner Base Tunnel, linking Austria to Italy (BBT Project – 64 km – cf. Figure 9 and Owner's interview in Appendix 1), four adits were built before signing the main contracts (Design and Build contract).). The adits represent the logistical accesses to the main tunneling work and, in the operation phase, will represent emergency exits connected to the emergency stops.

When used as working point access, the adit or the intermediate access should be designed to fulfil the following functions (cf. Figure 10 , Figure 11 and Figure 12):

- Transporting equipment ;
- Transporting personnel;
- Evacuating the spoil (mucking-out[1]);
- Supplying construction materials;
- Supplying fresh and evacuating ground and waste water;
- Ventilation (supplying fresh air and evacuating polluted air);
- Supplying electrical power;
- Telecommunications;
- Safety (escape route or heliport in case of blocking route due to weather);
- Supplying Cooling water(if necessary).

Figure 9 : Brenner tunnel, in green the 4 adits, in yellow a survey gallery all along the future base tunnel.

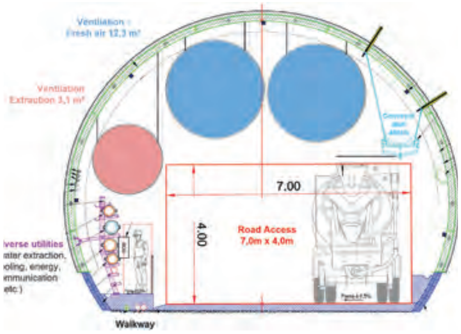


Figure 10 : Example of logistics equipment's during construction - cross section - Adit La Praz 2022 - TELT Project (Courtesy VINCI)

Figure 11 : Lötschberg, adit of Ferden during construction.

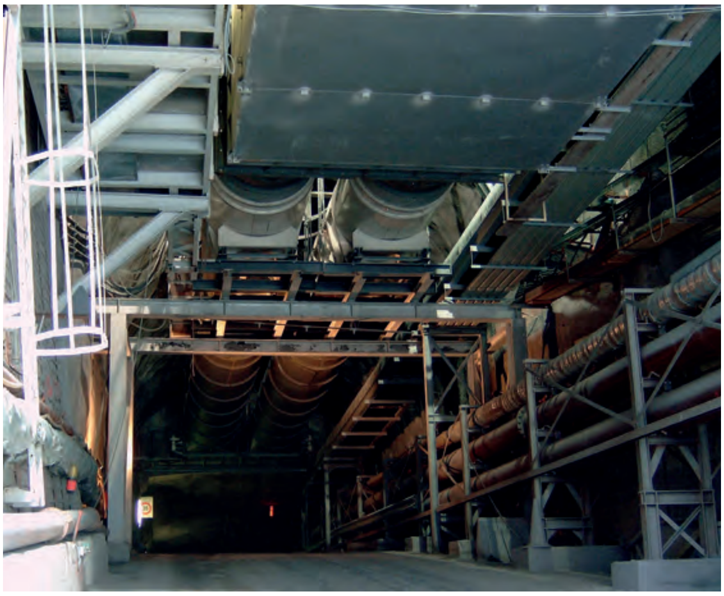


Figure 12 : Adit entrance Faido showing necessary supply lines.

[1] The use of conveyors for haulage is recommended since this reduces requirements in terms of ventilation and intermediate storage of excavated materials.

2.4.3.2 Numbers and sizes of the accesses

Depending on the size of the main work site and local conditions, the required installations may be quite significant in number and size (cf. ITA Report N12 from WG17 [4]). Therefore, when geological conditions are complex and logistics requirements are vast, it is sometimes necessary to **build several intermediate accesses** (galleries or shafts) **in order to fulfill all logistics requirements.**

Another relevant aspect to consider when designing the intermediate access is to consider all the logistics material that needs to be transported through it: apart from the excavation a considerable number of vehicles is needed for logistics itself (all those geometrical constraints have to be intended in addition to the one related to the size of the permanent equipment such as transformers and turbines for the service phase in hydro schemes).

The logistic demands for the supply of machinery are highly dependent on the method of excavation. While TBM's often require specially built roads and vehicles to supply their heaviest parts (up to 100 tons) to the jobsite, conventional tunnelling requires numerous different machines for excavation. For example, the **size of the adit may allow the delivery of the TBM for the main tunnel**, as shown in Figure 15. The difficulty here is to anticipate enough these needs in order to build adits of adequate sizing, sometimes several years before starting the main project. Therefore it is prudent for the owner/designer to make provisions for possible changes in the construction method or the size of the necessary equipment.

Depending on the type of contract, for example in a design-build contract, it is also possible to allow the contractor some flexibility in choosing the best type of intermediate access. In the case of the Pajares Tunnel in Spain (25km), an intermediate double 500m deep shaft was foreseen in the tender design. However, the Contractor decided to replace it by a 5.5km long access tunnel due to environmental reasons (see Owner's interview in Appendix 2).

Figure 13 : TBM used for Ceneri Base Tunnel adit at Sigirino.

Figure 14 : GOTTHARD Tunnel, TBM Parts Transportation.

Figure 15 : TBM supply in restricted space, Brenner (courtesy BBT).

KEYS LOGISTICS GUIDELINES TO ANTICIPATE

- Long and deep tunnels level often require the excavation of intermediate access points in order to be able to reduce the corresponding supply distances to a tradable level.
- The **anticipation of the logistics needs** is a key factor in correctly planning these intermediate **access points**, in particular through **defining their location and their size.**

2.4.4 Underground structures required for logistics

Depending on the logistics needs (e.g., shortening of the supply chain) and on the restrictions outside the construction site (environmental, political, morphological, geometrical, etc.) it may be necessary to install part of the logistics installation underground. This setup offers a dual advantage of being **completely invisible to residents** and **shortening supply times.**

The **creation of logistic plants underground** requires the construction of large caverns and a number of tunnel allowing a smooth flow of materials underground between the logistic spots, the adits and the main tunnel (in some reference cases, for example, four TBMs have been launched and operated starting from a single deep shaft; the latter represents an incredible logistic challenge).

Usually these caverns and tunnels are located at the bottom end of an adit, and are used to house a variety of installations, either for operation of machinery or for their maintenance, as illustrated on Figure 16 and Figure 17:

- Crushing plants and spoil handling installations;
- Batching plants;
- Pumping and Cooling plants;
- Water settling and pumping basins;
- Transformer stations and switches;
- Workshops and parking space for equipment and maintenance;
- Material Storage areas (including Underground explosive storage);
- Personnel welfare facilities;
- Assembly and disassembly chambers for TBM's.

Figure 16 : Example of caverns for logistic installations (ventilation, de-duster, conveyor belt) in Faido.

Figure 17 : Example of caverns for logistic installations (batching plant) in Ceneri.

Other logistical underground caverns are needed when excavating the main tunnel by means of TBM; the latter are represented by assembly and disassembly caverns (as shown in the Figure 18 taken at the Fréjus tunnel in France - cf. Owner's interview in Appendix 2, or in the Figure 19 taken in Brenner Base tunnel 2021) The required space for TBM's depends on whether a TBM is assembled at the portal or underground. Elements are pre-assembled as much as possible at the surface depending on the adit section.

A large and high cavern is required for the shield assembly. Gantries assembly usually require the widening of the tunnel in their assembly area.

The longer and deeper a tunnel project gets, the more installations are needed either in or alongside the main tunnel excavation, such as:

- Parallel supply tunnels
- Logistic cross passages as illustrated on Figure 20 (often inclined to allow train transfer between parallel tunnels thus creating redundancy in case of tunnel closures)

Figure 20 : Logistic cross passage in Gotthard, 2008 (Courtesy J. Classen).

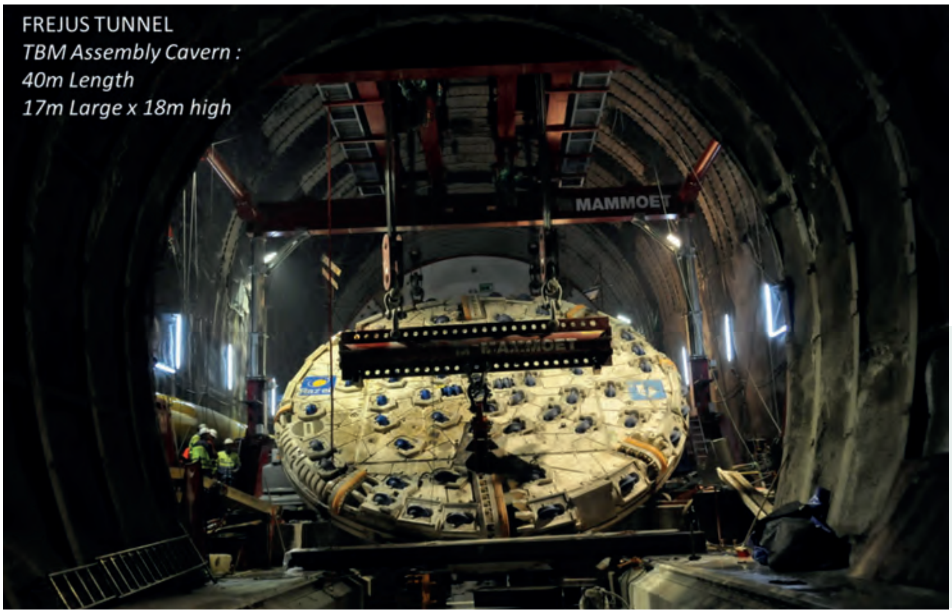


Figure 18 : Frejus Tunnel, TBM Assembly cavern in 2010, (courtesy RAZEL BEC).

Figure 19 : Brenner Base Tunnel, TBM Assembly cavern (courtesy BBT)

- Niches, recesses and sumps for transformer or pumping stations, or the placement of refuge chambers
- Enlargement of the main tunnel for booster stations for ventilation or conveyor belts as well as passing of traffic vehicles.

In the case of the Follo Line project in Norway (25km), as described in the Owner's interview in Appendix 2, pre-work contract to build two access tunnels (adits) from surface down to the attack point of the main contract. Bane NOR, as the Owner, took over all site installation from the pre-work contractor and handed it over to the main contractor, who decided and built additional logistic tunnels and caverns for the assembly and operation of four tunnel boring machines during the bid phase.

No general rules exist on whether the **construction of underground logistics spaces or the definition of their size and position** has to be made before the construction of the main tunnel or not. It is important to understand that these spaces and their related logistical needs are very much linked to the means and methods chosen by the contractor to build the tunnels. On the one hand, providing the Contractor with already built underground spaces saves a lot of time on the planning of the operation and can limit the risks of claims. On the other hand, the Contractor, whose primary expertise is logistics, may have alternative ideas. Already built structures may not be well suited to the Contractor's own needs, increasing the risk of a claim for construction delays due to, for example, under-sizing an underground logistics space.

In conclusion, the responsibility of the Owner, and its Designer, is **to define the constraints imposed on the installation of logistic plants underground** (such as the installation of concrete plants underground to limit impacts on the outside environment, or the use of electrical equipment, or the use of conveyors for transport, etc.) and to identify as much as possible the **needs in the design in order to have a robust financial forecast and an on-time project.**

KEYS LOGISTICS GUIDELINES TO ANTICIPATE

- It may be necessary to install part of the **logistics installation underground.** This setup offers a dual advantage of being **completely invisible to residents** and **shortening supply times.** On the other hand, underground facilities are usually custom-built due to their compact design and are more expensive to procure than equivalent facilities above ground.
- Usually, these caverns and tunnels are located at the bottom end of an adit, and are used to house a variety of installations, either for operation of machinery or for their maintenance
- The responsibility of the Owner, and its Designer, is to **define the constraints** imposed.

2.5 SUPPLIES

The construction of long and deep tunnels requires enormous quantities of supplies, understanding these requirements is crucial for assessing the feasibility of a project. Knowledge of the required supplies also aids in anticipating the structures and the spaces needed for a prompt start of the construction works (communication or energy lines, water reservoirs, electricity stations, parking and storage spaces etc…).

2.5.1 Power supply

Large construction sites of long and deep tunnels have an extremely high demand for energy supply. These requirements allow for proper functioning of the electromechanical systems serving underground construction activities (ventilation, cooling, lighting, and machinery such as jumbos and muck handlers). An important contribution to the required power is dictated by the excavation methods and advancing fronts.

Typical requirements in **TBM power** can easily reach **20 to 45 MW**. In addition, other activities related to the tunnel excavation as production of segmental lining, handling of the spoil, etc may also require additional power supply.

The Figure 21 illustrated some examples for ventilation power requirements from the Gotthard Base Tunnel.

Nevertheless with **increasing tunnel length these requirements can be overwhelmed by those ventilation and cooling.**

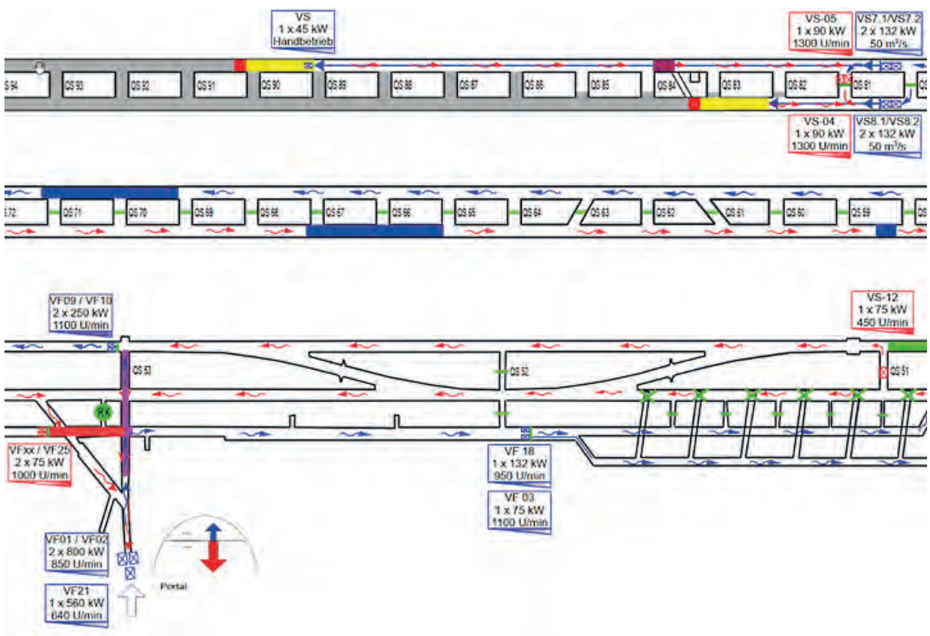


Figure 21 – Cooling and Ventilation Power supply requirement - Gotthard Base Tunnel [2].

While power requirements for TBM's or machinery remains more or less constant along the excavation process, cooling of such equipment, ventilation and air cooling require an rapidly increasing amount of power. An example for the cooling and venting requirements for the 30km south section of the Gotthard Base Tunnel is presented in the following table.

COOLING & VENTING REQUIREMENTS FOR THE 30KM SOUTH SECTION OF THE GOTTHARD BASE TUNNEL	
Cooling towers	21,0 MW
Cooling water distribution (1600m³/h)	20,8 MW
Cooling stations in the tunnel system & on TBM's	17,4 MW
Ventilation	4,5 MW
TOTAL	**63,7 MW**

Although the installation of the power supply and distribution is generally in the purview of the contractor, it is important that the Owner understands the power supply demand in order to define the supply concept (for example an autonomous power plant rather than connection to the existing grid) and thus starting the authorization process or the construction of the necessary infrastructure before starting the construction of the main tunnels. As the an extension to the existing grid requires long time, the anticipation of the power demands will **guarantee the availability of necessary power supply at the beginning of the construction works.** For this reason it is essential to estimate – from the planning phase – the power demand required to guarantee the necessary functioning of all activities to be carried out on site (this including the number, arrangement, electric power and all the characteristics that contribute to the identification of the systems and their components with a view to estimating the costs of installation, operation, maintenance and, once the work has been completed, dismantling or re-used for the local community).

KEYS LOGISTICS GUIDELINES TO ANTICIPATE

- **Estimate expected power demand** during construction time for the mains consuming activities;
- Check existing local supply options;
- Provide additional power generation if needed;
- Provide power lines and switch stations prior to main contract;
- Negotiate rates with local power suppliers;
- Considerations regarding redundant emergency power supplies (for example for ventilation)
- Design also adits and tunnels according to power requirements.

2.5.2 WATER SUPPLY AND WATER DISCHARGE

2.5.2.1 Water supply

Water plays a fundamental role in the execution of long and deep tunnels. Water demand needs to be estimated from the following requirements:

- Provision for site camp, offices and workshops;
- Concrete production, including spoil treatment plants;
- Provision for tunnel excavation machinery (TBM's, Jumbos etc);
- Provision for cooling;
- Provision for cleaning on surface and underground;
- Provision for fire fighting.

The required amount of water may well be in the range of several hundred cubic meters of water per hour, calling also for a well designed distribution system and the ability for easy extension with growing length of the tunnel.

Depending on the site conditions, water can either be gained from natural sources nearby (rivers, lakes etc.), as shown on Figure 22, or by using existing or installing new water pipelines or wells.

Sustainable solutions should also focus on re-using the natural ground water infiltrating the tunnel drive for the purposes mentioned above, if local regulations allow for it.

When designing the distribution system underground, a special focus needs to be put on fire fighting facilities along the length of the tunnel. As mentioned above, niches or sumps for pumping stations should already be considered in the preliminary design.

Figure 22 : Cooling plant including water reservoir and intake (Faido).

[2] External power supply needs new power transmission lines and power transformers, while autonomous power generation may be obtained from gas or fuel or, in the near future, by adopting green sources (solar or wind).

2.5.2.2 Water discharge

The amount of water leaving the tunnel is usually higher than what is pumped in, the total amount being made up of:

- Natural water inflow;
- Industrial (waste) water (for machinery needs, cleaning etc.);
- Cooling water;
- Rainwater over the site surface.

Depending on the site location, sudden large inflows of rainwater may end up in the treatment system which might not be designed for such a large flow. The discharge point in the natural surrounding may also impose that sudden rainwater is stored and disposed of with a maximum flow rate, requiring a temporary storage after treatment (means space is required again).

While the cooling water is usually circulating in closed circuits, natural and waste water are commonly collected in sumps, from where they are flowing freely through the tunnel invert to the portal (ascending tunnel drive) or need to be pumped through pipes to the portal or via the adits to the surface (descending tunnel drive).

Depending on the tunnel excavation method and the amount of natural water inflow, settling ponds may have to be foreseen already close to the tunnel front to extract suspended sediments before pumping. This in turn also requires adequate means for cleaning the ponds and transporting the sediments to surface. For this and other reasons provisions should be made to separate (dirty) waste and (clean) natural water at the source of their appearance (separation system for water outflow). As mentioned above, this will also allow to use the natural water as a sustainable source of supply.

Again space for sumps and pumping stations needs to be allowed for when designing the tunnel.

Water treatment plants are generally installed at the portals, and the top or bottom of the intermediate adits, as illustrated on Figure 23. Both underground and surface solutions need to be considered during design, allowing for enough space for settling ponds, water treatment plants and pumping stations.

Figure 23 : Water treatment plant under construction, Follo line, Norway.

Utmost priority should be given to re-use of the natural or treated water for site requirements. Connection to the nearest or most suitable discharge into natural water bodies (rivers, lakes) is needed for any excess water. Hot water flowing out of deep tunnels may need to be cooled down before discharge in the natural bodies.

Both recycle of the water for the tunnel production and disposal/ discharge of the water will often require installation of a water treatment plant. The reuse or discharge of the water will define the requirements for the treatment processes.

KEYS LOGISTICS GUIDELINES TO ANTICIPATE

- **Estimate expected water demand** during construction time;
- Estimate available ground water quantities ;
- Check existing local supply options;
- Check national regulations as environmental obligations concerning extraction and discharge of water;
- Provide additional water supply if needed;
- Provide enough space for water treatment facilities prior to main contract;
- Provide first modules of water treatment plant prior to main contract.

2.5.3 Supply of construction materials and machinery

External logistics is related to the provision and external storage of construction materials. External logistics can be extremely demanding in the case of narrow areas (steep terrain, depending on site location, local supply options and opportunities to re-use excavated material or natural water), which prevents local storage of material. Delivery of materials from sources far away is often a reality. In both cases transport costs and logistic are important factors which must be taken into consideration. For long tunnels, the amounts of materials are much higher than for the construction of short tunnels, and the logistic demands for the supply of machinery is highly dependent on the method of excavation.

As explained in the previous chapters, the delivery of construction material may require the construction of new roads, railways, access points and dedicated loading / unloading points, including the necessary storage areas. Especially where harsh weather conditions are to be expected, underground storage should be preferred over surface storage.

Storage capacity both on surface and underground should be foreseen for:

- Aggregates (in case the concrete is produced on site);
- Batching plants;
- Precast concrete segments (TBM) including bolts and gaskets;
- Rock support materials (bolts/mesh/ribs etc; both TBM and conventional);
- Waterproofing;
- Reinforcement for inner linings;
- Built-in components such as dewatering pipes and precast pump sumps;
- Explosive storage;
- Workshops;
- Spare parts storage.

The space for parking of vehicles needs to be anticipated too.

Once materials are delivered on site, the internal logistics inside the tunnel involve a timed process due to space constraints. Inside the underground excavations, idle areas need to be utilized for temporary storage.

The reuse of excavated material (e.g., as concrete aggregate) is additionally beneficial in order to reduce the external material demands on site. Therefore, considerable space should be allowed for muck handling facilities for crushing, washing, separation, stocking, and processing of potential aggregates.

All machinery used will need maintenance and repair, therefore enough space needs to be reserved for the relevant workshops and magazines, as detailed above in § 2.4.4. Underground structures required for logistics.

Figure 24 – Example for installations (conventional) in restricted space (Gotthard).

Figure 25 – TBM supply – Gotthard.

KEYS LOGISTICS GUIDELINES TO ANTICIPATE

- For long tunnels, the **amounts of materials are extremely high ;**
- **Define adequate storage capacity** both on surface and underground, taking into account also maintenance and repair of machinery;
- Internal logistics inside the tunnel involve a **timed process due to limited space constraints.**

2.5.4 Supply and extension of services

One of the most intensive logistic operations is the supply and later demobilization of temporary running installations for the tunnel drives, i.e. the extension of all the facilities and services. Just-in-time deliveries are often difficult, and so a considerable amount of these installations have to be stored on site.

Storage capacity both on surface and underground should be foreseen for:

- Conveyor belt components and spear parts;
- Rails;
- Water pipes (supply, natural water, waste water, cooling);
- Ventilation ducts and containers;
- Cable drums for power and communication.

2.5.5 Ventilation and cooling

High temperatures and **long ventilation** lines are characteristic of long and deep tunnels, as illustrated by the geological profile and the temperature curves in the Figure 26, showing the expected temperature of rock mass and water. Due to the length and the high temperatures, even cold air supplied from the outside will be heated along the ventilation ducting in a long tunnel. The blown air can therefore not be cool. It is not possible to cool down the entire tunnel but it is often necessary to cool locally the air at the working stations.

The definition of the cooling demand in terms of power and of the related infrastructure as well of the required ventilation needs to be estimated by the Owner in order to anticipate the contractors needs and so, start the time-consuming authorization processes. The chapter §3.4 details the issues regarding this topic.

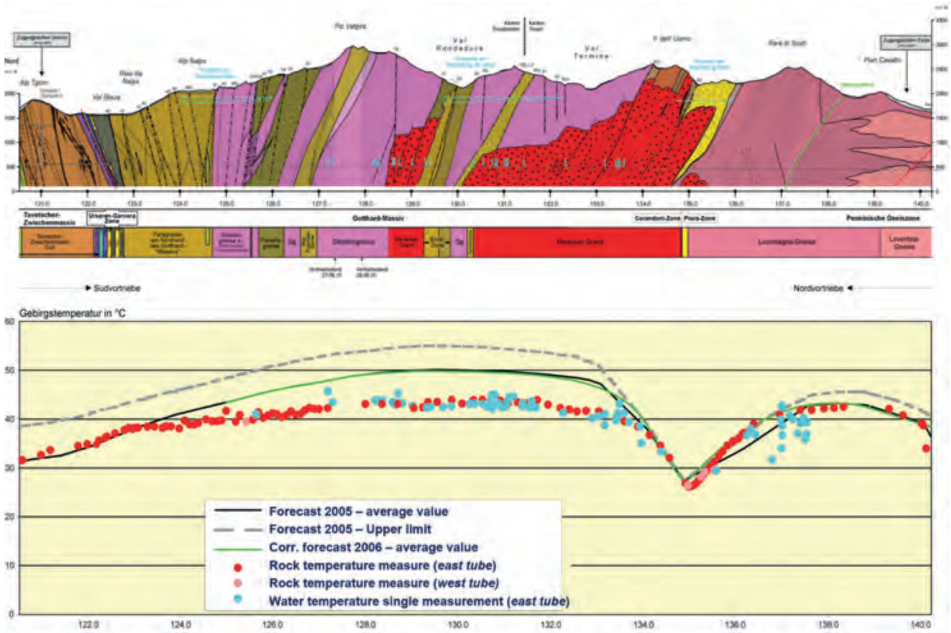


Figure 26 : rock and water temperature distribution predicted and measured on site (Faido).

KEYS LOGISTICS GUIDELINES TO ANTICIPATE

- **High temperatures and long ventilation lines** are characteristic of long and deep tunnels.
- Design ventilation and cooling according to rock temperature predictions.
- Anticipate the definition of the cooling and the ventilation demand in terms of power and of the related infrastructure.

2.6 CONTRACTORS CAMPS

Long and deep tunnels involve a great number of personnel (often several hundreds). Due to the construction schedule and, sometimes to the geological conditions, the construction of long and deep tunnels is mainly carried out by working 24/7. As a consequence, a logistical system able to support the construction works are needed :

- Shift arrangements which fulfil the national requirements regarding working conditions
- The mobilization of the manpower,
- The food and beverage supply,
- The location for personal hygiene and overnight, also including facilities for the workers spare-time (social rooms, fitness-rooms, etc).

Basically, two possible concepts exist in order to support the personnel:

- Construction of a temporary and dedicated camp (or village);
- Use of existing structures.

In remote regions, only dedicated camps will be possible. However, near cities and towns, both alternatives apply. Requirements can be reduced by hiring and educating local staff.

The advantage of a dedicated village is that it can be located close to or within the construction site, reducing all mobilization times. It also allows for 24/7 service without impacting on the routine of the surrounding villages and cities. Another advantage is that the environment, safety and hygiene requirements can be controlled by the Owner by setting the requirements in the tender specifications. Setting these requirements early on makes it clear what is needed, and thus Contractors will have the same concept when submitting offers. A disadvantage of a dedicated village is that it requires surface space.

Using existing structures is a benefit for the region that directly profits from the business generated by the construction site (apartments, hotels, etc.). This can be of great advantage for the acceptance of the project. However, this solution requires a detailed advance evaluation of the available structures. An underestimation of the availability can have dramatic consequences on timely beginning of the construction works. A disadvantage may be the daily traffic generated by the manpower going and leaving the construction site 24/7.

Figure 27 : Contractor Camp, Sigirino, Ceneri Base Tunnel.

KEYS LOGISTICS GUIDELINES TO ANTICIPATE

- Anticipate **camps for several hundreds of workers**, sometimes in remote aeras could lead to build dedicated camp.
- A balance between the interest of **dedicated contractor camp** adjacent to the construction site or the **use of existing structures** need to be done on case-by-case basis, regarding the local condition and acceptance.

2.7 ANTICIPATION AND POSSIBLE SYNERGY WITH THE OPERATIONAL PHASE

Under national and international safety regulations, and depending on the length of the main tunnel, it may be necessary to create intermediate access points to the surface for maintenance personnel and rescue teams. For example, for railways projects, safety regulations in Europe (TSI), impose separate traffic lanes in two tubes, and impose added emergency point each 20 km to securely manage rescue operations in case of fire. Other safety or operation structures (such as ventilation shafts) may also be required.

During the design phase, it is important to identify and benefit from the possible synergy that those structures offer during the construction phase. A large rescue cavern may be used, for example, during construction as a location for the underground production of concrete or other functions related to the tunnel construction.

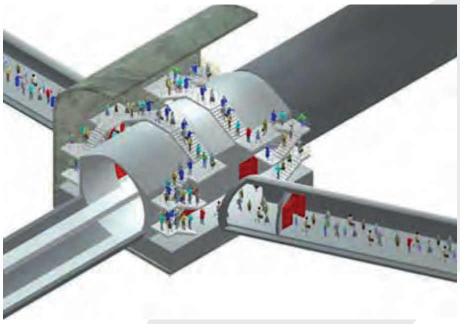


Figure 28 : Preferred Stopping Point, Pajares, Spain.

Figure 29 : PICTURE of the same point in the construction phase - bottom of the adit of 5.5 km – Ceneri, Switzerland.

Further synergies include enhanced equipment and training for local firefighting forces during construction, which then create a benefit for the operational phase of a traffic tunnel.

Figure 28 and Figure 29 shows, as an example, the underground “preferred stopping point” in the Pajares tunnel, Spain. During construction the cavern was used for logistics purposes.

Similar synergies were identified for the construction of the Gotthard Base Tunnel (see Figure 30) which highlight access tunnels of several kilometers, ventilation tunnels or shaft of hundred meters deep, bypasses, cross-overs between railway lines and the emergency point.

The same concept has been developed for the Follo line (see Figure 31): the tunnels and caverns designed for an efficient logistic during the construction phase of the Follo Line tunnels have been conceived already in the design phase in order to become a rescue area during the service phase; re-use of excavated underground space. The area has a direct access to the surface and are located approximately in the middle of the 20 km long tunnel-section. During the construction phase, the southern adit tunnel was normally used to bring down fresh air, in addition to all kinds of material, segments, and personnel. The northern adit tunnel was used to bring out used air, excavated material on conveyor belts, equipment, and personnel.

In the case of a hydraulic project, as shown in Figure 32, the multitude of caverns required in the operation phase could be used for logistics purpose in construction phase.

Figure 30 : Global operational system, Gotthard Base Tunnel, Switzerland.

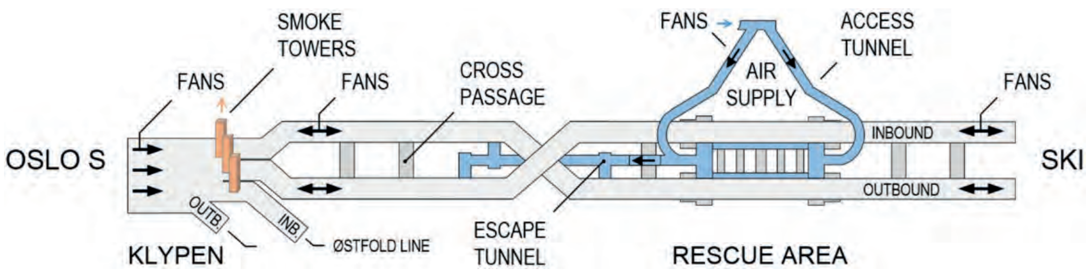


Figure 31 : Global operational system, Follo line, Norway.

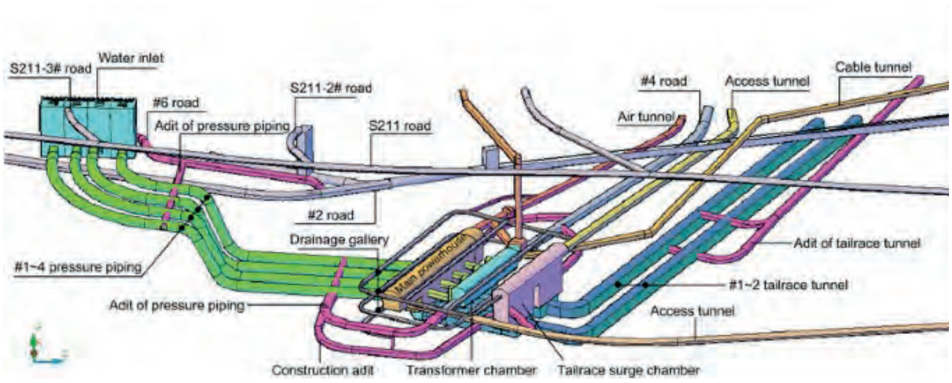


Figure 32 : Houziyan hydropower station in Southwest China.

KEYS LOGISTICS GUIDELINES TO ANTICIPATE

- In a logic of **sustainability,** but also for reasons of planning and economy, the possible **synergy with the operational phase** of the projects should make it possible to take advantage of the use of the required infrastructure as free space for logistic activities during the construction phase.

2.8 HEALTH AND SAFETY PROVISIONS DURING CONSTRUCTION PHASE

The aim of the following chapter is not to define the safety system, but just to highlight the specificities influencing the logistics system. A lot of the safety requirements have logistical consequences, such as the necessary ventilation, the accesses or the installation of rescue chambers. Key aspects necessitating special attention when designing long and deep tunnels are (list not exhaustive):

- Firewater;
- Smoke extraction;
- Communications, data and instrumentation readings;
- Personnel egress;
- First Aid mine Rescue/Fire Brigade;
- Ventilation air and redundancies ;
- Power supplies and emergency power systems,
- Flood protection devices (boats);
- Rail system;
- Pedestrian traffic.

Safety management for workers operating underground is an extremely important issue in tunnel construction and is closely linked to the ability of the rescue teams to intervene in case of an accident in order to access and extract personnel. The **success of the rescue teams is directly related to the ease and timely response of their deployment.** In the case of **long tunnels under a high overburden,** the work safety of all workers on the site becomes an even more demanding task, **emphasized if there are no intermediate access point and presenting small inner dimensions.**

It is mandatory to understand the impact of the **safety requirements on the inner size of the tunnel,** for those underground projects that are long, without intermediate access, and presenting a small inner size. Having a serious rescue plan developed from the design stage and maintained during the construction phases as the project evolves should be a must in order to ensure the safety of the workers. This plan should be defined together with the local fire brigade (if any). The risk of fire during construction exists and, as explained in the paragraphs below, having rescue chambers alone, is often not enough for long and deep tunnels, due to the limites accessibility and the rescue time.

Some countries as Germany propose to introduce minimum inner diameter size depending on the length of the tunnel from the last access point, in order to facilitate the access of rescue team and the installation of all the required equipment's [13] DAUB Guidelines «Guide to safety and health protection on underground construction sites", DAUB, German Tunnelling Committee, 2022. In this guideline, another aspect highlighted is that sufficient space for rescue chambers should already be planned for in the design phase, and when selecting the transport means and location of utilities. In smaller tunnels, regular excavation of lateral caverns to house the rescue chambers must be foreseen.

It is a normal procedure for the owner to define the dimensions of a tunnel with respect to its final purpose. Tunnel dimensions are the result of calculations for the operational phase (hydraulic flows, trains speeds, etc.), but in some case the safety issues during construction could lead to modify the time schedule or the final tunnel design dimensions accordingly:

- In this respect, the designers should consider the construction of the **auxiliary infrastructure** as a critical task in the construction schedule in order to make them **available as early as possible for evacuation or rescue operations.** e.g., for twin tunnels, the cross-passages should be excavated near the front. This simple analysis can modify the construction schedule in order to complete these different tasks early enough to make them available for rescue.
- The designers should study economic and technical solutions to balance the technical needs and to reduce risks while improving the safety level during construction. These solutions could be an increase of the inner dimensions and/or the early construction of auxiliary infrastructure, such as an intermediate access or ventilation shafts, for example.

Those considerations are usually provided under the form of Risk analyses and summarized in the Risk Register of the project.

In long tunnels evacuation is a time consuming process and access routes may be blocked. Refuge chambers may provide a critical lifeline to workers until rescue team arrives, however they may not represent, without combination to other measures, a stand-alone solution in term of safety. Requirements to refuge chambers are hard to come by, so a careful analysis of the tunnel project should be used to select or design the proper chamber, and the distances between them (see process description by Antretter [11]). Although, in general, the ideal refuge chamber is a standalone, redundant system that provides fresh air, mitigates carbon dioxide build-up, and maintains cool inside temperatures, attention shall be paid to the maximum occupancy time with respect to rescue time. As recommended in the ITA Report 14, about refuge chambers [10] :
"The period of time for which the chamber could be in use should be assessed on the likely time required to affect a rescue. It is recommended that refuge chambers are designed for a minimum occupancy time of 24 hours. Where this is considered insufficient, the project risk assessment should include a determination of the minimum occupancy time."

The consequences of fire scenarios on ventilation system are described in chapter §3.4.2.2.

KEYS LOGISTICS GUIDELINES TO ANTICIPATE

- In the case of long tunnels under a high overburden, **safety of all workers** on the site becomes an even more demanding task, **emphasized if there are no intermediate access point and presenting small inner dimensions.** This constraint needs to be introduced in the design plan with the highest priority ;
- A **global approach** (infrastructure, ventilation, access, evacuation routes, materials...) is needed to define the safety provisions during construction, and for example it is essential to:
  - Design tunnel dimensions to guarantee escape and rescue operations
  - Design tunnels to guarantee adequate ventilation (size of ducts) and placement of rescue equipment (refuge chambers)
- In some case the safety issues during construction could lead to modify the time schedule or the final tunnel design dimensions;
- Having a **serious rescue plan developed from the design stage** and maintained during the construction phases defined together with the local fire brigade (if any) is a must in order to ensure sage work environment in the tunnel.

3 >> Logistical Aspects To Manage During Construction

INTRODUCTION

The second part of the guideline deals with the **main challenges related to the logistical aspects during the construction** and provides some guidelines to define them. Theses main challenges detailed hereafter concern:

- Global traffic organization inside the tunnel system,
- Muck management and reuse of spoil,
- Concrete production and transport,
- Ventilation and Cooling,
- Importance of industrialization of construction methods ,
- Others aspects influencing logistics.

3.1 GLOBAL TRAFFIC ORGANIZATION INSIDE TUNNELS

Long and deep tunnels are characterized by long distances between the advancing faces and the external logistics areas. In order to supply all the construction material as well as the personnel to the sites underground, and in order to evacuate the excavated material, a transportation concept needs to be developed.

Main transportation systems, operated in addition to the construction equipment underground, as illustrated on Figure 33 are:

- Train;
- Belt conveyor;
- Multi Service Vehicles (MSV);
- Trucks;
- Hoists (shaft access).

Depending on the tunnel shape and section, the traffic underground needs specific underground structures such as:

- Enlargements for allowing the crossing of vehicles or as turning points;
- Temporary parking areas;
- Logistical by-pass for switching the traffic from one tube to the other (in case of multi-tube systems);
- California switches in case of trains.

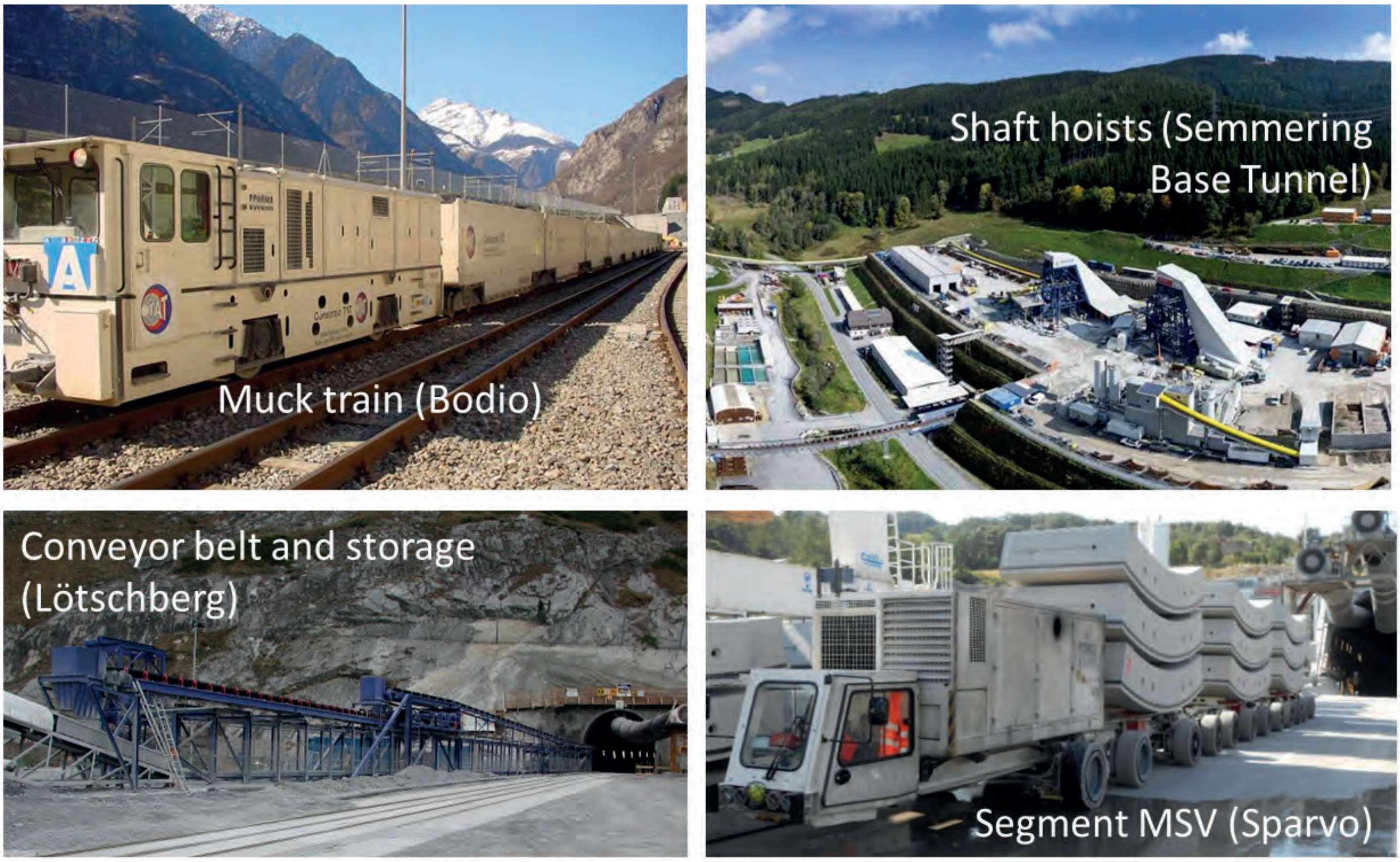
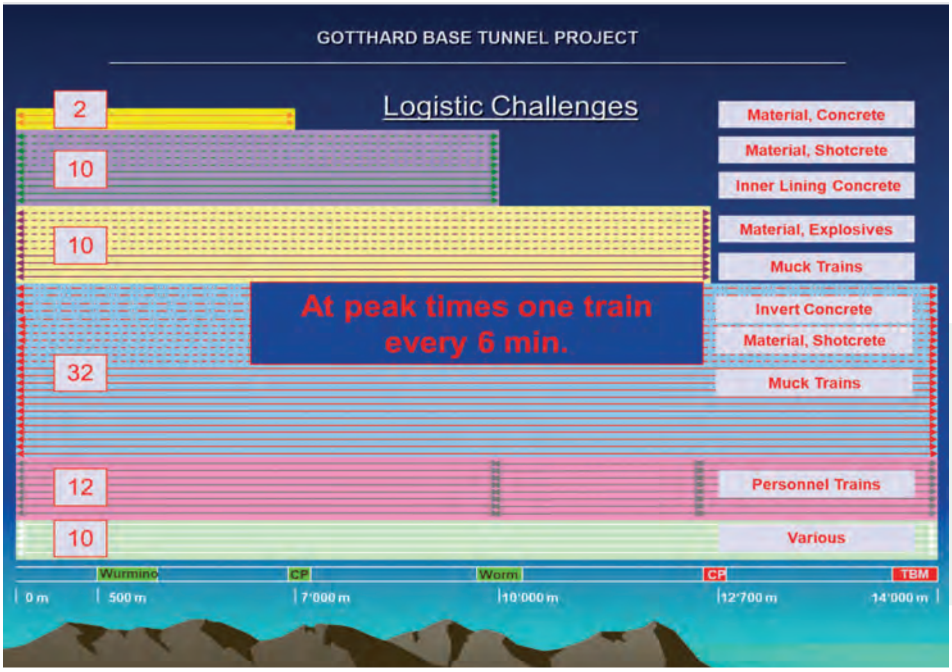


Figure 33 : Examples of transportation systems.

Although it is a Contractor's domain, the study of the transportation system and of the related traffic is crucial from the preliminary design stage of a project, as it allows for accurate estimation of the construction costs and potential logistical bottlenecks. While rail traffic is considered safer as individual driven vehicles, the design of tunnels and adits may well prevent the use of such a system due to slope angles and tight radii. Especially steep adits cannot be used by trains (although technical progresses allow inclined train use by equipping them with gear climbing), and even conveyor belt systems are limited in slope and radii, although extreme solutions have been realized (Jinping 2010).

In the example of the Gotthard Base Tunnel, a transportation concept based upon trains has been adopted, and very well planned. Figure 34 summarizes the logistical challenges experienced: due to logistical needs, during peak times, trains were passing every six minutes to supply the construction of the two base tunnels. A so-called guide office is needed to coordinate the trains, and a special timetable is used for passenger trains to and from the various jobsites inside the tunnel system. In addition, enough parking space is needed for the rolling stock. In this case the total rolling stock of 70 locomotives and 400 cars would line up to a length of approximately 3 km. However, it should be mentioned here that mucking by rail leads to high operating costs: due to their weight, the mucking trains put a strain on both the chassis of the wagons themselves and the track system. Mucking with a conveyor belt system is associated with lower operating costs.

As an example, for the main transports into and within the tunnel system during the excavation of the two Follo line tunnels (cf. Owner's interview in Appendix 1), the Contractor proposed to use Multi Service Vehicles (MSV) instead of trains. This choice paved the way for a more efficient and flexible operation of all transports into and within the tunnel system. The segments for the lining could for instance be loaded at the factory on the surface and being transported all the way into the TBMs for installation, instead of being re-loaded to a train down in the tunnel. The tunnel was wide enough for two MSVs to pass each other, which eliminated the need for having an operator to take care of the transports in the tunnels. All vehicles within the tunnel system could go in and out individually, independent of other transports. This system gave a huge flexibility for all kinds of transports within the tunnels.



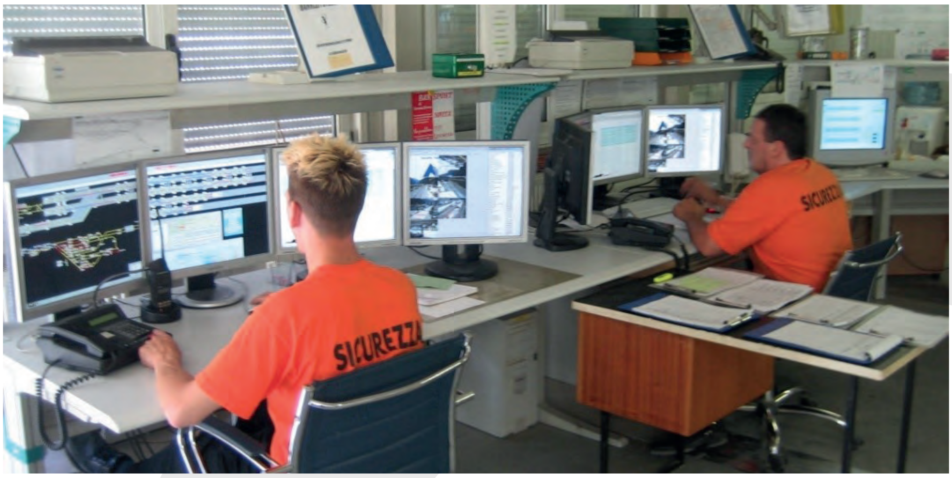


Figure 34 : Logistics challenges of the transportation concept at the Gotthard Base Tunnel, Switzerland.

KEYS LOGISTICS GUIDELINES TO ANTICIPATE

- Anticipate as much as possible the **study of the transportation system** and of the related traffic;
- **Flexible design** to allow for multiple choice of transport equipment;
- Setting up a traffic management organisation.

3.2 MUCK MANAGEMENT AND REUSE OF MATERIALS

The **correct management of muck is a crucial environmental aspect considerably impacting the logistics concepts of underground works.** For long tunnels, the amount of muck to be handled in a sustainable way is huge, compared to the amounts from short tunnels. The main strategy for the management of the muck should be that this is a resource of high value, but it depends on the quality of the material excavated. In a wider sense, the muck management starts with the classification of the rock mass type at the tunnel face and ends with the disposal of the material in the final deposit or as reused material (concrete aggregates, roads, dams, basement for future development of the deposit area, etc.).

The goal of this section is to give an overview of the muck management key aspects and principles. Detailed considerations about the topic are given in the Reports elaborated by the ITA Working Groups ITA WG 15 (1998) [8] and ITA WG 14 and WG 15 (2019) [5]. It is essential to prepare a **Tunnel Spoil Management Plan.**

This activity could be managed by a dedicated contract covering the whole project or be part of the main civil engineering contract. The best solution will be chosen on a case-by-case basis. Whatever the choice, the involvement of the project owner in the management of this subject remains essential, as highlighted in the detailed comparison of reuse of material in Swiss tunneling project [7] .

3.2.1 Mucking-out methods

The understanding of the available mucking-out methods is crucial: mucking out impacts the construction time as well as the infrastructures inside and outside of the tunnels. The selection of the mucking-out method may impact, for example, the geometry of the adits in terms of size, maximum slope and minimum radius.

The mucking-out from the tunnel face until the temporary disposal depends partly on the excavation method.

- Continuous methods:
  - Conveyor belts (mainly used for hard rock and EPB TBM's),
  - Slurry lines (used for slurry shield TBM's).
- Discontinuous methods:
  - Trains (used mainly for TBM's),
  - Trucks/MSV's (mainly used for conventional tunnelling).

Conveyor belts have been used in conventional tunnelling, but it requires crushing facilities close to the excavation face (Ceneri Base Tunnel).

From the temporary disposal area, the material is either reused on site, or transported to its final disposal area by means of belt conveyor, trucks, railway or ship/barge. Due to environmental reasons, and in order to limit the impact to the area along the transportation ways, transportation on train or belt conveyor represents nowadays the “state of the art”.

3.2.2 Reuse of excavated materials and space for temporary spoil disposal

The site logistics of a long tunnel are significantly influenced by the large quantities and the quality of the material being excavated. One of the main aims of the logistics organization is to reuse good quality material as soon as possible and to transport material that is no longer usable to a disposal site as quickly as possible. Several options exist for the re-use of the excavated material:

- Concrete aggregates, depending on the mineralogy of the rock;
- Basement for roads and railway, depending on the size and the shape of the spoil[3];
- Basement for buildings, residential areas depending on the size and the shape of the spoil;
- Covering of polluted material on shore and sub-sea;
- Off-shore filling in order to extend land or islands.

For the re-use of excavation material, is based upon a process consisting in

- Sorting the material;
- Analysing the spoil;
- Treating / processing the spoil;
- Storing before re-use or dumping to final disposal of the spoil. Sometimes, the excavated material is successfully adapted to reclamation areas that have already been compromised from the landscape point of view, such as, for example, depleted quarry sites. The construction of landfills follows the usual schemes of earth works. However, depending on the local legislation and on the excavation type, the re-use of the material as landfill (or its final disposal) may be subject to environmental restrictions impacting the treatment requirements on the spoil (e.g., use of chemical conditioners in the case of EPB machines).

The process above requires a large amount of surface and it is therefore crucial to have sufficient space to handle the material. The re-use of the excavated material is therefore not only an advantage in terms of costs, but it allows to reduce the demand in terms of disposal size volume.

At the design level it is important to elaborate a time schedule linking the planned production with the storage of material in temporary disposal sites (if any) and subsequently in the final disposal site. The latter requires realistic and precautionary assumptions preventing a large volumes of excavated material from being transferred in an unplanned manner to unplanned destinations, thus risking to cause delays in the progress of the work with negative economic impacts.

The Figure 35 and the Figure 36 highlight how huge are the required size of areas for temporary disposal of material for that type of projects. In the case of Brenner Project, a total of 4 million cubic meters spoil are foreseen.

Additional considerations on the topic are given in [5] ITA Report No. 021 «Handling, Treatment and Disposal of Tunnel Spoil Materials », Underground construction and the environment and mechanized tunnelling, Working Groups 14 and 15, April 2019 as well as in AFTES Guidelines «Excavated Materials GMVE» - Working Groups GT35, AFTES, GT35R1A2 [6].

The Figure 37 shows an example of a reuse site and the Figure 38 shows the spoil handling facilities , both in Switzerland projects.

[3] Due to the method of excavation, there is a great difference between the grain size curves of the excavated rock mass obtained from conventional drilling and blasting and rock TBMs. The latter is smaller than that obtained from drill and blast (DandB) excavation and it is characterized by a typically elongated and flattened shape. Therefore, this influences logistics equipment and machinery including primary and secondary crushing plants, sieve plants, washing plants, and others.

Figure 35 : Site set-up including space for temporary disposal of material in Guadarrama High Speed Rail Tunnels (courtesy ADIF).

Figure 36 : Hinteregger site plant view, Italian side of the Brenner Base Tunnel (courtesy BBT).

Figure 37 : Reuse of excavated material site, Modane 2005, (courtesy TELT).

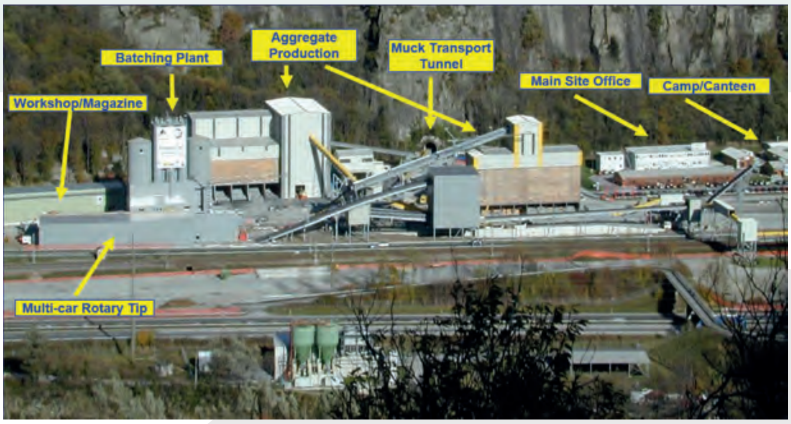


Figure 38 : Spoil handling facilities at Gotthard Base Tunnel south section (including spoil transport tunnel to final disposal).

KEYS LOGISTICS GUIDELINES TO ANTICIPATE

- Correct management of spoil is a **crucial environmental aspect** considerably impacting the logistics concepts.
- Mucking-out method impacts the construction time as well as the infrastructures inside and outside of the tunnels.
- Enough space for temporary spoil disposal and material handling facility, and all the reuse process is required.
- Implication of the owner in the reuse process, as highlighted in the chapters §2.2 Authorizations and environmental aspects and §2.3 Identification of final disposal site for spoil is essential.

3.3 CONCRETE PRODUCTION AND TRANSPORT

3.3.1 Cast in place lining and shotcrete

Concrete represents the main source of material to be supplied on site. Concrete is used for the construction of both primary and final lining as well as for most of the internal structures.

For long tunnels, where the construction will take place over several years, it is often beneficial to produce the concrete within the construction site instead of bringing it in from an external producer. Internal production may also contribute to less transports and easier logistic management.

For this reason, concrete plants have a fundamental role in the logistics system of large sites: the amount, the production capacity, their location as well as the supply concept of aggregates, cement and, finally, its transportation to the casting points are crucial aspects to be considered when conceiving the logistics of a long and deep tunnel. Figure 40 and Figure 41 illustrate the transportation solutions implemented for concrete with trains and a concrete mixer on a railcar, in the Gotthard Base Tunnel.

Sometimes, it is relevant to locate the concrete plant in an underground cavern , as illustrated in Figure 39. This setup offers a dual advantage of being completely invisible to residents and shortening supply times

The decisive factors influencing the logistical choices for the identification of the most suitable concept for concrete production and supply are:

- the proximity between the production site and the installation site (very short time to supply concrete where necessary);
- the sites in which they are located that allows them to be simply supplied with raw materials and other elements (water, cement, additives) that make up the various mix designs foreseen in the project (for the case of the concrete plant inside the precast segment factory) and environmental protection in the case of the underground factory.

In the case of shotcrete, either unreinforced or fiber- / mesh-reinforced, the entire process of preparation of fresh mixes and transport to construction sites requires high-quality technological and logistical support with focus on delivery speed and efficiency. Shotcrete may also need to be supplied in an emergency situation so that its supply chain should be secured (redundancy) and quick. Therefore, project solutions for shotcrete logistics during construction heavily depend on the quality and typology of transport machinery.

From a sustainability perspective, consideration could also be given to reusing the temporary concrete facility when the site is demobilized for local use or placing the concrete plant underground (see Fig 39 and discussion in chapter 2.4.4).

Figure 39 : Underground concrete plant, Ceneri Base Tunnel (Pini Group Ltd.).

Figure 40 : Concrete mixer railcars (Gotthard).

Figure 41 : Train filling station (Gotthard).

Figure 42 : Batching plant on the construction site close to South Portal at Rohtang Tunnel, India (Strabag and Afcons JV).

3.3.2 Precast concrete lining

If precast concrete lining is adopted for TBM driven tunnels, its design, testing, manufacturing, storing and installation plays an important role in the site logistics.
From the construction point of view, a dedicated precast concrete segment factory can be set close to the tunnel portals where sufficient space is available. This solution reduces the traffic associated with supplying materials to the job site compared to an external precast factory, and normally brings associated commercial benefits. In these cases, the re-use of the excavated rock as aggregates for the precast concrete lining has greater potential. Attention to the distribution of potentially suitable aggregates along the alignment and to the strategy of concrete testing should be paid, as the right rock for aggregates may not be available from the project start and/or not found continuously. Areas for temporary storage of excavated rock material while waiting for results for testing of the quality and chemistry (e.g. sulfur or mica content) of the material for aggregate production should be considered. If relevant for the performance of the project, the provision for space for precast factory, crushing facility and segment storage yard should be considered from an early project stage.

At the Follo line project, all the functions related to the operation of the four TBMs were located within the construction site, including the segment factory and production of the bi-component for back-fill of the segments, See Figure 43.

The size of the segment factory (production facility and storage area) is of course related to the predicted TBM advance rates. In the case of Guadarrama HSR tunnel in Spain, the average production of the two TBMs was 1,000 m/month with estimated peaks of 900 m/month for one machine, or 1,500 m/month for two machines. The segment factory at the North portal (cf. Figure 44) had a storage capacity of approximately 1,100 rings, and a strategic reserve of at least 800 rings.

Regarding precast segment supply to the TBMs during excavation from the tunnel portals, the tendency is to transport several rings on the same convoy (by train or multi service vehicles) to minimize the traffic in the tunnel, requiring long compositions that may impact the loading areas, especially in case of access shafts. Limitations to that principle are given by the slope of the tunnel, which limit the maximum weight of the convoy.

The choice of backfilling material for the precast lining should also be studied early in the design process, as it impacts the tunnel logistics. From a logistical point of view, inert materials like pea gravel or pumpable materials like bicomponent grouts or dry premix granular mortar are generally preferred compared to stabilized mortars (remark that pea-gravel generally goes with an invert filling with granular mortar which could be inert), as the last ones pose operational transport difficulties with increasing tunnel lengths.

Figure 43 : Follo Line construction site and segment factory (courtesy Bane NOR).

Figure 44 : Guadarrama - Segments factory (Courtesy ADIF).

Figure 45 : Follo Line - Segments transported on MSV are de-loaded within the TBM (courtesy Bane NOR).

Figure 46 : Precast area on the construction site close to South Portal at Rohtang Tunnel, India (Strabag and Afcons JV).

KEYS LOGISTICS GUIDELINES TO ANTICIPATE

- It is often beneficial to **produce the concrete within the construction site,** and that may also contribute to less transports and easier logistic management. In a sustainability perspective, consideration could also be given to reusing the temporary concrete facility when the site is demobilized for local use.
- Plan the **location of the concrete plants** need to consider:
  - the transport distance of the concrete to the delivery point;
  - extreme weather conditions.
- In case of shotcrete, the entire process requires high-quality technological and logistical support with focus on delivery speed and efficiency.
- Consider tailormade solutions for segment transport inside the tunnel.

3.4 VENTILATION AND COOLING

The aim of the following chapter is not to describe the necessity and scope of the ventilation and the cooling system, but just to highlight the consequence of their implementation on the logistics system.
The primary objectives of construction site ventilation are to:

- provide a sufficient volume of fresh air for the personnel involved in the work;
- dilute the emissions of the diesel-powered equipment and transportation vehicles (e.g. by adopting Sustainable solutions such as electric driven vehicles can substantially reduce ventilation requirements);
- maintaining the performance of machines equipped with thermal engines;
- fulfil the requirements concerning maximum concentration of pollutants in a work environment (e.g. dust);
- reduce or eliminate the dust caused by excavation operations.

A further objective is to support evacuation of personnel should an emergency event occur in the tunnel; based on the location of the fire, certain areas must be guaranteed to be smoke-free to provide specific escape routes, as underlined in chapter §2.8 Health and Safety provisions during construction phase. Besides this, construction site ventilation also reduces the heat produced by the machinery by implementing cooling measures.

In specific cases such as high-temperature rock masses, which are typically present at great depths or high external temperatures, the ventilation system can be supported by a specific air cooling system to ensure a acceptable working environment.

3.4.1 Regular construction site ventilation

The design of the ventilation system has to consider the following parameters:

- guaranteed high air quality directly at each work station in the tunnel system, meaning the main work environment;
- guaranteed dilution of contaminants such as harmful gases;
- temperature control in the work environment;
- ease of maintenance;
- ensure an acceptable noise level;
- flexibility.

Attention has to be paid in long tunnels to the construction site ventilation design as the large amount of vehicles used for logistics (typically powered by diesel) requires a large amount of air flow through the tunnel. The long distances to blow air, combined with the required high flows in many cases, mean that if ventilation ducts are used:

- large diameter ventilation ducts are needed, even parallel duct circuits, using significant space of the tunnel cross section;
- the long distances require high blowing pressures, with associated high ventilation leakage;
- the high flow required in the face combined with the high leakage level may generate an excessive air flow in the tunnel, which can be problematic.

In some cases, this may lead to limitations in the equipment used for logistics and therefore may limit the productivity of the excavation equipment. Alternative solutions with ventilation shafts or ventilation galleries to partially reduce the blowing distance with ventilation ducts can be explored.
The controls of the ventilation system should be made from the surface because in case of fire it may be necessary to shut down some fans.

Figure 47 : Ventilation Installation (duct + dedicated gallery) at the bottom of Ferden (Lötschberg Base Tunnel) .

Generally, speaking, two main configurations of ventilation concepts exist, as detailed in the ITA Report No. 08 Working Group 5, 2011 [7], or in AFTES GT27:

- Forced fresh air ventilation;
- Extraction ventilation system.

The forced fresh air ventilation system ensures that the working environment is provided with fresh, cool air from the surface. It is again important to remind that the management of the temperature underground strongly depends on the length of the tunnel as well on the outside temperature: sometimes it is so cold outside that workers stop the ventilation not to get cold. Sometimes on the contrary, even if it is cold outside, after a few km of ducting the air in the ventilation duct is warm and does not help for cooling the workstations. Moreover, when blowing warm and damp air in a clod environment may create fog and so problem of visibility in the tunnel.

The required amount of fresh air has to be determined according to the respective national regulations and is usually defined by the “installed power” of the diesel driven equipment in the tunnel and the number of workers.

In the case of Austria, for example, the following minimum requirements apply:

The maximum air flow in the tunnel should indeed defined in order to avoid airborne particles.

In long, deep tunnels, it takes a significant amount of power to push the fresh air forward through the long tunnel duct using surface or intermediary fans. There will be inevitable losses along the duct that increase with flow and pressure. It is advisable to inspect and repair the fresh air duct regularly to limit losses, pressure drops, and power spikes due to damage. Design choices such as continuous conveyors instead of muck trains, electric-powered locomotives, and efficient water-cooled systems can reduce the amount of air the system must mitigate, measurably reducing the ventilation demand.

In case of parallel tunnels, the length of ducts can be considerably reduced by limiting the ducts system to the area between the two advancing tunnel faces. The open area of one tunnel is used for fresh air supply, while the second tunnel is used for waste air transport. This requires a series of special measures such as closing all cross passages except for the ones closest to the faces to exchange air between both tunnels. Also the main tunnels have to be closed with so-called weather doors, which open automatically when vehicles are approaching. The system needs a lot of discipline of all employees but has been successfully operated at the Gotthard Base Tunnel (see pictures in Figure 48 below, and also the global system is illustrated on Figure 21, in chapter §2.5.1 Power supply).

MINIMUM REQUIREMENTS FOR VENTILATION SYSTEM IN AUTRIA	
Minimum oxygen content in the air	19%
Minimum air speed in the tunnel	0,20 m/sec
Minimum amount of fresh air	2m^2/min for each person and 4m^3/min for each installed KW of diesel driven equipment
Additionnal restriction	Avoidance of dangerous or otherwise detrimental concentration of health-endangering substances, such as carbon monoxide, nitrogen oxide, sulfur dioxide or respirable quartz or silicate dust.

Figure 48 : Inflatable or fixed weather doors to close cross passages and main tunnel (Gotthard Base Tunnel).

Extraction ventilation systems are suitable when the amount of dust at the face is high (especially in the case of roadheader excavation). This usually is the case when adopting TBM operating in open-mode in hard rock and conventional excavation in drill and blast. Extraction fans are also used to remove toxic gases after a blast.

A local extraction ventilation system is connected to dry scrubbers on the TBM and can be used to limit airborne dust in the tunnel. The system should extract the dusty air as close to the source as possible. Smaller, localized extraction systems with de-dusters can be useful near specific equipment such as conveyors or rock crushers. When shotcrete is used, a localized extraction system with a wet air scrubber is likely needed. The Figure 49 highlight how complex the system could be.

Limiting dust in the air is essential for workers to breathe properly (silicosis prevention is setting very stringent concentrations in silica dust particles) and see, and also prevent explosions from high concentrations of airborne particles that act as a flammable gas. See section § 3.4.2 on fire scenarios, nowadays, regulations are more based on the exposure of workers to pollutants (concentrations and time). To this respect, the optimization of the flow with variators and pollutants measurements may lead to significant savings, and so represent a sustainable way of managing the ai flow in the tunnel.

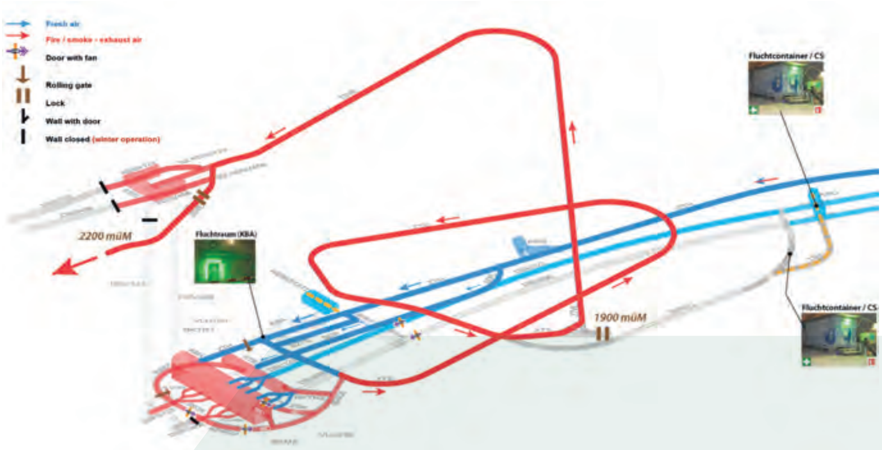


Figure 49 : Safety ventilation scheme – Nant de Drance 2015.

3.4.2 Ventilation and Procedures in Case of Fire, Fire Scenarios

3.4.2.1 Fire Prevention, Methane

The most efficient measure to avoid fire scenarios is prevention by reducing the fire sources when defining the equipment in the tunnel (limit wood, use flame retardant conveyor belts, cable insulation material, transformer insulators, limitation of acetylene bottles…). **Material selection** throughout the tunnel is therefore important. Ventilation materials are permitted to burn under direct flame but must self-extinguish once the flame is removed. Duct material may not melt or drip while burning and may not emit hazardous gases while burning[4]. Light alloys such as aluminum can spark very easily when struck, so they should be prohibited from tunnels where methane is present.

The flammable gas of primary concern for tunnel excavation works is methane, which exists naturally underground. The **likelihood of methane increases at greater mining depths.** Methane's lower explosive limit (LEL) is ~5% by volume, so it is a risk even at low air concentrations. The excavation work design must ensure that methane concentration is kept low and ignition sources are reduced. As evidenced from past tunneling accidents, methane explosions can cause severe destruction and injuries, and the damage cannot be mitigated after the fact.

Different Standards exist in countries (sometimes standards even differ within states such as California, USA) that outline requirements for operating in environments with flammable gases present. The goal of the standards is the exemplary monitoring of gas concentrations and the elimination of sources of ignition with proper equipment design requirements of standards used in tunneling include OSHA and the NEC, national electric code, in the United States and the ATEX directive in Europe.

3.4.2.2 Fire Scenarios and Emergency Ventilation

There isn't much that the ventilation system can do after an explosive fire from methane or dust, so it is critical to design systems to prevent this from happening in the first place. During non-explosive fires, the ventilation system becomes very important in maintaining worker safety and possible evacuation, as underlined in chapter §2.8 Health and Safety provisions during construction phase.

It is important that the ventilation system is powered by essential services, so it works during a fire or other emergencies. This is a reason why controls of fans should be at the surface.

The identification of construction risks as well as the definition of the mitigation and intervention measures (Fire-fighting scenarios and rescue scenarios for fire) are usually summarized in a safety plan. The latter is shared among the Contractor, Owner and external entities, such as the local fire brigade, police, and ambulance-services that may be included or that need to be informed in case of an emergency event. A regular update of the safety plan based on the construction process is mandatory.

The ventilation system should be used to supply emergency escape routes with fresh air-surpressure to keep them smoke-free. However, the ventilation system must not provide the fire with oxygen.

Depending on the local firefighting regulations for underground construction sites, the rescue and firefighting authorities need to be involved in the logistics planning and rescue plans. If a project does not provide its own rescue organization and relies on the local firefighting departments, there is often a need to improve or adapt the existing equipment for the special tasks of underground rescue operations. Special reserved vehicles need to be provided for the immediate transport into the tunnels.

Regular information and visits to the tunnel are mandatory for firefighting and rescue authorities, as well as the education of project staff to serve as scouts in case of an intervention.

[4] EN ISO 4589, "Plastics – Determination of burning behavior by oxygen index…"

In the specific case of long and deep tunnels, the main challenge is represented by the possible distance between the occurrence of the event and the last access point by emergency services. In order to ensure the safety in the tunnel, usual mitigation measures are the installation of rescue chambers, design an efficient ventilation scheme in case of fire incident, and have a strong cooperation with safety authorities.

Figure 50 : Tunnel Tag required in order to allow the rescue team to localize the workers trapped in the tunnel.

Figure 51 : Exit/Entrance of The North Portal at Rohtang Tunnel, India (altitude of 3.100 m above the sea).

3.4.3 Cooling System

The goal of the cooling system is to **keep air temperature in the work environment within the acceptable thresholds** prescribed by national and international laws. Typical heat generation sources are:

- Tunnelling equipment (TBM or conventional tunnel equipment);
- Logistic equipment (Locomotives, trucks, MSV's, conveyor belt drives);
- Hydration of concrete;
- Rock temperature;
- Ground water temperature.

Substantial reduction of cooling requirements can be achieved by sustainable solutions such as:

- Segmental lining instead of in-situ concret;
- Use of electrical driven vehicles instead of diesel;
- Direct intake of hot mountain water at the face into pipes (Remark: in order for that measure to be efficient for a long tunnel, the pipes must be seriously insulated).

The cooling system is tasked with distributing to the tunnels the amounts of cooling water required during normal operations. This system is used both to cool industrial equipment which generates heat when used and to capture and extract the heat from the rock mass. During normal operations, the cooling system acts as a network for industrial water and in case of emergency it acts as fire-fighting water supply. In long and deep tunnels, where rock temperature plays a more significant role, there are usually two systems:

- Industrial water circuit (cooling of TBM components, drilling, washing etc.);
- Cooling water circuit (air cooling).

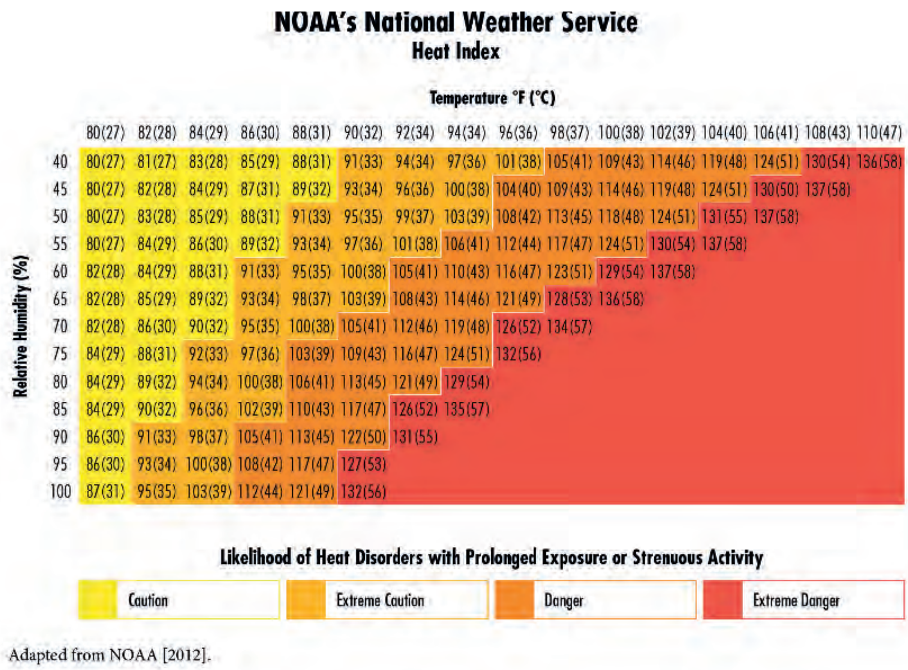
3.4.3.1 Cooling Goals in Tunnel

There are many sources of heat in tunnels from a TBM and other equipment in conventional excavation, but environmental heat from rock and groundwater becomes more dominant and pervasive as tunneling goes deeper and gets longer. Opposed to rather short tunnels it is no longer possible to cool the entire tunnel system to acceptable temperature values. Efforts of sufficient air cooling are concentrated on the main working areas (tunnel face/cross passages/inner lining). Any transportation vehicles need to be equipped with air-conditioned cabins. Working periods in tunnel sections not sufficiently air conditioned, for example for maintenance of the logistic lines, need to be kept short.

Standards or guidelines for acceptable working temperatures or heat stress vary between countries or projects. There are many factors involved in whether someone will experience heat stress or heat-related illness, such as age, health, activity level, exposure duration, etc. The most common indicator of dangerous conditions is the wet bulb globe temperature (WBGT), or heat index. This is essentially a measure of temperature that considers the influence of humidity.

NOAA National Weather Service publishes guidelines explaining the danger of high heat indexes. OSHA uses these guidelines while also acknowledging that heat stress is complex and there is no defined limit for workers. OSHA calculations assume heavy clothing can cause a person to experience temperature up to 3° hotter and strenuous work can cause significant heat stress even at lower heat indexes. Due to unpredictability of heat stress, the working environment should be kept well below the boundary of dangerous conditions. For underground work, the recommended acceptable limit for heat index is ~28°C (82.5°F)[5].

Even with air cooling systems in place to limit the heat index in working areas, the tunnel is still a harsh environment. It is recommended that the TBM is designed with fully air-conditioned operator cabins, refuge or rest stations, and cabs in transport vehicles. Workers should rotate shifts in the tunnel environment to limit heat exposure.


NOAA's National Weather Service
Heat Index

Temperature °F (°C)

Relative Humidity (%)	80(27)	82(28)	84(29)	86(30)	88(31)	90(32)	92(34)	94(34)	96(36)	98(37)	100(38)	102(39)	104(40)	106(41)	108(43)	110(47)
40	80(27)	81(27)	83(28)	85(29)	88(31)	91(33)	94(34)	97(36)	101(38)	105(41)	109(43)	114(46)	119(48)	124(51)	130(54)	136(58)
45	80(27)	82(28)	84(29)	87(31)	89(32)	93(34)	96(36)	100(38)	104(40)	109(43)	114(46)	119(48)	124(51)	130(50)	137(58)	
50	80(27)	83(28)	85(29)	88(31)	91(33)	95(35)	99(37)	103(39)	108(42)	113(45)	118(48)	124(51)	131(55)	137(58)		
55	80(27)	84(29)	86(30)	89(32)	93(34)	97(36)	101(38)	106(41)	112(44)	117(47)	124(51)	130(54)	137(58)			
60	82(28)	84(29)	88(31)	91(33)	95(35)	100(38)	105(41)	110(43)	116(47)	123(51)	129(54)	137(58)				
65	82(28)	85(29)	89(32)	93(34)	98(37)	103(39)	108(43)	114(46)	121(49)	128(53)	136(58)					
70	82(28)	86(30)	90(32)	95(35)	100(38)	105(41)	112(46)	119(48)	126(52)	134(57)						
75	84(29)	88(31)	92(33)	97(36)	103(39)	109(43)	116(47)	124(51)	132(56)							
80	84(29)	89(32)	94(34)	100(38)	106(41)	113(45)	121(49)	129(54)								
85	84(29)	90(32)	96(36)	102(39)	110(43)	117(47)	126(52)	135(57)								
90	86(30)	91(33)	98(37)	105(41)	113(45)	122(50)	131(55)									
95	86(30)	93(34)	100(38)	108(42)	117(47)	127(53)										
100	87(31)	95(35)	103(39)	112(44)	121(49)	132(56)										

Likelihood of Heat Disorders with Prolonged Exposure or Strenuous Activity

Caution | Extreme Caution | Danger | Extreme Danger

Adapted from NOAA [2012].

Figure 52 : NOAA Heat Index Danger Guide.

3.4.3.2 Water Cooling System Design

Some equipment can be cooled locally with heat exchangers, closed loop water or glycol circuits, or refrigeration cycles, all cooled by the incoming and return industrial water system the length of the tunnel. The incoming and return lines are installed along the tunnel wall from hose reels at the end of the TBM back-up. It is especially important to use well insulated, water-cooled equipment in long, deep tunnels to reduce power requirements for the ventilation system.
TBM systems or equipment that are generally water cooled:

- Main drives and gear boxes;
- Lube system for main bearing and pinion and main gear mesh;
- Hydraulic system;
- Variable Frequency Drivers (VFDs);
- VFDs;
- Air compressors;
- Roof and probe drill systems;
- Dewatering system;
- Aire conditioners.

Incoming water lines should be well insulated to limit warming before reaching the TBM. Chiller plants or ice slurry plants on the surface may be used to cool water before entering the tunnel. It requires more power and equipment to produce ice slurry on the surface compared to chilled water, but the mass of ice slurry is ~25% less than water and requires less pumping power into the tunnel.

A properly designed dewatering system will remove most geothermally heated water before it can transfer its heat into the tunnel environment.

3.4.3.3 Air Cooling System Design

As highlighted in chapter §2.5.5 Ventilation and cooling the surrounding rock in deep tunnels heavily influences the temperature of the working environment in the tunnel, as well as any inflow of geothermally heated water or steam.

The energy from broken and crushed rock adds heat back into the tunnel on its way out on the conveyor system or muck vehicles. Even the elevation change of the fresh air from the surface to the excavation face increases its pressure and adds heat to the tunnel. The air cooling system is responsible for cooling the tunnel environment from almost all sources of environmental heat.

On short tunneling projects, the typical ventilation design described in section 3.4.1 is enough to provide fresh air to the excavation face if flow rates are high enough. Providing high flow rates becomes onerous on long, deep tunnels due to the required power and expected losses. However, long and deep tunnels face an additional complexity caused by the occurrence of **simultaneous works** at several work stations, as:

- TBM location (single or multiple TBM's),
- Excavation and support of cross passages,
- Excavation and support of auxiliary infrastructures (others tunnels, emergency point …)
- Injection and waterproofing works,

- Lining of cross passages,
- Lining of main tunnel(s) in case of non-shielded TBMs,
- Maintenance and repair works.

Due to the large amount of workstations, fresh air is cooled and released only at the location of these works stations. Cooling needs therefore to be provided by a separate closed circuit cooling system that is fed from surface with cooled water from cooling towers and reservoirs.

A possible design solution for TBM's is to install water-cooled air chillers. An industrial water system is already used to cool other TBM equipment, so the same water system can be scaled up to cool the incoming fresh air. This design has limited cooling capacity based on the low temperature limitations of the incoming water and the efficiency of heat transfer to the fast-flowing air.

The most efficient solution is to use air chillers that are connected to a refrigeration circuit. The extra chillers and refrigeration equipment are mounted on the TBM back-up, as illustrated on Figure 53. A refrigeration cycle is more efficient than a simple heat exchanger for cooling the incoming air. It is also easier to provide more power to the TBM for the refrigeration than pump additional cooling water long distances.

The same system can be used for conventional drives, where mobile platforms including chillers and fans can be installed and placed close to the tunnel face, as illustrated on Erreur ! Source du renvoi introuvable.

Mobile air cooling systems consisting of a combination of air chillers and fans, connected to the cooling water circuit, will then be used to cool the moving work stations in the tunnel (for example the lining). A main characteristic for long, deep tunnels are **simultaneous works** to keep the construction time in acceptable limits. A work station could be:

- TBM excavation (single or multiple TBM's)
- Excavation and support of cross passages,
- Excavation and support of auxiliary infrastructures (others tunnels, emergency point …)
- Injection and waterproofing works
- Lining of cross passages
- Lining of main tunnel(s) in case of non-shielded TBMs
- Maintenance and repair works

Due to the large open space, fresh air is only cooled and released at these works stations in the tunnel system. The tunnel itself will remain at or above warm ambient rock temperature. Cooling needs to be provided by a separate closed circuit cooling system that is fed from surface with cooled water from cooling towers and reservoirs.

Figure 53 : Example of cooling equipment mounted on TBM.

Figure 54 : Example of a mobile air cooling station for conventional drive on a sled.

[5]OSHA Technical Manual (OTM), Section III: Chapter 4. "Heat Stress."

Figure 55 : Cooling installation at portal (Gotthard).

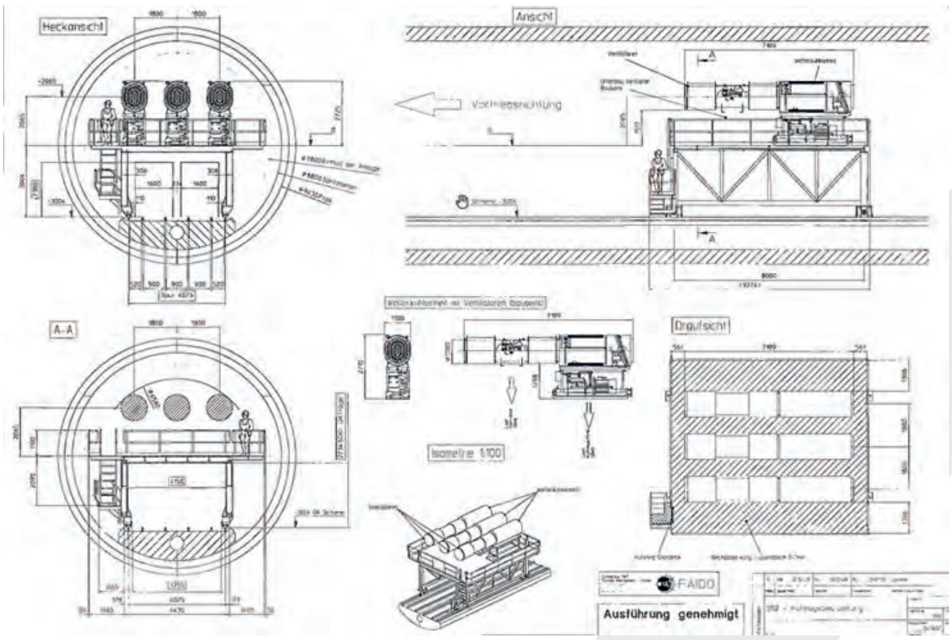


Figure 56 : Design of a mobile air colling system at portal (Gotthard).

KEYS LOGISTICS GUIDELINES TO ANTICIPATE

- Ventilation aspects:

  - **Sufficient power supply** needs to be anticipated (see chapter § 2.5.1 Power supply);

  - The **ventilation system** becomes very important in maintaining worker safety and possible evacuation on case of fire and **needs to be designed to cope with fire scenarios;**

  - Provide **sufficient space inside the tunnel** system for booster stations, chillers and fans;

  - If there are parallel tunnels, they can be used for ductless ventilation systems, avoiding high blowing pressures;

  - Monitor gas concentrations and eliminate sources of ignition with proper equipment design requirements.

- More specifically for **cooling:**
  - **Sufficient water supply** needs to be anticipated (see chapter § 2.5.2 Water supply and water discharge);

  - Design ventilation and cooling according to rock temperature predictions;

  - Provide enough surface space for cooling towers and reservoirs;

  - Install separate cooling water circuit;

  - Avoid additional heat sources by using segmental lining and electric vehicles.

3.5 INDUSTRIALIZATION AND OPTIMIZATION OF CONSTRUCTION METHODS AND LOGISTIC INSTALLATIONS

3.5.1 Mechanization of conventional tunnelling

While conventional tunnelling is still a sequenced work method, where all steps of excavation, mucking-out, rock support and lining are executed one after the other, the relevant logistic operations can be optimized. Instead of moving all supporting equipment in singular units at certain intervals, **innovative solutions include continual movement of all equipment using trailer systems with moving platforms,** as in the example of the system developed in Ceneri Base Tunnel [14]. They are either installed by hanging them from anchors in the tunnel crown, or putting them on portal cars on rails. Primary goal is to move the installations parallel to the excavation operation, while keeping the main passage for the construction equipment (excavators, boomers, trucks, MSV's etc.) free from obstacles.

A further sustainable solution is to place crushers near the face to be able to use conveyor belts for spoil transport instead of diesel-driven trucks, which represents most of the traffic in the tunnel.

A successful implementation of such a system has been performed at the Ceneri Base Tunnel in Switzerland, as illustrated in Figure 57, including a monorail system that was used for transporting rock support and other materials to the work front.

- Each installation basically consists of ventilation platform, heading platform, invert platform, monorail (single track suspension rail);
- Highly mechanized back-up system for main headings (drill and blast);
- Blowing and suction ventilation provides fast access to rock face and health protection;
- Simultaneous trailing of complete infrastructure and sufficient room for construction equipment; Rationalization of work flows and increased working safety thanks to free floor space for working and parking (Figure 58);
- Jaw crusher, towing conveyor and transfer conveyor for spoil removal logistics;
- A monorail guarantees direct supply of the heading (Figure 59);
- Tunnel invert continuously being constructed along with the heading.

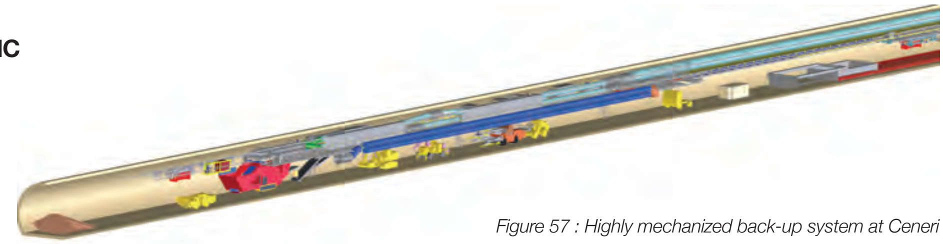


Figure 57 : Highly mechanized back-up system at Ceneri Base Tunnel (Rowa).

Figure 58 : Parking and driving space beneath the trailer platform.

Figure 59 : Monorail and crown fixation with bolts and chains.

3.5.2 Mechanization of in-situ concrete lining

Due to their length and related construction time requirements, the in-situ concrete lining of conventional or open TBM driven tunnels often needs to be casted in parallel with the advancing heading. In-situ concrete linings require a lot of preliminary works such as smoothening the surface, applying waterproofing membranes or curing. All these works need to be performed without interrupting the logistic services to the advancing tunnel faces ahead. In a search for industrialization of conventional methods, the use of dedicated machines, such as the so-called «WURM» system (a 700m-long trailing structure that could be moved in a caterpillar-like manner) used in the Gotthard Base Tunnel in 2004 for concreting, illustrated in Figure 60, represent a valuable solution (casting performance per month up to 720 m / month).

This machinery type consists of a series gantries, installed on a train, which are dependent on each other during its movement:

- Dismantling of utility lines to and from the TBM's (water, electricity, telecommunication etc. from the shotcrete surface;
- Re-profiling if necessary;
- Collection of water inflow;
- Smoothening shotcrete application as base for waterproof membrane;
- Cleaning of invert and drainage channels;
- Installation of drainage system;
- Installation of waterproof membrane (Figure 61);
- Installation of reinforcement if necessary (Figure 61);
- Casting of 24m of concrete inner lining per day;
- Curing of concrete for 3 days;
- Final cosmetics of concrete surface;
- Re-installation of utility lines.

Figure 60 : The WORM, Gotthard Base Tunnel, Switzerland.

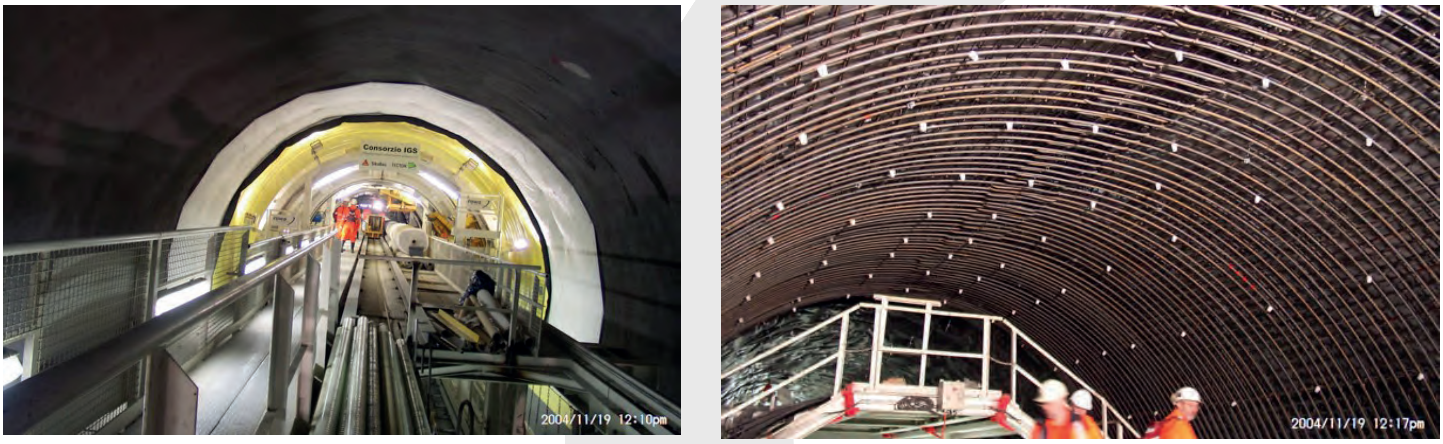


Figure 61 : Placing of waterproof membrane and reinforcement within the "WURM".

KEYS LOGISTICS GUIDELINES TO ANTICIPATE

- Innovative solutions for industrialization and optimization of conventional method are e strongly linked to the supply logistics system, and have been developed to facilitate the logistics of certain emblematic projects:
  - Inner in-situ concrete lining with dedicated machine;
  - Continual movement of all equipment using trailer systems with moving platforms.

3.6 OTHER ASPECTS INFLUENCING LOGISTICS

As described in this document, logistics in long tunnels are challenging and are normally the result of detailed analysis where certain compromise solutions have to be taken, and where typically all the space available in the tunnel is used for some purpose. Selected ventilation ducts and lines are normally as big as possible, with limited or no possibility of improving their capacity once the project is ongoing. Under these circumstances, if additional pollutants or unforeseen constraints are encountered in the ground, they can generate great impact to the tunnel logistics and in turn, to the project duration. For this reason, scenarios should be investigated and planned in order to minimize disruptions and maximize safety.

Special attention should be paid to investigate the presence of asbestos, gas (including but not limited to methane or hydrogen sulfide) and radioactivity (e.g. radon) among other things. These elements would impact the logistics in all types of tunnels, but in the case of long tunnels the impact is typically bigger as the solutions to deal with them are normally:

- Additional or complex ventilation systems, which are more difficult to implement with long distances between the working fronts and the source of ventilation.
- Reduced working times in the working fronts. Accessibility to safe areas may need to be created artificially.
- Specially defined black and white areas.
- Dedicated disposal areas;
- The use of systems to encapsulate the excavated material in order to minimize their exposure to the tunnel environment, which may be costly and also requires additional space in the tunnel.
- Additional cleaning facilities for personnel clothing, equipment and machines.

3.7 ADVANTAGES OF COMPACT SITE INSTALLATIONS

When there are possible, compact solutions for the operation of the tunnel construction may give huge benefits for the efficiency of the construction, but it may also reduce the total negative impact for the environment. To achieve such a compact solution, where all the functions related to the tunnel-production, including all kinds of workshops, location of segment production, area for permanent re-use of the excavated spoil, accommodation for the workers and offices for both the Contractors and the Owner, require access to a suitable area outside the adits to the tunnel.

For long tunnels, with several years of construction, it can be beneficial to arrange the site as a "permanent" site-area, with functional and to a higher degree more permanent solutions than normally used for projects with a shorter construction time.

In the example of the Follo line (cf. Figure 62), all the functions related to the tunnel production were located within the area outside the adit tunnels. Direct access to the construction site from the motorway (E6). The excavated material is re-used within the construction site as a basement for a future residential area, close to the project entrance.

Figure 62 : An example of an efficient rig-area at the Follo line project accesses.

4 >> Conclusion

Long and deep tunnels are characterized by **highly demanding logistics requirements way beyond the usual strategies for underground structures.** The longer and deeper a tunnel project gets, the more installations are needed either in or alongside the main tunnel excavation. An essential aspect in that context, **logistics very quickly becomes the decisive performance-determining factor** compared to the tunnelling equipment.

This guideline leads the Owner to make provisions already at the design stage for the logistics during construction with a very high priority and help him identify all the related consequences and helps him to identify as much as possible the needs in the design in order to have a robust financial forecast and an on-time project.

The solutions to implement a correct logistics could lead

- To build dedicated infrastructure (access roads, adits, caverns, niches…);
- To modify the time schedule;
- To modify the final tunnel design section accordingly;
- To improved acceptance from local population.

[1] Handbook on Tunnels and Underground Works , Volume 1 : Concept – Basic Principles of Design - Chapter 13 “Project acceptance strategy”, G. Dati, TELT, February 2022

[2] “Tunnelling the Gotthard”, Swiss Tunnelling Society, 2016

[3] ITA Report No. 003 «Environmental and sustainable development reasons for going underground», Working Group 15, January 2010

[4] ITA Report No. 012 «Adits for long and deep tunnels », Working Group 17, April 2013

[5] ITA Report No. 021 «Handling, Treatment and Disposal of Tunnel Spoil Materials », Underground construction and the environment and mechanized tunnelling, Working Groups 14 and 15, April 2019

[6] AFTES Guidelines «Excavated Materials GMVE» - Working Groups GT35, AFTES, GT35R1A2

[7] « Gestion et valorisation des matériaux d’excavation – Inventaire de grands projets suisses » – Swiss Tunneling Society FGU , 2016

[8] ITA Report 98_1-177 «Underground works and the environment», Working Group 15, 1998

[9] ITA Report No. 08 «Guidance on the safe use of temporary ventilation ducting in tunnels», Working Group 5, 2011

[10] ITA Report No. 14 «Guidelines for the Provision of Refuge Chambers in Tunnels Under Construction”, Working Group No. 5, 2018

[11] “Conception and Construction of a Tailor-Made Refuge Chamber for TBM” Andretter, Rainier. RETC June 2019

[12] “Supply and transportation logistics”, Book Túnel De Guadarrama, J. del Barrio, Adif / Ministerio de Fomento, 2005

[13] DAUB Guidelines «Guide to safety and health protection on underground construction sites”, DAUB, German Tunnelling Committee, 2022

[14] “Substantial mechanization main headings at the Ceneri Base tunnel” Switzerland Tunnel, April 2011

[15] “Experiences during tunnelling in extreme ground conditions in the Himalayas - excavation of Atal/Rohtang tunnel”, India, R. Bernard, FIDIC Award 2022 – Category “outstanding Project of the Year – large” – Mention Highly Commended - Transportation Tunnels

[16] “Instalaciones específicas de obra para la ejecución de túneles”, Manual de túneles y Obras Subterráneas, chapter 42, 2011, U.D. Proyectos E.T.S.I. Minas UPM, A. Sanz

[17] “Organización y logística de las obras de Pajares. Lote 1” , Book Túneles de Pajares, Jacobo Arnanz González, Alberto Busto Álvarez, Luis Bernardo Carballo Flórez, José Pablo Castro, 2009

[18] ITA Report No. 019 «TBM Excavation of Long and Deep Tunnels Under Difficult Rock Conditions», Working Group 17, 2017

[19] ITA Report No. 017 «Recommendations on the development process for Mined tunnels », Working Groups 14 and 19, April 2016

[20] ITA Report No. 026, Tunnel Spoil Handling, Treatment and Disposal Options from a Global Perspective, Working Group 14, May 2022.

>> NOTES

KEYS LOGISTICS GUIDELINES

ACCEPTANCE OF THE PROJECT

- Local project **acceptance strategies** need to be considered as an **integral part of the design and construction phases,** since acceptance is a continuous process of awareness building and subsequent consensus building
- Find the best possible compromise between construction and local needs over the short and long term
- The need for certain infrastructure in the project area may lead to **sustainable solutions well beyond the construction phase**
- A tailored communication strategy, taking into account all stakeholders, should be established from the beginning of the project, and during the construction phase, always remembering that the construction sites are the showcase of the project.

AUTHORIZATIONS & ENVIRONMENTAL ASPECTS

- It is recommended that the Owner obtains all major authorizations and permits for the project from the responsible institutions and authorities (as e.g., the land ownership) from the earliest possible time, before starting construction
- A It is recommended that the owner carries out a survey of all necessary permits based on a conservative design of the project (as a general rule, is recommended to ask for a wider scope than strictly required, thus avoiding to be constrained in the later project stages), considering both construction and service stage.

IDENTIFICATION OF FINAL DISPOSAL SITE FOR MUCK

- Long and deep tunnel excavation generates **large amount of spoil,** which need either to be treated and re-used, or to be transported and dumped;
- Determination of the size and location of the final disposal site should be incorporated into the project design phase
- Related planning and approval procedures is preferable to be completed prior to the start of tunnel construction

CONTRACTORS CAMPS

- Anticipate **camps for several hundreds of workers**, sometimes in remote aeras could lead to build dedicated camp.
- A balance between the interest of **dedicated contractor camp** adjacent to the construction site or the **use of existing structures** need to be done on case-by-case basis, regarding the local condition and acceptance.

ANTICIPATION & POSSIBLE SYNERGY WITH THE OPERATIONAL PHASE

- In a logic of **sustainability,** but also for reasons of planning and economy, the possible s**ynergy with the operational phase** of the projects should make it possible to take advantage of the use of the required infrastructure as free space for logistic activities during the construction phase

HEALTH & SAFETY PROVISIONS

- In the case of long tunnels under a high overburden, **safety of all workers** on the site becomes an even more demanding task, **emphasized if there are no intermediate access point and presenting small inner dimensions.** This constraint needs to be introduced in the design plan with the highest priority
- A **global approach** (infrastructure, ventilation, access, evacuation routes, materials...) is needed to define the safety provisions during construction, and for example it is essential to:
  - design tunnel dimensions to guarantee escape and rescue operations
  - design tunnels to guarantee adequate ventilation (size of ducts) and placement of rescue equipment (refuge chambers)
- In some case the safety issues during construction could lead to modify the time schedule or the final tunnel design dimensions

Having a **serious rescue plan developed from the design stage** and maintained during the construction phases defined together with the local fire brigade (if any) is a must in order to ensure sage work environment in the tunnel.

TO ANTICIPATE

ACCESSES	SUPPLY
Traffic outside the working site	***Power supply***
• The **traffic generated** by the construction of a long and deep tunnels is **an enormous, continuous logistical flow.** So the determination of **most suitable infrastructure** (roads, railroad , waterways …) in order to link the areas and manage this traffic flow **should be incorporated into the project design phase.** • It is preferable to tender and execute critical access and site infrastructures prior to the main construction works.	• **Estimate expected power demand** during construction time for the mains consuming activities • Check existing local supply options • Provide additional power generation if needed • Provide power lines and switch stations prior to main contract • Negotiate rates with local power suppliers • Considerations regarding redundant emergency power supplies (for example for ventilation) • Design also adits and tunnels according to power requirements
Accessibility of remote area	***Water supply and water discharge***
• Due to the nature of long and deep tunnels, often through mountainous regions, **portals are often located in remote areas,** characterized by absent or difficult accessibility => requires the construction of dedicated roads or other transportation way • The **severe weather conditions** that often characterize these regions (snow and extreme cold) further increase the complexity of access • Climatic conditions can have an impact on the time frame available for the construction works during the year and should be considered in the project time-frame.	• Estimate expected water demand during construction time • Estimate available ground water quantities • Check existing local supply options • Check national regulations as environmental obligations concerning extraction and discharge of water • Provide additional water supply if needed • Provide enough space for water treatment facilities prior to main contract • Provide first modules of water treatment plant prior to main contract
Excavation of intermediate access / adits	Supply of construction materials and machinery
• Long and deep tunnels level often require the excavation of intermediate access points in order to be able to reduce the corresponding supply distances to a tradable level.. • The **anticipation of the logistics needs** is a key factor in correctly planning these intermediate **access points**, in particular through **defining their location and their size.**	• **For long tunnels, the amounts of materials are extremely high** • **Define adequate storage capacity** both on surface and underground, taking into account also maintenance and repair of machinery • Internal logistics inside the tunnel involve a timed process due to limited space constraints
Underground structures required for logistics	***Supply & extension of services***
• It may be necessary to install part of the **logistics installation underground.** This setup offers a dual advantage of being **completely invisible to residents** and **shortening supply times.** On the other hand, underground facilities are usually custom-built due to their compact design and are more expensive to procure than equivalent facilities above ground. • Usually, these caverns and tunnels are located at the bottom end of an adit, and are used to house a variety of installations, either for operation of machinery or for their maintenance • The responsibility of the Owner, and its Designer, is to **define the constraints** imposed on the installation of logistic plants underground and to identify as much as possible the needs in the design to have a robust financial forecast and an on-time project	***Ventilation and cooling*** • **High temperatures** and **long ventilation lines** are characteristics of long and deep tunnels. • Design ventilation and cooling according to **rock temperature predications.** • **Anticipate** the definition of the cooling and the ventilation demand in terms of power and of the related infrastructure.

KEYS LOGISTICS GUIDELINES
GLOBAL TRAFFIC ORGANIZATION INSIDE TUNNELS
• Anticipate as much as possible the **study of the transportation system** and of the related traffic • **Flexible design** to allow for multiple choice of transport equipment • Setting up a traffic management organisation.
MUCK MANAGEMENT & REUSE OF MATERIALS
• Correct management of spoil is a **crucial environmental aspect** considerably impacting the logistics concepts. • Mucking-out method impacts the construction time as well as the infrastructures inside and outside of the tunnels • Enough space for temporary spoil disposal and material handling facility, and all the reuse process is required • Implication of the owner in the reuse process, as highlighted in the chapters in the chapters §2.2 Authorizations & environmental aspects and §2.3 Identification of final disposal site for muck is essential
CONCRETE PRODUCTION AND TRANSPORT
• It is often beneficial to **produce the concrete within the construction site**, and that may also contribute to less transports and easier logistic management. In a sustainability perspective, consideration could also be given to reusing the temporary concrete facility when the site is demobilized for local use • Plan the location of the concrete plants need to consider: - the transport distance of the concrete to the delivery point - extreme weather conditions • In case of shotcrete, the entire process requires high-quality technological and logistical support with focus on delivery speed and efficiency. • Consider tailormade solutions for segment transport inside the tunnel

TO MANAGE DURING CONSTRUCTION

VENTILATION & COOLING

- Ventilation aspects:
  - **Sufficient power supply** needs to be anticipated (see chapter § 2.5.1 Power supply)
  - The **ventilation system** becomes very important in maintaining worker safety and possible evacuation on case of fire and n**eeds to be designed to cope with fire scenarios**
  - Provide **sufficient space inside the tunnel** system for booster stations, chillers and fans
  - If there are parallel tunnels, they can be used for ductless ventilation systems, avoiding high blowing pressures
  - Monitor gas concentrations and eliminate sources of ignition with proper equipment design requirements
- More specifically for **cooling:**
  - **Sufficient water supply** needs to be anticipated (see § 2.5.2 Water supply and water discharge)
  - Design ventilation and cooling according to rock temperature predictions
  - Provide enough surface space for cooling towers and reservoirs
  - Install separate cooling water circuit
  - Avoid additional heat sources by using segmental lining and electric vehicles

INDUSTRIALIZATION AND OPTIMIZATION OF CONSTRUCTION METHODS AND LOGISTIC INSTALLATIONS

- Innovative solutions for industrialization and optimisation of conventional method are e strongly linked to the supply logistics system, and have been developed to facilitate the logistics of certain emblematic projects:
- Inner in-situ concrete lining with dedicated machine
- Continual movement of all equipment using trailer systems with moving platforms

>> Appendix 2 - International Database From The Owner's Point of View Regarding Logistical Aspects

This appendix is dedicated to highlight different owner's point of view regarding the logistic aspects to manage on that type of project. It is focus on all aspects which should be anticipated before the beginning of the main construction works, and on the management of such a project.

This database was collected by conducting interviews with specific project owners worldwide (Argentina, Austria, Chile, France, Japan, Italy, Nepal, Norway, Slovenia, Spain, South Korea, Sweden, Switzerland). Typical questions that need to be answered are for example what the client must/could prepare on site before signing the main contract.
This underlines that the **differences in approach between projects are important, and not necessarily linked to the country, but rather to the specificities of the project concerned, the local political context, and the methods of contracting chosen.**

A summary table highlighting the characteristics of each project and the key logistical elements is provided.

WG17 warmly thanks all the actors who contributed to this collection of information and agreed to share their experience.

>> Appendix 2 - International Database From The Owner's Point of View Regarding Logistical Aspects

>> Appendix 2 - International Database From The Owner's Point of View Regarding Logistical Aspects

GENERAL PROJECT CHARACTERISTICS									
Project Name	Country	Owner	Tunnel Market Area	Number of tubes	Length per tube (km)	Diameter of one tube	Cost of the project at the construction date (civil works)	Current status of the project	Type of contract
BASE BRENNER TUNNEL	Austria - italy	BBT	High spedd railway, Railway	Twin	64 km	10,70 m	9 567 M€	Construction	Design & Build
AGUA NEGRA TUNNEL	Argentina - Chile	EBITAN	Road, Highway	Twin	13,9 km	10,3 x 6,60 m	1 500 M$ USD	Study	Design-Bid-Build
LOS CONDORES – HYDRO POWER PLANT	Chile	ENEL	Hydroelectric	Single	14 km	4,52 m	1 120 M$ USD	Construction	Design-Bid-Build
FREJUS TUNNEL	France - Italy	SFTRF SITAF	Road, Highway	Twin	13 km	9,46 m	670 M€	Operation (2023)	Design-Bid-Build
TERZO VALICO TUNNEL	Italy	RFI	High spedd railway, Railway	Twin	27 km	9,73 m (TBM) to 11,3m (conventional)	1 600 M€	Construction	Design & Build
HIDA TUNNEL	Japan	CNE	Road, Highway	Twin	10,7 km	12,84 m	570 M$ USD	Operation (2008)	Design-Bid-Build
HAKKODA TUNNEL	Japan	JRTT	High spedd railway, Railway	Twin	26,5 km	9.5 to 13.0 m	720 M$ USD	Operation (2010)	Design-Bid-Build
SUNKOSHI MARIN DIVERSION	Nepal	State Department of Water Resource and Irrigation	Hydroelectric	Single	13,3 km	6,4 m	150 M$ USD	Construction (starting)	Design-Bid-Build
THE BLIX TUNNELS AT THE FOLLO LINE	Norway	Bane NOR	High spedd railway, Railway	Twin	20 km	9,98 m	1 000 M€	Operation (2022)	Design & Build
SECOND RAILWAY TRACK DIVAČA – KOPER	Slovenia	2TDK d.o.o	High spedd railway, Railway	Twin	20,7 km	8.3 – 8.5 (equivalent)	628 M€	Construction	Design-Bid-Build
PAJARES TUNNELS	Spain	ADIF	High spedd railway, Railway	Twin	25 km	9.9 to 10.1 m	1 964 M€	Construction completed (2009)	Design & Build
GUADARRAMA	Spain	ADIF	High spedd railway, Railway	Twin	28 km	9,50 m	1 841 M€	Operation (2007)	Design & Build
DAEGWALLYEONG TUNNEL	South Korea	Korea National Railway	High spedd railway, Railway	Single	21,7 km	12,46 m	250 M€	Operation (2017)	Design-Bid-Build
NEW BY-PASS STOCKHOLM	Sweden	Trafikverket	Road, Highway	Twin	18 km	17m x 10m	3 800 M€	Construction	Design & Build
CENERI BASE TUNNEL	Switzerland	Alptransit	High spedd railway, Railway	Twin	15 km	9,60 m	2 600 M€	Operation (2020)	Design-Bid-Build

High spedd railway, Railway *Road, Highway* *Hydroelectric*

>> Appendix 2 - International Database From The Owner's Point of View Regarding Logistical Aspects

LOGISTICS DETAILS							
Number of Access point	Disposal sites			Number of contractor camp	Energy, Water & Com	Excavation method	Examples of some specific logistics choise
	Number	Volume of Deposit material	Total excavated Volume				
7	7	17 000 000 m³	21 500 000 m³	6	NA	9 TBM + Drill&Blast	Belt conveyors + logisitics nodes (3 TBM were used in the pilot tunnel - not in use any more ; 4 TBM in the main tunnel - in use right now/in assembling phase; 2 TBM future use in the main tunnels)
2	2	2 800 000 m³	2 100 000 m³	2	A	Drill & Blast	'--
2	3	--	225 000 m³	1	NA	2 TBM + Drill&Blast	Speed limit
2	4	720 000 m³	--	NO	NA	1 TBM + Drill&Blast	Creation of a dedicated logistic gallery, perpendicular to the tunnel to the final deposit site
6	50	15 500 000 m³	8 415 000 m³	4	NA	2 TBM + Drill&Blast + Hydraulic hammer	Specifics equipments & logisitics to deal with asbestos risks
2	8	1 400 000 m³	--	2	NA	1 TBM + Drill&Blast	Winter conditions + a dedicated ventilation tunnel
6	6	2 210 000 m³	2 210 000 m³	6	NA	Drill & Blast	Belt conveyor + Disposal of evolutive materials (acidifying)
2	3	430 000 m³	430 000 m³	2	A	1 TBM + Drill&Blast	'--
3	1	100% reuse in rig area	9 MMt	2	A	4 TBM + Drill&Blast	Central rig area + Belt conveyor
12	2	2 200 000 m³	(*)	NO	NA	Drill & Blast	8 separated tunnels ; Reuse of materials *(*) The total volume of the excavated area will be known after the completion of the construction, because part of the tunnels passes through several huge karstic caverns*
3	4	--	5 640 000 m³	NO	NA	5 TBM + Drill&Blast	Water inflow ; lack of power supply in north portal ; conveyor belt
2	2	Capcity of 7Mm³	5 500 000 m³	NO	NA	4 TBM + Drill&Blast	Belt conveyor + train
6	3	--	2 700 000 m³	2	NA	Drill & Blast	--
5	5	--	7 100 000 m³	NO	A	Drill & Blast	Belt conveyor + boats + underground crushing
3	1	3 700 000 m³	9,81 MMt	1	A	2 TBM + Drill&Blast	Underground concrete plant

Disposal site, Contractor camp	*5*	*Decided by the Owner before tendering, with few adpatations during execution*
	5	*Done & define by the Contractor*
Energy, water & com	*A*	*Anticipated by the Owner (definition of requirements + prepared before tendering*
	NA	*Done & define by the Contractor*

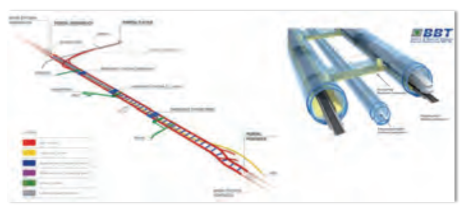
>> Appendix 2 - International Database From The Owner's Point of View Regarding Logistical Aspects

BASE BRENNER TUNNEL – BBT (AUSTRIA & ITALY)

MAIN PROJECT CHARACTERISTICS

Country	Italy and Österreich	**International Project**	Yes	**Project length**	64 km
Owner	BBT	**Type of Owner**	Public	**Ø excavated**	10,7 m
Engineers	Prolter, Rocksoil, Amberg, Lombardi, Hbpm, Obermeyer, Müller + hereth.			**Functionality**	Railway
Contractors	Actually: ISARCO scarl – BTC - Porr Bau GmbH Kematen - ATI Strabag SE / Webuild S.p.A.			**Number of tubes**	Twin + pilot gallery

Cost of the project (civil works)	Expected total costs including future adjustments for Inflation: **9.567.000.000 €**
Initial date of the project	1987 The feasibility study for a cross-border tunnel along the Brenner axis was made in 1987. A detailed study was made between 1999 and 2003 at the time of the preliminary design, including the geognostic survey activities. The project design for the acceptance was carried out between 2003 and 2010
Starting date of construction	The construction of the exploratory tunnel began in 2007
Current status of the project	Under Construction: completed at 61% in June 2021



CONSTRUCTION WORKS CONTRACT

Main reason for the chosen lots definition	Transborder tunnel between Italy and Austria. This choice was made mainly for logistical and technical reasons but also to optimise construction times and costs.
Number of constructions Lots	14 Construction Lots : According to the planning, the civil works will be carried out in 4 construction lots in Italy and 10 lots in Austria. This choice was made mainly for logistical and technical reasons but also to optimise construction times and costs.
Type of contract	Mainly Design & Build
Time & Cost management	Fixed Time and Cost contracts As a general rule, with contracts for works part of the costs are accounted for based on unit prices for works actually carried out and quantities of materials actually used, and part of the costs are paid as lump sums; uncertainty of the underground conditions and connected changes in time and cost are in any case the responsibility of the Client. However the time is defined by the contract schedule and there are penalties if the construction is delayed for reasons due to the construction company. The actually used materials are determined and paid for based on unit prices, whereas the items to which lump sums are applied are paid out as a percentage of the lump sum stipulated in the contract; payments are made monthly
Level of definition of underground logistics	During the design phase, BBT SE proposed some logistic solutions and imposed transport by conveyors or rail of the excavated soil. By tendering a bid based on both an economic proposal and technical solution, the contractor was able to propose some minor changes to the solutions, more adequate to its technical capabilities, sometimes even improvements. The payment method depends on the nature of the logistic solution. Sometimes they are paid as overhead costs or based on specific contractual clauses, mainly as fixed price items.
Remuneration of logistic structures	Included in the price
Does a difference exist between the type of contract adopted for the main construction works and the preliminary one, if any ?	There are no substantial differences between the type of contract adopted for the preliminary and main construction works. The preliminary works were carried out with Only To Build Contracts; the main construction works were also primarily carried out with Only To Build Contracts and in some cases as Design & Build contracts.

ACCEPTANCE AND INTEGRATION OF THE PROJECT

DISPOSAL SITES	**Number and volume of disposal sites**	There are 7 disposal sites, with a total capacity of 17,000, 000 m³ Among of which, 3 areas are located in Austria with a total capacity of 11,000,000 m³ and 2 areas in Italy with a total capacity of 4,750,000 m³.
	Were all disposal site defined before tendering the Construction works ?	Yes
	Who obtained the final authorization	The Owner is in charge of that
CONTRACTOR'S CAMPS	**Number of camps/villages exist or planned**	There are 6 camps located in Italia and Austria
	The location of the contractors camp was defined before tendering the Construction works?	Yes, the areas were identified in the preliminary project.
	Who obtained the final authorizations	That is in the Owner's purview.

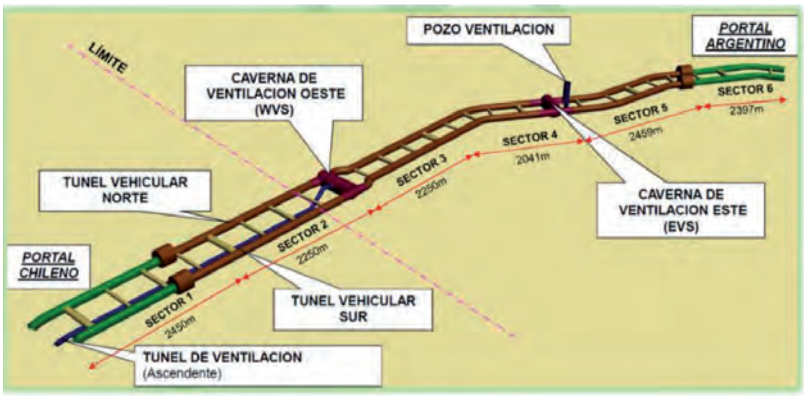
>> Appendix 2 - International Database From The Owner's Point of View Regarding Logistical Aspects

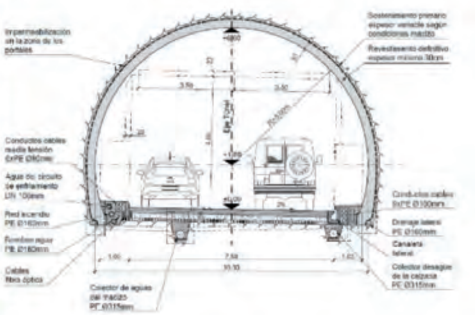
BASE BRENNER TUNNEL – BBT (AUSTRIA & ITALY)		
ENERGY, WATER & COM	**Who defined the requirements**	The costs relating to the supply of energy and water are included in the overall lump sum price of the contract and the requirements were decided by the Client.
	Were those supply/utilities prepared before tendering the Construction works	The supplies and utilities were and are prepared during the startup phase of the construction sites.
	Who obtained the final authorizations	BBT SE did a preliminary evaluation of the energy supply and gave the contractor access to the supply system. Subsequently, the contractor was in charge of obtaining the necessary authorizations and supply contracts, already paid for by BBT through the construction work contract.
ACCESSES (ROAD, RAIL, CABLE CAR…)	**Level of definition of the location of all accesses to the construction sites before tendering**	Yes, the location of all accesses to the construction sites was defined in the tender project. At total, there are 7 accesses (4 adits + 3 portals)
	Who obtained the final authorizations	BBT SE was in charge of guaranteeing the main access to the worksites, whereas the contractor proposed some improvement solutions and was in charge of getting them authorized by local authorities.
OTHERS		The tunnel design regarding the fault zones (e.g. Periadriatica fault) was carefully managed, also regarding the monitoring of water or hydrogeological resources and the environmental compensation measures.

LOGISITICS ASPECTS	
Type of logistic works anticipated (e.g. Geological exploration, Survey, Logistic accesses, Others)?	First of all, several geognostic surveys were carried out and a surface geological cartography was drawn up. The construction of the Aica-Mules and Innsbruck-Wolf exploratory tunnels was carried out in advance. On the remaining tunnel sections, the exploratory tunnel always anticipates the main tunnels excavation. The 4 adits, used as logistic accesses to the main tunnels were also built in advance as well as some logistic and environmental compensation works.
Main logistical constrains of the project (e.g. winter conditions, difficult accessibility, natural hazards, architectural/ environmental constraints, material supply…)	The main logistical constraints are: underground and external excavation soil transportation (limiting the usage of local roads through residential areas), finding disposal areas for the excavation soil, logistical aspects relating to the prefabrication of concrete tunnel segments, tunnel ventilation and cooling systems, lack of sufficient space for the construction site areas.
Other special constrains (if any) imposed to the Contractor outside the worksite	Prohibition of transit on local road and city centers by heavy vehicles (the highway is preferred), use of conveyors and rail system for excavation soil transportation, noise limitations near city centers, external encapsulation of noisy machinery (e.g. external conveyors).
Special constrains (if any) imposed to the Contractor inside the worksite	The usage of conveyors and rail system for the excavated soil transportation, an installation of an underground concrete mixing plant, usage of non-diesel vehicles inside tunnel (Italian legislation), the transportation of the tunnel segments by special trains or multi-functional vehicles.
Specific project choices	• **BELT CONVEYORS** (see fig.1 and 2): The belt conveyors system allows the easy and efficient transport of excavated material from the rock faces to the temporary/final storage areas and from/to the crushing and concrete production plants in the various construction site areas. The system evolves and gradually expands as work progresses.
	• **LOGISTICAL AREA** (see fig.3): Concerning the BBT system, all the spoil from each single volley/drift using drill and blast/TBM flows into the «logistics node» for the management of the material that is located at the point of intersection of the main tunnels with the exploratory tunnel and the Mules access tunnel. The logistics node is central to the entire construction process of Mules 2-3 construction lot because all the material flow coming from the excavation activities passes through it and must be sorted towards the disposal sites; the node is organized to link the two levels of the tunnel system: the lowest level in which the exploratory tunnel is located and the level on which the main tubes are excavated. Within this area, support systems for the rock faces and conveyor belts have been installed (and will be implemented over time). The final configuration of the belt conveyors system is dimensioned to manage peaks of 2000 ton/h of flowing material; therefore it will be necessary to have structures and logistics infrastructures capable of processing large quantities of material of different nature, which follows different paths depending on its final use. In the logistics node there will be transfer devices for each incoming conveyor belt; these are switch systems that allow to shift the material, according to its classification, i.e. its type of reuse, on different belts. The latter crosses the whole logistics node and reach either the well that connects the two levels of the tunnel (and from there conveyed, through hoppers, through the service tunnel to an aggregates selection system at the Hinterrigger disposal site) or continue their way to Mules (Genauen disposital site), crossing other belts which were built specially.
	• **TRUCKS AND TRAINS:** The supply of all the material needed for the various excavation phases is mainly carried out in the underground, using the following methods: for the sections excavated with conventional methods the supply of material is carried out with ordinary wheeled vehicles. The vehicles run from the temporary storage areas and / or from the concrete plant to the destination, as a function of the various activities provided for in the construction program. For the sections excavated with TBMs, rail transport systems (i.e. a system of shuttle trains) or multi-functional vehicles are used.

AGUA NEGRA TUNNEL (ARGENTINA & CHILE)

MAIN PROJECT CHARACTERISTICS					
Country	Argentina - Chile	**International Project**	Yes	**Project length**	13,93 km
Owner	EBITAN	**Type of Owner**	Public	**Ø excavated**	Inner Section of 10,30x 6,60m
Engineers	Lombardi (switzerland)			**Functionality**	Road
Contractors	To be Appointed			**Number of tubes**	Twin





Cost of the project (civil works)	**1500 Million USD**
Initial date of the project	2004
Starting date of construction	Not yet decided
Current status of the project	Technical pre qualification of international consortiums that declared their interest to compete for the construction phase.
CONSTRUCTION WORKS CONTRACT	
Main reason for the chosen lots definition	--
Number of constructions Lots	Only one Lot
Type of contract	**Bid to build on the basis of official basic engineering design** The basic engineering design of ground and underground works will be provided by the owner, but the contractor will have to evolve the official design to obtain construction and detailed designs. The bid will be decided on the basis of most convenient offer formulated for the basic engineering design provided.
Time & Cost management	Bill of quantities. Additional time costs not inherent to contractor's responsibility will recognized in particular items of potential geological variability, if approved by the owner.
Level of definition of underground logistics	Works should begin from both portals, located in Argentina and Chile, respectively. A ventilation tunnel (parallel and of smaller section than main tunnels) should be excavated in advance from the Chilean portal. The contractor will have the chance to make changes or logistic alternatives if approved by the owner
Remuneration of logistic structures	Included in the price
Does a difference exist between the type of contract adopted for the main construction works and the preliminary one, if any ?	No

>> Appendix 2 - International Database From The Owner's Point of View Regarding Logistical Aspects

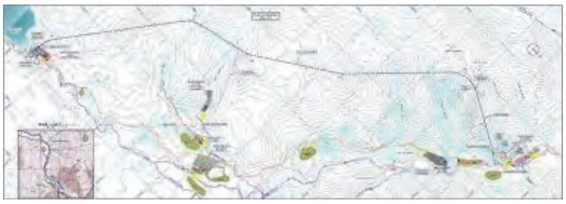
AGUA NEGRA TUNNEL (ARGENTINA & CHILE)		
ACCEPTANCE AND INTEGRATION OF THE PROJECT		
DISPOSAL SITES	**Number and volume of disposal sites**	Two sites, one on each country. Volumes of underground excavation are approximately equal for both fronts. The excavation material will be used for concrete aggregates and access roads embankments. The amount of waste material to be accommodated on the disposal sites will be, approximately, 200,000 m^3 for each tunnel portal.
	Were all disposal site defined before tendering the Construction works ?	Yes, though the contractor is in charge of obtaining the corresponding permits
	Who obtained the final authorization	The contractor is in charge of obtaining the corresponding authorizations
CONTRACTOR'S CAMPS	**Number of camps/villages exist or planned**	2. Two camps, one on each country, near the tunnel portals
	The location of the contractors camp was defined before tendering the Construction works?	Yes, It was defined before tendering
	Who obtained the final authorizations	The contractor will have to obtain final authorizations
ENERGY, WATER & COM	**Who defined the requirements**	The tunnel designer (Lombardi)
	Were those supply/utilities prepared before tendering the Construction works	Both governments will be responsible for providing electric energy power lines to the site of the works
	Who obtained the final authorizations	Owner
ACCESSES (ROAD, RAIL, CABLE CAR...)	**Level of definition of the location of all accesses to the construction sites before tendering**	Access roads to both portals are existing facilities
	Who obtained the final authorizations	The access roads are existing public facilities
OTHERS		--

LOGISITICS ASPECTS	
Type of logistic works anticipated (e.g. Geological exploration, Survey, Logistic accesses, Others)?	Geological explorations have been accomplished to define the basic engineering design. The contractor will have to conduct some additional geologic/geotechnical explorations to evolve the basic engineering design into construction and detailed design and a service access road to the site of the (4,5m diameter) 500 m deep vertical ventilation shaft is also provided.
Main logistical constrains of the project (e.g. winter conditions, difficult accessibility, natural hazards, architectural/ environmental constraints, material supply…)	Extreme winter conditions and high altitude ((4,000 m (Argentina) and 3600 m (Chile) above sea level)), as well as remote location from nearest towns (60 km apart) are the basic logistical constraints.
Other special constrains (if any) imposed to the Contractor outside the worksite	None
Special constrains (if any) imposed to the Contractor inside the worksite	None
Specific project choices	Drainage of underground water has to be conducted to each tunnel portal. On the argentine section of the tunnel, it will have to be pumped upwards towards the argentine portal. On the Chilean section, it will drain by gravity to the Chilean portal

LOS CONDORES – HYDRO POWER PLANT (CHILE)

MAIN PROJECT CHARACTERISTICS

Country	Chile	**International Project**	No	**Project length**	14 km
Owner	ENEL	**Type of Owner**	Private	**Ø excavated**	4.52 m
Engineers	ENEL (Mandatory)			**Functionality**	Hydroelectric
Contractors	Ferrovial Construcción (Civil works)- Voith (Equipment works)			**Number of tubes**	Single



The project consist in a tunnel the headrace tunnel (of 14 km long, 4.52 m diameter), and shafts and caverns

Cost of the project (civil works)	**1120 M U$**
Initial date of the project	2008
Starting date of construction	March 2014 (tunnel excavation in June 2015)
Current status of the project	The headrace tunnel construction started in 2014 and was achieved in 2021. The whole project, with the shaft and caverns, will be completed by 2023
CONSTRUCTION WORKS CONTRACT	
Main reason for the chosen lots definition	The final solution was chosen because was the better in use of the power generation vs cost.
Number of constructions Lots	2 constructions lots
Type of contract	Design – Bid - Build for the 2 Lots
Time & Cost management	Bill of Quantities
Level of definition of underground logistics	None : all the constructions start from the portals, defined previously by owner
Remuneration of logistic structures	Included in the price
Does a difference exist between the type of contract adopted for the main construction works and the preliminary one, if any ?	The Contractor had the possibility of making changes or proposing logistic for auxiliar tunnels, auxiliar works and all temporary works.

>> Appendix 2 - International Database From The Owner's Point of View Regarding Logistical Aspects

VLOS CONDORES – HYDRO POWER PLANT (CHILE)		
ACCEPTANCE AND INTEGRATION OF THE PROJECT		
DISPOSAL SITES	**Number and volume of disposal sites**	3 disposal sites were used, for a volume of 225 000 m^3
	Were all disposal site defined before tendering the Construction works ?	YES, IT´S NECESSARY FOR ENVIRONMENTAL PERMIT.
	Who obtained the final authorization	Owner (authorization for the site) and contractor (authorization for the management)s
CONTRACTOR'S CAMPS	**Number of camps/villages exist or planned**	One camp
	The location of the contractors camp was defined before tendering the Construction works?	Yes, by the Owner
	Who obtained the final authorizations	Owner for the environmental permit and the contractor for the construction permit.
ENERGY, WATER & COM	**Who defined the requirements**	Owner for the environmental permit and the contractor for the construction permit
	Were those supply/utilities prepared before tendering the Construction works	No, they were not.
	Who obtained the final authorizations	Owner
ACCESSES (ROAD, RAIL, CABLE CAR, …)	**Level of definition of the location of all accesses to the construction sites before tendering**	Yes
	Who obtained the final authorizations	Owners
OTHERS		YES, HANDLING OF EXPLOSIVES, STRONG WINTERS.
LOGISITICS ASPECTS		
Type of logistic works anticipated (e.g. Geological exploration, Survey, Logistic accesses, Others)?	Environmental permit, geological exploration, engineer for bidding	
Main logistical constrains of the project (e.g. winter conditions, difficult accessibility, natural hazards, architectural/ environmental constraints, material supply…)	Environmental constraints, winter condition, geological conditions, gravel for concrete	
Other special constrains (if any) imposed to the Contractor outside the worksite	Control of speed limit for transportation. Camps outsides of the project zone.	
Special constrains (if any) imposed to the Contractor inside the worksite	The constrains are in the document environmental permit. The owner defined the constrains	
Specific project choices	Our project have many logistic and restriction	

FREJUS TUNNEL (FRANCE & ITALY)

MAIN PROJECT CHARACTERISTICS					
Country	France - Italy	**International Project**	Yes	**Project length**	13 km
Owner	SFTRF- SITAF	**Type of Owner**	Public	**Ø excavated**	9,46 m
Engineers	SYSTRA (Mandatory) SWS SEA			**Functionality**	Road
Contractors	RAZEL-BEC (Mandatory) -BILFINGER BERGER			**Number of tubes**	Twin

Cost of the project (civil works)	**670 Million €** of which approximately **500M€ for the Civil works**
Initial date of the project	• 2001 Beginning of the studies with the award contract of Engineers. (the legislation about safety in tunnels has changed since the fire in the Mont-Blanc Tunnel in 1999) • 2002 Preliminary design of a Safety gallery of 4,50m diameter ; • 2005 Detailed Design ; • 2006 : Diameter increase up to 8,60m in order to allow 1 way circulation for safety engines • 2012 : at the Franco-Italian summit on December 3, 2012, the Italian and French prime ministers approved the opening of the safety gallery, which effectively transforms the Fréjus tunnel into a two-tube with one-way traffic in each tube.
Starting date of construction	The works for the safety tunnel have started in **July 2009**, on the French side. The TBM started the 5th of July 2011 and ended on the 7th of February 2013 for Lot 1 (French section). The TBM has then started in June 2013 the excavation of Lot 2 (Italian section).
Current status of the project	Civil works ended; Equipment works nearly ended. Opening 2022
CONSTRUCTION WORKS CONTRACT	
Main reason for the chosen lots definition	Transborder tunnel between Italy and France, with 2 Owners: SFTRF (France) and SITAF (ITALY)
Number of constructions Lots	Two lots for the civil works, one for each country, for political reasons in order to have local economic activity in each country. 5 Lots for Equipment
Type of contract	Design – Bid - Build
Time & Cost management	Conventional: Bill of Quantities TBM: Lump sum.
Level of definition of underground logistics	In the specifications all the logistics were installed at the French portal. But this was the contractor's responsibility, and during the execution the contractor propose 2 main evolutions : the assembly of the TBM in a dedicated underground chamber , and the construction of a logistic gallery for the evacuation of the mucking materials between the main tunnel and Socamo quarry
Remuneration of logistic structures	Included in the price
Does a difference exist between the type of contract adopted for the main construction works and the preliminary one, if any ?	No preliminary tunnel work

>> Appendix 2 - International Database From The Owner's Point of View Regarding Logistical Aspects

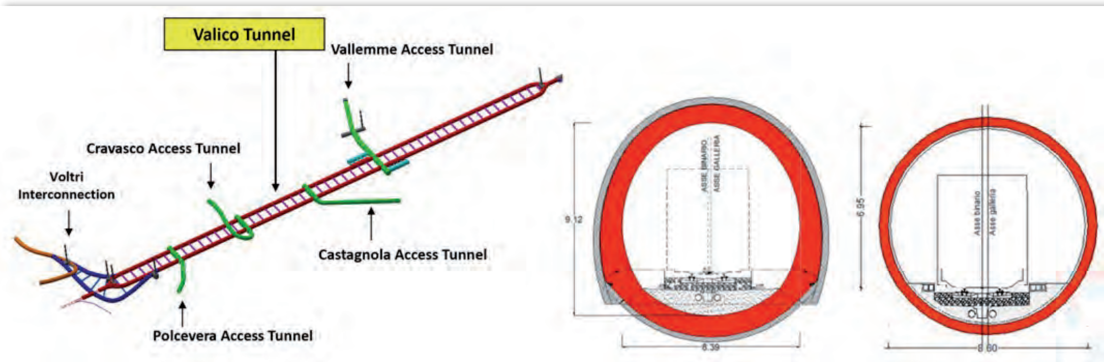
FREJUS TUNNEL (FRANCE & ITALY)		
ACCEPTANCE AND INTEGRATION OF THE PROJECT		
DISPOSAL SITES	**Number and volume of disposal sites**	The main site is Socamo Quarry , and old quarry filled by 640 000 m³ of muck deposit from Frejus 2nd tunnel The 3 others sites are 39 000 m³ n Valfrejus, 30 000m³ Illaz and 10 000m³ industrial pole of Frejus
	Were all disposal site defined before tendering the Construction works ?	For the French side, yes. For the Italian part, the deposit of the tunnel muck was only decided at the end of 2012 - beginning of 2013, when it became clear that the TBM was going to dig the Italian part from the French portal
	Who obtained the final authorization	SITAF
CONTRACTOR'S CAMPS	**Number of camps/villages exist or planned**	None. SFTRF prefers that people use local infrastructure
	The location of the contractors camp was defined before tendering the Construction works?	None.
	Who obtained the final authorizations	The Contractor – RAZEL-BEC
ENERGY, WATER & COM	**Who defined the requirements**	The Contractor – RAZEL-BEC
	Were those supply/utilities prepared before tendering the Construction works	Utilization of an existing Electric line ; The water comes from Italy through the existing tunnel, from abandoned sources
	Who obtained the final authorizations	The Contractor– RAZEL-BEC
ACCESSES (ROAD, RAIL, CABLE CAR…)	**Level of definition of the location of all accesses to the construction sites before tendering**	The platform near the French portal was included in the specifications. The contractor decided to build a dedicated access road, used only by people working on the project.
	Who obtained the final authorizations	The Contractor– RAZEL-BEC
OTHERS		--

LOGISITICS ASPECTS	
Type of logistic works anticipated (e.g. Geological exploration, Survey, Logistic accesses, Others)?	none
Main logistical constrains of the project (e.g. winter conditions, difficult accessibility, natural hazards, architectural/environmental constraints, material supply…)	The site installations were subject to winter conditions, and required specific installations, especially for the concrete plant outside with regard to cold temperatures.
Other special constrains (if any) imposed to the Contractor outside the worksite	On the French side, the segment plan t was located finally in Ste Marie de Cuines, 50 km away, instead of Modane (problems of price and availability of land). It was therefore necessary to have a dedicated area for the segment stocks and special authorizations for the traffic on the highway. On the Italian side, the segment factory was rebuilt to maintain activity in Italy as well, and the trucks carrying the segments had to cross the 13 km tunnel to feed the TBM.
Special constrains (if any) imposed to the Contractor inside the worksite	None except standard regulations (noise, dust …)
Specific project choices	Construction of a Logistics Gallery for the evacuation of the mucking materials perpendicular to the Safety Tunnel, between Socamo quarry and PM180 => No more inconvenient du to track circulation ; Directly to the final deposit place • Length = 487m , Excavated Section of 17m² (4,20 high x 4,40m large) • Equipped with Conveyor Belt : Descending belt for 670 000 m³ excavated material ; Climbing belt for pea gravel supplying and schist 0/31,5 for the Invert embankme

TERZO VALICO TUNNEL (ITALY)

MAIN PROJECT CHARACTERISTICS					
Country	Italy	**International Project**	No	**Project length**	27,25 km
Owner	RFI	**Type of Owner**	Public	**Ø excavated**	9,73 m (TBM) and 11,3m (conventional)
Engineers	COCIV (General Contracto			**Functionality**	Railway
Contractors	COCIV (General Contracto			**Number of tubes**	Twin

The project consists of about 53 km of a new 2 tracks railway line with 4 main tunnels: Serravalle Tunnel (7km), Pozzolo Tunnel (2 km), Campasso Tunnel (1km) and the Valico Tunnel (27,25km). The Valico Tunnel due to overburden (max overburden 600m) and length, is the only one of the 4 tunnels that can be defined a long & deep tunnel; therefore, the following data concerns the Valico Tunnel



Cost of the project (civil works)	Expected total costs **1.6 Billion Euro for the Terzo Valico tunnel.** The global project of 45km long (Terzo Valico Tunnel + long cut & cover + diverse works + Seravalle tunnel of 6 km) is about **4.356.487.580 €**
Initial date of the project	1990
Starting date of construction	2012
Current status of the project	Under construction: completed at 50% in june 2021
CONSTRUCTION WORKS CONTRACT	
Main reason for the chosen lots definition	--
Number of constructions Lots	This contract is divided into six non-functional construction lots, which have been financed during construction time.
Type of contract	The Cociv Consortium has been appointed as the general contractor and is responsible for design and construction (Design& Build contract).
Time & Cost management	Is a fixed time and cost contract. Times are managed through a contract schedule associated with penalties in case of delays, while for lump sum cost a monetary adjustment to prices based on the trend of annual inflation is foreseen. Monthly cost payments are managed through a percentage of the total lump sum amount related to work progress.
Level of definition of underground logistics	No, the contract tender did not impose underground logistic structures. The General Contractor was in charge of the design and the choice of logistic aspects. The project foreseen for the Valico Tunnel, 6 construction sites and 20 excavation fronts.
Remuneration of logistic structures	Included in the price
Does a difference exist between the type of contract adopted for the main construction works and the preliminary one, if any ?	There hasn't been a change of the type of preliminary contract, though the contract had numerous revisions and updates.

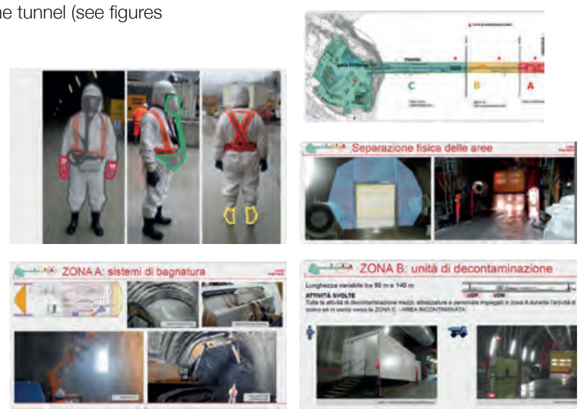
>> Appendix 2 - International Database From The Owner's Point of View Regarding Logistical Aspects

TERZO VALICO TUNNEL (ITALY)

ACCEPTANCE AND INTEGRATION OF THE PROJECT

DISPOSAL SITES	**Number and volume of disposal sites**	Approximately 50 disposal sites are planned for storage needs. The capacity of these sites is about 15.000.000 m3 and the volumes produced by the total excavation of Valico Tunnel will be, approximately, 10.000.000 m^3.
	Were all disposal site defined before tendering the Construction works ?	The General Contractor in the design phase envisaged a list of available storage sites with the relative storage capacity.
	Who obtained the final authorization	The General Contractor is in charge for the authorization request
CONTRACTOR'S CAMPS	**Number of camps/villages exist or planned**	The general contractor has made six camps, located between Piemonte and Liguria.
	The location of the contractors camp was defined before tendering the Construction works?	The General Contractor in the design phase chose the location of the camps in order to respond to logistical needs.
	Who obtained the final authorizations	The General Contractor is in charge for the authorization request
ENERGY, WATER & COM	**Who defined the requirements**	The costs relating to the supply of energy and water are included in the overall lump sum price of the contract and the requirement have been decided by General Contractor.
	Were those supply/utilities prepared before tendering the Construction works	The supplies and utilities were defined by the contractor in the initial phase of the work.
	Who obtained the final authorizations	The authorizations for supplies and utilities were obtained by the General Contractor
ACCESSES (ROAD, RAIL, CABLE CAR…)	**Level of definition of the location of all accesses to the construction sites before tendering**	The location of all accesses to the construction sites was defined in the preliminary project: major accesses road have been paid by client in the lump sum contract.
	Who obtained the final authorizations	The General Contractor is in charge for the authorization request.
OTHERS	An aspect that has a significant impact both in terms of time and costs and with stakeholders is the management of asbestos rocks. Great attention has been placed to face environmental aspects and to share all the information and environmental data coming from jobsite managements, with the stakeholders through dedicated web sites; great attention has also been placed to muck management with the use of conveyer belts to connect some specific adits to disposal sites.	

LOGISITICS ASPECTS

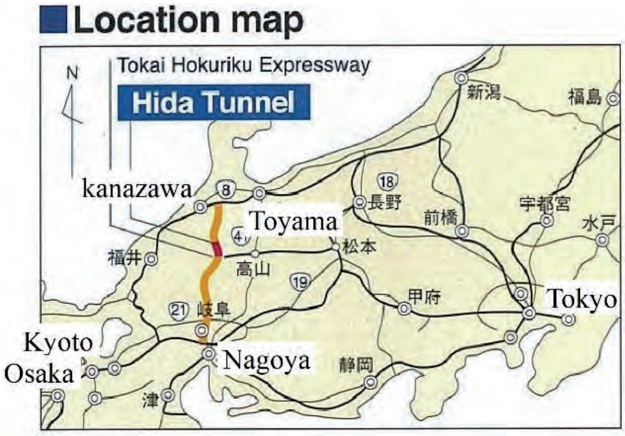
Type of logistic works anticipated (e.g. Geological exploration, Survey, Logistic accesses, Others)?	Geological explorations have been anticipated in the design phase also by means of the excavation of lateral service tunnels (Castagnola and Vallemme lateral tunnels); access road to the lateral adits also have been built before main works
Main logistical constrains of the project (e.g. winter conditions, difficult accessibility, natural hazards, architectural/ environmental constraints, material supply…)	The main problem during the construction of Valico Tunnel is the excavation of rocks with asbestos minerals.
Other special constrains (if any) imposed to the Contractor outside the worksite	To comply with the law and rules on asbestos management, the General Contractor had to study specific procedures. Technical measures have been developed for the safety of workers during the excavation. According to the environmental code, new operative protocols for asbestos soils disposal and recycling have been defined and applied.
Special constrains (if any) imposed to the Contractor inside the worksite	Referring to asbestos issue, monitoring of airborne fibers, protection measures and equipment (special work-suits, boots, mask …) vehicle decontamination, packaging of excavated material in big bags and specific disposal sites have been implemented.
Specific project choices	To reduce the risk of workers exposure to asbestos fibers, specific equipment's and plants have been installed into the tunnel (see figures 

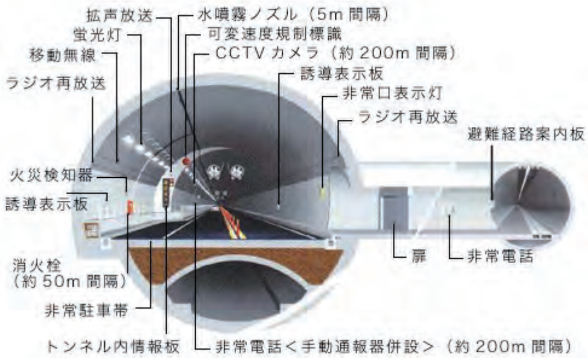
HIDA TUNNEL (JAPAN)

MAIN PROJECT CHARACTERISTICS

Country	Japan	**International Project**	No	**Project length**	10,712m
Owner	Central Nippon Expressway	**Type of Owner**	Private	**Ø excavated**	12.84 m
Engineers				**Functionality**	Highway
Contractors	Main tunnel (including Ventilation tunnel): Taisei-Nishimatsu-Sato JV Evacuation tunnel: Tobishima-Tekken JV			**Number of tubes**	Twin

Hida Tunnel is operating between the Hida-Kiyomi Junction and the Shirakawa-go Interchange, which connects the Tokai-Hokuriku Expressway and the Chubu Jukan Expressway (Takayama Kiyomi Road).
This section (approximately 25 km) passes through steep mountainous areas, so 10 tunnels have been constructed. Hida Tunnel is a long road tunnel with a total length of approximately 10.7 km that runs through Mt. The overburden is more than 1000m. The main tunnel is bidirectionnal traffic, and an evcuation tunnel, parallel to the main one runs all along.





TBM for Main Tunnel

Improved open-type
Excavation diameter : φ12.84m
Machine length : 19.5m
Machine weight : 310tons

Cost of the project (civil works)	Main tunnel: **66.5 billion yen.** Evacuation tunnel: **28.3 billion yen** **except pavement and equipment construction*
Initial date of the project	November 1993
Starting date of construction	Main tunnel: April 1998. Evacuation tunnel: October 1996
Current status of the project	Project has been completed and operation since July **2008.**

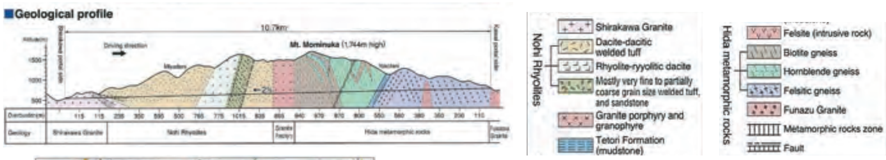
HIDA TUNNEL (JAPAN)		
CONSTRUCTION WORKS CONTRACT		
Main reason for the chosen lots definition		The main reason for the chosen lots definitions was to divide tunnels into main and evacuation one and not divided according to the content of the construction.
Number of constructions Lots		**2 constructions lots:** • Lot 1, Main tunnel (including ventilation tunnel), 10,700m (divided into 4 section) • Lot 2, Evacuation tunnel, 10,800m (divided into 4 section)
Type of contract		The general competitive bidding for 1st section (at remaining section, negotiated contract)
Time & Cost management		The construction price calculated from the quantity and unit price of each type of work is determined by the contract. When a new type of work emerges, the unit price is discussed between the client and the contractor. Basically, the contractor inspects the volume of the work constructed during that period four times a year by the client, and the amount of the work is paid. The construction period is agreed upon at the time the contract is concluded, but if the design is changed due to the unexpected appearance of a mountain mound, etc., it can be changed after mutual agreement.
Level of definition of underground logistics		Although it was indicated in the contract, it was reviewed during construction with a partial change in the construction method (TBM>ATM) and a change from one direction excavation to both direction.
Remuneration of logistic structures		Included in the price
Does a difference exist between the type of contract adopted for the main construction works and the preliminary one, if any ?		There was basically no difference, but there was temporary construction designed and carried out by the contractor for the preliminary words.
ACCEPTANCE AND INTEGRATION OF THE PROJECT		
DISPOSAL SITES	**Number and volume of disposal sites**	Main tunnel: During construction, there were more than originally planned, with five on the Toyama side and three on the Nagoya side. The quantity is about 1 million m^3 on the Toyama side and about 400,000 m^3 on the Nagoya side. Evacuation tunnnel: 5 on the Toyama side and 3 on the Nagoya side. The quantity is about 140,000 m^3 on the Toyama side and about 60,000 m^3 on the Nagoya side.
	Were all disposal site defined before tendering the Construction works ?	There were some disposal sites that were specified in the contract, but they increased during construction. Tunnels should be excavated from the other side (Nagoya side), so additional disposal sites should be necessary for that purpose.
	Who obtained the final authorization	Clients
CONTRACTOR'S CAMPS	**Number of camps/villages exist or planned**	Main tunnel: Two in total, one at each portal Evacuation tunnel: Two in total, one at each portal
	The location of the contractors camp was defined before tendering the Construction works?	Initially, camps were planned to be located near the portal on one side, but since tunnels should be excavated from both directions, camps were necessary at both sides.
	Who obtained the final authorizations	Clients
ENERGY, WATER & COM	**Who defined the requirements**	Contractors
	Were those supply/utilities prepared before tendering the Construction works	Main tunnel: It was indicated in the contract. Since a large amount of power consumption was considered to operate TBM, a private power generation facility was established. Evacuation tunnel: It was indicated in the contract. Electricity on the Nagoya side was distributed from a steel tower with special high voltage power because it was nearby.
	Who obtained the final authorizations	Clients
ACCESSES (ROAD, RAIL, CABLE CAR...)	**Level of definition of the location of all accesses to the construction sites before tendering**	Main tunnel: Since the portal of the main tunnel could not be accessed until the bridge work near the portal was completed, a working drift was set up near the portal to access it. The location of the portal of the working drift was set out in a place where residents could not see it and was considered to the environment. Evacuation tunnel: The form was to branch off from the side pit.
	Who obtained the final authorizations	Clients
OTHERS		None

HIDA TUNNEL (JAPAN)

LOGISITICS ASPECTS

Type of logistic works anticipated (e.g. Geological exploration, Survey, Logistic accesses, Others)?

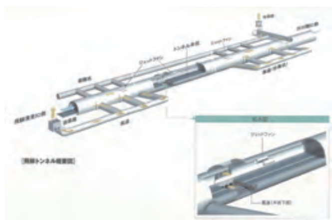
Main tunnel: The overburden is more than 1000m, and a high in situ stress has been supposed. The parent rock is Nohi-rhyolite, and the feature contains a lot of discontinuities, although the base of rock is very hard. Due to the discontinuity surface, the blocks of rock fall out in the shape of a dome ahead of the face.



Main Tunnel

Main tunnel was planned to excavate by TBM from the Toyama side, but since the existence of very weaken rock area was confirmed, it was changed to excavate by NATM. The ground condition was getting better and TBM excavation was launched. Due to repeated encounters with defective ground condition and fracture zones, the progress of excavation was delayed, so main tunnel was also excavated by NATM from the opposite site (Nagoya side). The excavation length from the Toyama side is 2.9 km for the NATM section and 4.3 km for the TBM section, for a total of 7.2 km, and from the Nagoya side It is 3.5km. On the Toyama side, excavation from the portal could not be carried out due to problems with the topography and scenery, so a working drift with a length of about 300m was excavated to connect the main tunnel from the work yard, and excavation proceeded from the intersection of the main tunnel to both sides.
The RC liners, which were the lining for TBM excavation, were transported from a new manufacturing plant near the site. Since a temporary storage area was set up on the factory premises, there was no need for a temporary storage area on site. Excavated muck from NATM were transported by dump truck, and those from TBM were transported to a temporary storage site 2km away using a belt conveyor.
A ventilation tunnel was required due to a long tunnel. It was originally planned to use the lower half of the TBM section as a ventilation duct, but due to the influence of the poor rock, the tunnel length to be excavated by NATM increased. Therefor the ventilation tunnel was excavated parallel to the main tunnel.
Since excavation of the main tunnel from the Toyama side was facing the difficulty, for the one of the purposes of drainage and geological confirmation the evacuation tunnel on the left side of the main tunnel and the ventilation tunnel on the right side were preceded. Since the ventilation tunnel was in advance, , it was possible to branch out of the ventilation tunnel and excavate a maintenance tunnel and turn around to the front of the TBM on repairing the face plate of the TBM. A detour tunnel to bypass the TBM assembly base later became part of the ventilation tunnel.
Ventilation tunnel: Toyama side 2.7km, TBM lower duct section 2.8km, Nagoya side 3.8km

Evacuation tunnel: Excavation began with TBM from the Toyama side, but TBM was restrained by soil pressure in the bad ground condition and could not be excavated. TBM was dug up, and additional tunnel was excavated by NATM in order to bypassed TBM. NATM tunnel went forward until it passed through the bad ground area. As the progress of excavation was not fast, tunnel by NATM was excavated from the Nagoya side like the main tunnel. The length of TBM is 6.4km and that of NATM is 4.4km. After completion, the evacuation tunnel was connected to the main tunnel by connecting tunnels. It was used as an evacuation passage, and it was also used as a power cable route to carry household electricity produced on the Nagoya side to Shirakawa Village.



HIDA TUNNEL (JAPAN)	
LOGISITICS ASPECTS	
Main logistical constrains of the project (e.g. winter conditions, difficult accessibility, natural hazards, architectural/ environmental constraints, material supply…)	Main tunnel: In both portal area (Shirakawa Village and Hida City), snow removal on general roads was conducted certainly, so there was no problem with heavy snow. Snow removal of construction area from the general road to the temporary yard and disposal site carried out by the contractor, and the cost was received from the client. There was only one heavy rain, and national road (Route 156) was closed to traffic. Since the closed period was short, there was no special impact on the delivery of materials for construction. The amount of water inflow reached 40t/min water at mass water zone. When clay contained in seepage water, drainage facility might not be able to be performed completely. So a 3,000m3 pit was set up at TBM assembly area in order to naturally settle clay. The Nagoya side was suspended in winter due to heavy snowy. The slope of tunnel from the Nagoya side was 2% down. When the pump was stopped in winter, the tunnel at 3km length was submerged completely. Evacuation tunnel: In both portal area (Shirakawa Village and Hida City), snow removal on general roads was conducted certainly, so there was no problem with heavy snow. Snow removal of construction area from the general road to the temporary yard and disposal site carried out by the contractor, and the cost was received from the client.
Other special constrains (if any) imposed to the Contractor outside the worksite	Main tunnel: Since the temporary storage site of excavated muck was about 1km apart from portal, a belt conveyor was installed there. In order to use the seepage water from tunnel for snow melting equipment (heat exchange) of the Shirakawa Interchange, a water supply pipe was constructed to the Shirakawa Bridge. Evacuation tunnel: Since 70tons per minute of seepage water were generated in total, a water supply pipe was constructed as a water source for Shirakawa Village. In order to cover the electricity used in the tunnel during operation, a hydroelectric power generation facility was installed outside the tunnel and a water supply pipe was constructed to supply the water.
Special constrains (if any) imposed to the Contractor inside the worksite	Main tunnel: Since it was necessary to assemble the TBM machine in the tunnel, at the machine assembly area tunnel should be widened from the normal cross-section to secure space.
Specific project choices	Main tunnel: As excavated muck transportation, dumps were used for NATM and belt conveyor was adopted for TBM. After excavating from the Toyama side to a point reached by NATM, TBM broke through at the point. TBM skin plates remained on site and the rest of TBM was dismantled on the spot. Since overburden exceeded 1000m, the situation of the ground condition at the level of tunnel was uncertain. In order to decide on whether to excavate with TBM, boring at the depth of 1,000m was performed from the ground surface and the geology of the tunnel level was investigated. Evacuation tunnel: Due to the high water pressure, the body of TBM was greatly deformed, TBM could not proceed and therefore a part of the skin plate remained on the site and the rest of TBM was dismantled.

HAKKODA TUNNEL (JAPAN)

MAIN PROJECT CHARACTERISTICS					
Country	Japan	**International Project**	No	**Project length**	26.5 km
Owner	Japan Railway Construction, Transport and Technology Agency (JRTT)	**Type of Owner**	Public	**Ø excavated**	9.5 to 13.0 m
Engineers				**Functionality**	High Speed Railway
Contractors	Lot 1: Sato, Mitsui, Chizaki, Tanaka JV Lot 2: Shimizu, Fujita, Ito, Kudo JV Lot 3: Kajima, Toda • Magara • Hozumi JV Lot 4: Okumura, Aoki, Morimoto, Terashita JV Lot 5: Tobishima, Dainippon, Kabuki, Shikanai JV Lot 6: Maeda, Takenaka, Fukuda JV			**Number of tubes**	Single (Double track)

The Hakkoda Tunnel is a tunnel of the Tohoku Shinkansen, a high-speed rail line between Tokyo (Tokyo) and Shin-Aomori (Aomori Prefecture), located in northern Honshu (Aomori Prefecture). It is a 26 km long, single bored double-track tunnel with NATM through the northeastern part of the Hakkoda mountain range.

Cost of the project (civil works)	**72,696 M JPY.** The original contract amount was 45,128 M JPY for all the construction lots, and after some design changes, the final amount was 72,696 M JPY. These contracts consisted only of underground civil works and did not include the cost of laying the tracks or fabricating the trains.
Initial date of the project	It was approved by the Japanese government in 1998.
Starting date of construction	July 1998 (tunnel excavation in May 1999)
Current status of the project	Excavation of the tunnel was completed (penetration) in February 2005 and the tunnel is now in service.
CONSTRUCTION WORKS CONTRACT	
Main reason for the chosen lots definition	The site was divided into six lots based on the construction period, topography, and construction conditions. In the middle four construction lots, working drifts were applied to shorten the excavated muck transport distance as much as possible.
Number of constructions Lots	6 construction lots: • Lot 1, Ichinowatari section, 4,325m • Lot 2, Yakata section, 4,300m (working drift: 718m) • Lot 3, Otsubo section, 4,300m (working drift: 740m) • Lot 4, Origami section, 4,400m (working drift: 1,332m) • Lot 5, Tsukinoki section, 4,530m (working drift: 948m) • Lot 6, Nashinoki section, 4,600m
Type of contract	Structural construction contract for the 6 Lots
Time & Cost management	The contract includes the cost of labor, materials, and machinery, and includes everything from the contractor's labor costs to administrative costs, electricity, and water. In addition, the contractor receives payment once or twice a year for the work performed, which must be approved by the client for the progress and workmanship. The construction period is known at the bidding stage and agreed upon at the time the contract is signed. Changes to the construction period can be proposed by both the client and the contractor, but cannot be changed without the agreement of both parties.
Level of definition of underground logistics	The location of the working drift was specified by the client. However, the specific structure of the working drift was determined after the contract was awarded, through discussion and agreement between the client and the contractor. Materials and equipment to be used were selected by the contractor.
Remuneration of logistic structures	Included in the price
Does a difference exist between the type of contract adopted for the main construction works and the preliminary one, if any ?	The preliminary contracting (studies related to logistics) was not performed because tunneling using working drift was already common practice. Planning for transporting excavated muck, etc., were included in the contracted work.

ACCEPTANCE AND INTEGRATION OF THE PROJECT		
DISPOSAL SITES	**Number and volume of disposal sites**	Two types of disposal sites (general type and environmentally consideration (managed) type) were selected. • Lot 1: Approx. 329,000 m³ (from natural ground) • Lot 2: Approx. 365,000 m³ (from natural ground) • Lot 3: Approx. 366,000 m³ (from natural ground) • Lot 4: Approx. 405,000 m³ (from natural ground) • Lot 5: Approx. 396,000 m³ (from natural ground) • Lot 6: Approx. 350,000 m³ (from natural ground)
	Were all disposal site defined before tendering the Construction works ?	It is not defined.
	Who obtained the final authorization	Client

>> Appendix 2 - International Database From The Owner's Point of View Regarding Logistical Aspects

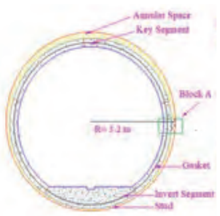
HAKKODA TUNNEL (JAPAN)		
ACCEPTANCE AND INTEGRATION OF THE PROJECT		
CONTRACTOR'S CAMPS	**Number of camps/villages exist or planned**	Site station: one at each tunnel portal (entrance 1 Ichinowatari lot, exit 6 Nashinoki lot) and One at the portal of each of the four working drifts (Lot 2 Yakata section, Lot 3 Otsubo section, Lot 4 Origami section, Lo 5 Tsukinoki section)
	The location of the contractors camp was defined before tendering the Construction works?	It is not defined.
	Who obtained the final authorizations	Contractors
ENERGY, WATER & COM	**Who defined the requirements**	Contractors
	Were those supply/utilities prepared before tendering the Construction works	It was not prepared, but if necessary, the contractor maintained it during the construction phase.
	Who obtained the final authorizations	Contractors
ACCESSES (ROAD, RAIL, CABLE CAR…)	**Level of definition of the location of all accesses to the construction sites before tendering**	If necessary, the contractors widened the access road during the construction phase.
	Who obtained the final authorizations	Contractors
OTHERS		The excavated muck contained mineralized altered rock, which required classification and other measures. Since the work yard was located in a state-owned forest, consultation with the Ministry of Agriculture, Forestry and Fisheries (Forest Management Bureau) was necessary. Because raptor nesting sites were located in the area, environmental preservation was required in some areas.

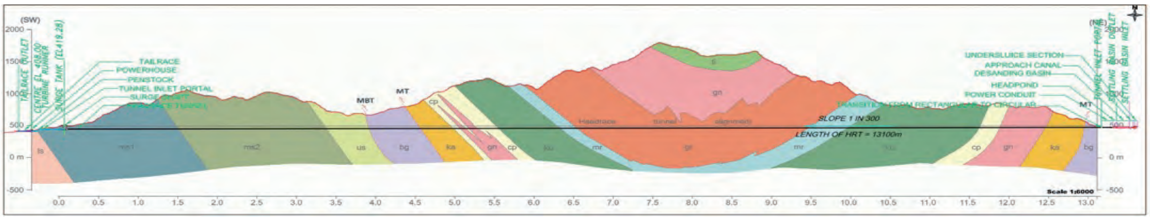
LOGISITICS ASPECTS	
Type of logistic works anticipated (e.g. Geological exploration, Survey, Logistic accesses, Others)?	• Geological/Geotechnical Studies: Studies have been conducted since prior to the start of construction, including an exploratory drift. The main reasons for this were the anticipated occurrence of mineralized altered rocks, the possibility of unconsolidated groundmass in areas of high groundwater table, and the need to confirm the degree of swelling pressure in the Neogene mudstone layers. • Preparation of access roads, etc.: In lot 2 through 5, the road leading to the work yard was narrow, so it was necessary to widen it and install a waiting area. In addition, the road to the disposal site also needed to be improved in the same way. • Preparation of power receiving and transforming facilities: Some construction sits in the mountainous region had no power distribution facilities, so new power distribution facilities were built to reach the construction sites by receiving and transforming the voltage from the high-voltage power transmission facilities for the nearby abandoned mines. The area surrounding the work yard originally had no facilities for receiving large-capacity power, such as large factories, so there were no substations nearby. Therefore, it was necessary to install equipment to prevent flicker when receiving power for construction.
Main logistical constrains of the project (e.g. winter conditions, difficult accessibility, natural hazards, architectural/environmental constraints, material supply...)	• Transportation and disposal of excavated muck: Because some mineralized altered rock was contained in the excavated muck and there was concern that it would acidify and release harmful substances when exposed to water, countermeasures were taken to prevent it from coming into contact with rainwater, such as installing a shed at the temporary disposal site and using waterproof sheets to cure the soil at the fill area. • Since a rare bird of prey was found nesting near the work yard in lot 5, a 2km long curved belt conveyor was installed between the work yard and the disposal site to suppress noise and vibration during the transport of excavated muck. This helped to reduce the impact on the breeding activities of raptors. • In lot 3, there was a possibility that the dust concentration control target (3 mg/m^3) would not be achieved because the length from the working drift portal to the main tunnel face was close to 5 km at times. Therefore, an intermediate ventilation shaft with a diameter of 1.5 m (42 m to the surface) was constructed to improve the dust concentration in the tunnel.
Other special constrains (if any) imposed to the Contractor outside the worksite	None
Special constrains (if any) imposed to the Contractor inside the worksite	Since the excavated muck contained mineralized altered rock and there were concerns about the generation of acidic water and leaching of toxic substances, it was separated and treated according to the judgment flow specified by the client.
Specific project choices	• Belt conveyor in the Tunnel Used in all lots. In lot 3, a fixed belt conveyor with a carrying capacity of 400 t/h was used in the working drift, and a extendable belt conveyor with a carrying capacity of 300 t/h was used in the main tunnel. • Anti-Flicker Equipment Used in all lots. Reasons for use are described above. • Intermediate ventilation shaft • Used in lot 3. Reason for use is as above.

SUNKOSHI MARIN DIVERSION (NEPAL)

MAIN PROJECT CHARACTERISTICS					
Country	Nepal	**International Project**	Yes	**Project length**	13,3 km
Owner	Department of Water Resource and Irrigation	**Type of Owner**	Public	**Ø excavated**	6,4 m
Engineers	To be Appointed			**Functionality**	Hydro
Contractors	To be Appointed			**Number of tubes**	Single

Sunkoshi Marin Diversion Multipurpose Project is a major inter-basin water transfer project. It aims to divert 67 cumecs of water from Sunkoshi River to Marin River (a tributary of Bagmati River) to provide round the year irrigation to 1,22,000 Ha of southern Terai. Length of headrace tunnel of the project is about 13.3 Km long and is hydro/irrigation tunnel used for water conveyance.





Cost of the project (civil works)	**150 Million USD** The total cost of the tunnel part of the project is about 150 Million USD (including VAT). The overall project cost is about 750 Million USD.
Initial date of the project	2014 It was government project, so did not need to wait for permission
Starting date of construction	Anticipated Starting Date of Construction of Tunnel is : February, 2021
Current status of the project	Shortlisting of Contractors for Tunnel Construction through Pre-Qualification Process
CONSTRUCTION WORKS CONTRACT	
Main reason for the chosen lots definition	
Number of constructions Lots	For the tunnel construction : One from Sunkoshi to Marin : Construction of Headrace Tunnel and Associated Structures For equipments & others : • Construction of Civil and Hydromechanical works of Headwork's, Powerhouse, Surgeshaft and Powerhosue • Construction of Electromechanical Works
Type of contract	• Construction of Headrace Tunnel and Associated Structures- **Unit-Rate (FIDIC Red Book) Contract** • Construction of Civil and Hydromechanical works of Headwork's, Powerhouse, Surgeshaft and Powerhosue- **Unit-Rate (FIDIC Red Book) Contract with Design Build for Hydromechanical Works** • Construction of Electromechanical Works- **Design Build and Operate**
Time & Cost management	Mostly Bill of Quantities and Lumpsum for General Item of Works (TBM cost included in the per metre cost of excavation)
Level of definition of underground logistics	Underground logistics were well defined with clear geometrics of them. Yes, it was provisioned to propose alternative logistics and payment was planned to be made based on the type of logistics made.
Remuneration of logistic structures	Included in the price
Does a difference exist between the type of contract adopted for the main construction works and the preliminary one, if any ?	No

>> Appendix 2 - International Database From The Owner's Point of View Regarding Logistical Aspects

SUNKOSHI MARIN DIVERSION (NEPAL)		
ACCEPTANCE AND INTEGRATION OF THE PROJECT		
DISPOSAL SITES	**Number and volume of disposal sites**	Three
	Were all disposal site defined before tendering the Construction works ?	Yes
	Who obtained the final authorization	Owner
CONTRACTOR'S CAMPS	**Number of camps/villages exist or planned**	2
	The location of the contractors camp was defined before tendering the Construction works?	Yes
	Who obtained the final authorizations	Owner
ENERGY, WATER & COM	**Who defined the requirements**	Owner
	Were those supply/utilities prepared before tendering the Construction works	Partially
	Who obtained the final authorizations	Owner
ACCESSES (ROAD, RAIL, CABLE CAR…)	**Level of definition of the location of all accesses to the construction sites before tendering**	Yes
	Who obtained the final authorizations	Owners
OTHERS		

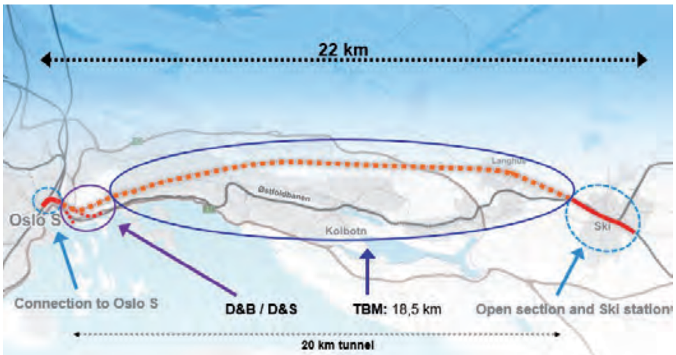
LOGISITICS ASPECTS	
Type of logistic works anticipated (e.g. Geological exploration, Survey, Logistic accesses, Others)?	Core Drilling, Survey
Main logistical constrains of the project (e.g. winter conditions, difficult accessibility, natural hazards, architectural/ environmental constraints, material supply…)	None
Other special constrains (if any) imposed to the Contractor outside the worksite	None
Special constrains (if any) imposed to the Contractor inside the worksite	None
Specific project choices	Too early to answer

THE BLIX TUNNELS AT THE FOLLO LINE (NORWAY)

MAIN PROJECT CHARACTERISTICS

Country	Norway	**International Project**	No	**Project length**	20 km (The tunnel)
Owner	Bane NOR	**Type of Owner**	Public	**Ø excavated**	9.98 m
Engineers				**Functionality**	High speed railway
Contractors	Lot 1. 1.5 km D&B/ Drill & Split: Condotte, but after cancellation AF ANLEGG Lot 2. 18.5 km TBM: AGJV (ACCIONA GHELLA JOINT VENTURE)			**Number of tubes**	Twin

The 20 km long Blixtunnel is the main part of the 22 km long Follo Line connecting Oslo Central station with Ski city. This is the core part of the InterCity railway line going from Oslo to the border of Sweden. The Follo Line will also be a part of a future high-speed railway line to the border of Sweden



Cost of the project (civil works)	**1000 M €.** This is an EPC contract, which consists of both Civil work and Railway system. Engineering is also a part of the contract
Initial date of the project	The early planning of the project started in 2007. Decision of: The location of the corridor/alignment was taken in 2009. The tunnel concept; Two single track tunnels instead of one double-track tunnel was taken in 2010. Excavation method; use of four TBMs excavated from one centrally located access point was taken in 2012. Approval of area development plans in 2013. Acceptance from the Government in 2014 Pre-qualification and issued Invitation to Tender in 2014. Contract award in February 2015 (EPC D&B for 1.5 km in the north) and in March 2015 (TBMs for 18.5 km of the tunnel section)
Starting date of construction	Pre-work (excavation of two access tunnels) started in June 2014. The main work started in June 2015. Start-up of the four TBMs in the period between September and December 2016.
Current status of the project	Excavation of the tunnels finalized in February 2019. The Blix tunnel and the Follo Line will be taken into operation in December 2022.
CONSTRUCTION WORKS CONTRACT	
Main reason for the chosen lots definition	In order to finalize the tunnel excavation (the tunnel ready for installation of railway system) within 4 years after contract award, it was decided to perform the excavation of the main part of the tunnel section by four TBMs operating from one centrally located access point, right next to the motorway, instead of performing the excavation by D&B from seven different access points. In the northern part of the tunnel section, the excavation should take place close to a number of sensitive underground installations. The excavation of this section would have been the last part of a 10.5 km long TBM section for the two machines which were planned to excavate in the northern direction, and this section would have been on the critical path for the entire Follo Line project. In order to have control of the time, this 1.5 km long section in the northern part of the tunnel was then awarded as a separate contract where the two tunnels should be excavated by a combination of careful D&B and Drill & Split.
Number of constructions Lots	2 constructions lots : • One access tunnel with connection to a rig area in the north for the D&B/ Drill & Split contract. • One rig area for the operation of the four TBMs. Two access tunnels had been excavated as pre-work. Additional logistic tunnels and two large caverns for assembly and start-up of the four machines were excavated by D&B. The rig-area was large enough to house all the activities related to the tunnel excavation, including factory for segment production and final deposit for all the excavated material.
Type of contract	EPC contracts for both Lots. The Contractors were responsible for engineering, procurement and construction of only the civil work for the northern 1.5 km of the tunnel section. For the TBM-contract, the contractor was responsible for engineering, procurement and construction of both civil work for 18.5 km of the tunnel section and of railway systems for the entire 20 km long tunnel.

<table>
<tr><th colspan="3">THE BLIX TUNNELS AT THE FOLLO LINE (NORWAY)</th></tr>
<tr><td>Time & Cost management</td><td colspan="2">The EPC-contracts are based on lump sums, but some parts of the work are reimbursable, based on documented costs and time consume. Changes are handled through a variation order system, where the Owner and the Contractor agree about the impact on both cost and schedule. As an agreement between the parties, the lump sums to be paid every month are in accordance with the agreed schedule. Payment for the reimbursable parts of the work is paid in accordance with achieved progress and documented costs. Compensation for the costs related to the contractor's management and facilities is a fixed percentage of the initial value of the work. This is paid as a part of the final account.
The duration of the works is agreed at the time the contract is awarded and can only be modified if the Owner agrees.</td></tr>
<tr><td>Level of definition of underground logistics</td><td colspan="2">Two access tunnels from the rig-area down to the underground area where the Blix-tunnel should be located were excavated as pre-work. As a part of the EPC-contract, the Contractor was responsible for the logistic at the site, both underground and on the surface. This also included excavation of extra tunnels in order to achieve an efficient performance of the work. Two large chambers were excavated in order to assembly the TBMs (two in each chamber), in addition to tunnels with extended size of the profiles, compared to the final profile of the Blix-tunnels, between the assembly chambers, and logistic tunnels with access to the assembly chambers and to the tunnels between the assembly chambers.
</td></tr>
<tr><td>Remuneration of logistic structures</td><td colspan="2">Included in the price</td></tr>
<tr><td>Does a difference exist between the type of contract adopted for the main construction works and the preliminary one, if any ?</td><td colspan="2">The two access tunnels, performed as pre-work were performed as a unit-price contract, while the main contracts for the two parts of the tunnel section were EPC-contracts.</td></tr>
<tr><th colspan="3">ACCEPTANCE AND INTEGRATION OF THE PROJECT</th></tr>
<tr><td>DISPOSAL SITES</td><td>Number and volume of disposal sites</td><td>EPC TBM: The rig area was divided on two levels

• Level at elevation 148: The rig areas is located in front of the access tunnels and has an area of approx. 25'000 m². Within this area, most of the workshops and a water treatment plant were located.
• Level at elevation 161: This is the rig area where the segment factories were located and the excavation material coming out of the tunnel with conveyor belts was handled. The total size is approx. 100'000 m².
• Next to this rig area is the spoil deposit with an area of approx. 100'000 m².

EPC D&B: Due to space limitation in an urban area could only two rather small rig areas be provided in the vicinity of the Sydhavna entrance tunnel. These rig areas allowed only for some basic equipment installations and some material storage.</td></tr>
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THE BLIX TUNNELS AT THE FOLLO LINE (NORWAY)		
ACCEPTANCE AND INTEGRATION OF THE PROJECT		
DISPOSAL SITES	**Were all disposal site defined before tendering the Construction works ?**	Both sites were defined before tendering the Construction works. Area development plans were approved by the municipalities before the tendering process. In order to be allowed to re-use all the TBM-excavated material within the main rig-area, this area was increased through an extended area development plan, approved by the affected municipality after contract award, but before the contractor needed the area.
	Who obtained the final authorization	Contractors in cooperation with the Owner
CONTRACTOR'S CAMPS	**Number of camps/villages exist or planned**	• For the D&B/ Drill and Split contract, the accommodation for the workers was located outside the rig-area, but the Contractor and the Owner had their offices within the rig-area • For the main contract (the TBM contract), all facilitates related to the tunnel excavation were located inside the rig-area, including the area for filling up the excavated material as a basement for a future residential area. This also included the offices for both the Contractor and the Owner and accommodation for approximately 500 workers.
	The location of the contractors camp was defined before tendering the Construction works?	Yes
	Who obtained the final authorizations	Contractors in cooperation with the Owner
ENERGY, WATER & COM	**Who defined the requirements**	The Owner built a transformer station to provide sufficient energy for the 4 TBMs including segment factory and facilitated water and sewage connections. Contractors took care of the rest.
	Were those supply/utilities prepared before tendering the Construction works	Yes
	Who obtained the final authorizations	Partly the Contractors and the Owner
ACCESSES (ROAD, RAIL, CABLE CAR...)	**Level of definition of the location of all accesses to the construction sites before tendering**	The accesses to both construction sites/ rig-areas were defined and approved by the relevant authorities before tendering. There were direct accesses from the main roads to both construction sites/ rig areas
	Who obtained the final authorizations	Partly the Owner and partly the Contractors
OTHERS		None

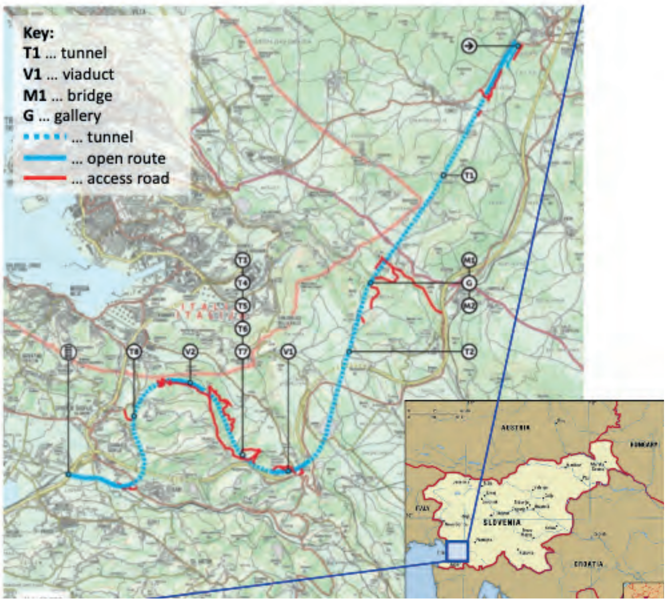
>> Appendix 2 - International Database From The Owner's Point of View Regarding Logistical Aspects

THE BLIX TUNNELS AT THE FOLLO LINE (NORWAY)	
LOGISITICS ASPECTS	
Type of logistic works anticipated (e.g. Geological exploration, Survey, Logistic accesses, Others)?	• **Geological/geotechnical studies.** The overburden of the tunnel section varied between 5 and 180 meters. The geological conditions were well documented in the tender documents. During the TBM-excavation, supplementary investigations were performed. Continuous overlapping probe-drilling from the TBMs and core-drilling every 400 meters. The results from these supplementary geological investigations corresponded very well with the results of the mapping performed in advance of the tendering process. • **Access to the tunnels:** Two access tunnels, one km each, were built as pre—work. The main Contractor excavated additional logistic tunnels for the operation of the TBMs and two large caverns for the assembly of the four TBMs • **An efficient rig-area.** The rig-area was large enough to include all the installations needed for the tunnel excavation. This included area for handling the excavated material, workshops, three factory-units (Carousels) for production of the segmental lining and the invert segments, area for accommodation of approximately 500 workers, canteen and offices for both the Contractor and the Owner.
Main logistical constrains of the project (e.g. winter conditions, difficult accessibility, natural hazards, architectural/ environmental constraints, material supply…)	• The arrangement of the rig-area gave space enough to handle the snow during the wintertime. Heating cables were installed in the main road within the rig-area where transport of the segments from the factory were transported down to the access tunnel. • All the material was transported on conveyer belts within the construction site for the TBM-operation. The conveyer belt was covered, in order to avoid snow and rain to be mixed with the excavated material. • Space enough for the three segment factory units, including the storage area for the segments • Use of multi-service-vehicles (MSV) for transport of segments, equipment, personnel, etc down in the tunnels and further in to the TBMs contributed to an efficient operation of all transports. • One water treatment plant in operation at the rig-area for the D&B/ Drill & split contract. Two water treatments plants installed at the main rig-area for treatment of the production-water from the TBM-excavation. Re-use of the production-water
Other special constrains (if any) imposed to the Contractor outside the worksite	• Make sure that the neighbors (not many) were not exposed to noise above defined levels during the night. • Control of the chemistry of the discharged water from the construction site.
Special constrains (if any) imposed to the Contractor inside the worksite	None
Specific project choices	• Conveyor belts. Use of conveyor belts inside all tunnels within the site for the TBM-excavation. This belt was 1200mm wide and with a speed of 2,5 m/s, which meant a capacity of 1600 t/h per TBM. • Originally specified train transport in the tunnels. The contractor recommended to replace the train-system with multi-service-vehicles (MSV), which opened up for a much more efficient and flexible handling of all kinds of transports in addition to a huge reduction of re-loading of segments, equipment, and people down in the tunnel system. The inclination of the two access tunnels (each one km long) was 10%, so train transport could not be used on that stretch. • Specification of the TBMs. Tailormade for the hard-rock conditions. Equipped with drills for performing pre-grouting from the TBMs in order to stop or limit leakages of water into the tunnel during excavation. The water leakages occurred when the tunnels (the TBMs) intersected fracture zones.

SECOND RAILWAY TRACK DIVAČA – KOPER (SLOVENIA)

MAIN PROJECT CHARACTERISTICS

Country	Slovenia	**International Project**	No	**Project length**	20.7 km (7 tunnels)
Owner	2TDK d.o.o.	**Type of Owner**	Public	**Ø excavated**	8.3 – 8.5 (equivalent)
Engineers	JV 2.TIR (Elea iC, IRGO, SŽ-PP, PAP, IBE)			**Functionality**	Railway
Contractors	1. LOT1 AND LOT2: JV KOLEKTOR CPG D.O.O. (SLOVENIJA), YAPI MERKEZI İNŞAAT VE SANAYI A.Ş. (TÜRKIYE), ÖZALTIN İNŞAAT TICARET VE SANAYI A.Ş. (TÜRKIYE)			**Number of tubes**	Single



Project Second Track is new modern railway connection from coastal area and national port to the mainland of Slovenia.
Project Second Track has length of 27.2 km with 20.7 km underground section and remainder on the open route and 2 longer viaducts. Underground section comprises altogether 7 tunnels with 3 longest tunnels (tunnels T1 6.7 km, T2 6 km and T8 3.8 km) being designed as twin tube tunnels consisting of the main tube and parallel service tube interconnected with cross-passages every roughly 500 m. Remaining tunnels will be at this stage constructed as single tube tunnels. Tunnels longer than 1 km (T4, T7) will comprise intermediate access tubes utilized as the emergency exit.
At the time being, preliminary stages already commenced for the parallel track which will complement the Second track to a full double-track railway line. Having longest three tunnels already constructed as double tube tunnels, only parallel tubes of tunnels T3 to T7 will have to be constructed and of course all bridging structures. Current forecasts show that construction of parallel track may start in 2026.

Cost of the project (civil works)	**628,3 M€** (without VAT)
Initial date of the project	Feasibility studies started in 1997 and the National Site Plan as a basis for start of the design process for the construction permit had been obtained in 2005. In the following some years several variants were studied and in 2011 the preparation of project documentation for the construction permit for the final alignment started. Construction permit was approved in 2016.
Starting date of construction	1. half of 2021
Current status of the project	under construction

CONSTRUCTION WORKS CONTRACT

Main reason for the chosen lots definition	Whole Second Track project is split into 2 lots which was suggested by consultants in the preliminary stages of the project. The main reason being the risk reduction for the Owner. The main concern of the consultants, especially from the financing point of view, was the potential problem if the contractor would have gone bankrupt or could not fulfil the contractual obligations. It is believed that having two contractors for both lots would efficiently reduce the risk since the remaining contractor could continue with works also on the other lot.
Number of constructions Lots	Two Lots • Lot 1: Divača – Črni Kal, • Lot 2: Črni Kal - Koper
Type of contract	Design – Bid - Build. Separate contracts for the detailed design and main construction works with preliminary stage consisting of design and construction of access roads
Time & Cost management	Cost&Time management follow closely the provisions of ÖNORM 2203. Critical Path Method (deadline adjustment)

>> Appendix 2 - International Database From The Owner's Point of View Regarding Logistical Aspects

SECOND RAILWAY TRACK DIVAČA – KOPER (SLOVENIA)		
Level of definition of underground logistics		Underground logistics are completely defined within the detailed design based on the construction permit and cannot be changed by the selected contractor. In general, all underground spaces shall be constructed using NATM from the main portals with the exception of tunnels T4 and T7 which may be constructed from intermediate accesses as well. All intermediate access drifts are geometrically completely defined. Since the design is completely separated from the execution, Contractor will not have possibility to propose changes of underground logistics.
Remuneration of logistic structures		Included (Construction site costs as per provisions of ÖNORM 2203 Logistics will be paid by the separate construction site costs as per ÖNORM 2203.
Does a difference exist between the type of contract adopted for the main construction works and the preliminary one, if any ?		In the preliminary stage, only access roads to portals had been constructed, while construction site plateaus and temporary portals will be part of the main construction works. Access roads were awarded by the regular construction contract, while main construction works follow the provisions of ÖNORM 2203.
ACCEPTANCE AND INTEGRATION OF THE PROJECT		
DISPOSAL SITES	**Number and volume of disposal sites**	Since alignment of the project runs through 2 main lithological units (carbonate and flysch formations), strategy of dealing with excavated materials depends on the material excavated. Carbonates will be processed for use as aggregates in concrete, shotcrete, for embankments, fills, unbound layers, asphalt, etc. Portion of excavated carbonates will be stored for the future parallel track. On the other hand has to be flysch material permanently deposited. Contracting Authority foresaw 2 major permanent landfill sites, (1) one within the existing limestone quarry where portion of abandoned part of quarry will be rehabilitated by introduction of good quality flysch materials (approximate volume of 1.500.000 m^3) (2) and (2) one in the area of pre-existing smaller landfill where poor quality flysch materials, sediments from karst features and concrete leftovers will be deposited (approximately 700.000 m^3).
	Were all disposal site defined before tendering the Construction works ?	Yes, disposal sites have been defined within the environmental permits
	Who obtained the final authorization	The Owner
CONTRACTOR'S CAMPS	**Number of camps/villages exist or planned**	The location of Contractor's camps had not been defined in advance within the project nor tender documentation and will have to be taken care of by the Contractor.
	The location of the contractors camp was defined before tendering the Construction works?	No, Contractor's camps had not been even defined in the construction permit.
	Who obtained the final authorizations	Contractor will have to obtain all regulator's approvals and permits as well as land for the camps.
ENERGY, WATER & COM	**Who defined the requirements**	The requirements for supply of energy, water and COM depend on the excavation means and equipment selected by the Contractor.
	Were those supply/utilities prepared before tendering the Construction works	No. Since selection of excavation means and equipment is the sole responsibility of the Contractor, they shall prepare and provide utilities needed.
	Who obtained the final authorizations	Contractor will have to obtain all regulator's and utility companies' approvals and permits.
ACCESSES (ROAD, RAIL, CABLE CAR...)	**Level of definition of the location of all accesses to the construction sites before tendering**	Yes, design and construction of access roads was completely separated from the tender of the main construction works and were already completed i.e. prior to the commencement of the main construction works
	Who obtained the final authorizations	The Owner.
OTHERS	Two tunnels in upper part of the Second Track run through the karst aquifers supplying water to the Slovenian and Italian coast and regulator required construction of tunnels which will drain just very limited volume of water from aquifers crossed. Very strict requirements led to the design of so-called undrained cross-section (tunnel fully lined with waterproofing membrane and exposed to high hydrostatic pressures of 1.5 MPa). Where hydrostatic pressures may exceed the given limit, pre-grouting and subsequent post-grouting will have to be performed to reduce the rock mass transmissivity. To avoid impact on the quality of groundwater, all materials used for tunnel support, pre- and post-grouting, excavation shall within the karst aquifers possess a valid drinking water certificate i.e. certificate proving that product as a whole or any of its constituents in fresh and hardened state does not have any deleterious effect on the drinking water. Furthermore, these two tunnels partially run through environmentally protected area within a narrow gorge where special measures regarding the construction activities will have to be implemented (construction site facilities shall be located on the plateau relatively far from the tunnel portals, special measures regarding the wastewaters and leakage of chemicals, fuels, oils and greases, etc.).	

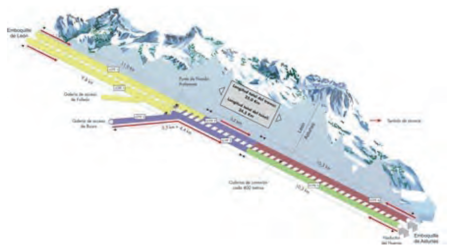
SECOND RAILWAY TRACK DIVAČA – KOPER (SLOVENIA)	
LOGISITICS ASPECTS	
Type of logistic works anticipated (e.g. Geological exploration, Survey, Logistic accesses, Others)?	Since two longest tunnels run through the carbonate formations with developed karst features, an extensive geophysical investigation is required during the construction for the detection of these features within the future tunnels and their vicinity to ensure stability and serviceability of tunnels as well as safety of constructors and users. Geophysical investigation will be performed in the rock mass ahead of the tunnel face using borehole georadar technique. Geophysical investigation programme will be performed by the Geophysicist under separate contract directly with the Owner. Geotechnical monitoring consisting of geological and hydrogeological documentation, geodetic monitoring of in-tunnel, surface and infrastructure monitoring points, and laser scanning of vital infrastructure in the influence zone of tunneling as well as geotechnical measurements using variety of geotechnical instruments (piezometers, inclinometers, lining pressure cells and strainmeters, borehole extensometers, jointmeters, laser distance meters) will be utilized to optimize the construction of tunnels and to limit their influence on the infrastructure in the influence zone. Geotechnical monitoring will be performed by the Geotech Engineer under separate contract directly with the Owner.
Main logistical constrains of the project (e.g. winter conditions, difficult accessibility, natural hazards, architectural/ environmental constraints, material supply…)	From the logistic perspective is project considered as favorable. Located close to the motorway which allows quick access as well as quick and efficient delivery of materials and transport of muck. Project runs through the little populated area with only small number of limitations imposed by regulators and local communities. Located close to the coast and Adriatic see harsh winter conditions are not expected. However, some snow and temperature below 0 may be expected in the upper part of the project in the mainland. No major natural hazards are expected in the area. Due to unfavorable layering of flysch formations potential smaller instabilities of slopes may be expected. Logistical constraints, however, contributed to merging of tunnels T5 and T6. In a narrow valley with steep slopes it would be very expensive and challenging to construct temporary portals for both tunnels. Hence the decision had been made during the detailed design to backfill the valley around future tunnels with low bearing concrete lacking fines which will act as a support of slopes and allow efficient tunneling through without surfacing. Technically such measure reduces the number of executed tunnels to 7, the new tunnel being named T56.
Other special constrains (if any) imposed to the Contractor outside the worksite	Muck and material transport in the vicinity of residential areas is only allowed on working days (Monday-Saturday) in the daylight time.
Special constrains (if any) imposed to the Contractor inside the worksite	Contractor of Lot 1 (mainly in carbonate formations) shall install crushers for crushing excavated limestone to produce aggregates at three locations allowed by the environmental permits. Excessive limestone shall be transported to a spot where Owner will provide crushing for the Contractor of Lot 2 who shall obtain aggregates from this location only. Also, locations of site batch plants are defined by the environmental permits and it shall not be allowed to erect them outside of the designated areas. In the areas where tunnels run with shallow overburden underneath populated areas, blasting is limited to the daylight time only. Tunnel T2 shall be along the whole length in the water safeguarding area driven upwards. To limit potential influence of water inflows when driving tunnel downwards, installation of water barrier shall be required at certain distance from the face to prevent flooding the complete tunnel. Special attention is required with regards to dealing with leakages of chemicals, fuels and oils in the entire carbonate area due to the porous structure of rock mass and potential pollution of groundwater.
Specific project choices	

PAJARES TUNNELS (SPAIN)

MAIN PROJECT CHARACTERISTICS

Country	Spain	**International Project**	No	**Project length**	25 km
Owner	ADIF Alta Velocidad	**Type of Owner**	Public	**Ø excavated**	9.9 to 10.1 m
Engineers				**Functionality**	High-speed rail
Contractors	Lot 1. FCC, NECSO JV Lot 2. ACS, DRAGADOS, OBRAS SUBTERRÁNEAS JV Lot 3. FERROVIAL AGROMAN S.A., SACYR, S.A.U., CAVOSA OBRAS Y PROYECTOS S.A JV Lot 4. AZVI S.A., CONSTRUCTORA HISPANICA S.A., FERNANDEZ JVCONSTRUCTOR S.A., COPCISA			**Number of tubes**	Twin

Pajares tunnels are part of what is known as Pajares By-Pass, which is a 49.7km long section of the high-speed rail line León-Asturias, between La Robla (León) and Pola de Lena (Asturias).
The Pajares tunnels is the most iconic project within the Pajares By-Pass. It is a high-speed rail tunnel located in the North of Spain. It is a 25km long twin tunnel going through the Cantabrian mountain chain.



Cost of the project (civil works)	**1964 M €** The awarded contract price was 906M€. The final cost of the works was 1964M€. These contracts only comprised the underground civil works, without including the tracks and other train and security systems/facilities.
Initial date of the project	Informative Study was completed and approved in 1999 The Estudio Informativo (Informative Study) was completed and approved in 1999, which triggered the public information process
Starting date of construction	March 2004 (tunnel excavation in June 2005)
Current status of the project	Excavation of the tunnels was completed in August 2009, track installation close to completion

CONSTRUCTION WORKS CONTRACT

Main reason for the chosen lots definition	The main reason for the chosen lots definitions was to try to adjust the construction time, set at 60 months in the projects. The intermediate accesses were selected so that they would allow the different sections to be independent and access was given to the most conflictive areas.
Number of constructions Lots	4 constructions lots : • Lot 1, La Pola de Gordón-Folledo (both tunnels), 10.688 m • Lot 2, Folledo-Viadangos (both tunnels), 3.867 m. • Lot 3, Viadangos-Telledo (East tunnel and security systems), 10.403 m. • Lot 4, Viadangos-Telledo (West tunnel and galleries), 10.403 m.
Type of contract	Design & Build for the 4 Lots
Time & Cost management	The contract includes an estimate or target price that is calculated from the estimated quantities and the unit prices for each activity/works package, to which a fee is added to account for the contractor's overall costs and benefit and to which also the discount offered by the appointed contractor in their bid is applied. Every month the contractor certifies the amount of work done in that period of time and gets paid according to the aforementioned unit prices plus the fee minus the discount. The duration of the works is agreed at the time the contract is awarded and can only be modified if the client agrees Conventional : Lump Sum reviewed with Bill of Quantities
Level of definition of underground logistics	The logistics were given in the Basic Project, but after the award of the design & build contracts, each contractor developed the Construction Projects, where the logistics were changed.
Remuneration of logistic structures	Included in the price
Does a difference exist between the type of contract adopted for the main construction works and the preliminary one, if any ?	The preliminary ancillary and enabling works were part of the main design and build works contract. The only preparatory works carried out were the drawing up of the Basic Project and a series of preliminary studies that included a borehole campaign later expanded in the construction phase.

>> Appendix 2 - International Database From The Owner's Point of View Regarding Logistical Aspects

PAJARES TUNNELS (SPAIN)		
ACCEPTANCE AND INTEGRATION OF THE PROJECT		
DISPOSAL SITES	**Number and volume of disposal sites**	Four disposal sites were used: • Lot 1: Buiza and Folledo, 2.078.920m³ (excavated volume, according to design) • Lot 2: Buiza, Folledo and DCRI-1 (La Pola de Gordón), 1.262.857m³ (excavated volume, according to design) • Lots 3 and 4: La Cortina, 2.304.500m³ (excavated volume)
	Were all disposal site defined before tendering the Construction works ?	Partially. The location of the disposal sites was already defined in the Informative Study and approved by the Environmental Impact Assessment; they were also captured in the Basic Project. However, the treatment of the excavated materials in lot 2 had to be further studied after the change implemented in how the tunnel was accessed (from two vertical shafts in the Basic Project to a horizontal access gallery), resulting in a new disposal site.
	Who obtained the final authorization	Contractors
CONTRACTOR'S CAMPS	**Number of camps/villages exist or planned**	None
	The location of the contractors camp was defined before tendering the Construction works?	N/A
	Who obtained the final authorizations	N/A
ENERGY, WATER & COM	**Who defined the requirements**	Contractors
	Were those supply/utilities prepared before tendering the Construction works	No, they were not. They were prepared during the construction phase and were covered in the Construction Project. New power lines were necessary to enable the energy supply.
	Who obtained the final authorizations	Contractors
ACCESSES (ROAD, RAIL, CABLE CAR…)	**Level of definition of the location of all accesses to the construction sites before tendering**	The location of accesses was very little developed in the Basic Project and it was better defined in the Construction Projects. It was actually constrained by the Environmental Impact Assessment, that limited the opening of new accesses within the environmentally protected areas. It was initially defined in the Basic Project, but later modified by the contractors during construction phase, after the changes in the direction of tunnel excavation and the changes in accessing the intermediate sections (see table of specific project choices). At the end there were three construction sites, one for each mouth of the tunnel (Pola de Gordón in the South and Pola de Lena in the North), and another one in the Buiza gallery access.
	Who obtained the final authorizations	Contractors
OTHERS		None. Only those constraints set by the Environmental Impact Assessment.

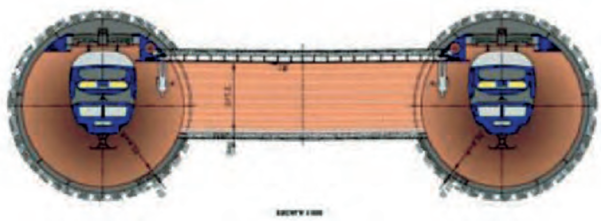
PAJARES TUNNELS (SPAIN)	
LOGISITICS ASPECTS	
Type of logistic works anticipated (e.g. Geological exploration, Survey, Logistic accesses, Others)?	• **Geological/geotechnical studies.** There were no further geotechnical investigations during the drawing up of the Construction Projects, but they were carried out in the construction phase instead. The studies carried out included the extension of the geological cartography, 69 boreholes and geophysics tests, as well as the follow up of the excavation face. • **Preparation, widening and betterment of the access roads for lots 3 and 4:** it was necessary to widen and improve the local road along a distance of about 10km, so that the TBM pieces could be taken to the assembly area close to the tunnel mouth. The existing road had a very winding alignment and very tight curves, and was not even 4m wide at some locations. It was widened by means of cuts and fills that presented very complex sliding slopes issues. • **Accesses.** It was necessary to construct a viaduct over the river Bernesga and a flyover over the current train line León-Gijón in order to access the South mouth in Pola de Gordón (lot 1).
Main logistical constrains of the project (e.g. winter conditions, difficult accessibility, natural hazards, architectural/ environmental constraints, material supply…)	• The issue with a greatest impact was the issues derived from the high infiltration flows during the excavation of the tunnels. (The tunnels vertical alignment is such that they descend about 420m from the South to the North mouth. This entails difficulties in the context of quartzite formations with high permeability and karstic limestone with high volumes of water). • The lack of power supply in the North mouth (lots 3 and 4). • Location of the tunnel segments manufacture and storage yards. In the North side (lots 3 and 4), the lack of space resulted in segments manufacturing yard set up further than 6km way from the mouth. Also, the segments storage yards were scattered and as a result, most tunnel rings had to be handled twice as a minimum and transported up to 20km to be installed inside the tunnel.
Other special constrains (if any) imposed to the Contractor outside the worksite	Basically, the ones given by the Environmental Impact Assessment, that included the use of a conveyor belt to carry the excavation arisings from the tunnels in lots 3 and 4, from the North mouth to the disposal site (La Cortina) around 1800m away.
Special constrains (if any) imposed to the Contractor inside the worksite	None, it was contractor's choice
Specific project choices	• **Conveyor belts.** Use of conveyor belts inside all tunnels. In lot 1 this belt was 1000mm wide and with a speed of 3m/s, which meant a flow of 1200t/h per TBM. • **Gallery used to take the TBM out.** The Basic Project considered the use of the Folledo gallery to assembly and launch the TBM, with an uphill excavation of the tunnel. The contractor in lot 1 changed the direction of excavation, which was carried out downhill. This meant that the gallery was then used as an underground structure to take the TBM out. • **Intermediate access gallery.** The Basic Project included a double 500m deep shaft as the access to the intermediate points during the construction phase. This access was replaced by a 5.5km long access gallery due to environmental reasons.

GUADARRAMA (SPAIN)

MAIN PROJECT CHARACTERISTICS

Country	Spain	**International Project**	No	**Project length**	28,4 km
Owner	ADIF Alta Velocidad	**Type of Owner**	Public	**Ø excavated**	9.5 m
Engineers				**Functionality**	High-speed rail
Contractors	• Lot 1 : Dragados y Construcciones SA, TECSA Empresa Constructora SA, NECSO Entrecanales Cubiertas SA JV • Lot 2 : Obras y Contratas Javier Guinovart SL, COMSA SA, Sacyr SA, Construcciones Laín SA, Obrascon Huarte SA, Hotchief Aktiengesellschaft JV • Lots 3 & 4 : FCC Construcción SA, Fomento de Construcciones y Contratas SA, Contratas y Ventas SA, ACS Proyectos, Obras y Construcciones SA, Vías y Construcciones SA, Ferrovial SA, Grupo Ferrovial SA JV			**Number of tubes**	Twin

The Guadarrama base tunnel is part of the Soto del Real (Madrid)-Segovia section within the Spanish high speed line Madrid-Valladolid.
It is a 28km long railway twin tunnel that goes through the Guadarrama mountain range.



Cost of the project (civil works)	**1841M€.** The total cost of the tunnels was 1841M€, including the four construction lots which include the platform and track.
Initial date of the project	1997 "Informative Study" was completed in 1997, which was used for public information and triggered various feasibility studies
Starting date of construction	February 2002
Current status of the project	Construction works completed; high speed line in service since Dec 2007

CONSTRUCTION WORKS CONTRACT

Main reason for the chosen lots definition	The reasoning behind the chosen lots definition lies in: • Trying to achieve high excavation rates with double shield TBMs, taking into account the data available at the time • Minimizing the environmental impact, avoiding intermediate accesses. • Maintaining acceptable TBM supply levels • Reducing risks
Number of constructions Lots	4 constructions lots : • Lot 1: from the South mouth to an intermediate point (Soto del Real side), West tunnel • Lot 2: from the South mouth to an intermediate point (Soto del Real side), East tunnel • Lot 3: from the intermediate point to the North mouth (Segovia side), West tunnel • Lot 4: from the intermediate point to the North mouth (Segovia side), East tunnel
Type of contract	**Design & Build for the 4 Lots** Each bidder made their proposals in response to a design and build tender. Those proposals led to an integrated project that the IP put together, which includes the best proposals from the bidders. Based on this integrated project, each bidder later prepared the constructive project (design for construction) corresponding to their lot.
Time & Cost management	Conventionnal : Bill of Quantities TBM : Lump sum The contract includes an estimate or target price that is calculated from the estimated quantities and the unit prices for each activity/works package, to which a fee is added to account for the contractor's overall costs and benefit and to which also the discount offered by the appointed contractor in their bid is applied. Every month the contractor certifies the amount of work done in that period of time and gets paid according to the aforementioned unit prices plus the fee minus the discount. The duration of the works is agreed at the time the contract is awarded and can only be modified if the client agrees.

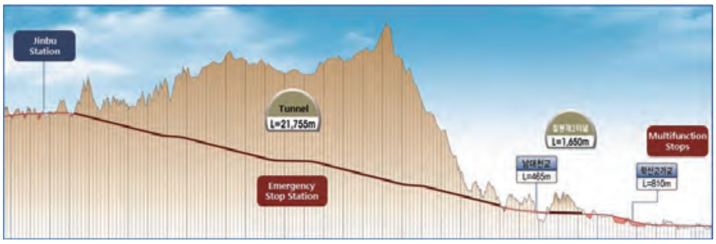
GUADARRAMA (SPAIN)		
Level of definition of underground logistics		The definition of the logistics during construction considered the use of double shield TBMs – which was a tender requirement – and was carried out by each one of the joint ventures. The proposed solutions were standardised and one common solution was implemented in both the North and the South mouths.
Remuneration of logistic structures		Included in the price of the tunnel
Does a difference exist between the type of contract adopted for the main construction works and the preliminary one, if any ?		The contractors were also in charge of any preliminary or ancillary works, that were not contracted separately to the main works. The preliminary works included: • Production of cartography in a 1/1000 scale, from a 1/5000 scale photogrammetry flight. • Geological/geotechnical survey in a 50km long and 10km wide strip between Soto del Real y Segovia
ACCEPTANCE AND INTEGRATION OF THE PROJECT		
DISPOSAL SITES	**Number and volume of disposal sites**	• South mouth: the project accounted for disposals at 3 locations (Virgen de los Remedios, La Pola, Los Navazales) but only one was required eventually (Virgen de los Remedios, the nearest one). The storage capacity of these quarries was over 4.000.000m^3, enough to accept the arisings from lots 1 and 2, where the excavated volume was around 2.5millions cubic meters. • In the North mouth there was only one disposal site (Lanchares). Its storage capacity was greater than 3.000.000m^3, and it was sufficient to store the generated volume, which was around 3 millions cubic metres. It is important to note that the disposal sites were actually quarries, where the material could be stored either permanently as a fill or temporarily if it could be reused. 22% of the excavated material was reused as concrete aggregates (for tunnel segments, structures or slab track), as fills or as sub-ballast in other sections of the rail line.
	Were all disposal site defined before tendering the Construction works ?	The specifications did not state the disposal sites. However, they did specify that the excavated material would be analysed to check if it could be reused, either in the works, in other sections of the train line or in other construction works or industries. Separately, the Environmental Impact Assessment demarcates the areas where the quarries must be located, without stating which are the quarries where the excavated material will be stored, either permanently or temporarily. • South mouth: disposal of arisings in quarries in the area of Tres Cantos and Colmenar Viejo; alternatively, around Bustarviejo-Valdemanco, in the vicinity of the train line Madrid-Burgos. • North mouth: disposal of arisings in quarries in the area of the Hontoria industrial state exclusively.
	Who obtained the final authorization	Contractors
CONTRACTOR'S CAMPS	**Number of camps/villages exist or planned**	None
	The location of the contractors camp was defined before tendering the Construction works?	N/A
	Who obtained the final authorizations	N/A
ENERGY, WATER & COM	**Who defined the requirements**	The requirements for the supply of water, energy and comms were defined in the projects presented by the JVs at tender stage, bearing also in mind the supply needs during the operational phase.
	Were those supply/utilities prepared before tendering the Construction works	No, they were not. They were part of the main works, associated to the construction project.
	Who obtained the final authorizations	Contractors
ACCESSES (ROAD, RAIL, CABLE CAR…)	**Level of definition of the location of all accesses to the construction sites before tendering**	The location of the construction sites was not defined before tendering, although it was covered in the Informative Study that was used for the Environmental Impact Assessment (EIA). The EIA required the Matarrubias thalweg not to be occupied in the South mouth. For that reason the tunnel alignment was modified so that the camp and the tunnel mouth laid outsideThe location of the accesses had to take into consideration the solution presented in the integrated project and the associated expropriations. One per lot, i.e. 2no in the North mouth and 2no in the South mouth
	Who obtained the final authorizations	Contractors
OTHERS		

GUADARRAMA (SPAIN)	
LOGISITICS ASPECTS	
Type of logistic works anticipated (e.g. Geological exploration, Survey, Logistic accesses, Others)?	The specification required the development of the geological and geotechnical studies through field and lab testing as follows: • Boreholes from the surface up to 10m below the vertical alignment, with a maximum distance between consecutive boreholes of 2km along the tunnel. • Further investigation in fault zones more than 50m thick, through boreholes where CCTV with 360 degrees coverage could be lowered. • Analysis and testing of the borehole samples in the lab
Main logistical constrains of the project (e.g. winter conditions, difficult accessibility, natural hazards, architectural/ environmental constraints, material supply…)	• The TBMs manufacturing, transport and assembly times. • The rock abrasiveness resulted in a more intensive than anticipated use of TMB cutters during the construction phase. This caused a certain lack of spare parts that was promptly solved by the manufacturers. • Water supply. Given the lack of resources, the awarded JV in the South mouth had to construct an 12km long water pipeline from the Santillana reservoir. • Regarding the energy supply, the environmental constraints meant the undergrounding of the whole line in the South side (8.5km long). In the North side the constraints were not environment related but safety related. 50% of the power line run parallel to the construction works of other sections of the high-speed rail, and given the risk of damage due to blasting, the energy supply was also buried in that area. • Low temperatures in the North mouth were also a very important constraint. The tunnel segments did not cure in time and it was necessary to heat up the manufacturing facilities. • Environmental constraints given by the Environmental Impact Assessment. As a result of those constraints, it was necessary to take the following steps: - Installation of facilities for rock crushing, in order to reuse the excavated material - Waste water treatment in the office and changing room areas - Treatment of tunnel water - Recycling the water used in the tunnels, in the segments manufacturing yard and in the aggregates classification and crushing (use of a closed circuit). • The specifications required the TBMs to have a double shield. This determined the excavation and segments installation cycles, and therefore the storage needs (both of segments and excavation arisings). • The geology of a fault meant a high risk of the TBMs getting trapped. It was decided to change the alignment, slightly increasing the length of the tunnel, to avoid this risk.
Other special constrains (if any) imposed to the Contractor outside the worksite	Transport of the excavated material. The Environmental Impact Assessment required the use of conveyor belts to transport the excavated material from the mouth to the quarries, so that the traffic in the area was not affected by the works. This meant the installation of conveyor belts as well as loading/unloading stations and the definition of new accesses from the unloading stations to the quarries. • North mouth. An approximately 4100m long conveyor belt was set up to transport the materials from the North mouth to the Lanchares quarry, by the Hontoria industrial state. The conveyor belt must run parallel to the existing railway, up to the closest point ot the quarry. • South mouth. A 1100m long conveyor belt was installed (parallel to the temporary access to the works) that took the materials from the South mouth to an loading station by the trainline Madrid-Burgos. From there, the excavation arisings were transported by train up to an unloading station nearby the quarries. From the unloading station the material was last transported by lorries to the quarries. Noise. The Environmental Impact Assessment required noisy activities not be carried out between 10pm and 8am at locations situated 500m away of consolidated urban areas or closer. The only night activity around urban area was the use of the conveyor belt in the vicinity of the Hontoria industrial state in the North side. In order to comply with the constraints, it was made sure that the equipment was compliant with all the European legislation related to noise levels
Special constrains (if any) imposed to the Contractor inside the worksite	None
Specific project choices	Double rail track, installed over a specific base segment. This solution allowed situations at intermediate points in the tunnels such as the concurrent construction of emergency galleries. • Conveyor belt - Designed for a medium flow of an optimum excavation cycle of 900 t/h and 1.100 t/h of instantaneous flow. - 1.000 mm wide, with a moving speed of 2,6 m/s and a maximum installed power of 1.250 kW (for the maximum length, split in the different motors). • Power supply line; • Water supply pipeline; • Waste water pipeline.

DAEGWALLYEONG TUNNEL (SOUTH KOREA)

MAIN PROJECT CHARACTERISTICS

Country	South Korea	**International Project**	Yes	**Project length**	21.7km
Owner	Korea National Railway	**Type of Owner**	Public	**Ø excavated**	12.46 m
Engineers	Yooshin, Cheil, Sunjin, and 6 others			**Functionality**	Railway
Contractors	Halla, Samsung C&T, and 6 others			**Number of tubes**	Single



Daegwallyeong Tunnel is the longest mountainous tunnel in Korea with a total length of 21.7km and height difference of 780m. It has 4 adits, one of which is directly connected from underground emergency stop station to the venue of 2018 Winter Olympics.

Cost of the project (civil works)	**351,000,000,000 KRW** **250,288,900 EUR** (Based on Sep. 2022 currency conversion)
Initial date of the project	Feasibility study: May 1996 to August 2000, Basic Design: December 2004~December 2006 Detailed Design: August 2008~June2012, Approval of the project: April 2012
Starting date of construction	June 2012
Current status of the project	Operating (since December 2017)

CONSTRUCTION WORKS CONTRACT

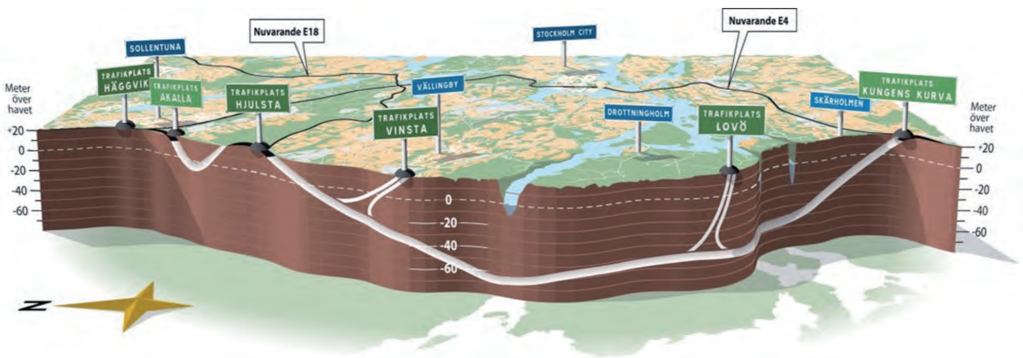
Main reason for the chosen lots definition	It is a tunnel that passes from west to east through a mountainous area called «Baekdu-daegan», which corresponds to the spine in the topography of the Korean Peninsula. The construction was divided into two lots considering the importance that construction should be completed in time for the 2018 Winter Olympics and the optimal construction period and cost.
Number of constructions Lots	2 Construction Lots
Type of contract	Design-bid-build (Separate contracts for design, construction, and supervision)
Time & Cost management	Fixed Time and Cost contracts (reviewed with Bill of Quantities) As general rule, the contractors reviewed the statement of construction cost (BOQ) presented by the project owner and entered into a contract with a fixed unit price and total amount. In the construction stage, when there were changes in geological conditions and construction items, the design was revised through the supervisor's review and field condition report. Then, changes were reflected in the construction cost and the contract was revised. In the case of this project, it was impossible to change the milestone because a special target date was set in preparation for the Winter Olympics.
Level of definition of underground logistics	During the design phase, a logistics solution for transporting excavated rocks and supplying various construction materials was proposed and applied without major changes in the construction stage. The excavated rocks were transported by heavy dump trucks through both portals and 4 adits.
Remuneration of logistic structures	Included in the price, the contractor made a bid by fixed unit price in the construction cost. The contractor considered the logistics solution and reflected it in the bid price. There were no changes in unit price during construction, but the changes in quantity were reflected. Adjustment of contract amount due to price fluctuations was reflected in accordance with regulations.
Does a difference exist between the type of contract adopted for the main construction works and the preliminary one, if any ?	There were no substantial differences the contract adopted for the main construction works. The preliminary works were carried out according with the contract.

DAEGWALLYEONG TUNNEL (SOUTH KOREA)		
ACCEPTANCE AND INTEGRATION OF THE PROJECT		
DISPOSAL SITES	**Number and volume of disposal sites**	There were 3 disposal sites with capacity of 3,000m^3/day
	Were all disposal site defined before tendering the Construction works ?	It was preliminarily defined, and the contractor redefined after the start of construction.
	Who obtained the final authorization	The contractor was in charge of that, and the owner supported that.
CONTRACTOR'S CAMPS	**Number of camps/villages exist or planned**	None
	The location of the contractors camp was defined before tendering the Construction works?	N/A
	Who obtained the final authorizations	N/A
ENERGY, WATER & COM	**Who defined the requirements**	Contractors
	Were those supply/utilities prepared before tendering the Construction works	No, they were not. They were prepared during the construction phase and were covered in the construction project. The installation cost was included in the project cost.
	Who obtained the final authorizations	Contractors
ACCESSES (ROAD, RAIL, CABLE CAR, …)	**Level of definition of the location of all accesses to the construction sites before tendering**	The location of access roads were planned in the design stage and it was better defined in the construction phase. It was actually constrained by the Environmental Impact Assessment which limited the opening of new accesses within the environmentally protected areas such as #3 adit. There were two construction sites, one for each mouth of the tunnel. In addition, sub-camps were set up at the entrances of the four adits. The location and size of the camp were reviewed at the design stage and finally confirmed by the contractor. The cost of setting up the camp was included in the contract price
	Who obtained the final authorizations	Contractors
OTHERS		None. Only those constraints set by the Environmental Impact Assessment.

LOGISITICS ASPECTS	
Type of logistic works anticipated (e.g. Geological exploration, Survey, Logistic accesses, Others)?	• **Geological/geotechnical studies.** There were no further geotechnical investigations in the construction phase. The boring survey was conducted by approaching a small trail, and it was impossible to construct a new road for the survey. Because the number of boreholes was limited, the results of physical exploration were used effectively, as well as the follow up of the excavation face. • **Preparation, widening of the access roads for lots 1 and 2:** it was necessary to widen and improve the local road for each portals. That were widened by means of cuts and fills.
Main logistical constrains of the project (e.g. winter conditions, difficult accessibility, natural hazards, architectural/ environmental constraints, material supply…)	There were no special logistical operational difficulties. However, it was difficult to operate a large dump truck due to the elevation difference (780m).
Other special constrains (if any) imposed to the Contractor outside the worksite	The tunnel was excavated by drill and blasting method, so careful attention was paid to blasting vibration and noise control. In addition the tunnel construction section is an environmentally very important area, and the tunnel was built with continuous monitoring by the local environmental protection group.
Special constrains (if any) imposed to the Contractor inside the worksite	None, it was contractor's choice.
Specific project choices	There was no special choice, and the restrictions and management of the environment were carried out very carefully. In addition, in order to operate the railway for the Winter Olympics, four adits were opened and construction period was fully accomplished.

NEW BY-PASS STOCKHOLM (SWEDEN)

MAIN PROJECT CHARACTERISTICS					
Country	Sweden	**International Project**	No	**Project length**	18 km
Owner	Trafikverket (the Swedish Transport Administration)	**Type of Owner**	Public	**Ø excavated**	Drill and blast: 17,0 m with a quite flat roof, about 30 at ramp connections.
Engineers	ÅF/AECOM			**Functionality**	Road
Contractors	Subterra, South AF-gruppen, Lovön Implenia, North			**Number of tubes**	2 parallel tunnels, 2 traffic interchanges from the underground tunnels up to the surface, 4 traffic interchanges



Objectives of the project:

- to connect the northern and southern parts of the region and
- to make travel possible between them without additional burden on Stockholm's central areas to create a by-pass for long distance traffic
- to improve the level of service on the Stockholm city access roads
- to improve the opportunities to create a common working and housing market for the whole region through equal accessibility
- to make possible a multicentric urban area
- to create conditions for development in a rapidly expanding region.

Cost of the project (civil works)	**41,7 Billion SEK (2021)** - around 3 800 Million Euros
Initial date of the project	The Government decided on 3 September 2009 to allow the construction of förbifart Stockholm according to the Swedish Transport Administrations proposal.
Starting date of construction	A construction start ceremony was held on August 19, 2014.
Current status of the project	Excavation of the tunnels is ongoing (93 % excavated in august 2022), installations and other construction works are ongoing.

CONSTRUCTION WORKS CONTRACT	
Main reason for the chosen lots definition	The main reason for the chosen lots definitions was to shorten the construction time and to be able to assign contracts to several contractors. It gave the project a possibility to design one part first and start construction while finishing the design and assignment of the following contacts. Design in the first one could be reused as far as possible in the others.
Number of constructions Lots	8 lots : • FSE 209 - Main tunnel Skärholmen. • FSE 210 - Access tunnels (Skärholmen & Sätra) and temporary jetty, Skärholmen. • FSE 302 - Main tunnel, access tunnel and temporary jetty, Norra Lovö. • FSE 308 - Main tunnel, access tunnel and temporary jetty, Södra Lovö. • FSE 403 - Main tunnel, Johannelund. • FSE 410 - Main tunnel and access tunnel , Lunda • FSE 607 - Access tunnel, Akalla. • FSE 613 - Main tunnel, Akalla.
Type of contract	Design & Build for the access and main tunnels.
Time & Cost management	Bill of Quantities. For Lovön Design and build with partnering (working against bonuses and time in cooperation).
Level of definition of underground logistics	The logistics were given in the project with access tunnels and open ramp tunnels. The contractor is not allowed to add access tunnels.

>> Appendix 2 - International Database From The Owner's Point of View Regarding Logistical Aspects

NEW BY-PASS STOCKHOLM (SWEDEN)		
Remuneration of logistic structures		Included in the price
Does a difference exist between the type of contract adopted for the main construction works and the preliminary one, if any ?		Only the rock tunnel works for access and main tunnels are design and build. Other contracts and preparatory works are generally turnkey contracts.
ACCEPTANCE AND INTEGRATION OF THE PROJECT		
DISPOSAL SITES	**Number and volume of disposal sites**	The excavated rock mass is transported by conveyor belts to temporary ports close to site and then by boat to two receiving ports in Mälaren. This choice was made to lower the carbon footprint and minimize traffic jams in the Stockholm area. South: One site with one temporary port. Lovön: Two sites with two temporary ports (south and north) North: Two sites but the excavated rock mass is transported by truck due to better communications. Volume: 7 100 000 m^3 rock mass
	Were all disposal site defined before tendering the Construction works ?	Yes
	Who obtained the final authorization	The owner.
CONTRACTOR'S CAMPS	**Number of camps/villages exist or planned**	No camps were planned. Some contractors set up their own camps.
	The location of the contractors camp was defined before tendering the Construction works?	No
	Who obtained the final authorizations	Contractors
ENERGY, WATER & COM	**Who defined the requirements**	The owner. **Water:** Reuses water in treatment plants where the process water is purified). **Energy:** Fortum. **Transportation:** The contractor uses cars (sometimes buses). **Installation during construction time:** Brings 4G fiber (the security system – locate workers and vehicles), power (strong current) and water (process water and extinguishing water).
	Were those supply/utilities prepared before tendering the Construction works	Yes
	Who obtained the final authorizations	The owner
ACCESSES (ROAD, RAIL, CABLE CAR…)	**Level of definition of the location of all accesses to the construction sites before tendering**	Yes
	Who obtained the final authorizations	The owner
OTHERS		None
LOGISITICS ASPECTS		
Type of logistic works anticipated (e.g. Geological exploration, Survey, Logistic accesses, Others)?		• **Geological explorations:** There was a tollgate for the critical passage under Lake Mälaren in the South where geological boreholes were planned. • **Preparatory works:** The preparatory works for such a project that passes densely populated areas are massive. From preparation works in existing tunnels that the project passes, moving roads and to moving cable paths.
Main logistical constrains of the project (e.g. winter conditions, difficult accessibility, natural hazards, architectural/ environmental constraints, material supply…)		• The transport of excavated rock mass with conveyor belts and boat (environmental constraint). • The work site location. • Winter condition in Sweden – hasn't been a major problem.
Other special constrains (if any) imposed to the Contractor outside the worksite		None
Special constrains (if any) imposed to the Contractor inside the worksite		None
Specific project choices		• **Crushing located underground:** Excavated rock masses are churched in a first step underground. • **Conveyor belts:** The crushed material is transported by conveyor belts to the temporary ports. • **Transportation of excavated rock masses by boat:** The excavated rock masses are transported by boat in South and Lovön. This choice was chosen to lower the carbon footprint and minimize traffic jams in the Stockholm area. • **Air exchange stations underground:** Since the rock tunnels are so long and the traffic will be quite intensive there are two underground air exchange stations with four shafts in each station (around 10 m in diameter).

>> Appendix 2 - International Database From The Owner's Point of View Regarding Logistical Aspects

CENERI BASE TUNNEL (SWITZERLAND)

MAIN PROJECT CHARACTERISTICS

Country	Switzerland	**International Project**	No	**Project length**	15.4 km
Owner	Alptransit	**Type of Owner**	Public	**Ø excavated**	9.7 m adit 9.6 main tunnels
Engineers	ITC (JV Pini Swiss Engineers and AFRY)			**Functionality**	High-speed rail
Contractors	Main underground lot: Società Italiana per Condotte d'Acqua SpA (Roma), Cossi S.p.A. (Sondrio) und Cossi SA (Lugano)			**Number of tubes**	Twin

The Ceneri Base Tunnel is the southernmost portion of the new railway link through the Alps crossing the Swiss Alps from North to South. The works were commissioned by AlpTransit Gotthard on behalf of the Swiss Confederation. The main tunnel is a 15.4km long twin tube with a single railway track.

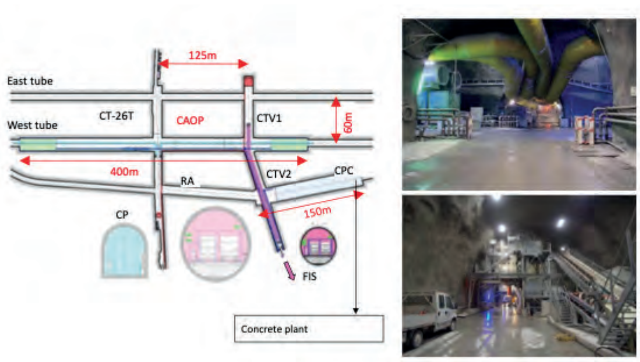
Alignment & Main disposal site and portal of the intermediate adit Sigirino.

Cost of the project (civil works)	Total costruction costs: 2.6 Billion CHF (including design, land expropriation, ground investigation, etc).
Initial date of the project	The design process started in the early 1990's. In September 1994, the first feasibility report was published. The construction permit for the main tunnels was issued in August 2005 (comprising of 500 pages of approval documents), about 2.5 years after the submission of the final design (submitted in March 2003). The design process lasted about 10 years. It is important to remark that, the initial design solution consisted of one single tube with two tracks. However, due to the number of accidents that occurred during the late 1990's and the subsequent update of the safety standards, the decision of having two single tubes connected by cross-passages was taken, thus requiring the update of the entire design documentation. The construction works started in February 2007.
Starting date of construction	The construction works started in 1997 with the excavation of the geological exploratory tunnel, located approximately in the middle of the alignment. In 2008, a 2.3 km long intermediate adit, running parallel to the exploratory tunnel, was excavated using a gripper TBM. The construction of the adit allowed the start of the mining activities of the main tunnels in 2010. The northern tunnel (approx. 8.3 km long) and the southern tunnel (approx. 6.3 km long) were excavated simultaneously using Drill and Blast method. The excavation works were completed in January 2016 and the tunnel was put into commercial service in December 2020.
Current status of the project	The Ceneri Base Tunnel has been put into operation on the 01.09.2020. The commercial operation of the line started in December 2020.

CONSTRUCTION WORKS CONTRACT

Main reason for the chosen lots definition	The splitting into several lots was chosen for the following reasons: • Time: all preliminary and preparatory lots allowed for the timely preparation of the activities in the main lots. The early preparation allowed a prompt start for the main underground activities. Moreover politically, the minor lots were allowed to start the construction activities considerably earlier than the main lots, thus making the political and financial processes more efficient during the ongoing live project (difficult to delay a live project); • Acceptance: the smaller lots allowed the local Contractors to benefit from the business generated from the Project and allowed a fairer division of the works between them; • Specialisms: the preparatory lots were divided according to the specific fields of specialisms (roads, rails, bridges, etc…). This decision allowed the most skilled Contractor for each preparatory activity to be selected and so, ensuring the quality of the works (necessary for considering the long duration of the project, also including the temporary works).
Number of constructions Lots	A total of approximately 20 construction lots (each with a value of several Million CHF) was awarded. Those lots were classified into three phases: • Preliminary works – geological exploration & exploratory tunnel • Preparatory works – access roads, construction site area, etc…) • Main works – main tunnels.

>> Appendix 2 - International Database From The Owner's Point of View Regarding Logistical Aspects

CENERI BASE TUNNEL (SWITZERLAND)	
Type of contract	The majority of the lots were based upon "standard" BOQ contracts. The only exceptions were represented by the lots referring to technological aspects for which the performance of the final structure had been defined and the design had been done by the Contractor (i.e., water treatment plant, muck treatment, railways technology). With respect to the lots of the main tunnels, two excavation methods were tendered (with two separate BOQ and two separate technical requirements specifications) : D&B and TBM. There was no possibility for the Contractor to tender an alternative method. This decision allowed the Owner to have the full control of the tendering process regarding a transparent and fair comparison between the tenders. Moreover, the detailed technical requirements allowed the Owner to have control of the work's quality particularly checking for compliance with the Swiss Standards (SIA) referred to in the tender phase documentation (as the tender was open to international contractors).
Time & Cost management	Time is managed by requiring the Contractor in the tender documents to define, for every support class, a contractual daily advance rate. Based upon the expected distribution of the rock support classes, it is possible to define the theoretical schedule of the works. The schedule is adjusted during the construction by taking into account the variation of the encountered geological conditions, and so, the adopted support classes required. By comparing the effective construction advance rate and the theoretical one calculated based upon the encountered geological conditions, it is possible to assess the performance of the Contractor (i.e. delay or faster advance).
Level of definition of underground logistics	The logistics concept represented one of the driving aspects for the project from the early design stages. The logistical needs determined the selection of the alignment as well as the construction strategy of the tunnel. Moreover, the early definition of the logistics concept allowed the anticipation of important aspects commonly sources of delays (e.g. process of land expropriation / acquisition). One of the main outcomes of the logistics needs and of the impact of the logistics on the surrounding environment, was the decision of having the intermediate adit (Sigirino access adit), located approximately in the middle of the alignment, and to carry-out the majority of the tunneling works from that point. The adit allowed to: • Reduce the social impact in the portal areas (located in densely populated areas); • Dispose of the muck close to the adit (i.e., a reduction of traffic); • Reduce the risk of delays to the schedule related to the critical excavations in the portal areas located in the urban environment within soft ground and underneath existing sensitive infrastructure. At the Sigirono adit, the logistics platform was designed by the Owner's engineers together with specialists (i.e. Holcim specialists for the concrete plant requirements) and by considering the experience of similar projects (in this case the Gotthard Base tunnel and the Lötschberg Base tunnel). The early understanding of the logistical needs required allowed the anticipation of all preparatory works by means of the preparatory lots (i.e., surfaces for intermediate muck disposal areas, water treatment plants, etc…), thus allowing the main Contractor to focus on the underground activities from the beginning of the project. In addition to the external works, the underground logistics caverns were designed and executed in the preliminary lots. The logistics within the caverns allowed the placing of the concrete preparation plant underground, thus producing concrete 24/7 with no impact on the external areas (due to noise, dust, etc.). The reduction of impact was a clear political requirement given by the local communities. After adjudication of the main Contract, the Contractor only requested to excavate additional logistics by passing between the tubes. The Contractor had the freedom to select the excavation and internal logistical concept. The summary analogy, the Owner prepared the "Hardware" of the Project and the Contractor brought the "Software".  *Logistic caverns located at the bottom of the intermediate adit.*
Remuneration of logistic structures	BOQ
Does a difference exist between the type of contract adopted for the main construction works and the preliminary one, if any ?	No. The only difference concerns "technological" tenders / contracts.

>> Appendix 2 - International Database From The Owner's Point of View Regarding Logistical Aspects

<table>
<tr><th colspan="4">NEW BY-PASS STOCKHOLM (SWEDEN)</th></tr>
<tr><th colspan="4">ACCEPTANCE AND INTEGRATION OF THE PROJECT</th></tr>
<tr><td rowspan="3">DISPOSAL SITES</td><td>Number and volume of disposal sites</td><td colspan="2">The outcome of the regional study of the possible disposal site clearly showed that the most appropriate solution was to dispose the majority of the excavated material in one disposal site located in Sigirino, at the location of the intermediate adit. The designed capacity of the disposal was 3.7 mio m3. The disposal considered all material which was not able to be reused as concrete aggregate as well as considering the volume required for the road and railway embankments,…</td></tr>
<tr><td colspan="2">Were all disposal site defined before tendering the Construction works ?</td><td>Yes. All sites were defined in advance.</td></tr>
<tr><td>Who obtained the final authorization</td><td colspan="2">All authorizations were obtained by the Owner. The early discussions with the local Authorities and the early land acquisition avoided delays (from the critical path) for the main construction works and ensured cost control.</td></tr>
<tr><td rowspan="3">CONTRACTOR'S CAMPS</td><td>Number of camps/ villages exist or planned</td><td colspan="2">One major camp was built in the vicinity of the intermediate adit. The camp was able to host up to 450 workers, working 24/7.
The camp was designed by the Owner and built during the preparatory works. The Owner's design ensured the quality of the buildings and the appropriate integration into the landscape due to close collaboration with the local architects.</td></tr>
<tr><td colspan="2">The location of the contractors camp was defined before tendering the Construction works?</td><td>Yes.</td></tr>
<tr><td colspan="2">Who obtained the final authorizations</td><td>Owner.</td></tr>
<tr><td rowspan="3">ENERGY, WATER & COM</td><td colspan="2">Who defined the requirements</td><td>Owner on the base of similar references and by hiring specialists.</td></tr>
<tr><td>Were those supply/ utilities prepared before tendering the Construction works</td><td colspan="2">Almost all utility requirements and their accessibility were designed by the Owner and build during the preparatory works:
• Energy: in collaboration with the local energy provider, the energy provision to the region was increased. New energy substations were built. The increase of the energy provision was well accepted by the local authority as, in the long-term (i.e. after completion of the construction works), the increased capacity allowed the energy requirements of the increasing local population to be fulfilled.
• Water: a new waterwork was built by the Owner and later it will be let to the local authorities. This decision allowed the political support of the project.
• Industrial water waste: designed and built by the Owner.</td></tr>
<tr><td colspan="2">Who obtained the final authorizations</td><td>Owner</td></tr>
<tr><td rowspan="2">ACCESSES (ROAD, RAIL, CABLE CAR…)</td><td colspan="2">Level of definition of the location of all accesses to the construction sites before tendering</td><td>All accesses (highway, roads, railway branch for sand and aggregates supply, etc..) were designed by the Owner and built during the preparatory works.</td></tr>
<tr><td colspan="2">Who obtained the final authorizations</td><td>Owner</td></tr>
<tr><td>OTHERS</td><td colspan="3">The architectural aspects, particularly the integration of the spoil deposits into the landscape required the creation of an architectural team (composed of national and local architects) responsible for the follow-up of the design and the construction. In addition to the spoil deposits, the team also were responsible for the camp, the portals, etc …</td></tr>
<tr><th colspan="4">LOGISITICS ASPECTS</th></tr>
<tr><td colspan="2">Type of logistic works anticipated (e.g. Geological exploration, Survey, Logistic accesses, Others)?</td><td colspan="2">All works not related to the main excavation works (i.e. main tunnels).</td></tr>
<tr><td colspan="2">Main logistical constrains of the project (e.g. winter conditions, difficult accessibility, natural hazards, architectural/ environmental constraints, material supply…)</td><td colspan="2">• Natural hazards: flooding due to the vicinity of the river (defining the level of the access adit and external work platform) and hillside rockfalls.
• Laws: working time, noise, dust criteria, e.g. definition of criteria
- the requirement of having an underground concrete production plant;
- the requirement of putting the ventilators underground and using the geological exploration tunnel (running parallel to the adit) as a ventilation tube;
- the requirement of adopting a blasting method based upon reduced charges.
• Morphology of the landscape: limited external space due to the valleys required the installation of logistical structures to be underground.
• Insurance policies.</td></tr>
<tr><td colspan="2">Other special constrains (if any) imposed to the Contractor outside the worksite</td><td colspan="2">According to governing laws (environmental impact, roads, …).</td></tr>
<tr><td colspan="2">Special constrains (if any) imposed to the Contractor inside the worksite</td><td colspan="2">Underground concrete plant.</td></tr>
<tr><td colspan="2">Specific project choices</td><td colspan="2">• Muck and aggregate transportation: use of belt conveyors and imposed material disposal sites;
• Contractor responsible for the muck management was selected by means of a dedicated and specific tender imposed on the main Contractor;
• Imposed energy and water provider;
• Imposed accesses;
• Imposed water treatement plant;
• Imposed location for disposal;
• Imposed Workers village.</td></tr>
</table>

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