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The Ferney cut-and-cover tunnel

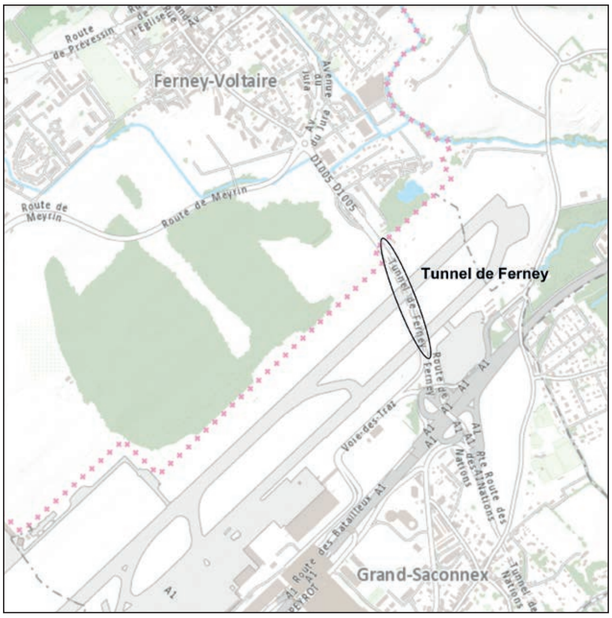
A project with several specific challenges

In a few years' time, the Ferney Tunnel, which is operated by the Canton of Geneva, owned by Geneva Airport and located on the French-Swiss border, will be used for both road and tram traffic. One of the main requirements for this project involves reviewing the structure's safety concept – particularly with regard to fire hazards. Since the tunnel is located underneath the airport's runways, business continuity issues are also critical (i.e., the tunnel's fire resistance).

1 Project presentation

1.1 Historic and administrative aspects

Situated under the Geneva Airport (GVA) runways, close to the French-Swiss border, the Ferney cut-and-cover tunnel (CCT) is 430 m long. It was built in the late 1950s to provide a link between Geneva and Ferney-Voltaire, a commune across the border in France, while allowing the airport to expand (Fig. 1). This was originally a cantonal project, but its ownership has since been transferred to the GVA. Its operation remains cantonal. Two emergency services work together in the event of an incident: the cantonal fire department and the GVA response teams.



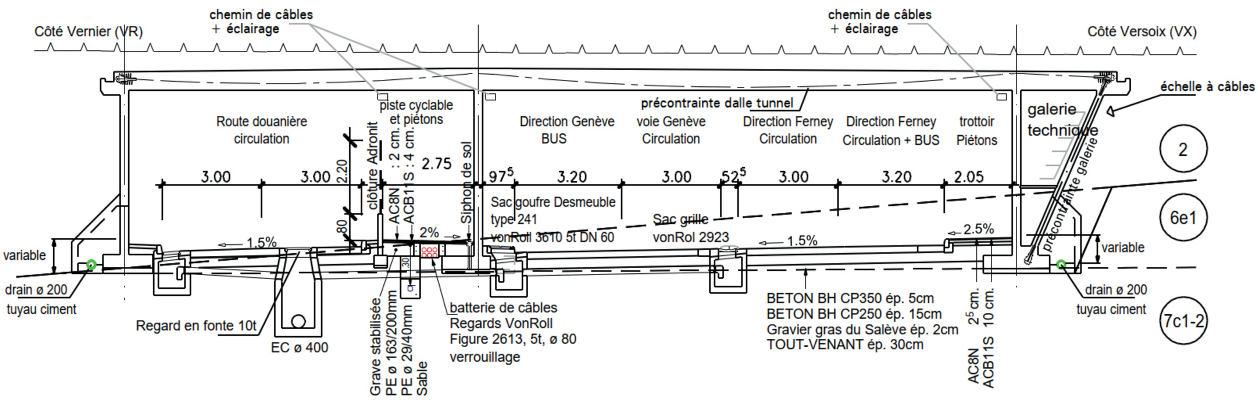
Credit: WSP

1 Geographical situation of the Ferney CCT

At present, the structure consists of two tunnels both with two-way traffic:

- The Ferney Tunnel: Two lanes in each direction, including one reserved for buses and cabs, customs transit and the N1 motorway
- The customs tunnel: One lane in each direction, serving the French GVA zone from Ferney-Voltaire, without crossing customs. This tunnel also has a dedicated area for alternative mobility (a bicycle path and pedestrian walkway), which is separated from the road by a customs fence.

There are two emergency exits between the two tunnels so that, in the event of fire in one tunnel, the other tunnel can be used as a fire escape area (Fig. 2).



Credit: T Ingénierie

2 Profile of the structure in its current state

Der Ferney-Tagbautunnel
Ein Bauwerk mit mehreren besonderen Merkmalen

Das Strassenbahnausbauprojekt bot die Gelegenheit, den Ferney-Tunnel zu sanieren und die Betriebskontinuität im Falle eines Ereignisses (z. B. eines Brandes) zu gewährleisten, sowohl für den Tunnel selbst als auch für die darüber liegenden Landebahnen des Flughafens. Die Installation einer Wassernebel-Sprinkleranlage wird eine der grössten Herausforderungen sein: Es ist das erste Mal, dass ein Tunnel in der Schweiz mit einem solchen System ausgestattet wird. Alle Beteiligten (Betreiber, Eigentümer, Rettungsdienste) erstellten gemeinsam einen Interventions- und Sicherheitsplan, der auf jede Phase des Projektes abgestimmt ist.

Il tunnel a cielo aperto del Ferney
Una costruzione dai numerosi e particolari tratti

Questo progetto di ampliamento tranviario ha offerto l’opportunità di rinnovare il tunnel del Ferney e di garantire continuità operativa in caso di incidente (p. es. incendio), sia per il tunnel stesso che per le piste dell’aereoporto che si trovano al di sopra. L’installazione di uno sprinkler ad acqua nebulizzata sarà una delle maggiori sfide del progetto (il primo tunnel in Svizzera dotato di un tale sistema). Il progetto ha permesso a tutte le parti interessate (gestore, proprietario, servizi di soccorso) di incontrarsi e di elaborare un piano d’intervento e di sicurezza in armonia con ogni fase del progetto.

1.2 Traffic and challenges

In 2019, traffic levels amounted to 22,800 vehicles per day, of which 2% were heavy goods vehicles (HGVs). Even though it’s not very long, the Ferney CCT represents a major economic challenge – with its substantial cross-border traffic. Closing the tunnel would cause severe congestion on secondary roads, which are already saturated with commuter traffic.

The Ferney CCT is authorised for transporting dangerous goods (TDG), but the number of TDG vehicles is very low according to a survey carried out in 2021 (less than one vehicle per day on average).

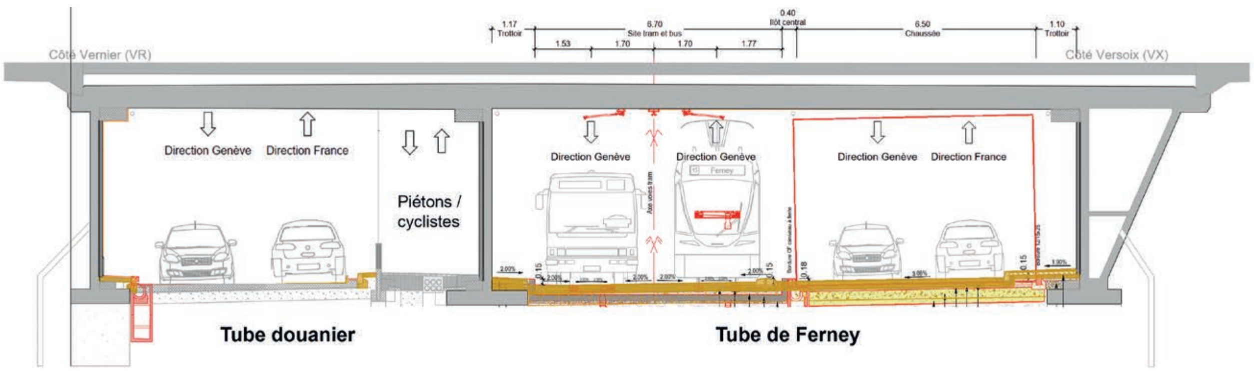
1.3 Construction methods and airport interfaces

The structure is made of reinforced and pre-stressed concrete, originally built to support the weight of the land cover, the taxiway slabs and the airport runway above.
Over the years, the CCT’s load-bearing slab has been doubled (1986) and then reinforced (2007) to guarantee the passage of 600-tonne aircrafts. The structure’s fire resistance, as well as the continued operation of the tunnel and the GVA, are therefore major issues to work with.

1.4 Future use

As part of the Nations-Grand-Saconnex tramway project, the Ferney CCT is set to accommodate a mix of road, tram and bus traffic. Two of the four existing traffic lanes will be dedicated to Geneva Public Transport (TPG) (Fig. 3). This concept is part of the incentive to create different types of environmentally-friendly transport infrastructure in France and to serve new residential and business areas in Ferney-Voltaire.

This substantial change in operations raises questions about safety, particularly with regard to fire risks and evacuation issues – especially given the potential increase in the number of people in the tunnel in certain circumstances.



Credit : T Ingénierie

3 Profile of the structure in its planned state by 2025

2 Designing a safety improvement programme based on a global safety analysis approach

The tramway development project has provided an opportunity to assess the overall safety of the structure in order to define a comprehensive and consistent renovation programme. The goal is to develop a coherent, cross-functional vision that incorporates both modes of transport and their specific operating characteristics.

A safety analysis approach has been applied to people (to identify the best safety measures for reducing the occurrence and severity of potential incidents) and operating issues (incidents analysed in terms of their social and economic impact).

These two approaches complement each other and have resulted in a coherent, rational programme that will ensure the highest possible level of safety for the planned structure – even during its construction phase (site operations).

As part of the federal planning approval procedure for the tramway, it was therefore agreed to carry out the following:

- A safety concept for the two tunnels as part of renovation work
- A Hazard Analysis, including modelling and simulating fire scenarios (smoke propagation and emergency evacuation), to validate the safety concept and make additional recommendations.
- A TDG risk analysis to quantitatively assess the level of risk corresponding to the tunnel's current and future condition. The goal is to confirm the structure's approval for transporting dangerous goods.

These elements will be presented in the following sections.

2.1 Safety concept

First, a regulatory comparison was carried out with the relevant technical standards to identify discrepancies and, therefore, possible safety provisions to be incorporated in the project.

SIA Standards 197 (tunnels) **[1]**, 197-1 (railway tunnels) **[2]** and 197-2 (road tunnels) **[3]** provide the basis for underground construction projects in terms of the construction itself, environment and safety. Although they concern planned tunnels and not tunnels in operation, these standards can be used as technical benchmarks for tunnels in operation, hence their relevance for the Ferney CCT. The FEDRO (Federal Roads Office) **[4]** - **[9]** and FOT (Federal Office of Transport) **[10]** Standards were also used as a basis for defining the safety provisions to be included.

In concrete terms, all possible provisions relating to civil engineering and equipment provided for by these road and rail standards will be incorporated into the CCT in its final state – with mixed traffic operation. In addition, certain safety provisions will go beyond the requirements of these technical standards (for example, the number of emergency exits, dynamic exit signage, etc.).

As a result of the CCT'S profile change and the new type of traffic planned, the new challenges coming to light mainly concern the following points:

- Adapting current equipment to ensure the tunnel remains 100% operational and suited to future traffic (e.g., lighting, signalling, video surveillance).
- The potential risk of a tram stopping at an emergency exit in the event of an incident, which could restrict and/or lengthen the emergency route for road users, or even prevent them from seeing certain exits. Wherever possible, TPG tram or bus exits will be included in TPG operating instructions in the event of an incident. Enhanced signage for exits (illuminated arrows on both sides) will help improve visibility.
- The risk of dual traffic operation in the CCT. It is vital that, in the event of an incident, traffic is stopped at the gates for all vehicles in order to limit the number of people in the CCT as much as possible and to facilitate emergency evacuation.
- The risk of recurring road congestion within the structure (an aggravating factor in the event of fire), potentially linked to the reduction in the number of road lanes for traffic levels similar to current levels (currently, taxis and motorised two-wheelers use the lanes reserved for buses, which will no longer exist).

These analyses have also made it possible to examine issues that are not specific to the future mixed-traffic operation concept, such as the structure's fire resistance, which is not linked to introducing the tramway.

The safety concept drawn up for the two tunnels has made it possible to prepare a construction programme that addresses the various issues inherent in the CCT, whether or not they relate to the future mixed-traffic operation concept. The main construction projects are as follows:

- Adapting the principle of collecting effluent from roadways and the tramway/bus platform (potentially hydrocarbons or toxic materials) and installing a slotted gutter with siphonic manholes to limit the size of a hydrocarbon slick in the event of accidental spillage
- Lowering the current height of the tunnel shoulder (wheelchair accessibility)
- Adding three emergency exits, limiting the distance between exits to 75 m and ensuring that existing exit doors comply with fire regulations
- Reinforcing signage at these exits
- Installing closing barriers at the entrances to the two tunnels
- Adding smoke detectors
- Installing ventilation in the technical gallery
- Resetting the AID (Automatic Incident Detection) system and adapting the monitoring system
- Adding a leaky feeder cable for radio communications (operators, emergency services and radio messages for tunnel users)
- Fire protection for the building structure (installing protective plates under the slabs)
- Setting up a water mist sprinkler system

2.2 Hazard Analysis

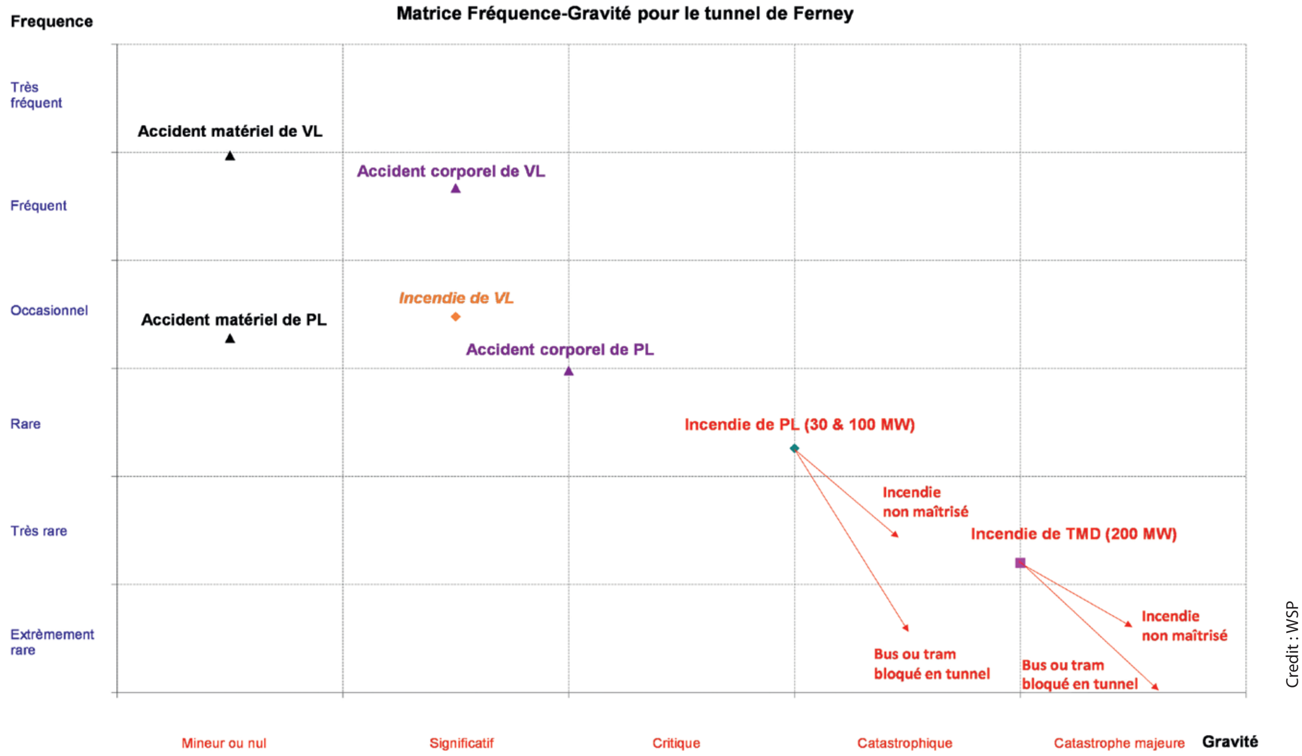
The Hazard Analysis (HA) [11] aims to:

- Describe incidents likely to occur during the operating phase and assess the nature and significance of their potential consequences
- Identify measures to reduce the probability of these incidents and their consequences from occurring

This is a cross-functional, scenario-based approach. Using this systemic approach, the HA ensures:

- The consistency and validity of the safety concept is verified
- There are no safety deficiencies
- The provision of additional recommendations on operating instructions and procedures in consultation with the fire brigade during incidents (fire, serious accidents)

The scenarios considered in the HA are presented in a Frequency x Severity Matrix (Fig. 4).



4 Frequency x Severity Matrix for the Ferney CCT

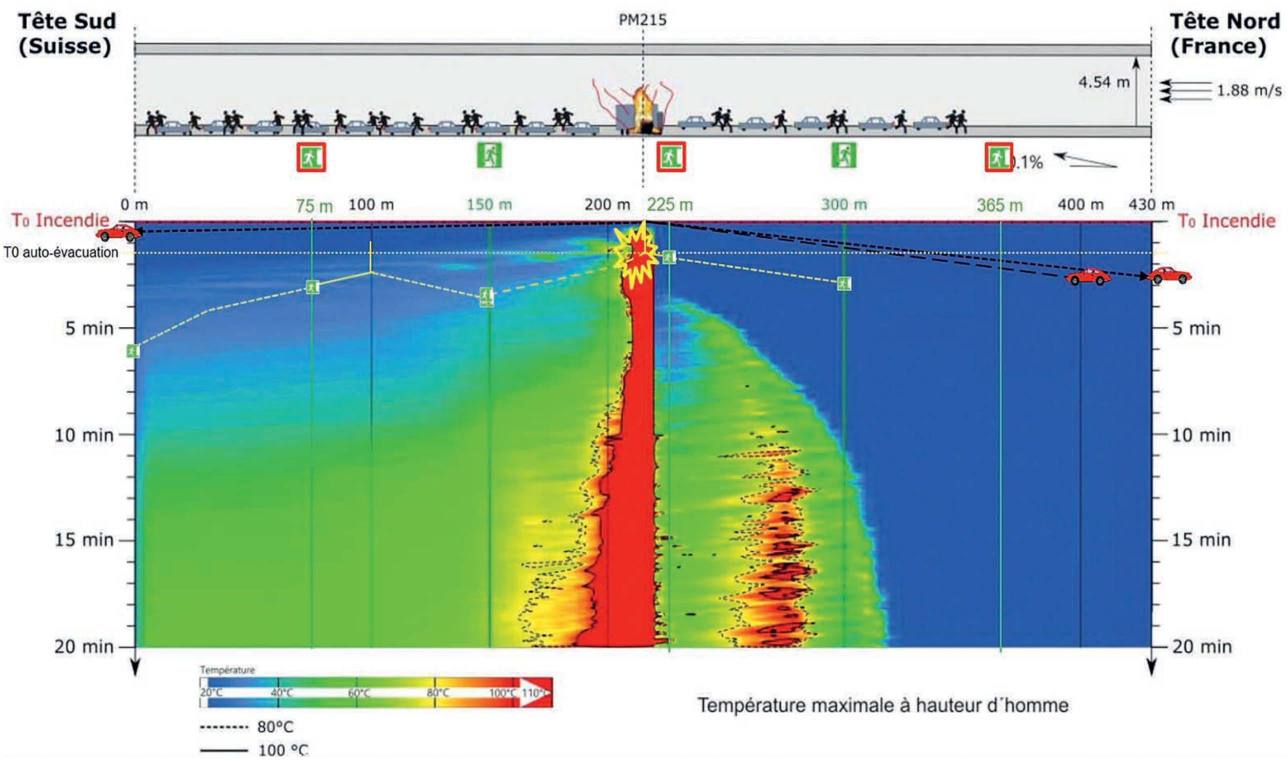
The HGV fire scenarios (Table 1) were modelled using dedicated 3D software to analyse smoke propagation within the structure at any given moment and over time, as well as changes in survival conditions within the tunnel (temperature, toxicity, visibility, etc.) (Fig. 5).

Scenario	Power	Position of potential fire in relation to north gate (customs side)	ΔP (from France to Switzerland)*	Traffic from Switzerland to France (vehicles per hour)	Traffic from France to Switzerland (vehicles per hour)	Blocked tramway
1	30 MW	215 m (centre)	5 Pa	1240	600	No
1 b	30 MW	215 m	5 Pa	1240	600	Yes
2	30 MW	215 m	20 Pa	1240	600	No
3	100 MW	215 m	5 Pa	1240	600	No
4	200 MW	215 m	5 Pa	1240	600	No
5	200 MW	215 m	0 Pa	1240	600	No

Credit : WSP

** air pressure difference between the two portals*

Table 1 *Modelled scenarios for the Ferney Tunnel and the customs tunnel*

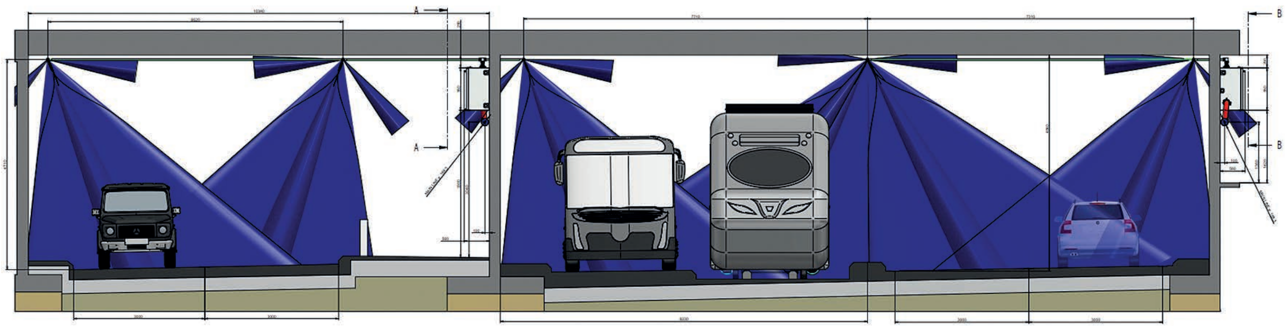


Credit : WSP

5 Example of a result produced within the HA framework presenting evacuation conditions in the Ferney Tunnel (in case of an HGV fire in the middle).

The HA concluded that the work proposed in the Ferney CCT safety concept will lead to a satisfactory safety situation in its future operation (the scenarios studied correspond to major overall situations). The two tunnels and their interactions (one serving as an escape route for the other in the event of a fire) were studied.

Although the safety level is satisfactory without a water mist sprinkler system (which is designed to protect the structure from fire), this system also represents significant added value in terms of tunnel user safety by significantly reducing the strength of a fire and, therefore, the temperature and toxicity of smoke (Fig. 6).



Credit: Supplier

6 *Illustration of water mist sprinklers in the Ferney CCT*

2.3 TDG risk analysis

The consequences of a TDG accident in a tunnel are very different from those of an accident in the open air. It is therefore necessary to carry out a tunnel risk assessment using a specific model.

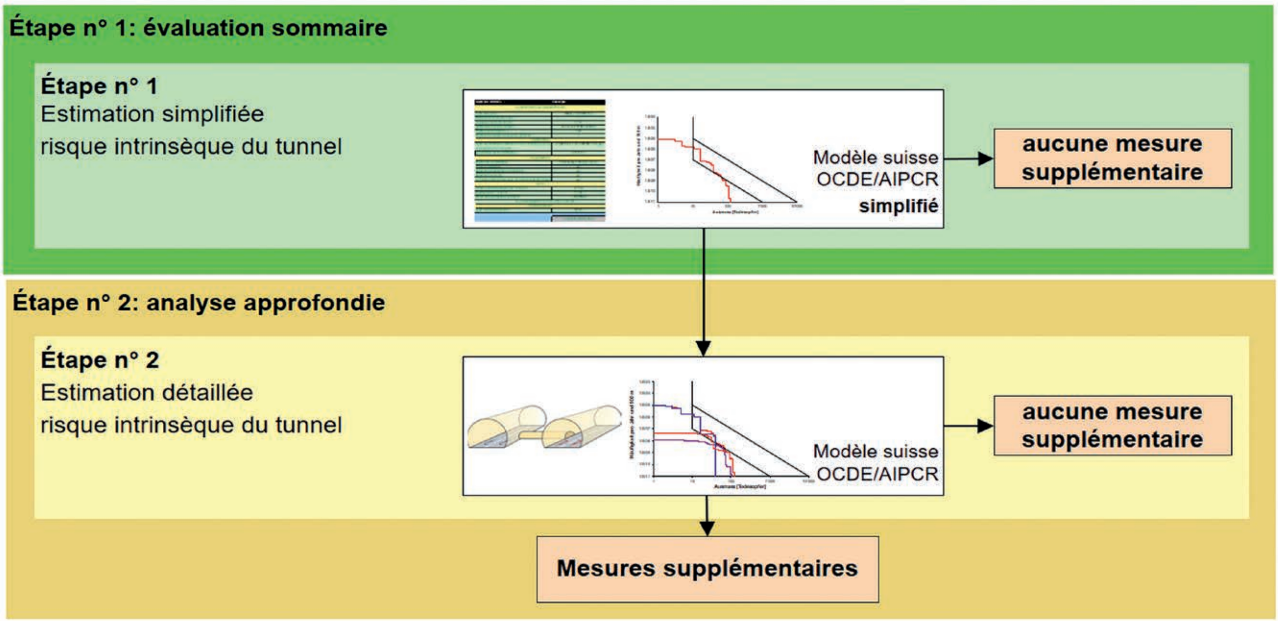
The "OECD/PIARC Swiss Model" **[12]** was developed on behalf of FEDRO (WSP development) in order to be able to quantitatively assess these risks, compare them with acceptability criteria, and ultimately decide on the authorisation regime for dangerous goods in accordance with international Agreement concerning the International Carriage of Dangerous Goods by Road (ADR) regulations **[13]**. To achieve these objectives, five TDG restriction categories can be implemented (**Table 2**).

Tunnel category	Restrictions
A	No restrictions apply to transporting dangerous goods
B	Restrictions on dangerous goods that could cause a very large explosion
C	Restrictions on dangerous goods that could cause a very large explosion, a large explosion or a large discharge of toxic substances
D	Restrictions on dangerous goods that could cause a very large explosion, a large explosion, a large toxic leak or a large fire.
E	Restrictions on all dangerous goods except UN numbers 2919, 3291, 3331, 3359 and 3373

Credit: FEDRO

Table 2 *Tunnel categories according to ADR*

Like each other signatory country, Switzerland can choose its own criteria and methodology for defining the category of its tunnels **[14]** and **[15]**. The method used by FEDRO **[12]** is shown in Fig. 7.



Credit: FEDRO

7 *Risk analysis and assessment procedure for transporting dangerous goods through road tunnels*

This method was applied to the Ferney CCT to ensure that it could be authorised for TDG traffic even in its current state – which was confirmed.

In its future state, the calculations carried out have led to the conclusion that TDG risk in the structure is also acceptable (particularly in view of the safety provisions and the low level of TDG traffic in the CCT).

3 Intervention and Safety Plan (ISP)

3.1 Challenges and implementation methods

Drawing up the intervention plan for such a complex structure involves a number of operational and intervention issues, which requires the interaction of many different parties:
- The Canton of Geneva and TPG, which operate the structure, and GVA, which owns it
- Airport and cantonal fire brigades, which need to work together to combat potential incidents
- Border control within the structure (interface with customs)
- Proper use of the sprinkler system

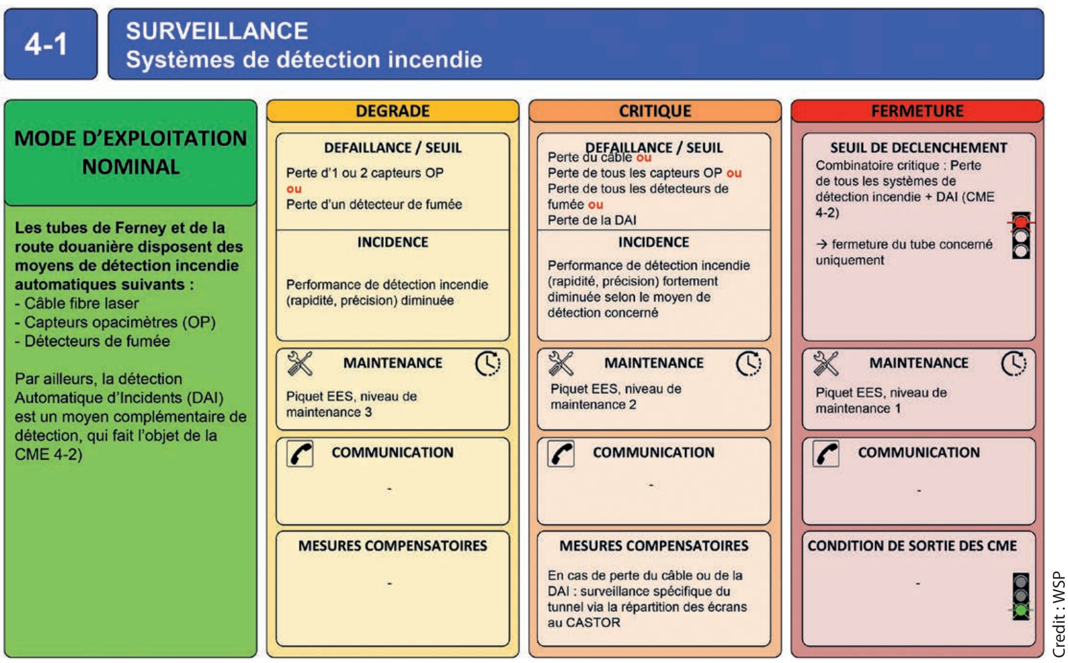
Workshops bringing together all of these parties have made it possible to draw up the Ferney CCT ISP (including the customs road) according to three timeframes, or, reference statuses:
- Current status
- Status during construction
- Future status

The ultimate goal is to define and coordinate emergency resources and to specify the principles of managing incidents. An ISP must be drawn up for each phase to ensure that the document is operational in all circumstances and in accordance with the specific operating conditions.

3.2 Operational documents

In particular, the following schemes have been drawn up in a collaborative manner:
- Warning system: guarantees the transmission of information between all parties involved and rapid access for public emergency services
- Synoptic Tables of Action: summarise and plan coordination and actions to be taken by each party, depending on the nature of the incident.
- A flow chart and timetable to trigger the sprinkler system to ensure that it is not implemented incorrectly or triggered too late.
- Minimum Operating Conditions: defining, for each piece of technical equipment, acceptable or unacceptable malfunction thresholds for the safe operation of the structure, as well as compensatory measures and emergency maintenance levels (Fig. 8).

Conducting one or more of these exercises will allow us to test the implementation of the emergency response plan and coordination between the various parties involved so that the plan can be adapted if necessary.



8 Example of a Minimum Operating Condition in the Ferney CCT

References

[1] SIA Standard 197:2004, Tunnel projects, general principles
[2] SIA Standard 197/1:2019, Tunnel projects, railway tunnels
[3] SIA Standard 197/2:2004, Tunnel projects, road tunnels
[4] FEDRO Directive 13001 "Ventilation of road tunnels, System selection, dimensioning and equipment", 2008 Edition, V2.03
[5] FEDRO Directive 13004 "Fire detection in road tunnels", 2007 edition, V2.10
[6] FEDRO Directive 13010 "Safety signage in road tunnels", 2011 edition, V2.07
[7] FEDRO Directive 13015 "Lighting installations", 2017 edition, V1.12
[8] FEDRO Directive 15003 "Traffic management on national roads (Framework Directive VM-NS)", 2016 edition, V2.01
[9] FEDRO Technical Manual 23001 "Operating and safety equipment", January 2021 edition
[10] FOT Directive "Safety requirements for existing railway tunnels", 10 August 2009
[11] CETU (Centre for Tunnel Studies) guide to road tunnel safety files
[12] FEDRO Documentation 84002 "Transporting dangerous goods in road tunnels – Analysis and evaluation of risks to people", 2023 edition, V2.01
[13] European Agreement concerning the International transport of dangerous goods by road, version in force on 1 January 2021
[14] Ordinance on transporting dangerous goods by road, dated 29 November 2002 (SDR) – 741.621, status as of 1 January 2021
[15] Ordinance on protection against major accidents, dated 27 February 1991 (OPAM), 814.012

PROJECT DATA

Region
Canton of Geneva, on the French-Swiss border (Ferney-Voltaire on the French side, Le Grand-Saconnex on the Swiss side)

Client
Geneva Airport

Design, site supervision and overall management
- WSP
- T Engineering

Key data

Construction period:	End of the 1950s
Start of operations:	2025
Construction costs:	CHF 25 million
Length:	430 m

Special features
Tunnel with sprinkler system - Mixed-traffic operation - Coordination between two emergency services - Recurring congestion - Customs border inside the tunnel