

Appendix 2.8 – FRANCE – the Duplex Tunnel A 86 in western Paris area

1. SUMMARY – DUPLEX LOW CLEARANCE TUNNEL A 86

The A86 Duplex, referred as the Duplex Tunnel, is located to the west of Paris on the A86 motorway between Rueil-Malmaison (92) and Versailles Pont-Colbert (78) (**Figure 1**). This tunnel, with low vertical clearance, has a main interchange with the A13 motorway.

The Duplex Tunnel is owned and operated by Cofiroute, a subsidiary of Vinci Autoroutes, and will be tolled until the end of its concession period in 2086.

The Duplex Tunnel was built in two successive stages:

- the northern section (Rueil – Vaucresson, exiting to the A13 motorway), with a length of 4.5 km, was put into service in August 2009.
- the southern section (Vaucresson – Viroflay), with a length of 5.6 km, which was put into service in January 2011.

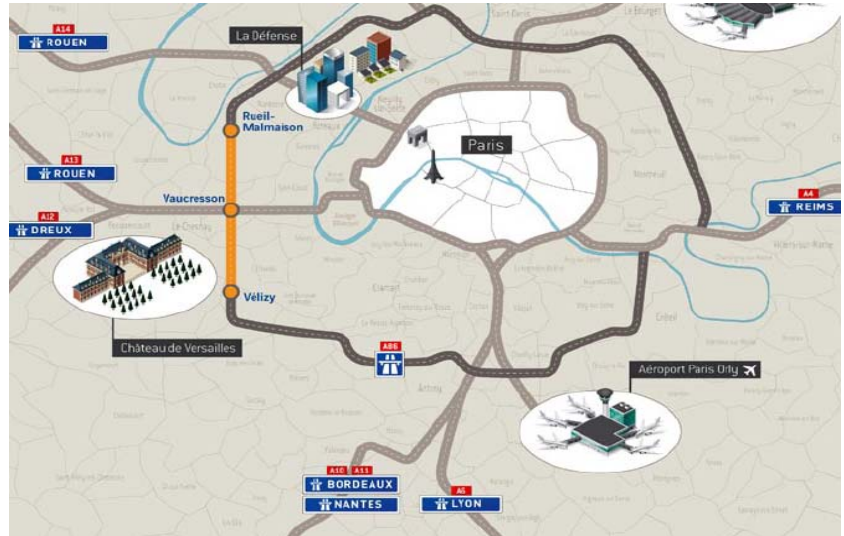


Figure 1 – A 86 Duplex tunnel situation

The total tunnel length is thus about 10.1 km, making it the longest road tunnel located entirely on French Territory.

The Duplex Tunnel is a single tube comprising two independent decks (or traffic levels), with unidirectional traffic on each level (two lanes in each direction). It is reserved exclusively for light vehicles with a height of 2m or less and with a laden weight of 3.5 tons or less. Vehicles over 2m high are prohibited, as are vehicles with a laden weight over 3.5 tons, vehicles fuelled by LPG or LNG, vehicles with an engine capacity less than 50 cm³ and vehicles without a licence plate.

The Duplex Tunnel is based on and complies with French regulations. During the design stages, a major new French regulation came into force in 2000 (the French inter-ministerial circular 2000/63). This led to modifications of the initial version of the project, in particular with regards to the ventilation / smoke extraction system, fire-fighting equipment as well as the fire resistance of the slab and partition walls.

2. MAIN CHARACTERISTICS

2.1 GEOMETRY

The horizontal alignment is quite complex. In addition to geological constraints, it has to take the presence of interchanges into account (the A13 which exists and the RD10 which has yet to be built).

The tunnel starts near the Seine River at Rueil-Malmaison and has an uphill slope until it reaches the A13 motorway. It then has a downhill slope under Viroflay and another uphill slope at Pont-Colbert at Versailles (**Figure 2**).

To the north, the Rueil-Malmaison road connection enables the A86 duplex to join the non-concession part of the A86, but also to join the secondary road network.

At the A13 interchange, slip roads (some of them covered) enable tunnel users to join the A13 motorway and the secondary road network.

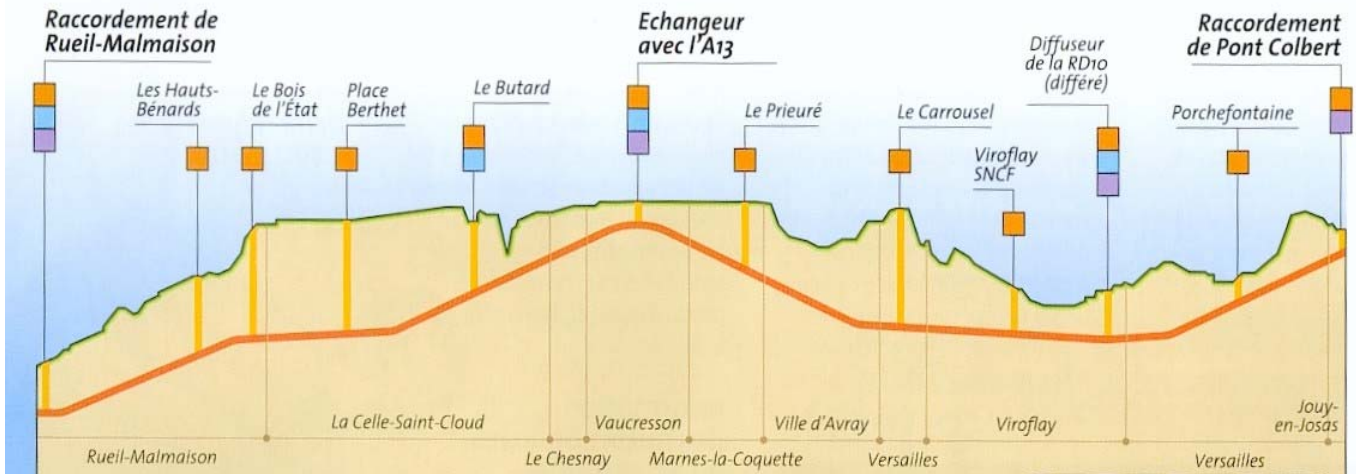


Figure 2 – Duplex Tunnel's vertical alignment

2.2 CROSS SECTION

2.2.1 Road Tunnel (Figure 3)

The tunnel comprises two decks, each with unidirectional traffic:

- Outer A86 (southbound) located on the lower level;
- Inner A86 (northbound) located on the upper level.

Each deck has two 3m-wide traffic lanes and a 2.5m-wide hard shoulder:

- On the lower deck, the hard shoulder is on the right of the slow lane;
- On the upper deck the hard shoulder is located on the left of the fast lane.

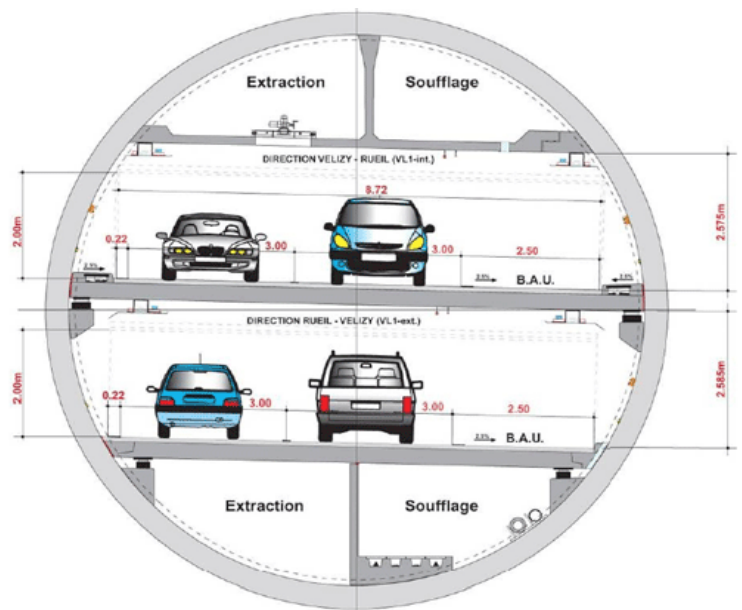


Figure 3 – Cross section

2.2.2 Escape facilities

The Duplex has 13 emergency shafts located throughout the tunnel (**Figure 4**), equipped with elevators (the distance between them varies between 500 m and 1,200 m).

These emergency shafts provide the emergency crews with access to the tunnel from the surface and enable them to evacuate users.

Watertight, smoke-tight, pressurised recesses, with a two-hour fire-resistance, are located every 200m.

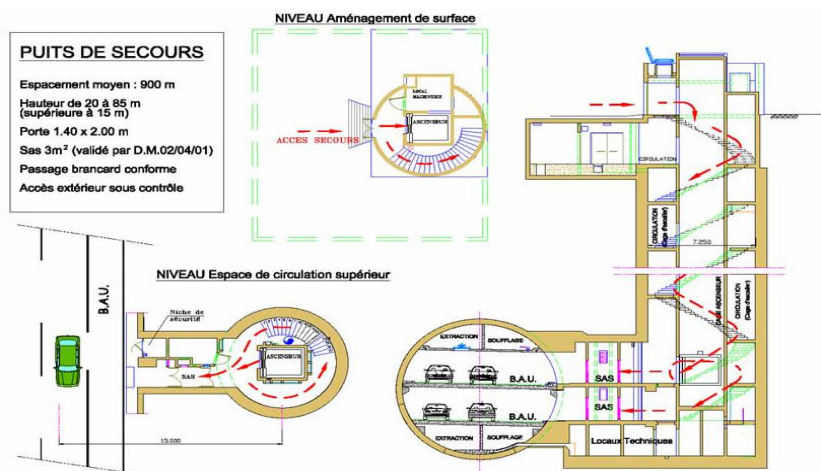
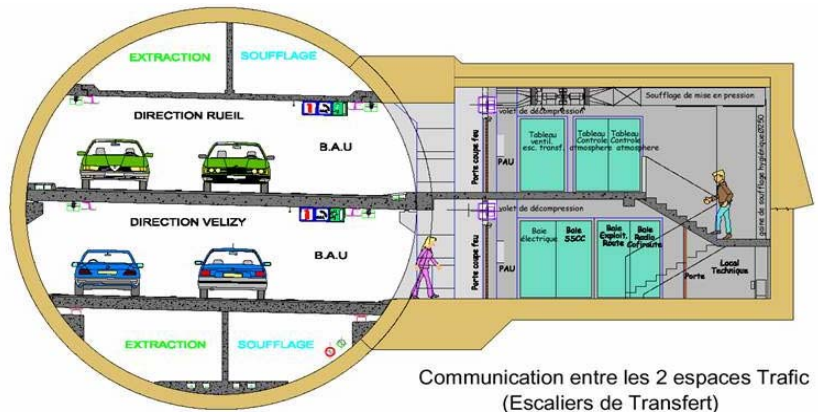


Figure 4 – view of an emergency shaft

Due to stairs linking both levels, these 54 recesses provide an emergency exit (Figure 5).

Each recess provides two possible emergency exit routes:

- in the event of an incident on the lower deck, it provides access to the safety of the upper deck,
- in the event of an incident on the upper deck; it provides access to the safety of the lower deck.



Communication entre les 2 espaces Trafic (Escaliers de Transfert)

	Circulaire	Projet
Surface	15 m ²	33 m ²
Porte	1.40 x 2.00	1.40 x 2.00
Largeur passage hors Escaliers	1.80 x 2.20	Conforme
Accès Handicapés	OUI	Conforme

Figure 5 – view of a transfer staircase

The Figure 6 on the right shows the overall concept of the escape routes:

- Connections between the two traffic levels with the spacing of 200 m,
- 12 emergency shafts to the surface level with a spacing varying between 500 m and 1,200 m.



Figure 6 – overall view of the escape routes

2.3 TRAFFIC CONDITIONS – BREAKDOWNS AND ACCIDENTS

At the slightest risk of traffic congestion, access to the tunnel is controlled by closing the toll gates located at the entrances and by facilitating the traffic flow leaving the tunnel by controlling the dynamic signing beyond the tunnel exit.

2.3.1 Traffic conditions

As previously mentioned, the Duplex is exclusively reserved for light vehicles with a height of 2m or less and with a laden weight of 3.5 tons or less. It is prohibited for vehicles over 2m high, vehicles with a laden weight over 3.5 tons, vehicles fuelled by LPG or LNG, vehicles with an engine capacity less than 50 cm³ and vehicles without a licence plate. Dangerous goods vehicles are also prohibited.

The speed is limited at 70 km/h inside the tunnel. Fixed speed cameras monitor compliance with speed limits. On road connections and interchange lanes and ramps, the speed limit varies between 30 km/h and 70 km/h according to the geometrical characteristics.

It is possible for users to obtain free information on traffic conditions via their mobile phone before continuing to the tunnel portals.

2.3.2 Traffic data

Traffic has increased continuously since the opening of the whole Duplex in 2011. In 2013, average traffic on working days increased by 12% with an average of 26,700 vehicles per day. In the same year, average traffic during the weekend and public holidays increased by 6.3%, with about 14,000 vehicles per day.

2.3.3 Breakdowns and accidents

Event	2011	2012	2013
Personal injury accident	3 (without fire)	3 (without fire)	No information collected
Damage-only accident	2 (without fire) : 1 due to loss of vehicle control and 1 due to an oversized vehicle	/	No information collected
Breakdown	1 (with fire)	2 (without fire)	> 1

There are few breakdowns and accidents in the Duplex and their number has remained stable between 2011 and 2012.

Any fire incident causes the immediate closure of the tube.

2.4 SIGNALLING

Bespoke road signs are used in the Duplex Tunnel:

Smaller than the corresponding standard signs, these retro-reflective signs are located above the carriageway.

Small illuminated road signs are used, rather than large non-illuminated road signs,

- Specific variable message signs (VMS) (**Figure 7**) are positioned every 400m above the traffic lanes. They comprise a single line of 18 characters length, 200 mm high, with the possible use of 2 flashing lights. There are 64 such signs in the Duplex.



Figure 7 – view of specific VMS

3. VENTILATION

The ventilation in the Duplex Tunnel is a combined system comprising (**Figure 8**):

- a transverse system on each traffic level with 6 ventilation plants (for injecting fresh air and extracting polluted air), designed to cope with a fire heat release rate of 15 MW,
- 29 smoke remote and motorised extraction dampers for each traffic level (spacing of 400 m) connecting to extraction ducts located beneath and above the carriageway (**Figure 8**),
- fresh air injection dampers, installed inside the fresh air gallery, with a spacing of 8 m,
- a semi-transverse system for the Rueil Malmaison interchange and for a part of the interchange with the motorway A13,
- a longitudinal system for the rest of the duplex.

For the tunnel entry ramps, the ventilation system is designed for a fire heat release rate of 10 MW (15 MW for additional robustness). The ventilation system for the escape routes is fully independent of the tunnel system. The escape routes are pressurised.

To limit smoke propagation in the tunnel network, two outside air fans are located at the entrances of each traffic level, which ensure the dilution of pollution. In addition, jet fans are used in the event of fire. Where ramps meet the tunnel, double air curtains (one per traffic direction) aim to isolate the ramp from the main tube.

The operation of the supply and exhaust air ventilation systems is dependent on the readings from different sensors. The ventilation system is managed automatically by a SCADA system, based on scenarios for normal operations and for fire incidents and specific environmental conditions. For an event to be classed as a fire, it must be validated by the supervisor.

When the levels of pollution are high over a long time, the tunnel is closed to traffic.



Figure 8 – concept of the ventilation system in the cross section

The aim of the ventilation system in the event of a fire is to prevent smoke from spreading in the traffic space. Therefore airflow is maintained in the traffic direction in order to avoid smoke-layering upstream of the fire place. Smoke extraction is carried out by the nearest damper to the fire. Should the fire spread beyond this damper, a reversed airflow is generated.

3.1 ENVIRONMENTAL ISSUES – AIR QUALITY

Inside the tunnel

- Pollutant emissions are low, as access is only allowed for light vehicles of less than 2m in height. Traffic jams are prevented in the tunnel.

In the neighbourhood of the tunnel

- The air quality is continuously measured (NO₂, CO, PM₁₀ and PM 2.5 concentration measures, in comparison with standard concentrations) in order to evaluate the impact of the tunnel on the environment.
- These measures are available for consultation on a web site dedicated to the Duplex Tunnel. At the Duplex tunnel portals, there is additional extraction capacity to avoid pollution problems.

4. FACILITIES AND OPERATIONAL EQUIPMENT

The Duplex Tunnel is equipped with standard operational and safety equipment. Therefore, there are few specific points for this tunnel:

Power supply

- 18 MW (equivalent to a town of 12,000 people), 3 electricity substations, 22 transformers.

Monitoring system

- 450 cameras, 70,000 command and control points.

Passive facilities to improve the comfort and the safety of users

- Presence of an emergency lane (hard shoulder) on the same side as the emergency exits,

- use of specific colours on the side wall around the emergency exits (green paint) and the safety recesses (orange paint),
- use of light colours for the carriageway and the side walls and dark colours for the ceiling,
- use of numerous white coloured lights (13,000 lights, 4,000 beacon lights) for good distributed of lighting throughout the tunnel.

Communication system

- safety messages are broadcast on 10 FM frequencies,
- the radio frequencies of the emergency services are available throughout the Duplex Tunnel,
- 237 emergency call points, 675 emergency call boxes (every 40m).

Water supply – drainage system – firefighting equipment

- Use of an innovative fire-fighting technology: a sprinkler system is installed throughout the tunnel. In the event of fire, for 30 minutes this system sprays water in the form of fine droplets, over an area of around 100m long centred on the fire. Its main aims are to: (i) control the development of the fire - (ii) facilitate the intervention of the emergency services - (iii) improve the survival conditions downstream of a fire.
- The fire network is permanently supplied with pressurised water. It can supply 2 pillar fire hydrants (2 x 60 m³/h) for one hour with a static pressure from 6 to 10 bars. There are 3 water reservoirs near the tunnel.
- In the event of a fire, the physical closure of the tunnel is ensured simultaneously by the toll operator and by a drop-down barrier, fitted with 2 flashing lights (R2) and with a B1 sign (direction forbidden).

5. SAFETY, EVACUATION AND BEHAVIOUR

Specific provisions for the disabled

Disabled users can evacuate to a safe place without assistance: in the transfer staircase, a special rescue room is designed to enable them to wait for assistance. These rescue rooms are fitted with emergency call points, loudspeakers and CCTV-cameras. In the emergency shafts, the presence of elevators enables them to reach the open road.

Risk analysis, emergency response and training

They are analysed during regular meetings organised mainly with the Ile-de-France Interdepartmental Road Directorate, which is the operator of the toll-free part of A86 network.

Management of tunnel users

It is made by continuous training and feedback through meetings regularly organised with the entire road operator staff.

6. OPERATION

The Duplex Tunnel is operated by a central control centre (staffed at all times), located at Uriel – Malaise (**Figure 9**). The control centre works in relation with 2 public bodies on a daily basis:

- The Ile-de-France Inter-departmental Road Directorate (DIRIF) which is a directorate of the Ministry of Ecology, Sustainable Development and Energy. DIRIF is in charge of traffic management on the road network which it operates on each side of the concession network.
- The Ile de France Regional Road Traffic Information and Coordination Centre (CRICR), which covers the whole of the Ile-de-France region. CRICR collects data on the traffic conditions in the Ile-de-France area and surrounding regions and provides road users with information. It also provides information and advice on road management measures planned during road works and specific events, such as demonstrations.

The Duplex control centre comprises a control room which is equipped with a video wall showing the tunnel's layout and CCTV images of inside the tunnel and the neighbouring area. All the information from the equipment inside the tunnel is monitored from the central control centre via the SCADA system.

An operation centre is located at the mid-point of the tunnel (Vaucresson Interchange with the A13), and is in charge of ramp maintenance and the cleaning of the surrounding area.

The general organisation is:

- During the day (6h-22h): 2 supervisors and 6 road patrollers,
- During the night (22h-6h): 2 supervisors and 4 road patrollers.

If a fire occurs:

- All entrances are automatically closed at the toll-gates.
- Emergency services and fire brigade teams then use specific vehicles (2 fire brigade vehicles and 1 ambulance available at the tunnel ends and at the interchanges) belonging to the operator and dedicated to the emergency services' intervention.



Figure 9 – view of the Duplex Tunnel's central control centre