

In France, several studies, aiming to contribute to a further optimization of lighting design and an improvement of its use are currently foreseen.

Case study: Evaluation of remotely controlled light sources

In order to reduce power consumption, whilst maintaining a sufficient level of safety, a system enabling 9,000 light sources to be remotely controlled was installed in tunnels on the A14-A86 in the Paris region (a 15km underground network in the district known as “*La Défense*”).

Reductions in power consumption are achieved in two ways:

- When the lamp is new, the light flow is at a fixed level (between 70% and 90% of its nominal level), in order to adapt lighting to requirements. This solution limits over-lighting at the beginning of a lamp’s life-cycle;
- In nocturnal mode: the lighting level is lowered according to the traffic in the tunnel at night.

In addition, maintenance tasks can be facilitated by:

- Optimizing the lifespan of the system by adapting lighting levels to the state of each lamp;
- Predictive maintenance, thanks to data acquisition for each lamp: wattage, voltage, intensity;
- Optimizing maintenance by a remote fault diagnosis.

The impact of this control system on the three pillars of sustainable development is shown in the table below.

TABLE 8. IMPACT OF CONTROL SYSTEM ON THE THREE PILLARS OF SUSTAINABLE DEVELOPMENT		
Pillar	Positive aspects	Negative aspects
Economic	Reduction of energy costs Improvement of life expectancy for lamps	Initial investment Maintenance of added equipment or construction
Social	User safety and comfort	
Environmental	Reduction of energy consumption (reduction of CO ₂ emission and preservation of resources) ⁴	More material use

4.4.4. Ventilation

The term “*ventilation*” combines several functions: sanitary ventilation, smoke extraction, and sometimes ventilation for environmental protection purposes. See PIARC Report [4].

Sanitary ventilation aims, in normal operating conditions, to maintain the air quality inside the tunnel in accordance with country-specific requirements⁴. In the event of fire, smoke extraction is designed to extract and/or control the smoke to enable users to get to safety and to allow emergency services to fight the fire.

The smoke extraction system meets very strict regulatory requirements and thankfully is very rarely used. Therefore, it is not subject to efforts to optimize its operation.

⁴ If there are no national regulations PIARC Recommendations could be used

The requirements imposed in terms of air quality are often determined in relation to the permitted concentrations for different pollutants (CO, NOx) and for opacity values (particles). Vehicle exhaust emissions have significantly reduced over recent years, but the type of pollutants taken into account has changed. As such, sanitary ventilation is still very frequently used. As the thresholds to adhere to are set by regulations and as airflow requirements are assessed, innovation can only address the systems which produce this airflow. This is why improvements have been made to the efficiency of air ducts on fans installed in the station (for transversal or semi-transversal ventilation) or on jet fans installed in spaces where traffic is moving (for longitudinal ventilation).

Sometimes the vitiated air is treated before being discharged to the outside. The next section provides explanations on this subject by presenting air cleaning systems.

Optimization of the ventilation process can be done:

- By controlling ventilation based on real time traffic data;
- By considering the natural ventilation (pressure difference between portals);
- By using the existing by-passes located not too far from the portal⁵;
- By monitoring the quality of information given by pollution sensors and temperature sensors.

Due to the recent emergence of vehicles using alternative fuels, the operational risks in tunnels may change because of the different characteristics of these vehicle emissions and the impact of these fuels in an emergency situation.

Case study: evaluation of the installation of new jet fans

It is noted that when a jet fan is installed in a tunnel, a considerable decrease in thrust occurs when the unit is very close to the vault of the tunnel or in a niche. This decrease can even be as much as 30%.

Equipping jet fans with inclined outlets has enabled a significant improvement in the in-tunnel thrust to be obtained.

In general, the absorbed power by a single jet fan may slightly increase and consequently can marginally impact the final results, but the total installed power decreases because the required quantity of new jet fans is lower than for conventional jet fans.



Illustration 6 - Picture of jet fans with inclined outlets.

⁵ When there are two tubes, this allows a short circuit for fresh air in the entrance of one tube and the exit of the second one.

The impact of this new type of jet fan on the three pillars of sustainable development can be seen in the table below.

TABLE 9. IMPACT OF NEW JET FAN ON THE THREE PILLARS OF SUSTAINABLE DEVELOPMENT

Pillar	Positive aspects	Negative aspects
Economic	Reduction of operating costs (energy and maintenance)* Lower initial investment (less jet fans) Higher availability of the tunnel for traffic	Cost of new jet fans
Social	(No significant impact)	
Environmental	Reduction of energy consumption (reduction of CO2 emission and preservation of resources)*	

*Depending on the solution retained

4.4.5. Air cleaning

We must remember that a road tunnel used by any given vehicle does not lead to more pollution than a journey by the same vehicle in the open air. However, this pollution is concentrated at certain points (each end of the tunnel and/or vitiated air extraction systems). This is why studies of a tunnel's extracted vitiated air are always very detailed, especially when a tunnel is located in a highly urbanized area.

In some countries, vitiated air treatment systems have been put in place, (a non-exhaustive list of examples follows).

In Spain: Since the M30 motorway to Madrid runs through a highly dense urban pattern, efforts have been made in order to avoid air pollutants that could eventually reach the population. Thus, several filtering stations are deployed at ventilation shafts along the tunnels. There are two different types of filters; on the one hand electrostatic particle precipitator filters, and on the other hand NO₂ active carbon filters.

In Japan, some long tunnels in urban areas have been equipped with noise suppressors, electrostatic precipitators and low-concentration nitrogen dioxide (NO₂) removal systems in order to minimize the influence on the surrounding environment.

In Italy, In Sottopasso di Monza (2.000m long twin-tube tunnel) that runs between Milano and Monza on a highly dense urban road, in Cesena (central Italy) and in Pozzano (south Italy) tunnel electrostatic precipitators have been installed on the exhaust air extraction system in order to minimize the polluted air impact on the urban environment.

In France, the French portal of the Mont-Blanc tunnel is equipped with electrostatic precipitators for particles in the exhaust air.

In Norway, there are a total of 8 tunnels with electrostatic precipitators:

- The environmental requirements for particle cleaning, both inside and outside Norwegian road tunnels, have to a high degree been politically motivated.
- With the exception of two tunnels (Strømsås and Lærdal) the precipitators initially used were first generation and were in operation over the period 1989 - 2012. The precipitators were ceiling mounted, by-pass mounted and one of them shaft-mounted.