State of Qatar
Public Works Authority
Assets Affairs
Roads O&M

Tunnels Concept of Operation

قطـر تستحـق الأفضـل
Qatar Deserves The Best

Approvals

Purpose
This Plan describes the required tunnel systems, practices, resources, functional requirements and management controls necessary for safe and sustainable tunnel operation. The plan has been reviewed by the Tunnel Design and Safety Consultation Group.
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Record of Review/Revisions

This Plan shall be reviewed at periods not exceeding annually and updated accordingly. The reviews, including nil returns, shall be noted below.

Date	Topic of Change	Section(s) changed	Rev No.	Approved (Name)	Authorised (Name)

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1 General Information

1.1 Introduction

A Specific Concept of Operation should be prepared for each tunnel at the planning stage by the designer based on adequate consultation with the Technical Approval Authority (TAA), Project Manager, Police, Emergency Authorities and the proposed Tunnel Operating Authority (TOA).

A Concept of Operations or Operation Philosophy for a Road Tunnel defines the measures, a Tunnel Operating Authority (TOA) will implement and the approach it will take to execute these measures, to ensure safe transit of expected traffic levels through tunnels located in its road network. It defines functions and processes. The Public Works Authority Ashghal is the TOA in Qatar.

The concept of operations is a tool habitually developed by the project designer primarily in the planning stage and it mostly addresses tunnel operations at a summary level. It is not intended to serve as a Tunnel Operations Manual where more detailed tunnel operational procedures and staffing requirements will be addressed.

The most essential element of a Road Tunnel Concept of Operations is that it accurately describes the tunnel systems and the functional requirements necessary for safe and sustainable tunnel operation; ensure users safety and safeguard the asset.

This functional description provides the systems designers with the basis on which all physical, operational, and systems parameters, integration and performance should be derived.

Typically, the process of defining these functions starts with the aim to fulfil the following main objectives of tunnel operations and then it expands into further operational details.

1. Prevention
2. Detection
3. Response
4. Incident Management
5. Recovery
6. Traffic Management

1.2 Scope

Ashghal Expressway Projects are expected to deliver in the region of 30 Road Tunnels. This could present various, safety, maintenance and operational challenges with a high financial impact, if a consistent approach is not followed in the design stages. .

This document broadly describes the operational control philosophy of Ashghal Highway tunnels, and how they integrate with the operation of the whole road infrastructure and is intended to give guidance to designers to ensure a consistent approach in the design and integration of safety and M&E systems for each Expressway Tunnel.

This document will only cover tunnel systems functionality and operators requirements and is only intended to provide a summary platform for the development of the Tunnels Operations Manual; it also provides tunnel designers guidance on tunnel systems functionality requirements and intended use, as per Ashghal expectations.

Some systems functionality descriptions included in this document for example the systems listed below are generic and will need to be specifically adapted and further developed by the designer for each particular tunnel in accordance with its specific characteristics:

- Traffic Management Plans
- Tunnel Incidents Matrix
- Ventilation operations procedures

This document has purposely kept to describing the essential principles rather than to be unnecessarily specific in some cases. The designer shall expand on the relevant principals based on the characteristics of each tunnel.

1.3 Glossary of Terms and Abbreviations

Commonly Used Terms	
Term	**Definition**
AADT	Annual average daily traffic, it is the total volume of vehicle traffic of a highway or road for a year divided by 365 days.
DMRB- BD78/99	The British Highways Agency Design Manual for Roads and Bridges Volume 2, Section 2: Design Of Road Tunnels.
DNO	The local electricity company. KAHRAMAA
IAN	Interim Advice Note
DMS	Dynamic Message Sign: A traffic sign capable of displaying any pre-programmed text message by means of an array of light-emitting diodes.
Emergency Roadside Telephone (ERT)	A telephone (sometimes known as a 'SOS' telephone) for use by members of the public to summon assistance.
Emergency Distribution Panel (EDP)	A panel recessed into the tunnel wall containing emergency equipment and electrical control equipment.
FM200	Colourless, odourless gaseous halocarbon commonly used as a gaseous fire suppression agent.
Google Maps	Desktop web mapping service developed by Google. It offers satellite imagery, street maps, 360° panoramic views of streets
GPS	Global Positioning System
Hydrocarbons	An organic compound consisting entirely of hydrogen and carbon. All forms of hydrocarbons can explode in many environments under certain conditions.
HGV	Heavy Goods Vehicle

Inergen	A breathable synthetic gas used as a replacement for Halon in automatic fire extinguisher systems.
IRV	Incident Response Vehicle
IRU	Incident Response Unit
ISO	International Organisation for Standardisation
Lane Control Sign (LCS)	A traffic sign that uses a red cross or green arrow to indicate lane availability.
MEWP	Mobile Elevated Work Platform
Mimics	A system graphic simulation presented on the visual display unit
MOI	Ministry Of Interior
MOR	Minimum Operating Requirements
NFPA	National Fire Protection Association (a United States trade association)
Ooredoo	International telecommunications company, provides mobile, wireless, wireline, and content services
PWA	Public Works Authority
PIARC	Permanent International Association of Road Congresses
QPRO	Qatar Permit Of Road Opening System
QCD	Qatar Civil Defence
RAMC	Road Asset Management Centre
RMD	Road Maintenance Department
Smoke Control Panel (Portal Panel, Fireman Panel)	A panel containing emergency equipment, access to some tunnel systems.

SACCARDO Nozzles	supply external air into a tunnel by fans situated in a fan chamber outside the tunnel
Tunnel Service Building (TSB)	Tunnel associated building where all tunnel support equipment is installed. Include any local control room.
Tunnel Design and Safety Consultation Group (TDSCG)	A consultation group convened to agree basic design and operational parameters for the tunnel.
Tunnel Operating Authority (TOA)	The Organisation responsible for the operation, inspection and maintenance of the tunnel.
Tunnel System	The mechanical, electrical or electronic and software installations in a tunnel.
TPMCS	Tunnel Plant Monitoring and Control System: Is the system that ensures full and efficient integration of all Tunnel Systems.
Traffic Plan	An arrangement of traffic signs and signals deployed in particular sequence to achieve a particular arrangement of traffic management.
VESDA	Very Early Smoke Detection Apparatus is an air sampling / laser based smoke detection system.
Video Automatic Incident Detection	An automatic system which uses dedicated CCTV cameras to monitor the tunnel interior and analyses the pictures to give early warning of an incident.
Uninterruptible Power Supply	A battery-supported standby power supply designed to maintain power to essential equipment with no perceptible break in supply during mains failures.
Wig-wag	A traffic signal that instructs traffic to stop by means of two alternately flashing red lights.
WZTMG	Work Zone Traffic Management Guide: A guide to assist in the safe management of traffic around road works.

Systems Related Abbreviations		
Abbreviation	**Context**	**Meaning**
ACB	Electrical Switchgear	Air circuit breaker
AQM	Air Quality	Air Quality Monitoring
AID	Traffic Surveillance	Automatic Incident Detection
AHU	Air Quality	Air Handling Unit
CACP	Fire Safety	Clean Agent Control Panel
CCTV	Traffic Surveillance	Closed circuit television
CO	Air Quality	Carbon monoxide
DMS	Traffic Signs	Variable message sign
E&M	Engineering Discipline	Electrical and mechanical
EDP	Tunnel Panels	Emergency distribution panel
ERT	Telephones	Emergency roadside telephone
FPL	Fire Safety	Fireman Panel
GUI	Control System	Graphic User Interface
HV	Electrical Distribution	High voltage (above 1000 volts ac)
HMI	Control System	Human Machine Interface
HVAC	Air Quality	Heating Ventilating and Air Conditioning
HLI	Fire Safety	High Level Interface

ITS	Traffic Control	Intelligent Transport Systems
I/O	Control System	Input / Output
LCS	Traffic Signs	Lane control sign
LED	Traffic Signs	Light-emitting diode
LV	Electrical Distribution	Low voltage (between 50 and 1000 volts ac)
LHD	Fire Safety	Linear Heat Detection
LAN	Control System	Local Area Network
LEL	Fire Safety	Lower Explosive Limit
MCCB	Electrical Switchgear	Moulded case circuit breaker
MFAP	Fire Safety	Master Fire Alarm Panel
MCC	Control System	Motor Control Centre
NO	Air Quality	Nitrogen monoxide
OPC	Control System	OLE for Process Control (OLE = Object Linking and Embedding)
PA	Emergency Systems	Public address
ppm	Air Quality	Parts per million
PTZ	Traffic Surveillance	Pan, tilt and zoom
PLC	Control System	Programmable Logic Controller

SCADA	Control System	Supervisory control and data acquisition
TDSCG	Operating procedures	Tunnel Design and Safety Consultation Group
TMM	Tunnel Operation	Traffic Management Mode
TETRA	Radio Systems	Terrestrial Trunked Radio
TOCC	Tunnel Operation	Tunnel Operations Control Centre
UPS	Standby Power	Uninterruptible power supply
UEL	Fire Safety	Upper Explosive Limit
VAID	Traffic Surveillance	Video automatic incident detection
VDU	Control System	Video display unit
VSL	Traffic Signs	Variable Speed Limit
VSC	Traffic Surveillance	Video System Controller
WAN	Control System	Wide Area Network
WFS	Fire Safety	Water Fire System

1.4 Relevant Standards and References

QCS 2014 *Qatar Construction Specification 2014*

PWA IAN 020 Rev A1 - *Road Tunnel Fire and Life Safety Systems*

NFPA 502: *Standard for Road Tunnels, Bridges and Other limited Access Highways*

NFPA 820: *Standard for Fire Protection in Wastewater Treatment and Collection Facilities*

NFPA 70e: *Standard for Electrical Safety in the Workplace*

NFPA: *Fire Protection Handbook, 20th Edition*

UK Highway Agency - DMRB BD 78/99 *Design of Road Tunnels*

UK Highway Agency - DMRB BD 53/95 *Inspection and Records for Road Tunnels*

UK Highway Agency - DMRB BA 72/03 *Maintenance Of Road Tunnels*

Directive 2004/54/EC of the European Parliament: *Minimum safety requirements for tunnels*

UK Statutory Instruments: *The Road Tunnel Safety Regulations 2007/2009*

The Handbook of Tunnel Fire Safety (*Richard Carvel and Alan N. Bear- 2005*)

Immersed Tunnels (*Richard Lunniss, Jonathan Baber – 2013*)

This is a non-exhaustive list and doesn't include any other applicable standards or regulations referred to in the documents listed above.

2 Tunnels Classification and Geometric Design

2.1 Tunnels Classification

Number of tunnels	Lengths	Categories NFPA 502 & IAN 020	Categories BD78/99	EU Directive 2004/54
35	< 90m	X	/	/
25	<150m	A	/	/
12	150m < , <240m	A*	D	/
3	240m < , < 300m	B	D	/
10	300m < , < 1000m	C	5 x C / 5 x D	5 x Class I
3	1000m<	D	B	Class II

(*) The tunnel is between 150m and 240 m long

The tunnels classification in the table above is based on tunnel length only and we must consider other factors to cage tunnel criticality such as: AADT, type of traffic allowed in the tunnel (HGV, Dangerous Goods Vehicles …), etc.

2.2 Tunnels

The level of tunnel equipment installation and integration required to safely operate a tunnel is influence by the tunnel geometric design, location, lengths, number of lanes, traffic type, traffic flow and speed and the tunnel intended utilisation such as unidirectional, dual directional traffic and contraflow utilisation.

An operational risk assessment must be conducted and a report prepared during the tunnel conception stage, where all tunnel related incident scenarios listed in Section 7.2: *Event Scenarios*, the risk rating associated with them and the mitigation measures provided by the tunnel equipment and operational procedures should be considered. The NFPA 502 and the BD78/99 documents can be used for reference.

3 Tunnels Facilities

3.1 Tunnel Service Building (TSB)

The TSB is the tunnel associated building where all tunnel support equipment is installed. It includes any local control room.

Centralised tunnels operation will be carried out remotely from the RAMC located on Asset Affairs site at Salwa.

Although the tunnels will eventually be operated as unmanned tunnels they shall be suitably equipped with a control facility to facilitate standalone operation during maintenance and emergency operations.

There should be two levels of control room provisions:

1. One workstation provision static or portable, including a SCADA terminal, a CCTV monitor and controller and any other necessary console.
2. 2 Workstation desks and 1 Supervisor desk, each comprising a SCADA workstation with 2 Monitors, one video wall with multiplex functionality a CCTV controller and a PA console where applicable.

Provision of either one of the options above will depend on the level of equipment installed in the tunnel and its category. Option 2 is not expected to be provided in tunnels lower than category B.

But in some cases where a small number of lower category tunnels are clustered in the same geographical area one local operations room with Option 2 provisions shall be used to service all the tunnels within that specific area.

The TSB will usually contain other tunnel systems and the ambient temperature and humidity shall be controlled to provide ideal operating conditions for the equipment.

Control and surveillance of traffic and monitoring of the tunnels systems will initially be carried out locally until the RAMC is fully operational.

Dedicated tunnel operators will be using the provisions described in Option 1 or 2 above to fulfil TOCC functions.

Tunnels operations will be eventually carried out remotely from a dedicated area within the RAMC when it becomes operational.

Local installations will be used during maintenance or emergency operations as and when necessary.

Unless it is not reasonably practicable a toilet and washroom facility is required in the TSB for tunnels in category A*.

Toilet and washroom facilities shall be provided in the TSB of tunnels in category B and above.

3.2 TPMCS

Automatic tunnel systems response should be utilised as much as is practicable to minimize risk of operator error and to decrease the response times.

However, overcomplicated automatic systems operation could sometimes become a disadvantage during tunnels incident management, for this reason the TPMCS must be simplified.

The TPMCS shall allow for local and remote manual override functionality for critical systems to give the operator the opportunity to modify, substitute for or cancel automated responses where appropriate to ensure tunnel users safety and asset protection.

The TPMCS is covered in more details in section 8.3 of this document.

3.3 Connection to RAMC

Provisions should be made for interfacing the local Tunnel Management System with the Master Traffic Management System located in the RAMC using standard protocols (to be confirmed with the Project Management Consultant).

The local TPMCS shall have first priority on all tunnel associated systems controls and shall exchange necessary data and information with the RAMC software.

To reduce operating costs the surveillance and monitoring of the tunnels shall be centralised in the RAMC, but sufficient numbers of Tunnel Operator Stations shall be provided in the RAMC to allow for a coordinated remote operation of all Ashghal Tunnels.

Initially 4 Tunnel Operator Stations are proposed in the RAMC when it becomes operational but 4 more Tunnel Operator Stations are likely to be required to manage the expected number of tunnels being delivered as part of the Expressway programme.

All tunnels on Ashghal's road network will be grouped into geographical areas taking in consideration their classification, criticality in terms of location and level of effect on the wider road network traffic fluidity.

Each geographical area shall be continuously monitored by 2 appropriately trained tunnel operators with the appropriate level of supervision.

3.4 Fall back Facility

To ensure network resilience an auxiliary remote facility with full tunnels management capability should also be provided. This provision could be part of the RAMC resilience arrangements.

In the absence of a central remote fall-back facility and in the eventuality of the RAMC operation being compromised local tunnel control rooms will be used.

The deployment procedures and the identified locations will be included in the Tunnel Emergency Plan.

3.5 Tunnel Service Building Safety and Security

Access to tunnels service buildings, fire safety, access and security should be monitored through the SCADA system.

Access control should be provided via magnetic cards or access codes with the capability to log information such as time in/out and information of all persons who gained access to the building.

4 Tunnels Operation

4.1 Tunnels Operational Approach

The road network or traffic system in Qatar is divided hierarchically into traffic corridors. Road tunnels are an integral part of the traffic system but due to their complexity and criticality, it is necessary they are given extra consideration and it is in most instances considered best practice to operate them from dedicated tunnels control rooms.

In Urban areas where there are a multitude of tunnels the operation is centralised and is carried out remotely from a Tunnels Control Centre or Centres by dedicated tunnel operators.

Ashghal shall follow the same international best practice by utilising a dedicated area in the RAMC where a team of well-trained tunnel operators shall remotely operate the tunnels.

The tunnels shall be considered as a closed equipment complex and shall be controlled by the tunnel operators at node level, where a node is the lowest level of a traffic system.

The tunnel operator shall be able to control all the tunnel systems including approaches' ITS necessary for implementing tunnel traffic management including lane and bore closures.

It is however necessary for the tunnel traffic status information to be transferred to the higher level (the corridor level), so that it is integrated to the wider traffic system.

The RAMC operator controlling traffic at the corridor level shall see the tunnel as a closed, open or semi closed node and shall implement wider traffic system controls to respond to the situation.

The Tunnel operator shall control the situation at the node level and implement the necessary operations to ensure tunnel users safety, protect the asset and return the tunnel to normal mode (Open node).

The co-location of both operations in the same centre is a significant operational and financial advantage.

4.2 Demarcation of ITS Control Responsibility

The demarcation between the Tunnel ITS and Network ITS shall be considered as per NFPA 502, the Tunnel ITS shall include any equipment that is installed to provide the means to:

1. Stop traffic approaching tunnel portals.
2. Stop traffic from entering the tunnel's direct approaches.

The Tunnel ITS shall be monitored and controlled by the Tunnel SCADA system to enable the tunnel operator to divert traffic from the tunnel entering the tunnel approaches from the appropriate decision point included in the tunnel diversion routes used during a tunnel incident (Local level).

4.3 Traffic Control

The monitoring and control of traffic within the tunnels, at the portals and approaches shall be undertaken by the dedicated tunnel operators 24/7. They shall also remotely monitor and control each tunnel system during day to day operation and in the course of their response to tunnel related incidents.

The tunnel operator shall be able to use the various traffic control systems to implement lane or tunnel bore closures and escalate any tunnel related emergencies to the Tunnels Duty Officer.

A roster of Tunnels Duty Officers for 24/7 coverage shall be prepared by the Tunnels Manager.

4.4 Operators Responsibilities

During normal operating mode, the tunnel operators are responsible for continuously monitoring tunnels traffic and systems status for alarms and alerts.

When and incident or event is detected by the operator he will be responsible for carrying out the following tasks:

- Event detection and Observation
- Confirmation and Gathering of Information
- Notification
- Situation Monitoring and Response
- Recording of Information and Event Logging/Follow-up

4.5 Tunnel Operations Control Centre (TOCC)

The TOCC functions to monitor and control the entire tunnel as well as the traffic control equipment on its approaches, must be made available in the local control location and the RAMC.

The minimum recommended provisions as per international best practice for a dedicated TOCC (not the TSB) are as follows:

- A video wall: for CCTV monitoring
- Several operator consoles (Minimum 2 depending on the number and the criticality of the tunnels being managed)
- A supervisor console.
- Other supporting rooms are recommended such as an equipment room, crisis management room, visitor gallery, and provisions of minimum welfare facilities for 24/7 staffing.

Although tunnels operation can be co-located in the RAMC for economic reasons, it is necessary it retains its individual identity as recommended by international best practice.

4.6 Records

Systems and procedures shall be put in place for the tunnel operators to log and record the sequence of all actions taken by all responders to tunnels related incidents and events that affect or have the potential to affect safety and traffic flow through the tunnels.

The collected information is mostly used by the tunnel management team to analyse the response sequencing and timeline and identify any opportunities for improvement in the response operations.

The main objective of this process is to promote quick response to incidents, a major factor in successful tunnels operations and life and assets preservation

5 Tunnel Systems Operating Modes

5.1 General

Tunnel Systems main function is to ensure tunnel safety and availability and to fulfil this function they must be fully and efficiently integrated into the TPMCS.

The TPMCS shall perform the following primary operations:

- Provide continuous, effective monitoring of major data derived from installed measuring systems such as air quality, wind speed, visibility, luminance and any other element defined in the tunnel design document;
- Monitor Plant running times and provide comprehensive periodic records of overall operating costs and energy efficiency;
- Provide continuous, effective monitoring of all Tunnel Systems identified in the tunnel design document;
- Alert Operators and maintainers to plant status (including changes in state), alarms, malfunctions, especially those likely to cause disruption to the safe operation of the tunnel;
- Provide clear, comprehensive displays and printed logs of plant status to the operator terminal;
- Record all monitoring information including the status of all system database points, alarm inputs and data trends,
- Provide comprehensive displays and printed logs based upon historical data,
- provide the required degree of supervision and control;
- Provide automatic and manual control of Tunnel Systems;

The supervision and control operations including automatic and manual controls shall be performed in 4 Operating Modes.

5.2 Normal Systems Operating Mode

5.2.1 Automatic Systems Operating Mode

The normal systems operating mode shall consist of all Tunnel Systems operating automatically in response to various controlling parameters, while they remain ready to respond to a changed conditions.

Examples of controlling parameters and automatic response include:

- Increased CO/NOx levels in the tunnel causing a ventilation system response,
- High water levels in the drainage sump causing the drainage pumps to operate.

The tunnels designer shall follow tunnels technical and regulatory requirements to develop design specification requirements for each particular system and shall identify the specific values in which the controlling parameters initiate an automated response for each of the various systems.

5.2.2 Predetermined Systems Operating Mode

The predetermined systems operating modes shall consist of all Tunnel Systems being operated in a predetermined or pre-programmed sequence, other than the normal mode.

This mode of operation can be arranged for special requirements such as morning and afternoon rush hour periods or VIP transit where the operation of a various system, such as ventilation, is pre-programmed to operate in a mode rather than operate automatically in response to a controlling parameter.

The controlling parameters always have priority in the event that additional system performance is necessary; however the systems typically should operate at a predetermined level that is determined based upon requirements.

This mode of operation may not apply to all tunnels or may not be initially required but needs to be considered during TPMCS design on a case by case basis, to establish if predetermined operating modes are required for any particular tunnel.

5.3 Incident Operating Mode

The incident operating mode shall vary depending upon the type of incident encountered and the tunnel operating procedures shall identify the appropriate system operations necessary for various incidents. The modes shall be pre-programmed to the largest extent possible in order to allow the tunnel operators to quickly respond in a minimal number of operations and in an efficient manner with reduced potential for operator error.

Examples of incident operating modes include the use of the traffic control systems, DMS, lane usage signals during tunnel incidents, and the use of Ventilation, Public Address, Fire Fighting systems during tunnel fire incidents.

The operator should for example be able to implement a partial or total closure of a tunnel bore including the appropriate tunnel diversion with one command on the HMI screen.

The Designer and the appropriate first responder agencies and stakeholders should coordinate their efforts to establish the appropriate incident response modes for the relevant tunnel systems.

5.4 Maintenance Mode

5.4.1 Tunnel Maintenance Mode

The maintenance operating mode shall consist of all Tunnel Systems operating in a predetermined way specifically prepared for the tunnel maintenance activities being performed. This mode may include a specific and detailed closure plan and specific operation or shut down of various systems to support the maintenance activities.

5.4.2 Partial Systems Capacity Operations

Maintenance requirements or failures and other circumstances may result in certain Tunnel Systems to be operated under partial capacity.

Tunnel Systems Minimum Operating Requirements (MOR) for each tunnel shall be determined based upon the level of the system redundancy, the ability to introduce permanent or temporary mitigating solutions and the impact on life safety.

These MOR must be validated with QCD and MOI. Tunnel operating policies and procedures shall be developed and included in the Tunnels Operations Manual, to document the various systems that are allowed to operate at a reduced capacity without closing the tunnel, to identify the acceptable level of reduced capacity, the triggers for closing the tunnel to traffic and any other mitigating provisions that must be put in place to maintain safe conditions for the tunnel users.

5.5 Tunnel Closure Mode

The Tunnel Systems operating in a predetermined manner specifically prepared for the tunnel closure. This mode shall include a specific Traffic Management Plan (TMP) with detailed traffic diversion plans, signage, communication plans and specific operation of various systems to support the closure.

5.5.1 Unplanned Closure

The RAMC operator shall have instructions to fully or partly close the tunnel by way of DMS, LCS and any other available means of automatic tunnel closure in the following events:

- Fire in the tunnel
- Tunnel Flooded

- Hazardous spillage
- Total failure of mains power, including Emergency Power Supplies
- Total failure of lighting
- Dangerously high levels of pollution
- Other safety critical reasons (road traffic collision, etc.)

5.5.2 Planned Closure

Tunnels closures for routine maintenance or inspection activities shall be programmed during periods of minimum impact on road traffic and the road space booked through QPRO.

Partial closure of tunnel bores to carry out maintenance activities may be considered but it is not recommended and it is not recommended in terms of maintenance personnel and motorists safety in tunnels.

5.5.3 Safety Procedures

No work shall be carried out in the tunnels without the permission of the Tunnels Manager.

Special access procedures should apply to all tunnels and associated buildings managed through a permit to work system.

The Emergency Services (Police and Civil Defence) and other governmental special services are the only organisations with powers to close or reopen the tunnels at any moment. Other Parties should need a permit from the PWA.

6 Tunnels Traffic Management Plan

This section briefly describes the various elements of the Traffic Management Plan; a more detailed description of the tunnel closure procedures shall be included in the Tunnels Operations Plan.

Each tunnel on Ashghal road network shall have its specific Traffic Management Plans relevant to its location, various characteristics and corresponding to its various closure modes with detailed traffic diversion plans, signage, communication plans and specific operation of various systems to support the closure.

Tunnel closure modes shall include full bore closures, lane closures and full tunnel closure.

6.1 Traffic Diversion Plans

When there is a need to fully or partially close a tunnel, a properly laid out Tunnel Diversion Plan is warranted to divert tunnel traffic onto the adjacent road network. These plans should be developed and programmed by the systems integrator for a particular tunnel to cater for all possible tunnel closure scenarios.

The Tunnel Diversion Plans shall include all the necessary diversion routes, all traffic signals and messaging signs to be utilised during the diversion implementation and any other necessary element for the diversion. The plan shall also specify the corresponding function or status of each traffic signal and messaging sign on the affected route during the diversion.

Typical functions may include adjusting traffic signal timing and phasing to channel unexpected traffic flow.

Deployment of pre-planned and pre-approved messages sequencing at all the DMSs strategically located in the vicinity will give advance warning to motorists regarding the incident and promote self-re-routing of traffic before reaching the congestion point.

6.2 Tunnel Closure Signage and Systems

The following signage and systems may be used in the tunnel, its approaches and on the adjacent roads.

- Lane Control Signs
- Dynamic Message Signs
- Wig Wag or Aspect Signals
- Physical Gates or Barriers
- Traffic Signals (Adjacent Roads)

Planned closures shall be reinforced with traffic cones, lanterns and signs in accordance with the WZTMG

6.3 Communication Plans

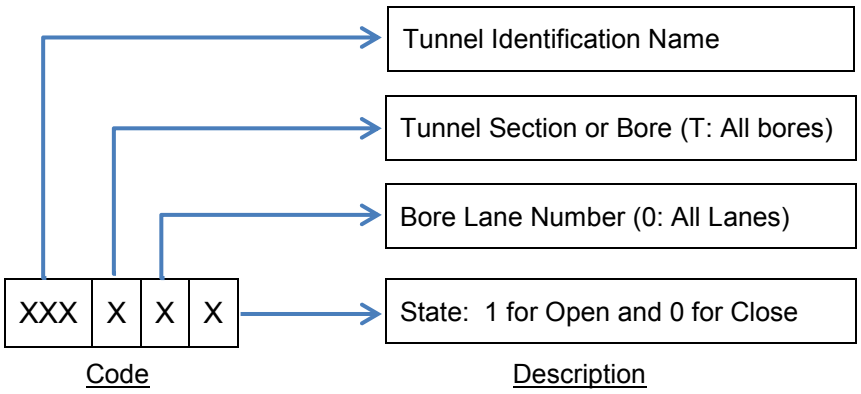
A tunnel Traffic Management Plan shall include all lines and modes of communication necessary for its implementation, this shall include:

- Communication with various stakeholders
- TMCS interfacing with various relevant software
- Messages on DMS
- Media
- Advance warnings and announcements
- Use of Google Maps, GPS information, internet

6.4 Traffic Management Modes

The tunnels shall be put into operational mode or Traffic Management Mode as a result of a particular situation or event. Each Traffic Management Mode shall be titled in line with or similar to the following format.

Mode Code	Description
xxxA00	Bore A – Closed
xxxB00	Bore B – Closed
xxxT00	Tunnel Closed (Full Closure)
xxxAn0	Bore A – Lane n Closed
xxxBn0	Bore B – Lane n Closed
xxxT01	Tunnel Open (Fully Open)
xxxA0X / xxxB0X	Bore A or Bore B – speed limit X



The number of combination of Traffic Management Modes for each tunnel will depend on its geometry, the number of lane it contains and its adjacent environment.

One click of button to select a particular TMM will activate the closure equipment deployment sequence to implement the associated closure.

6.5 The Means of Stopping Traffic Entering Tunnels

In the IAN 020 and NFPA 502:2014 document specify two levels of Traffic Control requirement based on the tunnel category:

Level 1: Stop traffic approaching tunnel portal (7.6.1)

Level 2: Stop traffic from entering tunnel's direct approaches (7.6.2)

The means of stopping traffic entering a tunnel shall include the following:

- Lane control signs
- Dynamic messaging signs
- Red traffic signs (Flashing red signs on DMS) / Flashing Amber Beacons
- Use of various communication methods to raise public awareness (Radio, Tarsheed (Awareness) campaign, leaflets, DMS, Bluetooth, google maps, GPS information …)
- Barriers shall not be required for Category B,A and X tunnels
- All category C&D tunnels shall be provided with ducting from the tunnel to a pit at a suitable location for installing a suitable barrier system or other suitable arrangement post project completion to future proof the installation.
- Barriers shall be provided for Category D tunnels (ref IAN 020) where there isn't enough distance to provide the appropriately spaced ITS, the installation of the barrier doesn't introduce a risk to motorists and the operational risk assessment concludes that the reduced ITS provisions for these tunnels will not meet the safety level provided by using a barrier.

7 Tunnels Events Management Procedures

7.1 Event Risk

The likely risk scenarios or events which may occur in the tunnel and on its approaches shall be identified. These shall be considered in detail with the appropriate parties, and engineering solutions for all relevant areas of the tunnel and its approaches and shall be developed by the tunnel design organisation when appointed.

A systematic approach must be followed to evaluate the event probability and the event Impact, to classify the risk from any given event into one of the following response categories:

- Eliminate
- Avoid
- Prevent
- Mitigate
- Accept

The scope and extent of the engineering solutions to be developed to deal with the identified risks will depend on its response category.

7.2 Event Scenarios

Generally events scenarios or incidents which may occur in the tunnels and approaches can be grouped into the following four categories; these events include, but are not limited to:

7.2.1 Vehicle related incidents

- Fire in tunnel
- Vehicle Collision
- Breakdowns
- Debris on road
- Overheight vehicles
- Traffic queues
- Hazardous loads spillage / release
- Slow moving loads

- Abnormal Loads
- High Concentration of emission fumes
- Low visibility

7.2.2 Non vehicle related incidents

- Pedestrians in the tunnel
- Animals in the tunnel
- Vandalism
- Terrorist attack

7.2.3 Tunnel Systems related incidents

- Lighting failure
- Ventilation failure
- Pumping failure
- Telephones out of order
- Power Failure

7.2.4 Weather hazards:

- Fog
- Rapid, air vapour condensation on windscreen, mirrors etc.
- High winds
- Flood
- Dazzle from the sun
- Sand Storms

Annexe A. contains a typical Tunnel Incidents Response Matrix including all the relevant elements of a tunnel incident management. The Matrix is generic and needs to be further developed for each tunnel separately depending on its characteristics.

8 Emergency Response

8.1 Emergency Plan

Emergency response shall be addressed in the Tunnels Emergency Plan. The plan shall provide specific pre-planned detailed information and procedures that shall be used in dealing with a major incident / emergency within the Tunnels.

The emergency procedures in the plan shall be developed in accordance with international best practice and in consultation and collaboration with QCD and MOI.

8.2 Emergency Exercises

Periodic desktop and live emergency exercises shall be carried out to test the emergency procedures described in the Tunnels Emergency Plan. (Note: United Kingdom Highways Agency inspection standard BD 53/95 specifies an interval between emergency drills of 3 years under normal circumstances, or exceptionally 5 years. The European Directive 2004/54 on minimum safety requirements for tunnels in the trans-European road network requires full-scale exercises at least every 4 years and desktop exercises annually.)

Many tunnel operators in various countries outside the European Union have adopted the EU Directive 2004/54 as international best practice and Ashghal RMD made the decision to adopt some elements of the directive as best practice to ensure its tunnels are managed safely.

The frequency for full-scale exercises and desktop exercises for Ashghal Tunnels shall be agreed and recorded in the Tunnels Emergency Plan.

8.3 Scene Management

During a response to a major incident/emergency in any of the Ashghal Tunnels, when the implementation of the Tunnel Emergency Response Plan is deemed necessary, a scene manager will be deployed and directed by the Tunnel Duty Manager to attend the incident. (The Tunnel Duty Manager will be the scene manager if he attends the incident scene)

The Scene Manager will be the focus point for communication on site and he may require taking control of the tunnel systems locally from the tunnel TSB or the tunnel dedicated control room, if applicable, to fulfil his responsibilities.

The Scene manager responsibilities will be covered in detail in the Tunnel Emergency Response Plan.

Personnel carrying out Level 2 response as described in paragraph 10.5.2 may also require taking control of the tunnel systems locally from the TSB or the tunnel dedicated control room, if applicable, to carry out operations as per the Tunnel Manager or his deputy's directions or following approved protocols.

9 Tunnel Systems

9.1 Tunnel Systems Operating Environment

Designers and contractors shall ensure equipment selected for tunnel installation complies with the following outdoor ambient design conditions.

Temperature (maximum) 50°C

Ground Temperature 35°C

Consideration should also be given to the dusty and sandy environment; in which the installed equipment may be operating in.

The enclosed nature of road tunnels signifies that pollutants from vehicle emissions are not able to disperse; this will result in higher deposits of contaminants that are known to accelerate the galvanic corrosion of metallic equipment used in road tunnel.

Specifiers shall take extra care to select steel components with the appropriate characteristics; care is also required to ensure metal mixing is avoided.

All electrical and communication cables installed in the tunnels shall be Low Smoke Zero Halogen.

9.2 Systems

Tunnel systems in general are two categories, Tunnels Safety Systems and Tunnels Safety Systems Support Equipment such as the electrical power supply.

The TPMCS should ensure systems integration and operational coordination of the two systems categories by monitoring, collating data from, and controlling them to enhance tunnel traffic fluidity and users safety.

The list below represents all the systems which could be integrated into the TPMCS. Selection of the systems to be installed would depend on the recommendations from the Specific Operational Risk Assessment for each tunnel.

Some of the systems listed below are typically installed when the need is identified in the relevant design standards or recommended in the Operational Risk Assessment.

1. High Voltage Switchgear & Transformers
2. Low Voltage Distribution

3. Tunnel Emergency Panels
4. UPS System
5. Generators
6. Tunnel Lighting
7. Tunnel Ventilation
8. Pumped Drainage
9. Attenuation Tanks (Sump) level monitoring systems
10. Attenuation Tanks (Sump) Gas Detection and Ventilation Systems
11. Attenuation Tanks (Sump) Fire Detection and Suppression Systems
12. Monitoring Instrumentation, including air quality monitoring, Anemometers, Flood Monitoring, Temperature
13. Way finding Signs
14. Cross Passage Doors/ Egress Doors/ Escape Gallery and Stairs
15. Fireman's Panels
16. Linear Heat Detection System
17. Tunnel Fixed Fire Extinguishing Systems
18. Traffic Monitoring Systems
19. Closed Circuit Television (CCTV)
20. Video Automatic Incident Detection (VAID)
21. Overheight Detection System
22. Traffic Control Signs: DMS, LCS, Traffic Signals
23. Emergency Telephones
24. Radio Rebroadcast and Break-in System
25. Public Address System
26. Mobile Phone Antennae System
27. TSB Fire Detection, Alarm and Suppression Systems
28. Buildings Access Control and Security Systems
29. TSB HVAC

For Tunnels with mechanical ventilation for smoke control, it is best practice to install Fireman Panels (FPL) at the tunnel entrance portals to Control the ventilation, lighting and also control PA when applicable.

These panels are exclusively made available for use by the Fire Emergency Services during response to a fire incident.

Designers should consider the practicability of providing these FPLs, for category C tunnels and above and when ventilation is specified

9.3 Tunnel Plant Monitoring and Control System

9.3.1 Overview

The tunnel systems listed above will be integrated, monitored and controlled when applicable by the TPMCS, executing the following functions:

1. Monitor the equipment status and condition
2. Relay and present equipment outputs (Digital or Analogue) and Alarms in a user friendly GUI
3. Automatic control of equipment based on programmed parameters using corresponding equipment outputs.
4. Manual control of equipment using GUI
5. Recording historical data and trends

The TPMCS is composed by the Tunnel Systems monitoring and control PLC which in turn interfaces with the SCADA server, and the SCADA client machine or user terminal.

The TPMCS consist of two networks as follows:

- PLC network
- SCADA network

9.3.2 PLC Network

The PLC shall interface at Tunnel System equipment level, such as environmental sensors and electrical contacts within the tunnel bore, outside the bore and within the TSB or tunnel associated buildings.

Control software within the PLC shall provide the control functionality, derivation of status information and integration.

The PLC installation shall be in a Master/ Standby configuration to ensure redundancy and continuity of operation in case of PLC failure.

Communication of the PLC network shall be through dual redundant fibre optic network running a suitable protocol designed for safety related systems. Modbus is the protocol generally used by Tunnel SCADA integrators.

All Ashghal tunnels shall use the same protocol to allow for easy integration of all systems into one master tunnels SCADA software.

A touchscreen HMI panel shall be provided and connected directly to the Master PLC network control cabinet, to enable maintenance Engineers to view detailed network, engineering and maintenance information and to carry out control operations, subject to a suitable password being provided.

The touchscreen HMI panel shall also enable tunnel operation from the control cabinet if the SCADA Terminal becomes unavailable.

9.3.3 SCADA Network

The SCADA System provides Supervisory Control and Data Acquisition functionality. The SCADA Server should interface with the PLC for the gathering of system status information and should issue commands to the PLC as requested by the operator.

It is important to note that it is the PLC, not the SCADA, which should be in control of the Tunnel Systems functionality. PLC's are inherently robust and reliable and thus eminently suited to the required level of control.

The SCADA PCs can be seen as providing a ‘window’ into the PLC's through which the operator can observe system status and initiate controlling actions.

A fundamental feature of the system is that the PLCs are able to continue controlling the tunnel systems, even in the event of total loss of the SCADA Servers and Terminals.

9.3.4 SCADA Functionality

Overall functionality of the TPMCS may include, but is not limited to, the following:

- Monitoring and control of lighting

- Monitoring of environmental sensors and initiate relevant systems controls as appropriate
- Monitoring of electrical supplies and distribution (DNO and Emergency)
- Monitoring and control of pumping equipment
- Monitoring and control of Ventilation equipment
- Monitoring and control of other HVAC
- Monitoring of run hours
- Global Alarm Resets
- User Security
- Control Priority
- Alarm And Event Handling
- Monitoring and control of variable thresholds and set points.
- Monitoring of building services such as fire and intruder alarms
- Monitoring of panel door contacts (Safety Critical)
- Monitoring of emergency phones
- Monitoring of portal lighting control panels
- Analogue data archiving to separate trend database
- Real-time and historical trending of analogue points
- Data Logging And Archiving
- Historical Data Browser
- Help Facility
- User Account Administration
- Multi Systems integration for events management

In general, the same level of functionality is available at all workstations. Under normal circumstances, the system shall be operated from the TSB workstation.

In addition to the set of functions described above, the following additional functions shall be available at all SCADA terminals (unless otherwise stated):

- Graphical Modelling
- Lighting Hours Run
- Historical Functions
- Data Trending

- Alarm and Event Handling
- Data Logging and Archiving
- Graphics Mimics Development and Run Time Display
- OPC Client Interface to SCADA Server
- Alarm and Event Viewing
- Alarm Acknowledgement
- Alarm Banner Control

9.3.5 Priorities

9.3.5.1 SCADA Terminals Priorities

As described in paragraph 3.3 the local tunnel SCADA terminal has priority on RAMC terminals but to avoid potential conflicting commands between local and remote terminals, access and control priorities should be determined by the following system control configuration:

- Operator access priority determined by log-in credentials status
- Login credentials can over-ride terminal access priority (e.g. Supervisor /Administrator on a low priority terminal has priority over an operator at a higher priority terminal)

Process for the transfer of system control between terminals:

i. Operator attempts to control, Graphical User Interface (GUI) flags "Are you requesting control?", or Operator initiates a request for control - request is presented on the current control terminal.

ii. Control transfer request is granted by the operator at the current control terminal or control is automatically transferred after a predetermined time-out.

9.3.5.2 Tunnel Systems Control Priorities

Where a system is integrated to more than one other system, two automation modes are configured for automation priorities, to avoid potential conflicting commands between the different systems,

Response Mode:

Manual or automatic response, it is the automatic operation of a system triggered by another system, or manual operation of a system triggered by human intervention. (E.g. ventilation fans operating automatically when the pollution level in the tunnel reach a programmed trigger value)

Control Mode:

Manual or automatic response, This is the same as the Response Mode in terms of activation, but in this case the triggering system or human operator has priority and can take control of the controlled system even if it is already in the Response Mode, and will only relinquish control to a higher hierarchy system or operator. (E.g. Fire in the tunnel response will, by way of the Fire Alarm System or the operator via HMI, automatically take control of the ventilation fans even if the ventilation fans are already in operation for pollution control)

9.3.6 User Accounts

In order to control access and manage restrictions to authorised users, access levels are defined and assigned. The following user accounts shall be available, with associated access privileges and operating functions:

- View only – default state, no password required
- Operator – restricted to screen pages required to control traffic, tunnel systems for events response and emergency situations, status and alarm list filtered for relevant information only, report generation
- Maintenance Engineer – restricted to screen pages required to carry out maintenance and repair functions, full status and alarm list, report generation
- Supervisor – all of the above plus user management functions, database management functions, report generation
- Administrator /Programmer – full access to SCADA application programme

9.3.7 SCADA Terminal MIMICS

The following main graphics mimics shall be included as a minimum:

- Overview Screen (including, geographical map with superposed tunnel or tunnels plans and ITS equipment)
- Schematic Map of the tunnel including safety systems arranged into an easier grasp layout.
- Lighting
- Electrical Distribution

- Tunnel Ventilation
- Service Building Security
- Environmental
- Pumping
- Fire Safety
- System Network Communications
- Parameter Input screens
- Lighting Control Popup window

9.3.8 Alarm and Event Monitoring

Alarm priorities shall be categorised as follows:

- **URGENT** safety related alarms, which require immediate action
- **ALERT** system or maintenance alarms which do not immediately Jeopardise tunnel operation
- **RECORD** all other events that are part of the normal operation of the tunnel

All Urgent and Alert notifications shall require operator acknowledgement. A full list of alarms and their priorities shall be generated during detailed system design.

The alarms list window shall contain all the necessary information such as affected system, date, time, status, category…

9.3.9 Systems Monitoring and Control

The TPMCS system integration will be described in detail in the subsequent sections, and in the Tunnel Incidents Response Matrix in Appendix A.

9.3.10 Operator Workstation

The tunnels local control rooms where specified, shall be designed and equipped for 24/7 operations as defined in paragraph 2.2.

Because CCTV is an important aspect of the safety systems, a video wall of the appropriate size is required.

Local operator's and supervisor's workstations where specified shall contain the following equipment:

- SCADA Workstation with two screens for tunnel system monitoring
- CCTV video wall of appropriate size to display multi feeds and be used by two operators
- PA control console
- CCTV control console
- Telephone

International standard ISO 11064 defines standards for the ergonomic design of control centres. This standard aims to provide general principles of ergonomic design appropriate to a range of industries, including tunnels. The principle of this standard shall be applied.

9.3.11 Equipment and Material Selection

All PLC and SCADA network components and software shall be selected from the Ashghal Infrastructure Affairs Supplement to QCS 2014; Section 29 Part 23, 24 and 25 containing shortlists of approved systems.

9.4 Electrical Distribution System

The Electrical power distribution system consist of medium voltage, low voltage and emergency power distribution systems for the supply of all electrical components associated with the tunnel, including lighting, ventilation, pumps, and other fire/life safety equipment.

The Electrical power distribution system shall be a redundant electrical system capable of supporting all tunnel systems on full load during normal operations and all safety critical systems supplied by the emergency power distribution system during Kahramaa power distribution failure.

Redundancy could either be achieved by the provision of two independent electrical power connections from two independent substations or one power connection and a standby emergency power generator.

The electrical system shall when practicable be designed to allow routine maintenance without disruption of the traffic in each tube.

In case of a breakdown of the main power supply, the emergency power system shall supply uninterrupted electrical power to the critical loads (for example, fire/life safety related equipment).

An online Uninterruptable Power Supply (UPS) shall be installed to provide power to critical loads for which a momentary power outage or interruption is not acceptable. This includes the following:

- Tunnel emergency lighting
- All other emergency lighting
- Emergency signs
- Fire alarm systems
- All voice communications systems
- All data transmission and control systems
- All traffic detection and control systems
- All tunnel environmental monitoring
- All security systems
- Buildings emergency lights, fire alarm systems, emergency equipment

The UPS shall be designed to provide a minimum of 2 Hours critical systems autonomy if it is installed as a standalone emergency power and no diesel powered standby electrical generator is provided.

If the emergency power consist of an UPS combined with a diesel powered standby generator which is set up to start automatically when a mains failure is detected and to run until mains power is restored, only a limited amount of UPS provision is needed to cover the short period required for the standby generator to start and run up to speed, and also for the possibility that the generator fails to start automatically. In this case the high cost of installing and maintaining full UPS systems is prevented by using a partial UPS with between 30 minutes and 1 hour critical systems autonomy, depending on the level of security required, and the whole life costing against the consequences of loss of supply (e.g. tunnel closure) for each particular tunnel.

If the UPS malfunctions, the power shall automatically connect the load directly to the normal supply while opening the output power side of the UPS. A maintenance by-pass shall be provided to enable manual transfer of the load to the normal supply for routine service or maintenance of the UPS.

Provision of power metering systems on the low voltage side shall allow continuous monitoring and recording of the energy consumed by individual systems such as ventilation, lighting (threshold, interior and total lighting), UPS, general electrical equipment and total energy for the tunnel.

9.4.1 Monitoring and Control

Monitoring and control of the Electrical Distribution System shall include but not limited to the following:

1. High Voltage Transformers
    - Monitor Status of incoming and outgoing supply

2. LV Supply
    - Monitor Status of incoming supply
    - Monitor Status of main breakers

3. UPS
    - Monitor Health Status of inverter
    - Monitor Health Status of battery
    - Monitor operation status

4. Power Metering Systems
    - Monitor and record main power consumption, Voltage and Current
    - Monitor and record systems power consumption, Voltage and Current

5. Generators
    - Monitor operation status
    - Monitor Run Hours
    - Monitor Fuel tank Gage
    - Automatic start generator for weekly maintenance run

6. Automatic Changeover Switch
    - Monitor Status
    - Operation

9.4.2 Record

- Generator Run Hours
- All power consumption, Voltage and current metering

9.5 Lighting

The lighting system comprise

- The tunnel lighting and emergency lighting
- Escape routes lighting and Emergency Lighting
- Tunnel service building lighting and emergency lighting

9.5.1 Tunnel Lighting System

The tunnel lighting system shall be divided into three different zones: the threshold zone, the transition zone, and the interior zone. Each zone has different lighting parameters and characteristics defined to accommodate the eye adjustments needed by motorists transitioning from outside to interior brightness levels.

A step down method is generally used as a practical way to gradually reduce the luminance in the threshold and transition zones to the level in the interior.

The threshold zone helps the eye to adapt to the darkness inside of the tunnel. The length of this zone depends on the traffic speed limit and the Safe Stopping Sight Distance (SSSD). The luminance in the threshold zone can be adjusted with respect to changes in the exterior luminance, measured by photometers outside the tunnel portals.

9.5.2 Emergency Lighting System

Emergency lighting must meet specific requirements including fire-resistant cabling, minimum illumination levels, time for supply interruption and uniformity ratio. For emergencies, lighting is supplemented with emergency exit signs to guide pedestrians to emergency exits.

To achieve emergency lighting provisions an appropriate number of tunnel lighting luminaires shall be identified and must be connected to the emergency power supply from the emergency distribution boards and be wired in separate fire rated cables. Supply interruptions cannot be greater than 0.5 seconds. Inside the emergency walkway, emergency lighting shall be supplied via the UPS.

9.5.3 Monitoring and Control

Monitoring and control of the Lighting System shall include but not limited to the following:

9.5.3.1 Normal Operation

Tunnel lighting shall be controlled by a lighting controller, by continuously obtaining average luminance of the tunnel entrance and surroundings from suitably positioned luminance photometers; and adjusting lighting levels in the tunnel accordingly.

If the photometer for a particular tunnel bore becomes faulty, the lighting controller will activate predefined lighting level. The minimum of two settings is required number 1 is night light setting (low level) and number 2 being day setting (high level).

The tunnel SCADA system should interface with the lighting system to:

- Monitor and display the changes in lighting levels
- Display faulty luminaires (including identification numbers) on the lighting mimic
- Monitor and record luminaires run hours

9.5.3.2 Emergency operation

The SCADA system shall have automatic and manual control provision to trigger the lighting controller to switch the lighting in the tunnel to a desired level.

- Manual control of the lighting is triggered by the operator using panel or desktop HMI
- Automatic control of the lighting is triggered by another tunnel system as programmed (i.e. A fire detected in the tunnel by LHD will switch the lighting levels to 100%)

9.6 Tunnel Ventilation

There is generally sufficient natural air movement through some tunnels to maintain satisfactory air quality. However it is sometimes necessary to equip certain tunnels with mechanical ventilation and extraction.

Mechanical ventilation requirements for a tunnel will be established during the concept design phase. But as per the new 2014 revision of the NFPA 502 ventilation shall not be required for tunnels with lengths less than 240 metres and is only mandatory for tunnels with lengths equal or over 1000 metres.

For tunnel between 240 meters and 1000 meters a ventilation requirement analysis shall be conducted by the designer to determine if mechanical ventilation is required for pollution or smoke control.

There are many types of ventilation systems with different levels of complexity from fans running forward, reverse and at variable speeds with anemometers to monitor air speed in the tunnel and adjust fans speed to obtain the desired output.

The appropriate method of ventilation shall be established during the detailed design. But the main objectives of ventilation systems in Tunnels are:

- To prevent the accumulation of harmful pollutants and ensure adequate air quality and visibility is maintained throughout the Tunnel at all times and under all traffic conditions.
- To prevent back layering of smoke during a Tunnel fire incident and maintain a smoke-free environment along the escape path.

Operation of the Ventilation fans for air quality, visibility and smoke control shall be triggered and controlled automatically and manually by the TPMCS.

Manual overrides shall also be made available at the fans control panel. Emergency stops shall also be installed adjacent to each fan.

9.6.1 Air Quality and Visibility Control

A certain number of fans operations shall be automatically triggered in the affected tunnel bore, when any of the measured CO/NOx and visibility values reach a predetermined set point. The fans shall automatically stop when the value drops under the set point.

If pollution levels continue to increase and reach the second set point or the design threshold value the rest of the fans are automatically activated and the operator shall receive an alarm.

The fans shall continue running until the levels fall below the first set point.

If the threshold value is exceeded, the tunnel is considered unsafe and immediate action is required. Closing the tunnel to traffic may be required.

9.6.2 Smoke Control in the tunnel Bore

The intended safety function of a smoke control system is to ventilate the smoke and gases to maintain a tenable environment for the evacuation of motorists from the tunnel bore, and for the safe entry into the tunnel by firefighters, irrespective of the type of ventilation system selected for smoke control.

The ventilation system must have redundancy such that loss of one or two fans does not reduce the system's ability to deliver the required performance.

Smoke recirculation in the adjacent bore should be considered and avoided during detailed design where applicable.

9.6.3 Escape Routes

Positive pressurisation may in some cases be needed to stop smoke from entering the fire escape routes when necessary.

Air circulation in the escape routes during normal operation will be fulfilled by using air handling units or controlled vents. The system will include automatic dampers which will close automatically when ventilation is switched on for smoke control.

9.6.4 Filtration

To reduce environmental impact in the portal area especially for urban tunnels in built up populated areas, air filters are sometimes included in the design in both exit portals or exhaust shafts.

This air cleaning system is a bypass that removes most of the particulate matter, emissions and also addresses the noxious gases.

Designers are recommended to include filtration in their design if air extraction is used.

Air filtration is also necessary when ventilation is achieved by using centrifugal fans to drive air from outside into the tunnel through SACARDO nozzles. The filters are in this case installed before the fans to filter sand and small particles from the air before it is pushed by the fans into the tunnel.

9.6.5 Monitoring and Control

Monitoring and control of the Ventilation System shall include but not limited to the following:

Automatic controls should be handled by the Master PLC. Precautions should be put in place to avoid overloading the electrical supply when starting the fans. A sequential start of the fans is usually implemented to solve the overload issue.

9.6.5.1 Air Quality Control

AQM system operational response will have 4 levels

Level 1: Clear - No operation

Level 2: Ventilation Stage 1 (predetermined number of fans starts)

Level 3: Ventilation Stage 2 (all fans are running)

Level 4: Urgent Alarm, fans keep running / consider closing tunnel

The table below give an example of AQM Set Point values for ventilation and tunnel status responses (Set Point values selection will depend on the designed ventilation performance)

AQM Operational Response	Level 1	Level 2	Level 3	Level 4
Ventilation Response	Stopped	Stage 1	Stage 2	Stage 2
Tunnel State	Open	Open	Open	Closed
CO (ppm)	< 35	≥ 35	≥70	200
NOx (ppm)	< 0.5	≥ 0.5	≥ 1	2
Visibility $1/10^3$ m^{-1}	< 5	≥ 5	≥ 7	12
Recovery Action	No operation	Stop Fans when values fall to Level 1	Stop Fans when values fall to Level 1	Open tunnel & stop fans when values fall to Level 1

Set Point values were supposed by using the ventilation design parameter in combination with the pollution parameters threshold values guidelines listed in the PIARC Technical Committee Report: Road Tunnels: Vehicle Emissions and Air Demand for Ventilation -2012.

9.6.5.2 Maintenance Control

i. Remote manual and local fan control arrangement shall be made available to the operator to enable him to inhibit or manually operate the fans as and when required.

ii. All fans shall be programmed to automatically run for a pre-programed lapse of time and frequency as determined by the manufacturer maintenance recommendation.

9.6.5.3 Smoke Control

Tunnel Ventilation System operation for smoke control shall be implemented by the Master PLC in accordance to a fire ventilation Cause & Effect Matrix list specific to each tunnel.

Smoke control mode will be automatically activated by any of the available fire detection systems

In principle the sequence of operation automatic or manual should allow for three steps:

1. Confirmation (Confirmation Mode): Confirmation of fire (automatic or manual)-
2. Evacuation (Evacuation Mode): Ensure ventilation will not direct smoke towards evacuating people.
3. Smoke control (Control Mode): Fans operated automatically or manually to be determined by tunnel specific cause effect ventilation deployment in accordance with the tunnel risk evaluation.

9.6.5.4 Monitoring

Ventilation monitoring by the SCADA system will include:

- Monitor and record fans run hours
- Monitor and record fans motor temperature
- Monitor and record fans motor vibration

9.6.6 Other Ventilation

Forced ventilation systems shall be installed in tunnel associated buildings and drainage / attenuation tanks where air exchange is necessary to keep an area safe or provide an ideal operating environment for the equipment.

The forced ventilation systems is composed of Air Handling Units (AHU) or exhaust and intake fans and shall be controlled via a dedicated MCC including a shared or dedicated PLC for monitoring and automatic control.

For safety critical operation such as drainage retention tank ventilation a duty and standby fan system should be provided.

Operation of the fans should be activated and controlled automatically and manually by the TPMCS.

9.6.6.1 Functions

An AHU system could be installed to fulfil the following objectives:

1. To ventilate an electrical equipment room.
2. To control the atmosphere in the UPS Room and prevent dangerous accumulation of Hydrogen released by the batteries.
3. To ventilate and exchange the air in drainage attenuation tanks to keep the internal atmosphere inert by keeping the concentration of explosive gases at safe levels.
4. To ventilate and exchange the air in drainage attenuation tanks to keep the internal atmosphere safe from poisonous gases and keep the oxygen concentration to acceptable levels.

9.6.6.2 Monitoring

Monitor system state and monitor & record fans run hours as a minimum.

9.6.6.3 Control

Control shall include but not limited to the following:

9.6.6.3.1 Automatic control and operation

The following automatic control shall be fulfilled via the MCC

1. Under normal operating conditions the duty fan should run 15 minutes per hour to ventilate the tunnel drainage sump. If the duty fan is not available the standby fan shall assume the role of duty fan.

2. Duty and Standby cyclic changeover shall provide duty fan rotation based on the total running hours of each fan.

The following automatic control shall be fulfilled via the system integration (TPMCS)

1. Operation of AHU shall be inhibited upon a fire alarm signal being generated by two consecutive heat detection sensors in the protected area.
2. In the UPS Room where applicable, the fans shall operate automatically if the hydrogen concentration reaches the threshold level (500 ppm). (Generally the frequent air changes achieved by running the AHU as described in item 1. Of paragraph 9.6.6.3.1 will prevent Hydrogen concentration ever reaching dangerous levels.
3. The duty fan shall operate if the monitored gases concentration in the tunnel drainage attenuation tank reaches 10% of LEL

   The duty fan shall stop running if the concentration drops below 10% of LEL

9.6.6.3.2 Manual control and operation

The manual operation of the AHU should be available locally at its dedicated MCC or remotely at a SCADA terminal.

The fans will operate continuously if they are turned on manually from the MCC and can only be turned off manually from the MCC. The MCC shall be designed with overheat protection.

9.7 Drainage

9.7.1 Tunnel Drainage

The tunnel drainage system objective is to discharge collected water from inside the tunnel and to provide safe driving conditions.

Any surface water or spilt liquids collected in the Tunnel shall be handled by the drainage system.

The tunnel drainage function is either fulfilled by a dedicated sump and pumping system, or an attenuation tank and direct connection to the adjacent public drainage system.

The drainage tank should be installed in the lowest point of the tunnel to promote gravity drainage.

9.7.1.1 Tunnel Sump / Attenuation Tank Fire and Explosion Protection

Fire Protection for the tunnel sump or attenuation tank when required shall be provided by:

1. Hydrocarbons and Oxygen monitoring system
2. All equipment installed in the drainage tank including the pumps must be Explosive Proof rated.
3. Ventilation to control the composition of the atmosphere in the sump
4. A fire alarm and an automatic foam fire suppression system

At three levels: Level 1 - Item 1 & 2 of the list above.

Level 2 - Items 1, 2 & 3 of the list

Level 3 - Items 1, 2, 3 & 4 of the list

The level of fire protection provisions for the drainage sump or attenuation tank shall be in accordance with the current version of NFPA 502 and NFPA 820.

There is no specific reference in NFPA 820 to drainage sumps or attenuation tanks connected to a Tunnel carriageway; it appears that storm sewers (Surface Water Sewers)

are addressed in general and Level 2 or Level 3 protection provisions are considered not required.

In the other hand BD78 specifies Level 3 protection is required for drainage sumps or attenuation tanks connected to a Tunnel carriageway, with a road tunnel being defined as a subsurface highway structure enclosed for a length of 150m, or more.

For this reason all category C&D tunnels as per IAN020 classification shall be provided with Level 3 drainage sumps or attenuation tanks protection.

9.7.1.2 Pumped Drainage

If the pumping station option is required and retained, it shall as a minimum include two pumps (1 duty + 1 standby).

The pumps shall be operated directly from the pump control panel:

1. Automatically based on pre-set values obtained from an Ultrasonic level detector connected directly to the panel, the Ultrasonic level detection system should be backed up by a float level detection system.
2. Manually from the pump control panel.

The pump control panel shall be designed to provide overload and overheat protection for the pumps.

Duty and Standby cyclic changeover shall provide duty pump rotation based on the total running hours of each pump.

From a tunnel operator perspective the drainage system must be integrated into the tunnel SCADA system for monitoring and control. But as the control function is already fulfilled by the drainage SCADA system which is managed by Asset Affairs Drainage Operation and Maintenance Department, the tunnel SCADA will only monitor the pumping station to avoid control conflicts.

Containment provision shall be included to prevent any contaminated or hazardous spills discharging into the surface water drainage system.

The simplest way to achieve this is to continuously monitor the storage tank content and inhibit the pumps if any hydrocarbons are detected. The Storage tank will be emptied and the content disposed of by the tunnel operator using special tankers.

Other more elaborate ways are used with retention tanks, automatic penstocks, skimmer pumps and discharge holding tanks, but removal by tankers is necessary for both options. The only difference is the reduction in the volume of the contaminated storm water to be handled.

9.7.1.3 Tunnel Drainage Monitoring

The tunnel SCADA system shall interface directly with the drainage SCADA system to obtain the following information:

For Pumped Drainage:

- Fire detection status / alarm
- Fire suppression status
- Hydrocarbons Detector readings and status
- Pumps status (Stopped, Running, Off line, Auto, Manual)
- Retention tank levels (Low, High , High / High)
- Retention tank gas detector readings and status

9.7.2 Sewage Holding Tank

When toilets are provided in the TSB it may be necessary to install a sewage holding tank if it is not possible to directly discharge to the public sewage network.

The sewage holding tank will collect the discharged sewage water from the toilet, the pantry and general drainage from the TSB.

The tank level should be monitored by the SCADA system and present a High Level Alarm. When the operator receives a Tank High Level Alarm on the SCADA monitor he will make arrangements for it to be emptied manually using trucks.

9.7.3 Flood Warning Sub-system:

As part of the ITS deployment water level sensors will be installed in the Tunnels to detect surface water on the tunnels carriageway. The system is directly connected to the TPMCS and provides alerts to the operator when a certain level of water is detected on the carriageway.

Redundancy of this system will be provided via operational procedures using CCTV, weather information from monitoring stations,

9.7.3.1 Control and Monitoring

When a flood warning alarm is received the TPMCS will automatically activate the tunnel approach DMS and LCS to warn drivers to reduce speed water on carriageway. The operator will monitor the situation and activate a tunnel closure using one command from the SCADA terminal.

The SCADA system will also monitor the status of the sensor and will present an alarm to the operator if the sensor is offline.

9.8 Tunnel Environment Monitoring

9.8.1 Air Quality Monitoring System:

Monitoring of different level of CO, NO gases and Visibility will be done via the SCADA System. In case the level of the gases exceeds a set value, the SCADA system automatically operates the Ventilation System as described in Para 8.6.5.

The monitoring equipment shall have the following characteristics:

	Measurement Range	**Accuracy**
CO Monitoring	0 – 100 ppm	+/- 1 ppm
NOx Monitoring	0 – 30 ppm	+/- 2 ppm
Visibility Monitoring	0 – 0.015 m^{-1}	+/- 0.0002 m^{-1}
Wind Speed Monitoring	0 – 15 m/s (bi-directional)	+/- 0.5 m/s

9.8.1.1 Monitoring

- The SCADA system shall monitor and record CO, NOx and Visibility measurements
- Alarm will be raised if the measurements reach ventilation trigger values.

9.8.2 Anemometer

Anemometers are provided along the tunnel to monitor the air velocity inside the tunnel. These sensors shall have the characteristics listed in the table above.

9.8.2.1 Monitoring

- The SCADA system shall monitor and record air velocity readings

9.8.3 Temperature Sensor:

Temperature in the TSB should be monitored and an alarm should be raised if the temperature exceeds the equipment ideal operating ambient temperature.

9.8.4 Hydrocarbons Monitoring in Drainage attenuation Tanks

When the drainage attenuation tank or wet sump is directly connected to or under the carriageway a gas detection system shall be provided for continuous monitoring of oxygen, explosive gas and toxic gas levels within the tunnel attenuation tank or wet sump.

This will provide continuous monitoring of the tunnel sump atmosphere and detect any possible presence of flammable liquids spillages in the drainage system or presence of gases that might harm the maintenance operatives.

The appropriate response shall be triggered using either one of the following integrated systems when applicable.

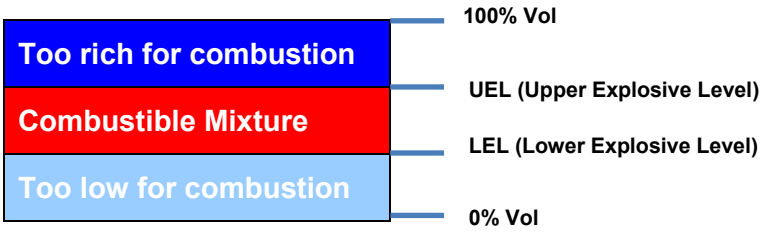
- Sump Ventilation
- Drainage pumps
- Foam suppression system
- Isolation dumpers

The gas detection system shall be explosive proof, have the appropriate ingress protection and have a short detection and response time.

Sensors reading and monitoring shall be arranged in two stages corresponding to low and high concentrations of hydrocarbon gases.

9.8.4.1 Monitoring and Control

The explosive gases concentration must be kept at safe levels as illustrated below:



Alarm thresholds:

The system will monitor the concentration of each gas and if the gas concentration rises above 20% of LEL, Level 1 Alarm response measure is activated:

- Sump Ventilation
- Inhibit drainage pumps
- If the gas concentration decreases to lower than 10% of LEL the ventilation fans receive a command to stop

Return of the drainage pumps to automatic status can only be activated by the operator via the SCADA terminal once absence of any hazardous spillages is confirmed.

If, however, the concentration keeps on rising, when it reaches 40% LEL, Level 2 Alarm response measures are activated.

- Audible alarm
- Level closely monitored by the operator
- Ventilation continues operating

If the concentration reaches LEL, Level 3 Alarm response measures are activated

- The foam extinguishing system activation sequence starts
- Tunnel Closure

Properly designed gas detection systems should rarely or never reach the Level 2 Alarm range.

Fuel leak detection systems in the sump will not offer the required protection provided by Hydrocarbons /Gas Monitoring systems and are not accepted as a substitute for fulfilling the required protection.

9.9 Traffic Monitoring and Control System

9.9.1 Video Surveillance System:

The entire tunnel and utility building should be continuously monitored through a Video Surveillance System with PTZ cameras and all the video feeds should be recorded for an interval consistent with Qatar ITS deployment strategy.

The system shall enable the tunnel operator to view the whole of the Tunnel(s) and their immediate approaches.

The VSC shall be interfaced with the SCADA system, but the control of the cameras shall be done via a camera control console. The operator shall be able to view multi camera images simultaneously.

In the emergency walkways and escape routes, fixed view cameras shall be installed for monitoring pedestrian evacuation.

Mounting height and location for each camera must be designed to provide the required coverage and field-of-view in case one or two cameras become unavailable. Installation locations must also consider ease of maintenance and cleaning.

9.9.1.1 Control and Monitoring

Any incidents triggered by the AID system, Access Control System, Emergency Telephone system, Enclosure Proximity Switches received from the SCADA system will automatically give a command to the VSC system to direct the appropriate camera on the incident area, to record the feed and present a pop up containing the images from the feed on the tunnel operator screen.

9.9.2 AID System

When an AID system is specified and provided it shall facilitate as a minimum the detection of the following incidents in the tunnel:

i. Stopped vehicles;
ii. Slow moving vehicles (speed configurable);
iii. Smoke concentration;
iv. Pedestrian(s) and Animal(s);
v. Large object/debris;
vi. Vehicles moving in the wrong direction.

9.9.2.1 Monitoring and Control

The AID monitoring and automatic control operations through SCADA are listed in the following Response Plan Matrix.

Incident Detected	Systems automatically activated
Stopped vehicles	CCTV , DMS , LCS, Red Traffic Signal
Slow moving vehicles	CCTV, DMS, LCS
Smoke concentration	CCTV, Fire Alarm, Ventilation, DMS, LCS, Red Traffic Signal
Pedestrian	CCTV , DMS, LCS, Red Traffic Signal
Large object/debris	CCTV , DMS, LCS, Red Traffic Signal
Vehicles moving in the wrong direction.	CCTV , DMS, LCS, Red Traffic Signal

When slow moving vehicles or stopped vehicles are detected, the Tunnel Control Room operators will closely monitor the air quality and visibility through SCADA and investigate the cause using CCTV.

In tunnels with no mechanical ventilation the operator may need to close the tunnel if pollution levels exceed tolerable limits.

9.9.3 Lane Control Sign (LCS)/ Variable Speed Limit (VSL) Sign System:

The LCS/VSL signs should be provided within the tunnels and on the approaches, to allow the tunnel operator to manage traffic for various conditions and incidents by providing information/guidance to the tunnel users on lane open/close/change, variable traffic restrictions and variable speed limits.

The operation of the signs will be implemented by the tunnel SCADA system following pre-determined traffic management and control plans. (See Para. 6.4)

9.9.4 Traffic Signals

Traffic signals or an equivalent solution shall be provided at the tunnels portals and should be controlled both manually and automatically by the TPMCS. The traffic signals shall not be activated separately but as part of a full tunnel traffic management system.

9.9.5 Traffic Closure Gates or Barriers

In some tunnels over 1000m long, to ensure that vehicles are not able to enter the tunnel if it is closed for emergency situations, such as fires or accidents; locally operable traffic closure gates or barriers are installed at the tunnel portals and at the entrances of the on ramps approaching the tunnel portals.

For tunnels in Qatar barriers shall be considered for Category D tunnels where there isn't enough distance to provide the appropriately spaced ITS, but can only be implemented if the operational risk assessment concludes that the reduced ITS provisions for these tunnels will not meet the safety levels provided by using a barrier.

For all Cat C & D tunnels where barriers are not required ducting from the tunnel to a pit at a suitable location for installing a barrier or other suitable arrangement, post system installation, shall be adopted for future proofing the installation and facilitating the installation of barrier at a later date if the need is ever identified.

9.9.6 Traffic Detection

A suitable Traffic Detection system, to monitor and provide real-time traffic volumes within the tunnels, shall be provided.

Detected time-stamped historical traffic data shall be collected, processed and archived to assist traffic management and planning.

To avoid duplication of systems functionalities and reduce cost, traffic detection should be achieved through already installed systems when possible. For example the AID system could be configured to provide the traffic detection functionality and remove the need to install traffic detectors (e.g. magnetometers or inductive loops)

The traffic detection system shall be interfaced with the SCADA system to provide the tunnel operator with the following basic information:

- Vehicle Counts
- Vehicle Types
- Traffic Trends
- Historical data

9.9.7 Overheight Vehicle Detection System

When a tunnel is located in a route with potential passage of high vehicles, an Overheight vehicles detection systems should be installed before the last junction on the tunnel approach to allow the over height vehicle to deviate.

When an Overheight vehicle is detected, warning DMS signs with flashing beacons, horns, and signs with strobes are activated. The vehicle will be deviated away from the tunnel.

9.9.8 Dynamic Message Signs

Dynamic Message Signs (DMS) should be placed where appropriate, at the tunnels portals and on the approach roadways to inform and divert tunnel traffic and to clear traffic downstream of fire incidents in tunnels.

DMS messages should be supported by LCS, VSL and Traffic Signals. Pre-determined approved messages shall be programmed into the DMS controllers for implementation.

See Annexe B. for Approved Tunnel DMS messages.

The operator will not be able to write any messages on the DMS without prior approval from the PWA.

9.9.9 Warning and Prohibitive Signs

When the need for dynamic or static warning and prohibitive road signs has been identified, such as:

- Traffic Signal Ahead
- No HGVs
- No Vehicles carrying Explosives or Flammable Materials
- No Cyclists / Pedestrians / Animals

These signs must be installed conveniently at decision points to allow the intended audience to detour and avoid entering the tunnel.

In addition to these safety signs, if other signs may be used (for example, “Turn on Headlights” and “Tunnel”) they should be placed at a suitable distance from the tunnel portal.

All traffic signs must be installed according to the latest version revision of Qatar Traffic Control Manual.

9.10 Fire Life Safety and Security Systems

Fire life safety systems must meet the requirements of NFPA 502. Designer shall consider the following factors in the tunnel fire safety systems design: Tunnel height, nozzle installation height (if a fixed fire extinguishing system is being installed), expected fire load, environmental conditions (e.g., corrosion, sand and heat), water application rate.

However the expected fire load the most critical factor and the most difficult to predict, as quoted in the Fire Protection Handbook, Section 21 - Chapter 11: “One of the major factors to be considered in the fire protection of a road tunnel is the unknown nature of the potential fire load. … for the typical road tunnel, where an innocent-looking truck may be carrying a load that is capable of supporting a fast-growing, potentially lethal fire, but that is not necessarily “classified” as hazardous cargo.”

The design Peak Fire Heat Release Rate for mechanical ventilation for Ashghal tunnels shall be 50MW with a fast growth rate as defined by NFPA 72 Table B.2.3.2.3.6. (IAN 020, Paragraph 11.4.1)

9.10.1 Access Control System

In addition to the CCTV system, an intrusion detection system shall be installed to detect opening of all tunnel escape doors, TSB doors and pedestrian traffic in the egress walkways.

To limit access to only authorised people, card key or code access control with intrusion detection must be provided for access to the TSBs.

Unauthorised entry to the TSB will trigger the intruder alarm system sirens and will send an alarm to the SCADA system to be recorded and displayed on the operators’ screens.

Authorised access will be notified in the SCADA system. For monitoring purposes the SCADA system should record time of access / exit and the personnel who gained access using the info from the access card or the access code used.

Any access of unauthorised person to the TSB shall trigger an Alarm on the SCADA system.

When an opening of the escape door or pedestrian traffic in the egress walkways is detected open the intruder alarm shall send an urgent alarm to the SCADA system

The SCADA system shall send a command to the VSC system to focus the appropriate camera on the opened doors for record and display. Pedestrians in the egress walkway will be monitored via the dedicated CCTV system.

9.10.2 Fire Alarm System

The fire alarm and detection system should consist of an addressable digital system with manual and automatic alarm initiation, automatic heat and smoke detectors, and dedicated signal line circuits.

All installed fire alarm detection and initiation systems such as smoke detection systems, heat detection systems and manual call points systems shall be integrated to one Master Fire Alarm Panel (MFAP) via a dedicated High Level Interface (HLI) for each detection system. The MFAP shall monitor and control all of the connected devices.

The MFAP shall be integrated for control with all relevant fixed fire extinguishing systems such as Foam Fire Suppression System, Clean Agent Fire Suppression System in the tunnel associated buildings and area and Deluge & Mist Systems in the tunnel tubes when applicable.

Integration with other systems is also necessary such as:

- AHU fire dampers
- Air conditioning systems

9.10.2.1 Fire Detection Methods in the Tunnel Bores

Heat detection, smoke detection and flame detection are the typical means of automatic fire detection in road tunnels.

The following are the different types of fire detection:

- Video cameras with Automatic Imaging Detection (AID) technology / Optical Detectors / Aspiration Detectors for smoke detection
- Linear Heat Detection systems for heat detection
- Video cameras with Automatic Imaging Detection technology / Optical Detectors for flame detection

Depending on the criticality and classification of the tunnel one or more of these systems may be necessary to ensure redundancy and increase safety.

The most used type of detection systems in road tunnels worldwide are:

- Linear Heat Detection and AID in the tunnel bores
- Optical, Aspiration (VESDA) and Linear Heat Detection.

For tunnels where an AID system is already provided for other detection requirements it should be also used for smoke detection and avoid installing an additional fire detection system. Unless the tunnel Operational Risk Assessment identify fire detection redundancy as a requisite and 2 or more detection systems including AID are required.

For tunnels where a fire detection system and fire suppression system are required a dedicated fire detection system should be installed in addition to any available AID system.

9.10.2.2 Fire Detection Methods in the TSB

Automatic smoke and heat detectors, manual fire alarm boxes, and horn/strobe alarms are installed in the TSB.

9.10.2.3 Positive Alarm Sequence / or double Knock Alarm Sequence

To prevent false alarms from triggering a fixed fire extinguishing response and resulting in costly replenishing operations and traffic delays, the firefighting systems should be configured with a positive alarm sequence or a double knock alarm sequence.

1. Positive Alarm Sequence:

On receipt of the alarm signal the TPMCS will send a command to the VSC to direct and focus the relevant zone camera on the affected area to enable the operator to quickly confirm whether it is a false alarm or not. The operator will have the opportunity to inhibit the fire extinguishing system if a fire is not confirmed.

After a predetermined time delay the fire extinguishing system will be automatically activated if the operator takes no action.

If the system is not stopped by the operator, a dialler will communicate the alarm to Civil Defence after expiry of the time delay.

2. Double Knock Alarm Sequence:

Two consecutive sensors must activate before the system will go into full alarm and trigger the fixed fire extinguishing system. The operator will have the opportunity to inhibit the fire extinguishing system if a fire is not confirmed after the first alarm.

A dialler will communicate the alarm to Civil Defence after the second sensor is activated.

9.10.2.4 Monitoring and Control

The SCADA system shall:

- Monitor all of the Alarms received and Actions performed by the Fire Alarm system.
- Send commands to the VSC to direct and focus the relevant zone camera on the affected area.
- Have provisions to manually control the fixed fire extinguishing system to enable the operator to manually activate or stop the system from activating.

- Automatically operate the ITS systems, PA system, Air-Conditioning System, Ventilation fans, Pressurization fans and Motorized dampers when applicable.

9.10.3 Fire Fighting Systems

9.10.3.1 Tunnel Standpipe and Hose System

The Water Standpipe and Hose System, including necessary pumps, pressure regulating equipment and fire hose connection, should be installed where applicable as prescribed by IAN 020 and NFPA 502 and Civil Defence requirements.

In case of a fire alarm, the firefighting pump is activated by the TPMCS. Water extraction occurs through fire hose connections.

The major components of the Standpipe and Hose System are:

- One jockey pumps
- Two firefighting pumps (operation mode 1+1)
- Fire hose connections
- Pressure regulating equipment

9.10.3.2 Water Based Tunnel Fire Fighting System

Water Fire Systems (WFS) are installed where required for life and asset protection during fire incidents in tunnels. WFS are normally installed to fulfil the following objectives:

- Control fire
- Cool air temperature
- Prevent fire spreading in the tunnel

The WFS consist of any of the following systems:

- Deluge Sprinkler Systems
- Deluge Water spray Systems
- Deluge Water Mist Systems

- Deluge Foam / Water Mix System (After motorists are evacuated, foam can be activated by the operator to assist fire fighters with extinguishing the fire).

The WFS should have a dedicated fire detection system for automatic operation.

To ensure the WFS are only activated in the affected area in case of fire, it should be divided into zones covering sections of the tunnel with predetermined spans. The dimension of each section is wall to wall with the lengths fixed during the design.

The system must be installed to allow simultaneous discharge of three adjacent deluge zones, in case of a fire, the zone in which the fire is detected and the two nearby zones (before and after).

However, to avoid issues with immediately dumping the deluge water on moving traffic, activation of the WFS shall follow the Positive Alarm Sequence principle described in paragraph. 9.10.2.3 (*Positive Alarm Sequence / or double Knock Alarm Sequence*)

The operator shall be able to manually operate the system from the MFAP and the SCADA terminal.

Tunnel operators shall have up to 60 seconds during the alarm investigation phase to evaluate the fire condition and inhibit the system. (The time delay clock shall be adjustable)

9.10.3.3 Monitoring and Control

The SCADA system should monitor any auxiliary equipment which is critical to the operation of the WFS. For example operation of a valve in a certain zone, operation of pumps, water presence levels…

The WFS will perform all the sequential operations to activate automatically upon:

- Manual activation by Operator
- Receiving an alarm from the Linear Heat Detection system or any other dedicated fire alarm system.
- Operator confirmation of fire as part of the positive alarm sequence
- 15 seconds elapsed with unacknowledged fire detection by CCTV or Smoke Detector
- Second detection by CCTV/Smoke detector
- 60 seconds elapsed with no reset

Any Alarm from one of the detectors in any circuit within the affected area or manual activation by the operator shall:

i. Illuminate Alarm indicator and display allocated indicator for affected zone on local panel and SCADA terminal.
ii. Energize alarm bell
iii. Send alarm signal to MFAP /TPMCS
iv. After time delay sequence completed the WFS shall activate

The TPMCS will perform the following automatic actions when the pre- discharge alarm signal is received:

i. Set TMM plan including DMS messaging for closure
ii. Trigger PA message
iii. Trigger radio rebroadcast (where applicable)

9.10.4 Fire pumps

Fire pumps where installed to maintain any of the firefighting systems water pressure and flow, will operate automatically on demand and their activation is executed by the system control panel.

Manual operation shall be made available locally from the fire pumps control panel. The SCADA system will only monitor the pumps for status, and run hours.

9.10.5 Emergency exit signs

The emergency exit signs guide motorists inside the tunnel to the cross passages and the emergency walkway in the event of an emergency. These exit signs and all safety signs must be connected to the emergency power supply system. It will be desirable to be able to monitor status of these signs for malfunction detection.

9.10.6 TSB Clean Agent Fire Extinguishing System

9.10.6.1 Introduction

Electrical switchgear, communication and control equipment installed in TSB rooms are critical to tunnel safety and availability. This equipment may be damaged by the application of water or other extinguishing agents such as powder and foam.

For this reason it is important to complement the standard building fire safety provisions offered by local regulations with a clean agent fixed fire extinguishing system to protect the electrical assets and ensure continuous operation during a fire incident in the protected area.

Designer shall consider during the system design and selection that protected areas may be temporarily manned and they also shall make provision for ventilating the extinguishing agent storage cylinders storage area to extract any inert gas release caused by cylinders venting to relieve excess pressure caused by high temperatures.

9.10.6.2 Essential Requirements

The clean agent systems are automatically activated by a confirmed coincidence operation of fire detectors in the protected area.

Manual activation shall be possible from the Main Fire Detection Alarm Panel, from the entrances to the protected areas panels and at the Clean Agent Control Panel (CACP).

A manual/override key switch shall be incorporated in the CACPs adjacent to the entrance to all Rooms, to allow personnel accessing the area to lock off the automatic activation.

The status of the system shall be visually displayed at the Main Fire Detection and Alarm Panel, Fire Repeater Panel, SCADA system and outside each door to a room or zone.

Status messages to be displayed are (MANUAL●AUTOMATIC) visual and (PRE-DISCHARGE●DISCHARGED) visual and audible alarm.

The PRE-DISCHARGE alarms are activated at least 30 seconds before the extinguishing agent is released.

The fixed fire extinguishing system shall have the following characteristics:

- Good extinguishing properties (causing the minimum overall damage)
- Enablement of uninterrupted tunnel operation or limited interruption
- Non-toxicity
- Most environmentally Friendly
- Minimal consequential damage to adjacent equipment (water damage, corrosion, pressure blast damage on activation, etc.).

Dry powder automatic extinguishers are not acceptable. To fulfil the requirements mentioned above, standard practice for TSBs fire extinguishing systems is to use an Inert Gas system such as FM200 or the recently introduced environmentally friendly aerosol systems (must be an approved and certified system) such as FirePro.

3.2.3.2 Ventilation Dampers and Air Conditioning Units

If any fire alarm is activated. The ventilation dampers operation and the air conditioning units shut down in the affected zone shall be initiated automatically, when necessary, to ensure effectiveness of the clean agent fire extinguishing system. All area/zone doors should also be designed to be self-closing and shutdown when the fire alarm is activated.

9.10.6.3 Monitoring and Control

A local panel shall be installed adjacent to each access door to a room where the extinguishing system is installed to enable the maintenance engineer gain local control.

The local panel will include:

- An Auto / Manual switch
- An audible alarm
- A flashing strobe or lamp
- Illuminated indication. (Pre – Discharge, Discharged, Auto , Manual)

Automatic operation of the system:

1. Activation of any one of the detectors in any circuit within the affected area shall:

    i. Illuminate Alarm indicator and display allocated indicator for affected zone on local panel
    ii. Energize alarm bell (1st Nock alarm)
    iii. Send alarm signal to MFAP /TPMCS

2. Subsequent operation of a “Cross-zoned” detector within the affected area shall:

    i. Illuminate “pre-discharge” indicator on the control panel and display allocated indicator for affected zone on local panel
    ii. Activate shut down or closures of any associated equipment, such as ventilation dampers, AHU, door or electrical equipment.
    iii. Activate discharge horn/strobe (2nd Nock alarm)
    iv. Start the adjustable delay timer (0-30 seconds)
    iv. Send alarm signal to MFAP /TPMCS

3. After time delay sequence completed the following shall occur:

    i. Activate the fire suppression system

Manual operation:

1. Operation of a “Manual Override”

    i. Illuminate “pre-discharge” indicator on the control panel and display allocated indicator for affected zone on local panel
    ii. Activate shut down or closures of any associated equipment, such as ventilation dampers, AHU, door or electrical equipment.
    iii. Activate discharge horn/strobe (2nd Nock alarm)
    iv. Start the adjustable delay timer (0-30 seconds)
    v. Send alarm signal to MFAP /TPMCS

2. After time delay sequence completed the following shall occur:

    i. Activate the fire suppression system

9.10.7 Foam Fire Extinguishing System

Accidental spillages could possibly introduce hazardous liquids in the tunnel drainage system such as petrol and diesel, which could result in an explosive atmosphere forming in the drainage retention tanks, the reason why hydrocarbon sensing systems are installed as described in section 9.8.4. (*Hydrocarbons Monitoring in Drainage attenuation Tanks*)

Fixed foam extinguishing systems and dry inlets to enable Civil Defence to inject additional foam from the surface when necessary shall be also provided and shall be activated by the final stage of Hydrocarbon gases sensor detection as a preventative measure.

The foam system can also be activated automatically by fire alarm or manually as per the double knock sequence described in sub section 9.10.2.3. (*Positive Alarm Sequence / or double Knock Alarm Sequence*)

9.10.8 Fire Extinguishers

Portable fire extinguishers shall be located in every emergency panel in the tunnels as prescribed in the IAN 020 and Civil Defence Requirements. When the door to the fire extinguisher cabinet is opened, a contact switch is activated and will present an alarm on the SCADA terminal.

9.10.9 Motorized Pressure Relief Dampers and Fire Traps

Motorized pressure relief dampers where installed in the tunnel or in its associated buildings shall be monitored and controlled by the TPMCS.

Depending on the required functionality the SCADA system shall initiate the opening or the closing of the Motorized Dampers or Fire Traps.

9.11 Tunnel Voice Communication Systems

The Voice Communication Systems enable communication between tunnel operators, tunnel motorists and the emergency services.

The main objective of Voice Communication Systems is to enable communication during emergency and to instruct and guide them to exit dangerous areas. It consists of the telephone system for emergency and maintenance purposes, the radio system for radio frequency and voice communication inside the tunnel and of a public address system (PA) for announcements to tunnel drivers in case of emergency.

9.11.1 Radio Rebroadcasting System:

Radio rebroadcasting system where provided shall guarantee uninterrupted radio communication inside the tunnel, at the tunnel portals and inside the walkways. The tunnel radio system allows for two-way radio emergency communication for the following groups: MOI Agencies, Civil Defence, Ambulance Services and tunnel operators. A system is required for communication of fire fighters with the fire command.be located in the communication room in the TSB.

It provides the primary means for voice communication in the tunnel areas during normal operation and in case of emergency.

The detailed design should coordinate with the relevant authorities to determine the required channels and frequencies. Ashghal RMD is currently using the Ooredoo TETRA service and any rebroadcast equipment to be installed in the tunnels shall be compatible with Ooredoo TETRA.

The terminal for the radio system is to be located in the TSB. The SCADA system needs only to monitor the status of the equipment.

9.11.2 GSM Coverage

At the TSB and inside the tunnel, mobile phone antennas and equipment should be installed to provide mobile phone coverage within all tunnel areas where required.

The SCADA system only monitors the status of the equipment

9.11.3 Telephone System

9.11.3.1 Emergency Telephone System

Emergency telephones in the tunnel provide voice communication between persons in the tunnel area and the operator in the local control room or at the RAMC.

The Emergency Telephone System shall be visualised on the SCADA terminal screen. The off-hook emergency telephones are highlighted on the active screen and the view of the nearest CCTV camera shall be automatically shown. The operator can then determine the appropriate response to be initiated.

The Emergency telephone system should be configured to automatically report any problem with the phone or phone line to the TPMCS.

Emergency telephones where installed shall be fast one touch dialling (autodial on handset lift) and can be used in place of manual fire alarm boxes

Emergency telephones should be installed inside the tunnel, inside the emergency walkways and adjacent to emergency exit doors.

9.11.3.2 Maintenance Telephone System

Maintenance telephones should be installed in the TSB to enable operation and maintenance staff to communicate from different locations in the tunnel and its associated buildings. The emergency telephone system could achieve both functions if configured to do so.

9.11.4 AM/FM Radio Rebroadcast System

This system where applicable allows the tunnel operator to break in into radio stations emissions and broadcast pre-recorded announcements to tunnel motorists through their vehicle radio.

The PA pre-recorded messages shall be used for radio broadcast announcements.

Local radio stations are connected to the system, so that motorists can continue listening to radio programmes while in the tunnel.

9.11.5 Public Address (PA) System

The PA system is installed to perform public announcements and enables communications from tunnel operator to tunnel motorists, such as providing verbal direction to tunnel motorists in case of emergency.

The acoustic properties of the tunnel and PA system determine the quality of the audibility in the tunnel and affect the effectiveness of communication during and emergency, for this reason, acoustic properties should be taken in consideration during the design and selection of equipment.

The message shall be audible in all parts of the tunnel including, emergency corridors and galleries.

The PA messages shall be in two languages Arabic and English and played sequentially.

The tunnel operator can play back pre-recorded messages at a press of a button he will also be able to make announcements through the PA console microphone and able to select broadcasting zones separately.

Poor audibility of the PA announcements to motorists could be addressed by use of the re-broadcasting system mentioned in Para. 9.11.4, it allows messages to be received via the car radio. However, the PA is still used once the motorist has left the vehicle, or if they do not turn their radio on.

The PA messages are automatically activated by the SCADA system to respond to a particular tunnel incident. It can also be manually used to announce message by the Control room operators or from the SCADA system.

SCADA system shall automatically activate PA system in response to pre-defined alarms.

A PA system pre-recorded messages library shall be made available for announcement through SCADA. Additional pre-recorded messages can be announced from the SCADA System and added to the library.

See Annexe C. for approved text to be used to record Tunnel PA messages.

9.12 Data Transmission and Control Systems

9.12.1 Communications Network

The tunnel communication network should be a redundant, fail-safe LAN and WAN Ethernet network using copper and fibre optics based structured cabling with remote I/O units monitoring status and alarms. Connectivity should be provided locally in the TSB and remotely in the RAMC.

Status of all routers and switches within the network should be monitored by the tunnel SCADA for faults and unavailability.

9.12.1 Wireless and Bluetooth Communication

The availability of wireless and Bluetooth communication will open a multitude of opportunities for increased safety and improved response and operation. This technology is not being proposed at present.
Other technology solutions could be considered in the future such as using GPS information; live internet updates (google maps...)

9.13 Miscellaneous

1.1 Air- Conditioning Units:

Air- Conditioning Units are provided in TSB rooms to maintain the recommended ambient temperature for the tunnel systems.

In case of fire, the respective TSB room Air-conditioning unit is automatically switched off by SCADA. When the fire alarm is re-set, the SCADA system automatically activates the units.

10 Staffing

The following defines the minimum staff level necessary to ensure operational and maintenance of Ashghal tunnels is in accordance international best practice.

10.1 Tunnel Manager

The person with overall responsibility for matters relating to the administration, operation and maintenance of tunnels, as defined in Regulation 8 of the Road Tunnel Safety Regulations 2007.

10.2 Senior Tunnel Engineer

The Tunnels Manager's deputy assisting in matters relating to administration, operation and maintenance of tunnels.

10.3 Maintenance Engineers

Reporting to the Tunnel Manager in matters relating to tunnel maintenance, ensuring tunnel maintenance is conducted in accordance with the relevant standards.

10.4 Tunnel Control Room Operator

The role of the operators will be the routine monitoring of the system, fault and incident management on a 24/7 basis using: CCTV; the Tunnel SCADA and other installed ITS. All operators will be trained on the use of all tunnel systems and procedures. They will also be trained on compliance with CCTV and Control Room regulations and protocols.

10.5 Tunnels Standby and Call-Out Team

10.5.1 Tunnels Duty Manager

The Tunnels Manager and Senior Engineer will be on a rolling weekly standby roster for incidents requiring a Tunnels Duty Manager. For minor incidents the Tunnels Incident Response Unit (IRU) will be called out to deal with the situation and the Tunnels Manager or his deputy will be informed via a text message followed by a report the following day.

10.5.2 Incident Response Units (IRU)

Emergency response call out will be carried out on three levels:

1- Level 1: responses by network Incident Response Vehicle (IRV) for general issues (i.e. Debris removal, surface patching, drain blockage related flooding);

2- Level 2: responses by Tunnels core team or third parties for tunnels specialist systems or operational issues.

10.5.3 Tunnels Core Maintenance Team

All team members involved in the tunnels operation and maintenance, either on full time or as required basis will be trained on the basic operation and maintenance of tunnel systems. The core maintenance team members will have further training to be able to carry out advanced fault finding and diagnostic procedures on tunnels systems. All operational personal will have the necessary standard training (i.e. MEWP operation, Confined Space Entry and all relevant safety training).

Tunnel Staffing will be covered in details in the Tunnel Operation and Maintenance Manuals.

Appendix A: Ashghal RDD Comments Review Sheet with RMD Responses

Comments Review Sheet 02/05/2016 with RMD Responses

The following table details comments provided by Ashghal Road Design Department concerning this Tunnel Concept of Operation Document and the Responses from Road Maintenance Department. The responses have been discussed and addressed during TDSCG Meeting No 5.

Number	Comment	Response
1	List shown in page 7 of 74 is just indicative? Cannot considered as exhausted when missing Lighting/ Luminance operation & conditions response management for example.	The rest are usually covered by standards and functionality is the same for all tunnels, but will indicate in the paragraph that the listed systems are examples.
2	What is the difference between a DMS (Dynamic Message Sign) and an Enhanced Message Sign technically, and what's the reason /purpose of this segregation?	Same- Enhanced Message Sign- removed -
3	At 2.4 (page 16 of 74) "*Provision should be made for interfacing the local TMS with Master Traffic System in the RAMC using standard Modbus protocol*" may we put in a more generic way without the phrase: ~~*—using standard Modbus protocol .*~~ —Or just associate it with provisions of 8.3.2. "PLC Network", in a generic form, not specifying protocols or technical details, just the philosophy of interfacing/interconnection which needs to be served.	Changed to " Standard Protocol (to be confirmed with the Project Management Consultant)"
4	At 2.4 (page 16 of 74) there is mention about "auxiliary remote facility with full management capability". What will be the type of this facility and what kind of "rights" will have (in access, operation, management, etc). How will be authorized and controlled, etc.	This is a fall back facility and should provide full operation. The rights and access arrangements are similar at all locations as described in para 9.3.5. Will elaborate in the paragraph to make it clearer.
5	3.1 – Tunnels operation: About approaches' ITS, where it is considered a limit (or should considered a limit)? The discretion of duties and area of responsibility between Tunnel operator and RAMC operator. Should remain in such a general level view or define some terms in responsibilities, area of coverage-distance, devices under control, etc.	The limit should be considered as per NFPA 502 1. Stop traffic approaching tunnel portals 2. Stop Traffic from entering tunnel's direct approaches The designer should use the standards to identify the limit to include diversion. Paragraph 4.2 added to define the limit (Please note 3.1 is 4.1 now)
6	3.2 – same as before, maybe need to consider defining Zones of Control (for Tunnel operators/management)	Only "ITS" that is integrated with SCADA to fulfil the objectives listed in the response for 5 are controlled by the tunnel operator. This has been added
7	8.3.4. –"SCADA functionality" – Do we expect SCADA system to be able to run/apply predefined scenarios/sequence of events (kind of smart automatic management), other than isolated parameters' keeping/monitoring and 1-step response? Do we need a "low level" "less complexity" SCADA tool of simple tasks-responses, or should be a mention for a SCADA with advanced capabilities and more complicated properties/ actions?	8.3.4 Now 9.3.4: Only lists all necessary SCADA functionalities. How they are combined for each system will be dictated by the operational requirements for each system. Systems Integration added to the list.
8	8.6.5.1 and 8.8.1 : "Air Quality Control" – where they come the values/ thresholds shown on table for ppm limits, etc? Is it right to provide such values and in such way to a ConOps document? (maybe should be a matter of the Tunnel Manual later on, not at this stage)	PIARC Technical Committee Report: Road Tunnels: Vehicle Emissions and Air Demand for Ventilation - 2012. Due to the absence of Specification Document for each tunnel system we run the risk of ending up with inconsistencies in the designs, so we need to provide the values. Will add the reference to the PIARC document and point out that the value for each level can be adjusted. Now 9.6.5.1 and 9.8.1

9	In comparison with comment 8 above, what about Lighting/ Luminance or even for smoke and visibility issues? There is no correspond table with relative thresholds, zones, timings, limits, etc. For consistency reasons and keeping the origin of purpose for a high level document, like ConOps, either should provide all the details for all subsystems the same way here, or (recommended) leave these details for the Tunnels Manual by reducing the volume of the Conops document, and keep only the principles and general operation philosophy.	Visibility is covered in the table; lighting luminance is covered under the lighting system not the ventilation. Lightning is covered extensively in the CIE88 Standard which applies to tunnels in Qatar and we should not need any more explanation than provided in 8.5.
10	8.7.3 – "Flood Warning Sub-system" : Is there any text missing or just a typo-?	Typo
11	1.1 - It mentions Tunnel Operations Authority without defining the Authority. How is it formed? Does it exist?	Presently Ashghal but it could change to the Ministry Of Transport and Communication. In the context of this document we look at the Function rather than the physical organisation.
12	1.2 - It mentions Tunnel Operations Authority without defining the Authority. How is it formed? Does it exist?	Definition will be added to glossary of terms and definitions
13	2.2 - First define Tunnel Service Building	Already defined in the commonly used terms table, will add in the relevant paragraph
14	4.3 - Mention Shutting down of the Tunnel and appropriate Traffic Diversion	It is a general description of operating mode which will include many actions one of which is closing the tunnel and traffic diversions, the focus was intended to be on the systems. Closing the tunnel will be covered in the document.
15	4.5.2 - Add: Partial closure may be considered	added
16	5.1 - Change as follows: *When there is a need to shut down a tunnel whether fully or partially, a properly laid out Traffic Diversion Plan is warranted to divert daily tunnel traffic onto the adjacent roadway network. These plans should be prepared well in advance of any eventto cater for all possible scenarios.* *The Traffic Diversion Plans shall be developed to cover each tunnel closure scenario. The plan shall include all the pre-planned diversion routes. The plans should specify the function of each traffic signal and messaging sign on the affected route during the diversion implementation.* *Typical functions may include adjusting the traffic signal timing and phasing to channel unexpected traffic flow. Also, a pre-planned, Pre-approved messaging sequencing needs to be implemented at all the DMSs in the vicinity of the closure area. This would greatly help raising awareness of the incident which may positively result in some self-re-routing by Traffic much before the congestion point.*	Ok - But *Traffic Diversion Plan* will be changed to Tunnel Diversion Plan.
17	5.4 - Last Para: Delete the word "shall" for proper sentence continuation	OK

18	8.6 - Para 2: What about the tunnels >240m <1000m?	Reference to IAN 020 will be added.
19	8.9.1 - Last Para: Should we delete "non-consecutive"? Doesn't the philosophy apply to any camera malfunctioning?	It may be very difficult to provide coverage if 2 consecutive cameras are out. Confirmed in the TDSCG meeting. The number of camera specified in the ITS design will provide necessary coverage. The paragraph amended accordingly
20	8.9.7 - Para 1: Dynamic Message Signs (DMS) should be placed for the tunnels where appropriate; at the tunnel portals and on the leading roadways to inform and detour tunnel traffic and to clear traffic downstream of incidents in tunnels.	amended accordingly
21	8.9.8 - Last line: All traffic signs must be installed according to the latest Qatar Traffic Control Manual.	amended accordingly
22	8.11.4: Add the clause to include Bi-Language for PA systems	included
23	Tunnels Classification is an important concept that should not be a sub section under section 2 Tunnels Facilities. It is recommended that the Tunnels Section is converted into a section of its own.	A section has been added: 2. Tunnels Classification and Geometric Design. All other sections numbering has increased by 1.
24	Tunnels Facilities section requires a chapter dedicated to Bored Tunnel sections. Design and operation approaches depend on the cross-sections design, bore geometry, number of bores, merges, diversions, cross passages, etc.	Most of the tunnels being constructed are cut and cover, the only exception perhaps is P028 tunnel? Consideration should particularly be given to cross-sections when refurbishing existing tunnels where there are constraints with equipment installation. For new tunnels the minimum traffic envelope dimensions should be accounted for in the design and the cross-sections should cater for it. Cross passages, Escape routes, are all part of the design process and the requirements should already been identified in the Operational Risk assessment. However due to the lack of a Qatar Standard Tunnel Design document which cover in details tunnel geometrics, a section will be added : Tunnels Classification and Geometrics. A small paragraph will be added to direct the readers to BD78/99.
25	Tunnels Facilities contents do not contain any reference to tunnel approach and exit road sections. Tunnel operations and management plans should be inclusive of exit ramps prior to tunnel entrances. Tunnel exits and emergency services facilities need to be considered.	**Agree** and will be extensively covered in Tunnel operations and management plans. A brief mention will be added to this document.

26	The document is described as a concept of operations, but includes design requirements, as an example section 2.2. For avoidance of doubt, design and operation requirements should not be mixed in a concept of operations document.	There is a lack of standard Design Specifications for each tunnel system. 2.2 Now 3.2 are minimum requirements for carrying out the essential controls by the tunnel operator and are included for consolidating the design due to the lack of the necessary specifications. Same apply for all other systems, it intend to give the operator requirements without going into too much detail.
27	Section 2.3. The expectation would be that the system presents the information of any event detected to an operator with a suggested action to be carried out. Operator acknowledgement of the information presented in a pop up window on screen is a requirement. Programmed sequences of operation are to be limited to the event that the control system is not reachable by an operator, in this case, loss of communication, or disaster, that sets a part of the Plant out of service or unable to reach a higher level of the control hierarchy. The reason for this suggestion is that automated systems are unable to handle exceptions to the predefined scenarios and may choose a sequence of operation that is not fit for purpose. When an operator is not available to acknowledge the action to be carried out automatically, then the system shall have a predefined failsafe operation mode to either keep the tunnel open or close the tunnel under degraded operation conditions. This would probably be best addressed with further research on the anticipated operational scenarios and a comprehensive non-linear layered event matrix.	This true for some cases but there are many cases where programmed automatic control is necessary and should not rely on operator intervention: Example: Detection of trigger levels hydrocarbon in the sump = automatic inhibits the drainage pumps, operation or inhibit of the AHU. The suggested approach however is only necessary on a number of predefined scenarios where confirmation of the operator is necessary. The different scenarios responses will be defined for each particular tunnel by the designer using the Tunnel Incidents Response Matrix (Escalation mode: confirm or automatic control)
28	It is recommended to include sections which define what is an operator, who is an operator, the training and skills requirements for the operations staff for tunnels. The same should apply for supervisors and maintenance engineers. Consideration for training programs, courses, tests, certifications, etc. should be made.	The tunnel operator responsibilities are described in 4.3. Tunnel O&M staffing , training, competency management, will be described in detail in the Tunnel Operator Manual, this information is not deemed necessary for the tunnel system designer and the construction of the tunnels. A brief description of each role will be added in a section 10.
29	Scenarios that cover tunnel operations and require documentation for non-operators, like police, fire brigades, etc. are missing. These processes and scenarios are a fundamental support mechanism in managing potentially dangerous incidents and need to be covered with this document. Emergency responders are critical to tunnel safety and incident resolution.	Documentation for first responders is always covered in the emergency plans not the CONOPS. See 8.1. The emergency services design requirements should be covered by the designer for each particular tunnel.

30	Our view of the event matrix is that the current listing is linear and does not cover a multiple event stacking scenario. As an example we note that dangerous goods vehicles frequently travel through tunnel and underpasses, including those carrying radioactive materials. A combination of a vehicle stoppage followed by a fire and secondary and tertiary issues caused by spillage of radioactive materials needs to be considered as an example. How to respond and whom in this case is not clear.	Linear event matrix provide all the necessary information to the designer to develop concise system integration with one button touch control and a manageable number of I/O and provide the operator the necessary functions to address multi event scenarios wish will usually be included in the operators manual (training)/ Emergency plan. First responders response is covered in the Tunnel Incidents Response Matrix
31	In operation the possibility exists for multiple different events in multiple different lanes in all directions of traffic occurring at the same time. The operation of tunnels is therefore different and more complex than the matrix presented in this document. Further development is required to assess all scenarios in full. It is not recommended that fully autonomous automated operation is used when an incident is detected. Exceptions to this include the loss of communication which would imply that operators are therefore not available to assess the incident. In this case the system shall set the tunnel to a safe closure or reduced service level, whichever is safer.	For the possibility of multiple different events see response above All tunnels in Qatar are unidirectional In the Tunnel Incidents Response Matrix the location is left blank to allow for inclusion of all possible locations when developing the matrix for each particular tunnel.
32	We note that the tunnel systems section requires more detail and attention to move more towards operations rather than a focus on specifications.	This is a generic document to be used for developing more detailed information for each particular tunnel.
33	Section 3.3 Clear roles and responsibilities are to be defined for all of the staff involved in tunnel operations, including supervisors, maintenance engineers, etc. Please identify all the relevant staff for tunnel operations and provide such definitions for all of them. Include the relevant Authorities having Jurisdiction over tunnels operation as stakeholders.	This information will be included in the Tunnel Operation Manual. But a brief description is included in the Section 10.
34	Partial Capacity System Operation is called Degraded Operation Mode. Degraded Operation mode definitions and scenarios need further development, and are closely related to the outcomes arising from the event matrix.	The main degraded scenarios relevant to the development of the I/O list for systems integration are included in the Tunnel Incidents Response Matrix. The rest are operational issue and do not affect the level of integration of the systems and are usually addressed using soft element not systems and will be included in the Tunnels Operation Manual.

TDSCG Member: PWA - RDD - ITS team *(rev.1 – combined)*

Appendix B: PMC Comments Review Sheet with RMD Responses

Comments Review Sheet received 12/06/2016 with RMD Responses

The following table details comments provided by the Expressway Project PMC (KBR) concerning this Tunnel Concept of Operation Document and the Responses from Road Maintenance Department. The responses have been discussed and addressed during TDSCG Meeting No 8.

Review No: P000-G052-01-R0

Project: TDSCG - Tunnels Working Group

Supplier Transmittal / Submittal No. : AAR ALF-052

Supplier Transmittal Title: Tunnels Concept of Operations - Draft

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Qatar Deserves The Best

Date Document Received: Mon 02/05/2016 09:01

No	Comment	by	Response	by
1	Paragraph 8.2 **"The list below represents all the systems which should be integrated into the TPMCS"** This statement needs to be amended as it reads the SCADA will monitor/control all and every system mentioned, leading to excessive design and increased MEP & SCADA installation and operation cost. Not all the systems are necessary to be monitored / controlled through SCADA. This can be further discussed to decide which system needs to be integrated to SCADA.	HA	This has been corrected during first review reading, the latest revision has: **"The list below represents all the systems which could be integrated into the TPMCS"** which makes it less prescriptive. However depending on the need of the TOA all the systems could be necessary to be monitored, especially for unmanned tunnels.	Salim Azzi
2	Paragraph 8.2 - Add the ''staircase pressurization fans'' to the systems - Add the ''Tunnel and TBS emergency lighting and exit signage system'' to the systems - Amend item 15 to read ''Manual Override Panels'' for more clarity as it covers both MEP and ITS override panels. - Amend item 17 to read ''Tunnel fire suppression systems'' normally the fixed fire system is referred to the sprinkler system - Amend item 29 to read '' TSB HVAC system''	HA	8.2 now 8.2 is a general list of all systems Item 1 &2 : normally Escape Route Pressurization is a tunnel ventilation sub - system and Tunnel and TBS emergency lighting and exit signage system are a sub system of Lighting and fire safety and are listed further into the document within the relevant system section. item 3: For consistency with the EXW appellation will change to" Manual Override Panels" Item 4: Fixed fire extinguishing system is as per definition what we are accustomed to in tunnel operators jargon , it could be Fixed water fire extinguishing system (in this case sprinkler, mist or deluge system) Fixed gas fire extinguishing system and so on. Item 5: done	Salim Azzi

3	Paragraph 8.2 **"For Tunnels with mechanical ventilation for smoke control, it is best practice to install Fireman Panels (FPL) at the tunnel entrance portals to Control the ventilation, PA when applicable and lighting."** I believe it is most practical to install the MEP & ITS override panel in the tunnel control room so only the trained operator is responsible to deal with it. The civil defence presumably are not familiar with these panels and what are the facilities installed in each specific tunnel	HA	Will change from **best practice** to **common practice** as this is normally used by tunnel operators especially for unmanned remotely monitored tunnels where there is a risk of loss of communication and the fire services as first responders need to take basic control of the most critical systems during a fire incident on scene. It is considered **Best Practice** by tunnel operators in the UK.	Salim Azzi
4	Paragraph 8.3.1 **"The tunnel systems listed above should be monitored and controlled by the TPMCS, which should be executing the following functions"** Same as comment 2	HA	added "when applicable"	Salim Azzi
5	Paragraph 8.3.2 **"The PLC installation shall be in a Master/ Standby configuration to ensure redundancy and continuity of operation in the case of PLC failure"** We understand your concern to attain the maximum system availability, but the ideal 100% availability cannot be attained in reality. Selecting a robust PLC manufacture can ensure highest system availability with early fault detection and diagnostic capability. Relaying only on one PLC with no hot standby can be economical choice if the maintenance quick response and technical support can be assured. The override panels, standalone subsystem controller and the local control panels can all be considered as a mitigated solution during the master PLC failure. This needs to be further discussed and agreed together.	HA	This is standard design for Tunnel SCADA Master PLC to have redundancy and is in line with GF Specimen Design that has been endorsed by Ashghal.	Salim Azzi
6	Paragraph 8.3.4 **Overall functionality of the TPMCS includes, but is not limited to, the following:** **- Monitoring of electrical supplies and distribution (DNO and Emergency)** **- Monitoring and control of other HVAC** **- Monitoring of panel door contacts** Same as comment 2, these two items is not necessary to be monitored / controlled through SCADA. The temperature sensor installed in TBS is enough to be monitored. The monitoring of electrical supply and distribution should be specified to be limited to the main panels i.e. transformers, SMDB, Generator, ATS, and main DBs only.	HA	This is meant to be a general statement and may **include** has been added to the statement - Transformers, SMDB, Generator, ATS, and main DBs are the electrical supplies and distribution. For item number 2 - We must shut down ventilation and Air conditioning units is case of fire detection prior to triggering the fire suppression system. HVAC - TSB Ventilation is also often monitored for faults such as filter dirty, dumper close /open/ fault, Air con fault etc. - monitoring of panel door contacts are panel doors in the tunnel.	Salim Azzi
7	Paragraph 8.3.7**"The following Popup windows should be available for control functionality"**Please don't limit the popup windows to the mentioned items and allow for additional windows that can be added when necessary	HA	Has been changed to the following during the first review reading: "The following main graphics mimics shall be included as a minimum: "	Salim Azzi

8	Paragraph 8.3.10 **"The tunnels local control rooms where specified, shall be designed and equipped for 24/7 operations with at least two operator workstations"** What is the required number of operator workstation in case that one control room will monitors more than one tunnel ?	HA	Added supervisor workstation. The Tunnels will be monitored remotely from the RAMC, local control rooms servicing more than one tunnel have been addressed in 3.2 But in some cases where a small number of lower category tunnels are clustered in the same geographical area one local operations room with Option 2 provisions shall be used to service all the tunnels within that specific area. 1. One workstation provision static or portable, including a SCADA terminal, a CCTV monitor and controller and any other necessary console. 2. 2 Workstation desks and 1 Supervisor desk, each comprising a SCADA workstation with 2 Monitors, one video wall with multiplex functionality a CCTV controller and a PA console where applicable. (the number of operators monitoring more than one tunnel will depend on the tunnels complexity and the mental load of the operators for example in our case P003 AND P012 where few tunnels are controlled from one room 2 operators with a team leader is sufficient)	Salim Azzi
9	Paragraph 8.4 **"An online Uninterruptable Power Supply (UPS) shall be installed to provide power to critical loads for which a momentary power outage or interruption is not acceptable"** Please remove the –''All emergency lighting'' item as it is already repeated. Please amend the – ''Tunnel emergency lighting'' to read Tunnel and staircase emergency lighting and exit signs or add as necessary	HA	changed to: • Tunnel emergency lighting • All other emergency lighting • Emergency signs	Salim Azzi
10	Paragraph 8.4.1 **"4. LV Supply, Monitor status of Breakers''** Same as comment 9, the item can read that all LV CB will be monitored, I believe that only the necessary CB needs to be monitored rather than all of them for cost saving for MEP and SCADA	HA	Again this is a general statement: •Monitor Status of breakers is different from Monitoring Status of all Breakers. There are now cost effective provisions to monitor all breakers within the LV panels (i.e. Schneider) to enable predictive maintenance. But for clarity it has been changed to include essential breakers only. 8.4.1 is now 9.4.1	Salim Azzi
11	Paragraph 8.4.1 **"5. Generators"** Normally the generator will be communicated with the SCADA through Modbus communication rather than the hardwired, thus most of generator signals can be monitored in SCADA such as the coolant level, engine temperature,…..etc. the fuel tank level will remain hardwired interfaced	HA	The intention in this paragraph is only to describe what needs to be monitored and controlled the how is for the designer to decide there is no mention of hardwired.	Salim Azzi
12	<u>General Comment</u> I would prefer to add a general statement in all the system monitoring saying that the stated monitoring signals are not limited to whatever mentioned and will follow the final approved I/O list, we might need to add more signals to be monitored for each system	HA	Will change where necessary to: Monitoring and control of the xxx System shall include but not limited to the following. But in some particular cases we do not need excessive amount of I/Os.	Salim Azzi

13	Paragraph 8.6 **"But as per the new 2014 revision of the NFPA 502 ventilation shall not be required for tunnels with lengths less than 240 metres and is only mandatory for tunnels with lengths equal or over 1000 metres."** The NFPA 502, 2014 specifies the 1000m mandatory requirement for the emergency ventilation and not applied to the normal mechanical ventilation requirements. It is meant to specify that the mechanical ventilation provided shall be of fire resistance material in tunnels equal to or over 1000m in length. Please revise	HA	The geometry of tunnels being built in Qatar and the traffic characteristics is such that it is highly unlikely that mechanical ventilation will be required to keep acceptable pollution levels in tunnels lower than 240 metres. The statement is correct: 1000 m and plus Tunnels: Ventilation is mandatory, tunnels under 240 m ventilation is not required and tunnels between 1000 and 240 is conditional mandatory requirement to have ventilation for pollution or smoke control. The sub section has been further developed to address the comment. 8.6 is now 9.6	Salim Azzi
14	General CommentAs far as the SCADA and PLC system will be provided in all tunnels, thus it will be cost effective if we will allow the SCADA to perform specific control functioning and omit the different system controller. As an example, the SCADA can control the operation of jet fans based on the air quality monitors readings. So we can omit this function from the Ventilation control system and the ventilation supplier will provide only equipment rather than a complete system with controller. This needs to be further discussed and agreed together. It will benefit in a huge cost saving if such approach be implemented and becomes a generic approach in all expressway tunnels	HA	This is already stated in the document for example for ventilation: in 9.6.5 "Monitoring and control of the Ventilation System shall include but not limited to the following:Automatic controls should be handled by the Master PLC. Precautions should be put in place to avoid overloading the electrical supply when starting the fans. A sequential start of the fans is usually implemented to solve the overload issue."	Salim Azzi
15	Paragraph 8.6.6.1 Please don't limit the air conditioning system provided for tunnel service building or attenuation tank to the AHU, we might use DX system or individual split AC system, normally the AHU will require a chiller to supply chilled water and this additional cost will not be justified	HA	AHU per definition is a system used to regulate and circulate air and could be any of the options listed.	Salim Azzi
16	Paragraph 8.7.1.1 Tunnel Drainage Monitoring **"The tunnel SCADA system shall interface directly with the drainage SCADA system to obtain the following information"** It is not clear to us how will be the interface between the Tunnel SCDA system and the drainage SCADA system. Which system will obtain the information from the other system? How the drainage SCADA will be connected to the tunnel drainage system? What is the case if the drainage SCADA is failed?	HA	This is just to specify our requirement as tunnel operators it is up to the designer to come up with the solution, normally the tunnel SCADA cover all systems in the tunnel but in our case, the drainage department manage the pumping stations, if the drainage SCADA fails the drainage department will be alerted and will deal with the issue, a loss of communication Alert will be presented to the Tunnel SCADA System.	Salim Azzi
17	Paragraph 8.7.2 Sewage Holding Tank Please allow the possibility for discharging the sewage holding tank accumulation into the nearest public sewage network and not only being emptying manually by tankers	HA	My understanding is that the public sewage network is not available in most cases. But it has been included.	Salim Azzi

18	Paragraph 8.10.1 We don't see any beneficial purpose for interfacing the access control system to the SCADA, do we really needs to monitor this system on SCADA or it can be omitted?	HA	It is essential, the TSB contain critical systems and the tunnels will mostly be unmanned. This is best practise in tunnels.	Salim Azzi
19	Paragraph 8.10.2.4 Normally the fire alarm control panel FACP will be installed in the control room, is there any need to interface it with the SCADA? if the intention is to continuously monitored the fire alarm system when the tunnel is unmanned after the Central traffic control system is in service, it can be communicated directly without going through the local SCADA	HA	Communicated, by a dialler? With thirty plus tunnels this is not practicable, we do not need the operators to be dealing with a multitude of systems, interfacing of FACP is necessary.	Salim Azzi
20	Paragraph 8.10.3.1 • **Two jockey pumps (operation mode 1+1)** The design of standpipe and hose system in all expressway projects is relaying on only one jockey pump to compensate the slight pressure drops. Please revise	HA	Has been changed	Salim Azzi
21	Paragraph 8.10.5 We don't see any necessity to interface the emergency exit signs to the SCADA. Please Clarify if there is a necessity to do that	HA	It is not absolutely necessary but it is useful to know if any sign is out. (It will be desirable to be able to monitor status of these signs for malfunction detection has been added. to leave the option open.)	Salim Azzi
22	Paragraph 4.5.2 VIP closures will not always be through QPRO. This type of closure doesn't fit in 4.5.3.	RA	VIP Closures in terms of systems are similar to any other closure, and due to senility and security the procedural particularities will be dealt internally by the relevant operational staff.	Salim Azzi
23	Paragraph 5.1 Are tunnels which are pre-opened as part of construction phasing covered?	RA	Tunnels which are pre-opened as part of construction phasing will not be handed over to RMD and will not be deemed complete. (It is not in this Concept of Operation scope)	Salim Azzi
24	Paragraph 5.2 Define WZTMG.	RA	a brief definition added in the first part of the Glossary of terms and abbreviations.	Salim Azzi
25	Paragraph 6.1Should tunnel events matrix be attached, or referred to?	RA	The document could be used as standalone once some short user instructions are added- it can therefore be attached as an Annexe. Same for PA and DMS	Salim Azzi
26	Paragraph 6.1 Include tunnel strikes/tunnel structure damage, and sand accumulation inside tunnels and at portals..	RA	Tunnel strikes and tunnel structure damage has been included in Event Id TV06.	Salim Azzi

27	Paragraph 7.1 Append a sample emergency plan?	RA	Not necessary in this document.	Salim Azzi
28	Paragraph 8.2 Note that the Civil Defence have not commented on FPLs, and as such these are missing from all EXW designs.	RA	The mention of this fireman panels is meant to be as a guidance not a requirement as this is common practice often used by tunnel operators especially for unmanned remotely monitored tunnels where there is a risk of loss of communication and the fire services as first responders need to take basic control of the most critical systems during a fire incident on scene.	Salim Azzi
29	Paragraph 8.3.10 This report has earlier described two tiers of control rooms; one with one workstation and the second with two workstations. To the contrary, 8.3.10 states all control rooms will have at least two workstations.	RA	8.3.10 is now 9.3.10 and has been amended to refer to earlier description in paragraph 2.2	Salim Azzi
30	Paragraph 8.6.1, 8.8.1 Sandstorms to also trigger fans.	RA	Starting the fans during a sandstorm will risk introducing more sand into the tunnel. During sand storms the sand is expected to accumulate at the approaches and portals.	Salim Azzi
31	Some spelling/grammatical errors. E.g. SACADA in Section 8.8.4.1 (page 50)	RA	noted	Salim Azzi
32	Paragraph 8.9.2 Note that AID in the EXW designs have largely synced AID cameras to breaks in the median - cross passageway doors.	RA	noted	Salim Azzi
33	Paragraph 8.9.6 EXW designs also have loops/MAGs in tunnels.	RA	noted and will be mentioned	Salim Azzi

Annexe A: Tunnel Incidents Response Matrix

The Tunnel Incidents Response Matrix table represents a typical Tunnel Incidents Response Matrix including all the relevant elements of a tunnel incident management.

The Matrix is generic and needs to be further developed by the project team of each tunnel specifically taking in consideration its various characteristics.

The outputs from the fully developed Tunnel Response Matrix for a specific tunnel will provide the inputs necessary for the development of that tunnel's systems integration plan.

The events in the Tunnel Incidents Response Matrix are divided into four groups:

- Vehicle related event
- Non –Vehicle related event
- Tunnel systems related event
- Planned maintenance and special events

Each row contains a tunnel specific event corresponding to one of the groups listed above and the columns represent the following:

Incident ID: Each Incident will have a unique identification tag

Incident: Incident description

Location: When further developing the matrix for each specific tunnel the project team will need to consider the various locations within the tunnel where a particular event could occur and make any necessary changes to the actions in the relevant columns. (Example: A vehicle breakdown in lane one or two or three will result in the implementation of different traffic plans).

Monitoring/ Detection / Triggering System:

Manual: the operator monitoring the tunnel via CCTV and the SCADA terminal could detect an event, or receive a notification call through the public phone network or any Emergency Road Telephone located in the tunnel.

Auto: An event could also be notified automatically by a tunnel system, for example the AID system will detect smoke and trigger an alarm. (The AID in this case is the triggering system)

Escalation or Response Modes:

Confirm Mode: The operator confirmation is required before escalation to other mode. Time delay is required for automatically triggered systems to allow the operator to confirm and stop the operation if necessary.

Response Mode: Manual or automatic response, it is the automatic operation of a system triggered by another system, or manual operation of a system triggered by human intervention. (E.g. ventilation fans operating automatically when the pollution level in the tunnel reach a programmed trigger value)

Control Mode: Manual or automatic response, This is the same as the Response Mode in terms of activation, but in this case the triggering system or human operator has priority and can take control of the controlled system even if it is already in the Response Mode, and will only relinquish control to a higher hierarchy system or operator. (E.g. Fire in the tunnel

response will, by way of the Fire Alarm System or the operator via HMI, automatically take control of the ventilation fans even if the ventilation fans are already in operation for pollution control)

Evacuation Mode: Full tunnel closure and evacuation of all road users.

Fire Response Mode: Only applicable when an extinguishing system is installed in the tunnel to control fire (e.g. Water Deluge System) and a fire incident has been confirmed. The relevant extinguishing systems will operate following a positive Alarm Sequence / or Double Knock Alarm Sequence.

Recovery Mode: Is when a system migrates from a response state to its normal state automatically (e.g. Electrical Power Change over switch transferring the tunnel load back on the main incoming supply from the generator, when the electrical power supply is re-established.

Maintenance Mode: When the systems are made off line for maintenance or are operated for a determined amount of time and regular intervals (e.g. the ventilation fans and the drainage pumps.

Sub-System Responses: A sub-system response initiated by a response mode.

Automatic: This is activated, by a triggering sub system

Manual: This is activated by the operator for a manual response.

Other Actions: Are actions to be completed by the control room operator, but some could be automatic (e.g. the fire alarm could be programmed to dial the nearest Civil Defence Station, as first alert, confirmation from the operator will result in Civil Defence responding to the fire incident).

The project team for a specific tunnel will be able to develop the SCADA integration matrix for the tunnel by using the matrix in this Annexe and the Tunnel Operational Risk Assessment.

	Incident ID	Incident	Location	Monitoring / Detection /Triggering System			Sub-System Responses				
				Manual	Auto	Escalation Mode	Auto	Manual	Other Actions by The Operational Control Room Operator	Comment	
VEHICLE RELATED EVENT	TV01	Vehicle breakdown		● CCTV ● Emergency Telephone	● VAID ● Emergency Phone of hook ● Emergency Panel Open	Confirm Mode Control Mode	● Zoom in CCTV on incident, ● Set TM plan ● Increase lighting, ● PA system message ● Radio Rebroadcast Message	● Zoom in CCTV on incident, ● Set TM Plan ● Increase Lighting ● PA system message ● Radio Rebroadcast Message	● Confirm ● Call Police ● Call Breakdown Recovery Vehicle		
	TV02	Loss of load, Objects in carriageway		● CCTV ● Emergency Telephone	● VAID ● Emergency Phone of hook ● Emergency Panel Open	Confirm Mode Control Mode	● Zoom in CCTV on incident, ● Set TM plan ● Increase lighting, ● PA system message ● Radio Rebroadcast Message	● Zoom in CCTV on incident, ● Set TM plan ● Increase lighting, ● PA system message ● Radio Rebroadcast Message	● Confirm ● Call Police ● Call ISU		
	TV03	Hazardous Fluid Spillage/ Toxic Gas release		● CCTV ● Emergency Telephone	● VAID ● Flood detection unit ● Hydrocarbon detection system in retaining Tank	Confirm Mode Evacuation Mode Control Mode	● Zoom in CCTV cameras on incident, ● Set TM plan ● Increase lighting, ● PA system message ● Radio Rebroadcast Message ● Inhibit Drainage Pumps	● Zoom in CCTV on incident, ● Set TM plan ● Increase lighting, ● PA system message ● Radio Rebroadcast Message ● Inhibit Tunnel bore Ventilation	● Confirm ● Call Emergency Services ● Call ISU		
	TV04	Vehicle Collision		● CCTV ● Emergency Telephone	● VAID ● Emergency Phone of hook ● Emergency Panel Open	Confirm Mode Control Mode	● Zoom in CCTV cameras on incident, ● Set TM plan ● Increase lighting, ● PA system message ● Radio Rebroadcast Message	Zoom in CCTV cameras on incident, ● Set TM plan ● Increase lighting, ● PA system message ● Radio Rebroadcast Message	● Confirm ● Call Emergency Services ● Call ISU		
	TV05	Vehicle Fire		● CCTV ● Emergency Telephone	● Linear Heat Detection ● VAID ● Emergency Panel Door ● Fire Extinguisher Pressure Switch ● Emergency Telephone of hook ● Visibility Monitor	Confirm Mode Evacuation Mode Fire Response Mode	● Zoom in CCTV cameras on incident, ● Set TM plan ● Increase lighting, ● PA system message ● Radio Rebroadcast Message ● Ventilation on Fire Emergency Mode ● Deluge system triggered in affected zone	● Zoom in CCTV cameras on incident, ● Set TM plan ● Increase lighting, ● PA system message ● Radio Rebroadcast Message ● Ventilation on Fire Emergency Mode ● Inhibit Ventilation ●Deluge system triggered in affected zone	● Confirm ● Call Emergency Services ● Call ISU ● Call Tunnel Manager or Deputy		
	TV06	Tunnel Equipment or structure hit and damaged by passing Vehicle.		● CCTV ● Emergency Telephone	● SCADA Alarm for loss of affected system ● VAID?	Confirm Mode Control Mode	● Zoom in CCTV cameras on incident ● Set TM plan	Zoom in CCTV cameras on incident ● Set TM plan	● Assess damage ● Call Tunnels maintenance team ● Make safe under full Tunnel bore closure if necessary.		

	TV07	High Volume of slow moving traffic		● CCTV	● VAID ● Traffic monitoring Device	Confirm Mode Control Mode		● Carry out a Tunnel sweep with CCTV (Check Cause) ● Set advance warning TM plan	● Check AQM is operational		
	TV08	Explosion		● CCTV ● Emergency Telephone	● VAID ● Emergency Telephone of hook ● Emergency Panel Door	Confirm Mode Evacuation Mode	● Zoom in CCTV cameras on incident ● Set TM plan ● Increase lighting, ● PA system message ● Radio Rebroadcast Message	● Zoom in CCTV cameras on incident ● Set TM plan ● Increase lighting, ● PA system message ● Radio Rebroadcast Message	● Call Emergency services ● Monitor through CCTV ● Call Tunnel Manager or Deputy.		
Non Vehicle Related Event	TNV01	Loss or overhanging Tunnel Equipment,		● CCTV ● Telephone call	● VAID? ● SCADA Alarm for loss of affected system	Confirm Mode Control Mode	● Zoom in CCTV cameras on incident ● Set TM plan ● Increase lighting	● Zoom in CCTV cameras on incident ● Set TM plan ● Increase lighting	● Confirm ● Call Tunnels maintenance team ● Make safe under full Tunnel bore closure if necessary.		
	TNV02	Pedestrian or Animal in bore		● CCTV ● Telephone call	● VAID ● Emergency Telephone of hook ● Emergency Panel Door	Confirm Mode	● Zoom in CCTV cameras on incident ● Set TM plan ● Increase lighting	● Zoom in CCTV cameras on incident ● Set TM plan ● Increase lighting	● Confirm ● Call Police ● Call ISU	set portal DMS with " SLOW // PEDESTRIAN" message or set appropriate bore closure with DMS and Lane closure signs	
	TNV03	CO/ NOx High level first trigger….			● AQM Reading on SCADA Terminal. ● Level 1 Alarm	Control Mode	● Ventilation on Level 1 Pollution Clearing Mode ● Ventilation Stop when levels drop below ……	● Ventilation on Level 1 Pollution Clearing Mode ● Stop Ventilation when levels drop below…..	● Monitor		
	TNV04	CO/ NOx High level second trigger…..			● AQM Reading on SCADA Terminal. ● Level 2 Alarm	Control Mode	● Ventilation on Level 2 Pollution Clearing Mode. ● Ventilation revert to Level 1 Pollution Clearing Mode when level drop below…… ● Ventilation Stop when levels drop below ……	● Ventilation on Level 2 Pollution Clearing Mode. ● Revert Ventilation to Level 1 Pollution Clearing Mode when level drop below…… ● Stop Ventilation when levels drop below ……	● Monitor		
	TNV05	Fumes / Low visibility		● CCTV	● Visibility Reading on SCADA Terminal. ● Low visibility Alarm	Confirm Mode Control Mode	● Operate Ventilation ● Stop Ventilation when visibility levels drop below …..	● Carry out a Tunnel sweep with CCTV (Check Cause) ● Implement TE5 if fire is detected ● Increase lighting	● Monitor		

	TNV06	High Level alarm in sump(1)			● Sump Level Monitor ● Reading on SCADA Terminal. ● High Level Alarm 1	Control Mode	● Start Drainage Pump1 ● Pump1 Stop when Level reach Low-Low	● Monitor Tunnel with CCTV	● Monitor		
	TNV07	High-High Level alarm in sump(2)			● Sump Level Monitor ●Reading on SCADA Terminal. ● High-High Level Alarm 2	Control Mode	● Start Drainage Pumps 1&2 (Pump 1 should already be running) ● Pump 2 Stop when Level reach Low ● Pump 1 Stop when Level reach Low-Low	● Monitor Tunnel with CCTV	● Monitor		
	TNV08	Flooding in Tunnel bore		● CCTV ● Emergency Telephone	● Flood detection unit ● SCADA Alarm	Confirm Mode Control Mode	● Set TM Plan	● Carry out a Tunnel sweep with CCTV ● Check Pumped Drainage system on SCADA ● Set TM Plan	● Call ISU ● Call Police ● Monitor	Increase lighting, set CCTV on location, inform Police, set appropriate bore or Tunnel closure or, if deemed safe, set DMS to "SLOW // FLOODS" and leave Tunnel open.	
TUNNEL SYSTEMS RELATED EVENT	TS01	Electricity Supply Failure			● Reading on SCADA Terminal. ● Power Failure Alarm	Response Mode Recovery Mode	● Critical Loads fed through UPS ● Generator Starts ● Change over switch transfer load on generator. ● Detect Electricity Supply re-established ● Change over switch return load on Electricity Supply ● Generator Off	● Monitor SCADA Terminal	● Call Tunnels Maintenance Team		
	TS02	Generator Failure			● SCADA Terminal. ● Generator Failure Alarm	Response Mode		● Monitor on SCADA Terminal	● Call Tunnels Maintenance Team		
	TS03	UPS Failure			● SCADA Terminal. ● UPS Failure Alarm	Response Mode		● Monitor on SCADA Terminal	● Call Tunnels Maintenance Team		
	TS04	Power Failure including Emergency Power		● Notice loss of Systems		Response Mode			● Call Police immediately to implement emergency closure		
	TS05	VAID camera failure			● SCADA Terminal. ● VAID Failure Alarm	Response Mode		● Increase vigilance monitoring through CCTV	● Call Tunnels Maintenance Team		

TS06	Loss of Lighting in the Tunnel Bores		● CCTV	● SCADA Terminal ● Lighting Failure Alarm	Response Mode	● Set TM Plan		● Call Police to support emergency closure ● Call Tunnels Maintenance Team		
TS07	CCTV Camera Failure		● Notice loss of Systems	● SCADA Terminal. ● CCTV Failure Alarm	Response Mode		● Increase vigilance monitoring through VAID	● Call Tunnels Maintenance Team		
TS08	Emergency Phones Failure			● SCADA Terminal. ● Emergency Phone Failure Alarm	Response Mode		● Increase vigilance monitoring through CCTV	● Call Tunnels Maintenance Team		
TS09	Advanced TM signage failure (DMS)			● SCADA Terminal. ● DMS Failure Alarm	Response Mode			● Call ITS Maintenance Team ● Inform Tunnel Manager or Deputy		
TS10	Tunnel lane control signs (LCS) failure			● SCADA Terminal. ● LCS Failure Alarm	Response Mode			● Call ITS Maintenance Team ● Inform Tunnel Manager or Deputy		
TS11	Radio Break-in total failure			● SCADA Terminal. ● Radio Break In Failure Alarm	Response Mode			● Call Tunnels Maintenance Team ● Notify Civil Defence		
TS12	Total failure of the Public Address (PA) System.			● SCADA Terminal. ● PA Failure Alarm	Response Mode			● Call Tunnels Maintenance Team		
TS01	SCADA Asset (Terminal) in fault Tunnel System in operation		● Notice loss of VDU							
TS13	SCADA Local access available, remote access non operational									
TS14	SCADA Local and remote access non operational									
TS15	All AQMs Faulty			● SCADA Terminal. ● AQM Failure Alarm ● Traffic monitoring Device ● Traffic monitoring Device Alarm	Response Mode 1: Free flowing Traffic Response Mode 2: Stationary Traffic		● Monitoring traffic through CCTV ● Operate Ventilation on Level 1 Pollution Clearing Mode ● Stop Ventilation when traffic becomes fluid.	● Call Tunnels Maintenance Team		

	TS16	Cross Bore Doors (CBD) or Fire Escape Door (FED) Defective switch generating fault through SCADA			● SCADA Terminal. ● CBD/FED Failure Alarm	Confirm Mode		● Zoom in CCTV camera on door location	● Call Tunnels Maintenance Team		
	TS17	Drainage Pumps failure (All)			● SCADA Terminal. ● Pumps Failure Alarm	Response Mode			● Call Drainage Maintenance Team		
	TS18	Gas alarm in sump 20% of Lower Explosive Limit (LEL) Reached			● Sump Gas Monitor ●SCADA Terminal. ● LEL trigger Alarm	Control Mode	● Sump Ventilation on ● Ventilation run for enough time to change one sump volume of air. ● Explosive Gas concentration reaches 10% of LEL? Yes ● Sump Ventilation off No ● Ventilation should run for enough time to change one more sump volume of air. ● Repeat cycle until Alarm is clear				
	TS19	Gas alarm in sump reaches 40% Lower Explosive Limit (LEL)			●Sump Gas Monitor ●SCADA Terminal. ● LEL trigger Alarm	Fire Response Mode	● Sump Foam Extinguishing System (Time Delay) ● Sump Ventilation off				
	TS20	Fire in sump			● Sump Fire Alarm ● SCADA Alarm ● Fire Alarm Sounder	Fire Response Mode	● Sump Foam Extinguishing system triggered (Double Nock)		● Call QCD		
PLANNED MAINTENANCE	TM1	Maintenance involving one bore closure		Planned Maintenance Call from supervisor	● QPRO	Maintenance Mode		● Set TM Plan ● Set Systems on SCADA in Maintenance Mode _INHIBIT MODE-			
	TM2	Maintenance involving both bores closure		Planned Maintenance Call from supervisor	● QPRO	Maintenance Mode		● Set TM Plan ● Set Systems on SCADA in Maintenance Mode _INHIBIT MODE-			
	TM3	Ventilation Fans			● Programmed	Maintenance Mode	Run Fans for recommended duration and frequency.				

Annexe B: Dynamic Message Signs Messages Library

(TBA)

Annexe C: Public Address Messages Library (text)

(TBA)