

APPENDIX A: TYPICAL WEAK POINTS AND POSSIBLE UPGRADE MEASURES

The list below is not exhaustive; but provides some examples to show how solutions may be very different from case to case. These examples shall not be considered as a check list but as indicative examples only.

A.1. DRAINAGE SYSTEMS

Safety issue description: these two cases describe the typical problem of adapting drainage systems in existing road tunnels in order to deal with Dangerous Goods Vehicles incidents (spillage or fire scenarios).

A.1.1. Construction of slot gutter with siphons, flame traps and gully

Objective:

- reduce the pavement surface spread in case of leakage, mostly with Dangerous Goods;
- reduce the fire intensity (fire size, time development, spread, etc.);
- avoid fire spreading inside drainage system;
- no monitoring system required.

Construction conditions:

- possible implementation during night closures in closing only one lane – if possible;
- low impact on traffic;
- low inconvenience for users;
- temporary reinforcement of signalling and patrol;
- drainage system has to be entirely renewed.

Operational consequences:

- additional maintenance procedures for new system.

A.1.2. Construction of storage tanks

Objective:

- safety improvement at portals,
- environmental protection of water resources.

Construction conditions:

- construction outside of traffic space,
- no inconvenience for users,
- temporary reinforcement of signalling and patrol.

Operational consequences:

- maintenance requirement,
- SCADA impact (new sensors' back up onto the existing system),
- adapt emergency response plan.

A.2. FIRE PROTECTION

Safety issue description: Structure and mechanical & electrical systems have to be protected in order to maintain operating conditions in the case of a fire. These examples deal with cases where the structure and cable fire resistance is insufficient.

A.2.1. Structure fire resistance**Objective:**

- protection of the structure.

Construction stage impact:

- in the case of complex work associated with heavy civil repairs: closure of a tube is needed;
- in the case of fixing protection boards or spraying techniques: night closures. Closure period depends on the method and organisation;
- impacts on traffic;
- inconvenience for users.

Operational consequences:

- emergency Response Plan refinement,
- the protection implementation may require removing / putting back some systems (lighting, CCTV, etc.).

A.2.2. Cable fire protection**Objective:**

- protection of cables.

Construction conditions for cable protection:

- construction of a trough or additional material;
- usually complex: cables have to be temporarily removed – their function has to be maintained;
- construction may be possible during night time lane closures;
- part of the work requires tunnel closure. Closure period depends on the method and organisation;
- impacts on traffic;
- inconvenience for users.

Operational consequences:

- emergency Response Plan refinement.

A.3. USUAL RENOVATION ISSUES WHICH REQUIRE MONITORING & CONTROL SYSTEMS

Safety issue description: it may be the case that appropriate monitoring systems and a SCADA network are not implemented in old existing road tunnels. The objective here would be to implement such systems to comply with regulatory standards and objectives in terms of operation and emergency response plans. If these are implemented, some adaptations may have to be realised due to other systems modifications.

A.3.1. Signalling systems

Objective:

- improve signalling and communication with the users,
- improve guidance to escape routes,
- improve traffic management,
- signs to stop traffic entry to tunnel and inside tunnel (barriers, lights),
- monitoring by the control centre.

Construction stage impact:

- signalling on the side wall: construction possible during night by lane closure;
- signalling above traffic space: preparation outside – implementation during night, short closure of the tube for lifting and fixing;
- cables for supply and remote: during night with a lane closed;
- low impact on traffic;
- low inconvenience for users;
- temporary reinforcement of signalling and patrol;
- test during low traffic periods.

Operational consequences:

- emergency Response Plan refinement;
- SCADA Software update required.

A.4. EMERGENCY EXITS

Safety issue description: these cases illustrate the issue of implementing new emergency exists to reduce distance between egress points to comply with prescriptive requirements.

A.4.1. Example for twin tube tunnels

Tunnel situation:

- unidirectional tunnel 2 tubes,
- good ground conditions.

Construction conditions:

- if closing a tube is acceptable:
- no particular difficulties, system can be established to reopen each morning in time;
- if closing one tube is not acceptable:
- construction during the night,
- closure of left lane and width reduction of right lane,
- short temporary closures.

Alternative solutions:

- cross Passages,
- creation of a parallel escape gallery.

Operational consequences:

- emergency Response Plan adaptation (access of rescue team),
- monitoring means (SCADA upgrade),
- potentially operating in Minimum Operating Condition during the works.

A.4.2. Example for a single bore tunnel

Tunnel situation:

- bidirectional tunnel 1 tube, 2 lanes.

Construction conditions:

- special connections needed from shelters,
- particular operating procedures.

Alternative solutions:

- construction of new safety exits,
- parallel gallery as escape route from shelters,
- use of existing tunnel bore space for new, fire-protected escape passage (for example in the crown, side or invert).

Operational consequences:

- emergency Response Plan adaptation (access of rescue team and evacuation of users),
- monitoring (SCADA upgrade),
- complete tunnel closure during works.

A.5. VENTILATION SYSTEMS

Safety issue description: these cases illustrate the typical issue of upgrading ventilation systems in existing tunnels to meet safety objectives. This would be the case where the existing tunnel has been constructed prior to the regulation update or an assessment of significant changes in terms of traffic has been made.

A.5.1. Example for simple unidirectional tunnel with 2 tubes

Tunnel situation:

- unidirectional tunnel 2 tubes,
- existing ventilation system: longitudinal,
- traffic increase and fire conditions require more air flow or higher air flow velocity,
- solution: add additional fans.

Construction conditions:

- new fans may be installed during short tunnel closures,
- complementary power supply may be installed during night with one lane closed,
- modification of SCADA, may be tested during low traffic period.

Alternative solutions:

- alternatively, but most costly, Saccardo nozzles can be implemented at portals or fan rows at portals in elevated crown,
- intermediate shafts, especially for urban tunnels,
- according to the length, smoke exhausts at intervals may be required.

Operational consequences:

- emergency Response Plan adaptation (access of rescue team).

In case of a complex situation (e.g. regular traffic jams, ramps in the tunnel etc.), further refurbishment requirements would be required, e.g.:

- control and management of longitudinal airflow,
- particular consideration of aspects such as work phasing and corresponding refinement of emergency plans and operating conditions.

Tunnel situation:

- unidirectional tunnel 2 tubes,
- existing ventilation may be longitudinal or semi transverse,
- numerous traffic jams,
- particular atmospheric conditions at portal, with strong natural air flow inside the tunnel.

Refurbishment requirements:

- control and manage longitudinal air velocity,
- Create or keep smoke extraction (smoke exhaust, dampers).

Civil works implications:

- investigation of all possible conditions,
- very detailed construction method analysis, in order to target construction time with precision of less than one day,
- strategy of works staging with regard to closure possibility,
- in case of staging – evaluation of the safety conditions when temporary reopening between two construction stages,
- tight survey and control of the upgrade works in order to respect the programme.

Solutions for controlling air velocity:

- the implementation of boosters at each portal;
- the installation of jet fans or injectors:
- build recess to install jet fans,
- adapt the power supply and the data transmission network,
- modify the SCADA;
- organisation of upgrading works:
- civil for recess needs closure of the tube,
- other works as for previous example.

It may also be the case that the ventilation control system is not automated or implemented. In some of these cases, if a specific ventilation response is required, an operator has to instigate manually; or the ventilation control requires detailed information from sensors that require upgrade. Also, in some existing tunnels it may be necessary to upgrade the fans in order to increase their fire resistance.

A.5.2. Ventilation control**Objective:**

- to provide or improve the automatic ventilation control during normal operation and in case of a fire emergency.

Construction conditions:

- anemometers may be required;
- study of the fans' real thrust and its reaction time;
- real scale tests would require tunnel closure for short periods, preferably at night or during low traffic periods;
- low impact for users;
- SCADA modifications.

Operational consequences:

- emergency Response Plan adaption;
- SCADA modification.

A.5.3. Pollution sensors and anemometers**Objective:**

- to equip the tunnel with a higher number of pollution sensors and anemometers;
- to increase the information about the air quality inside the tunnel and improve the resilience of the system to a sensor failure.

Construction conditions:

- new devices can be installed during a very short lane closure;
- this can be carried out at night or during low traffic periods;
- very low consequences for users;
- requires SCADA modifications;
- it may require changes in signal acquisition devices.

Operational consequences:

- maintenance;
- SCADA modification (new signals).

A.5.4. Heat resistance of fans**Objective:**

- to equip the tunnel with heat resistant fans;
- includes cable protection if necessary.

Construction conditions:

- fans can be replaced during short tunnel closures;
- SCADA must be tested;
- low impact for users;
- low consequences on traffic;
- temporary reinforcement of signalling and patrol;
- test during low traffic periods.

Operational consequences:

- maintenance;
- Emergency Response Plan adaption.

A.6. CLOSED CIRCUIT OF TELEVISION AND AUTOMATIC INCIDENT DETECTION SYSTEM

Safety issue description: it may be the case that the Closed Circuit TV and/or the Automatic Incident Detection System are not implemented in old existing road tunnels. The objective here would be to implement such systems to comply with regulatory standards, and to improve the response time in case of incident in the tunnel. In existing tunnels with a CCTV system, it may be necessary to upgrade it and/or replace the cameras if a new AID system is going to be installed.

A.6.1. Proper location of the cameras

Objective:

- to avoid dazzling the cameras by outdoor lighting. Placing the last camera oriented towards the interior;
- to make the detection by the AID system easier. Proper spacing between cameras;
- to avoid a large number of images in the Control Centre. Proper spacing between cameras;
- to provide 100% coverage.

Construction conditions:

- consequences on traffic, due to the closure of a lane or the whole tunnel;
- possible implementation during night time and closure of a lane.

Operational consequences:

- video Server re-configuration;
- new masks generation and AID system reconfiguration;
- re-programming and re-configuring the SCADA system;
- Emergency Response Plan adaptation.

A.6.2. Automatic Incident Detection (AID)

Objective:

- to immediately detect any incident, in order to efficiently manage the emergency;
- to automate the Emergency Response Plan.

Construction conditions:

- if it is necessary to modify the transmission system of the cameras, or to add new equipment for this purpose, it can be carried out during night time and closure of a lane;
- new equipment in technical rooms at the tunnel portals and in the Control Centre.

Operational consequences:

- re-programming and re-configuring the SCADA system;
- Emergency Response Plan adaptation.

A.7. CONTROL SYSTEM

Safety issue description: in some existing tunnels, it may be necessary upgrade the control system because it doesn't have redundancy at network level, at equipment level and/or at SCADA level.

A.7.1. Control system redundancy**Objective:**

- to protect the control system against the break of the communication network, against the failure of the equipment (switches, PLC, servers, etc.) or against computer problems.

Construction conditions:

- if the installation of new fibre optic wiring is required, it will be done in a cable tray or in a duct under road or pavement. Construction possible during night by closing a lane;
- if new equipment installation is required, it will be done in the technical rooms and in the Control Centre, so traffic will not be significantly affected;
- if the updating of the control computer system is required, it will be done only in the Control Centre, so it will not have repercussions for traffic.

Operational consequences:

- emergency Response Plan adaptation;
- re-programming and re-configuring the SCADA system.

A.8. COMMUNICATIONS SYSTEM

Safety issue description: it may happen that radio communication system and/or public address system are not implemented in old existing road tunnels. The objective here would be to implement such systems to comply with regulatory standards and objectives.

A.8.1. Radio communication**Objective:**

- to provide a communication system in the tunnel interior to the emergency services, in case of emergency;
- to help the tunnel users to maintain normal driving conditions, by providing FM radio rebroadcast.

Construction conditions:

- the leaky feeder cable will be installed in the ceiling, requiring complete tunnel closure;
- antennae and amplification equipment must be installed in the vicinity of the tunnel portals;
- tests can be done in normal traffic conditions.

Operational consequences:

- operating personnel and emergency services must be provided with terminals, in order to communicate in the tunnel interior;
- emergency Response Plan adaptation.

A.8.2. Public-address system**Objective:**

- to offer a straight information system for tunnel users in an emergency situation, assisting evacuation.

Construction conditions:

- speakers are usually installed in the tunnel sidewalls, so it may be done with lane closure;
- few disadvantages for users;
- few consequences for traffic.

Operational consequences:

- emergency Response Plan adaptation;
- programming and reconfiguration of the SCADA system.

A.9. ELECTRICAL SUPPLY SYSTEM

Safety issue description: as a consequence of the incorporation of new equipment with an increased electrical load in an existing tunnel (ventilation systems, water pumps for fire fighting systems, lighting system, etc.), an extension of the electrical supply system might be required. In some cases it is necessary to provide the tunnel with additional UPS to ensure the operation of the emergency equipment.

A.9.1. Extension of the electrical supply system due to increasing the power demand**Objective:**

- to provide the necessary electrical supply to the new equipment installed.

Construction conditions:

- first of all, an estimation of the new equipment power consumption must be completed;
- consultation with the Electricity Board to ensure that the present electrical network is able to support the extension, or else an extension of the network is needed;
- an evaluation of which electrical equipment must be upgraded or replaced must be done (transformer, electrical cabinets, wires, etc.);
- an extension of the technical rooms, where electrical supply system equipment is placed, might be required in order to house the new electrical equipment;
- some of these works could be completed during night time, with low impact on traffic (for example, an electrical transformer replacement). However, other works could have a higher impact (for example, a technical room extension).

Operational consequences:

- additional maintenance procedures;
- SCADA impact (more signals must be controlled).

A.9.2. Installation of a secondary source of electrical supply**Objective:**

- To provide the tunnel with a secondary source of power supply, to ensure the operation of the safety equipment in case of an electrical failure.

Construction conditions:

- estimation of required power and consultation with the Electricity Board;
- establish the tunnel equipment to incorporate (transformers, electrical panels, connections switching system, etc.);
- possible technical room extension to hold the new equipment;
- some of these works can be done at night, with limited impact on users (e.g. the replacement of a transformer). Other works, however, would have a greater impact (e.g., the extension of a technical room could cause the cut of the power supply for a few days).

Operational consequences:

- additional maintenance procedures;
- SCADA impact (more signals must be controlled).

A.9.3. Installation of an Uninterruptible Power Supply (UPS)**Objective:**

- to provide the tunnel with a secure power supply, to ensure the continued operation of emergency equipment (control system, closed-circuit television, etc.).

Construction conditions:

- estimate required power, to choose the appropriate UPS;
- changes in low voltage electrical cabinets (upstream and downstream of the UPS);
- these works can be done at night.

Operational consequences:

- additional maintenance procedures;
- SCADA impact (more signals must be controlled).

A.10. LIGHTING SYSTEM

Safety issue description: new regulations for lighting requiring systems in some existing tunnels to be upgraded.

A.10.1. Lighting system upgrade**Objective:**

- to improve the driver's visual comfort,
- to fulfil the lighting regulations in those existing tunnels where lighting system is poor or insufficient.

Construction conditions:

- installation of new cable trays and an extension of main electrical cabinet could be needed,
- lamp replacement is possible during night time, with a lane closure,
- consequences on traffic,
- inconvenience for users.

Operational consequences:

- additional maintenance procedures,
- SCADA impact (more input/output signals).