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TITLE:

REHABILITATION OF AHMED HAMDY TUNNEL 01
(SOUTH TUNNEL)

ITS Technical Specifications

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SUEZ CANAL AUTHORITY AHMED HAMDY TUNNEL

TUNNEL MANAGEMENT SYSTEMS UPGRADE

Basis of Design, Functional Requirements, and Technical Specifications

Table of Content

1   INTRODUCTION

1.1   DOCUMENT OBJECTIVES

This BOD and Functional Requirements document describes the Supervisory Control And Data Acquisition (SCADA) of the Ahmed Hamdy-1 road tunnel under Suez Canal (Egypt) along with the communication system requirements and the connected ITS sub-systems. The objective of this document is to provide an overview of the necessary technical elements for the design of the tunnel management system.

1.2   REFERENCE DOCUMENTS

The reference documents are the design documents prepared for the new AHT-2 Suez tunnel and the Ahmed Hamdy-1 tunnel drawings:

AHT1-REH-SOL-RDS-DWG-xxx

Design Report Building Services (EAAF-0002-40-ME-5070-R-1-0-0-0)

Design report Communications (EAAF-0002-40-ME-5060-R-1-0-0-01)

Design report Command and Control (EAAF-0002-40-ME-5080-R-2-0-0-01)

Concept of Operations & Safety Concept (EAAF-0002-40-ME-5000-R-2-0-0-02)

1.3   REFERENCE STANDARDS AND DOCUMENTATION

In the Detailed Design of ITS Systems, the following project documents and reference Standards have been considered:

Standards:

- Directive 2004/54/EC of the European Parliament and of the Council on Minimum Safety Requirements for Tunnels in the Trans-European Road Network

- NFPA 502 Standards for Road Tunnels, Bridges and Other Limited Access Highways

- Technical Reports by the European Thematic Network Fire in Tunnels: Fire Safe Design for Road Tunnels and Rail Tunnels

- Design Recommendations by the World Road Association

- EN 12966-1 Vertical Road signs—Part 1: Variable message signs standard defines several parameters regarding the spacing, sign dimensions, luminance classes, character heights and times required for driver at different speeds.

- TIA-942 Telecommunications Infrastructure Standard for Data Centers

- TIA-758-B Customer-Owned Outside Plant Telecommunications Infrastructure Standard

- IEC 61508-1:2010 Functional safety of electrical/electronic/programmable electronic safety-related systems. Parts 1-7.

- EC 61511-1:2016 Functional safety - Safety instrumented systems for the process industry sector.

- IEC 61131-3:2013 Programmable controllers - Part 3: Programming languages.

1.4 LIST OF ABBREVIATIONS AND TECHNICAL TERMS
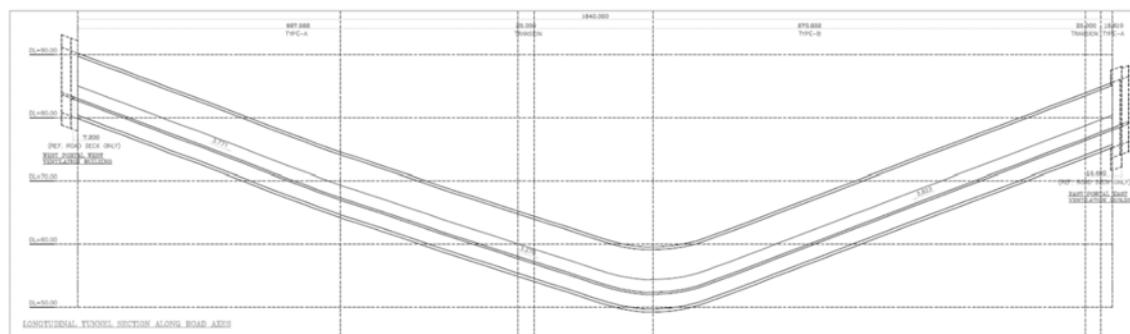
The definitions presented below are the key terms used in this document.

Abbreviations	Meaning
AI	Analogue Input
AO	Analogue Output
CCB	Control Centre Building
CCTV	Close Circuit Television
CEDC	Cairo electrical power network
CIM	Computer Integration Management
CPU	Central Processing Unit
DI	Digital Input
DO	Digital Output
EMC	Electromagnetic compatibility
FAT	Factory Acceptance Tests
HV	High Voltage
HVAC	Heating Ventilation air-conditioning
IFAT	Integration Factory Acceptance Tests
I/O	Input / Output
LAN	Local area network
LCS	Lane Control Signal
LV	Low Voltage
MODBUS	Modbus is a network trademark of Gould Modicon.
MV	Medium Voltage
OLM	Optical Link Module
ORM	Optical Redundancy Manager
PABX	Private Automatic Branch eXchange
PB	Push Button
PC	Personal Computer
PLC	Programmable Logic controller
RIO	Remote Input / Output
PROFIBUS	Process Field Bus
SCADA	Supervisory Control and Data Acquisition
SCS	Supervisory Control System
SNMP	Software package allows Ethernet management.
SOS	Emergency telephone system
TCP/IP	Transmission Control Protocol / Internet Protocol
UPS	Uninterrupted Power Supply
VMS	Variable Message Signs
VTR	Video Tape Recorder
WS	Workstation
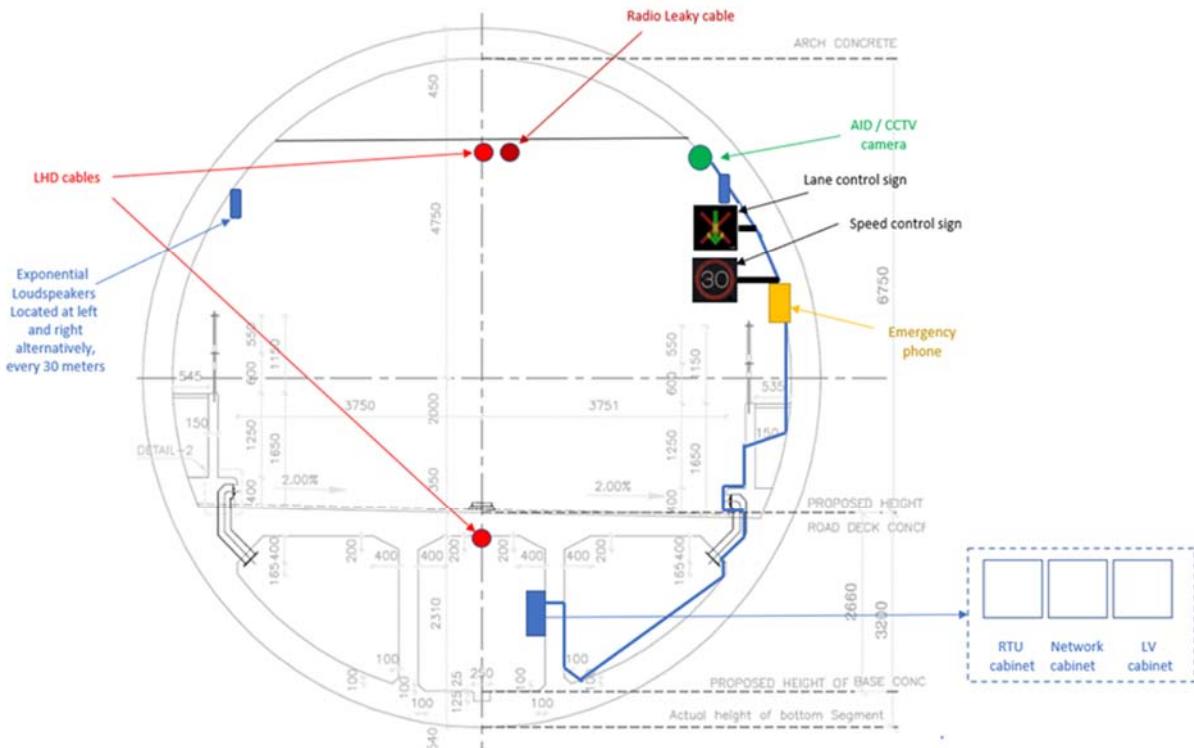
Note: For further detail, please refer to dictionary in appendix.

1.5 Tunnel Overview

Ahmed Hamdy Road tunnel site is made-up from one tunnel that should be used for one direction flow under Suez Canal tunnel while the new Ahmed Hamdy-2 Road tunnel should serve the reverse traffic flow. The tunnel is 1.63 km long and has an outside diameter of 11.6 m. The tunnel reaches a maximum depth of 51 m below ground level. The tunnel is controlled by two main technical stations located in both the East and West Technical buildings. Figure 1 and Figure 2 present the tunnels sections.

Figure 1 : Tunnel sections

Figure 2 Tunnel tube section

The Man Machine Interface (MMI) should be located at both existing control center buildings (CCB) and allows the supervision of the whole site equipment. The Master PLC system shall be redundant and distributed where PLC A will be located at West Technical building and PLC B located at East Technical building with hot standby configuration so that each of them can carry all control functionalities of the tunnel in case the other is out of service.

Emergency stations should be located along each tunnel approximately every 180 meters. Each emergency station includes an industrial grade SIP telephony / intercom system, emergency light panel, fire alarm break point, control panel for RIO to collect data from surrounding sensors and devices, industrial grade Gigabit switch to connect smart devices within 90 meters from each side including IP cameras, IP intercom, traffic lane control signs, speed control signs, and more and finally a low voltage panel to power the surrounding equipment.

The SCS system of the Ahmed Hamdy tunnel should include integration points with the new Ahmed Hamdy-2 tunnel control system in order to manage intercorrelated scenarios such as reversing traffic in the other tunnel in case of using emergency vehicle in the reverse direction in case of fire and more.

1.6 Design recommendations for Ahmed Hamdy-1 tunnel

According to the differences in the architecture of the Ahmed Hamdy-1 and Ahmed Hamdy-2 tunnels, we would recommend the following changes in equipment setup inside the tunnel:

- Emergency stations should be installed on the left side (north) walk so that the right-side walk remain clear for pedestrian evacuation.

- Lane control signs and speed control signs should be installed on the side walls of the tunnel every 250 meters and overall dimension should be 50cm x 50cm. Since the maximum clearance is 5 meters, we cannot install the VMS signs in the ceiling and one large VMS can be installed on the entrance gantry only. At each station there should be 2 square signs both installed on the side wall one showing the speed limit and one showing a lane opening or closure sign (green flash or red X signs). The lane closure sign should be installed on the right side as well to control the right lane.

- The fiber communication cables should be installed in the concrete duct banks on the left and right sides forming the redundant ring network from East to West and closing the ring from both ends of the tunnel through the service building east and west through the redundant core switches. Interconnection with existing AHT-2 network is then achieved by connecting the core switch East and West to the existing core switches respectively by 10Gbps fiber connections as described in the network section.

- Every 160 meters the duct bank will have a sleeve for cable connection to the emergency station control cabinet including the industrial network switch and RIO providing Ethernet and control services for all devices in the tunnel. Network and control cables will be installed on side wall cable trays.

- At each emergency station every 160 meters there will be a low voltage panel to supply the control cabinet (including the network switch and RIO) and supply all the field equipment within its service area.

- CCTV cameras every 80 meters will be installed on the side walls and connected to the nearest switch in the emergency station and one of each 2 cameras will be located in proximity of the emergency station in order to monitor the surrounding and the utilization of the emergency phones.

- AID system should be video based and processing the CCTV camera streams connected to the nearest industrial switch inside the emergency cabinet. Radar based AID is not recommended for the tunnel project due to the repeated reflections inside the tunnel.

- The Liner Heat Detection control cabinets will be connected to the Master PLC directly via Modbus TCP (to be discussed according to the current installed LHD system). It is preferable to install the LHD control panels in the edge of the service gallery from both sides to be as close as possible to the termination box of the LHD cable.

- The tunnel closure barriers and traffic light will be connected to the nearest RIO. Optional it is possible to consider a wide VMS at the tunnel entrance with free text display.

- At each emergency cabinet there will be a LED illuminated emergency sign and a flash sign showing the distance to the nearest evacuation direction.

2 Centralized Tunnel Management System

2.1 Tunnel Control and Communication System Overview

The main objective of the Control Architecture is to quickly detect the emergency situation and issue a first response, which includes acting over nearly all the tunnel systems. The centralized control system will be responsible for the control, management, and surveillance coordination of the tunnel safety installations. The main objective of this system is to achieve the following conditions:

- Maximum safety and comfort regarding driving conditions for users in transit, throughout the tunnel, as well as for the operators, who perform operation and maintenance duties.

- Optimum devices performance (security, life cycle, energy resources, duty-cycle, etc.)

- Optimum, stable, and coordinated operation of all systems

The Control Architecture system acquires data from equipment installed in the field. Once acquired, this information is processed by algorithms, what produce control orders, which are sent to field elements.

Data obtained from the field devices are transmitted to the Control Centre, where the current state and performance of the tunnel is monitored. This monitoring process produces actions over the systems that are transmitted to the equipment in the field.

In short, the Control Architecture system performs the following tasks:

- Acquisition of information and data generated by the equipment installed in the field. These data include both measurements made by the sensors and technical alarms due to the operational status of equipment.

- Transmission of all measures and technical alarms from each of the field devices to the Control Centre

- Processing of all the information acquired by the sensors, showing the status information of the roadway in real time, and allowing access to all the information provided by the security and surveillance systems.

- Incident detection based on the measurements and alarms generated by the sensors. Execution of action based on these incidents.

- Transmission of orders to equipment and sensors deployed in the tunnel, either manually or from scheduled performance strategies

- Historical record for future reference

The Control Architecture system interfaces with other security and surveillance systems in order to manage them and coordinate the tunnel control. This coordination allows one system to act automatically in a programmed way because of the data supplied by other system.

The Control Architecture System has as main objective to allow the Control Centre to:

- Know and show the real time performance and state of each field device for every system.

- Act in an automatic, semi-automatic (with operator's confirmation) and manual way on the field device.

2.1.1 Reference standards

In the Detailed Design of ITS Systems, the following project documents and reference Standards have been considered:

Standards:

- Directive 2004/54/EC of the European Parliament and of the Council on Minimum Safety Requirements for Tunnels in the Trans-European Road Network

- NFPA 502 Standards for Road Tunnels, Bridges and Other Limited Access Highways

- Technical Reports by the European Thematic Network Fire in Tunnels: Fire Safe Design for Road Tunnels and Rail Tunnels

- Design Recommendations by the World Road Association

- TIA-942 Telecommunications Infrastructure Standard for Data Centers

- TIA-758-B Customer-Owned Outside Plant Telecommunications Infrastructure Standard

2.1.2 SCS Functional requirements

The Ahmed Hamdy-1 tunnel will have an integrated control system that will allow management of all field equipment (ITS systems, fire protection, lighting, ventilation, etc.) from the existing Control Centre, ensuring continuity of the operation of all safety systems. This system will also ensure the continuity even in case of failure for any of the Master PLCs.

The control system of the tunnel, Toll Areas and Control Centre deploys distributed control architecture, so, part of the control logic is distributed in technical rooms, master SOS stations inside the tunnel. The levels that are part of the control architecture (Levels 0 and 1) are comprised mainly of:

- Level 0: Remote Terminal Units (RTU)

    o Modular equipment that acts as a signal hub. This equipment uses multiple input/output digital/analog cards or Modbus serial interfaces.

    o Act as an interface with each field elements or sub-systems

    o Process local degraded mode scenarios

    o Have redundant communication interfaces to the Level 1 Master PLC

- Level 1: Redundant Master PLCs

    o They have direct communication with the Control Centre SCADA server and the Remote Terminal Units (RTU) in the field

    o They can manage field equipment in based on automated scenarios or manual operator control from SCADA workstation or can delegate the control to the local RTU CPU or field service engineer direct access.

In general, regarding the characteristics of the equipment, they are scalable and modular, so that the configuration can be easily changed without interrupting the service. This allows increasing the number of input/output interfaces, replacing damaged elements, replacing revised versions of cards and improving system performance.

This equipment is robust and allows manipulation without causing communication failures.

2.1.3 SCS Architecture
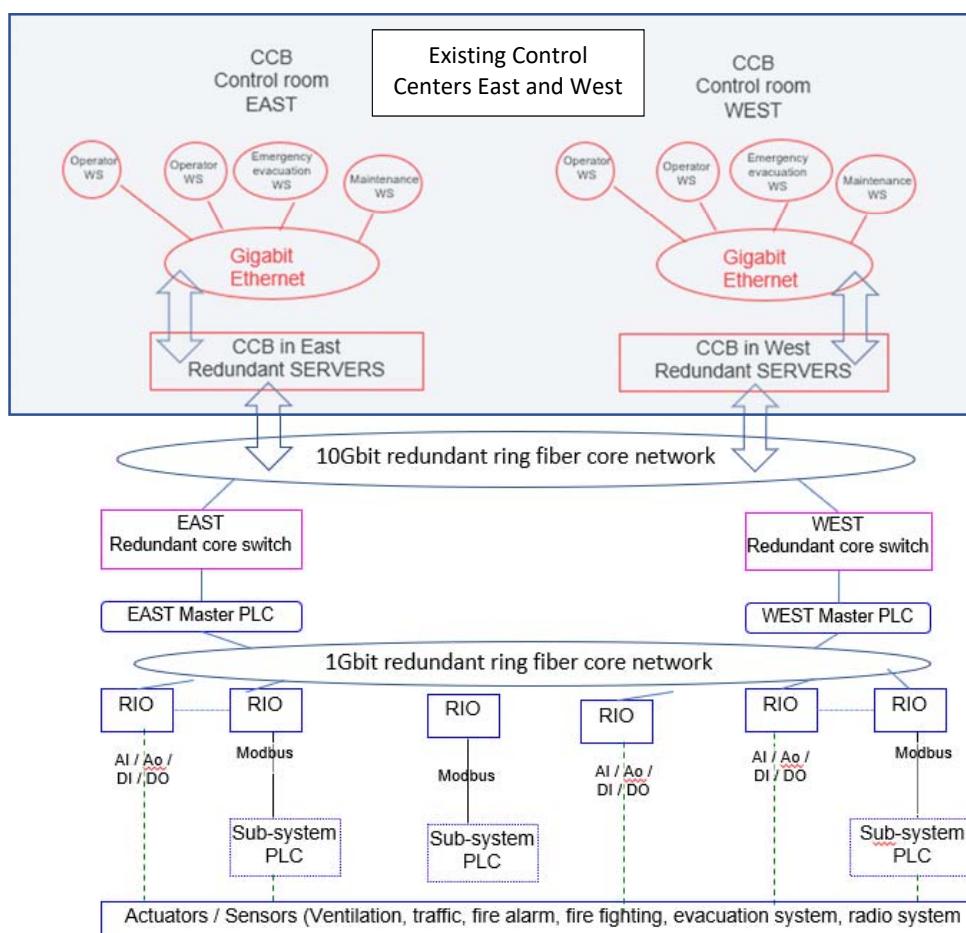
The SCS holds the following main functions: The SCS will be able to monitor and control tunnel systems and sub-systems. It enables the access to any supervision view and to send commands to the whole site equipment, according to the control mode of the equipment. The archiving and backup functions allows the site manager to perform data analysis offline. The system monitoring and maintenance functions are designated to technical manager. The system software for configuring and programming the SCS is attributed to the data processing engineer.

The operators manage the whole installation with SCS equipment located in the Control Centre Buildings East and West. This will require the review of the new requirements for integrating the new systems into the existing SCADA solution or locating two new SCADA workstations in the same control rooms along with new SCADA servers that will be located in the new technical buildings East and West.

The servers and storage should be installed in a 19-inch rack located in both Technical buildings East and West and should include sufficient CPU power and storage for installing the SCADA software and video management keeping in mind to keep 30 days of video streams in the online archive for fast retrieval.

Section 4 includes the details of the required equipment and storage.
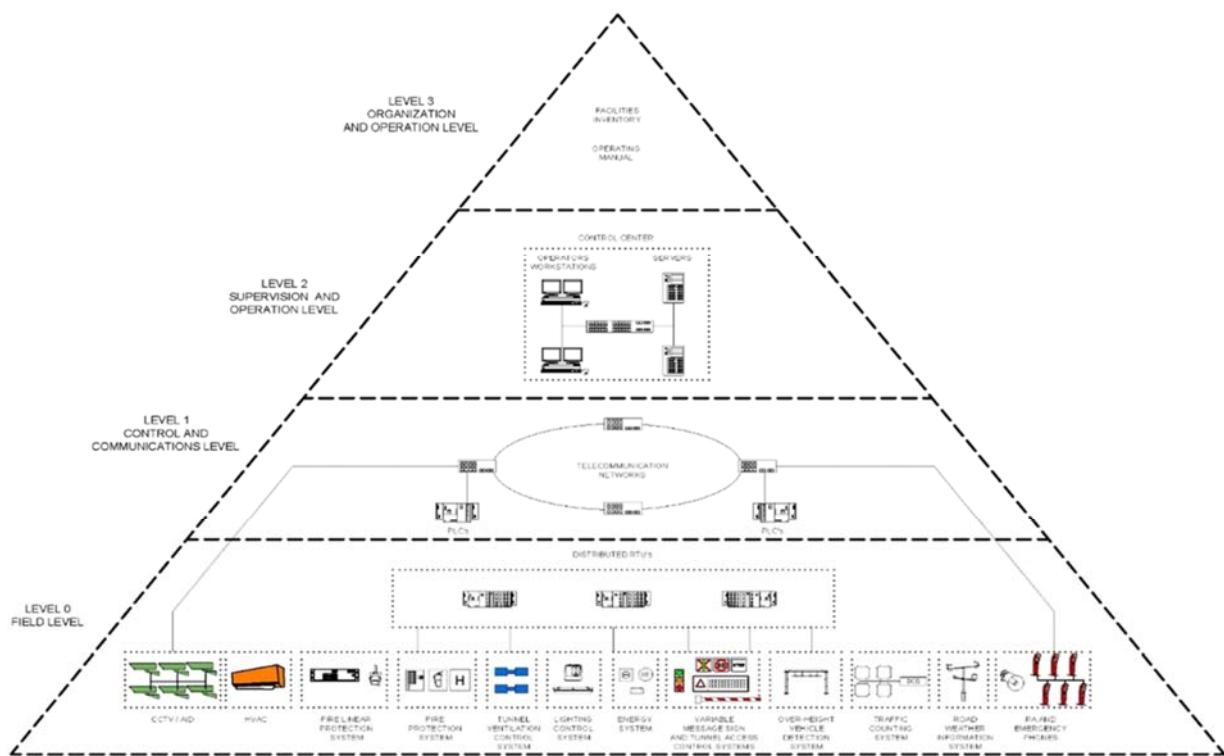
The SCS is based on a distributed hierarchical structure built from the 3 levels. Figure 3 overviews the level interconnections.

Figure 3 Control system connectivity

- The level 2 is made of redundant servers, workstations, and printers (MMI). (Existing CCB can be utilized for controlling the AHT-1 new systems).

- The level 1 is made of redundant programmable logic controllers (main PLCs) and core switches.

- The level 0 is made of remote input / output (RIO) and independent packages such as CCTV, measurement stations, public address, etc...

Typical architecture of tunnel management systems is shown in Figure 4

Figure 4 Tunnel management architecture

2.1.3.1 LEVEL TWO

Level Two equipment are already implemented in the scope of Ahmed Hamdy-2 tunnel and therefore we only need to verify that they fulfill the basic below requirements:

Servers

Level two is composed of two redundant servers for data processing, data communication, and data storage. Servers are composed of 2 server computers in each CCB, arranged in hot stand-by configuration. The server status is either master or stand-by. In normal operation one master is elected and the other server is running in stand-by mode. In case of master failure, the stand-by computer handles master status. This switching is performed automatically and allows SCS functionalities in degraded availability mode. In case of both servers' failure in the West CCB, all servers and supervisory functionalities are performed by the East CCB servers. In normal operations, servers are configured for providing the following functions:

- Holding and updating the real time data base,

- Updating the data base of the stand-by server if alive,

- Time stamping alarms and events,

- Recording alarms and events,

- Storing and archiving data.

Note: the alarms event will be managed following 3 priorities: Warning, Default, and critical levels.

Control room workstations

The SCS is based on two triple-screen operator workstations for SCADA system, one triple-screen maintenance workstation and one emergency workstation located in the main control room in both East and West. The system is completed by one double-screen emergency evacuation workstation to run public address, access control and radio management systems master control software. The use of one or another station depends upon the wished functionality and the access level authorizations.

Workstations are composed of personal computers and are designed to allow the following functions:

- Supervision, detailed process views,

- Operator controls,

- Processing automatic sequences,

- Alarms logging and event monitoring,

- Trending.

In case of one triple-screen operator workstation failure, overall tunnel management is performed from the available operator workstation.

The triple-screen operator workstation is designed for tunnel management functions. This station is named « SCADA operator station ». The workstation is composed of personal computer and is designed to allow the following functions:

- Same function as operator workstations,

- Trending and historic,

- Generation of report on office software.

One triple-screen maintenance workstation is designed for tunnel maintenance functions, common for both tunnels. This station is named « maintenance station ». The workstation is composed of personal computer and is designed to allow the following functions:

- Same function as operator workstations,

- SCS equipment diagnostics,

- Maintenance operations (back-up, dedicated reports, time set-up),

- Networks management (SNMP protocol software).

- Programming and configuration utilities,

- Data base modifications,

- Privileges and passwords definition.

One triple-screen emergency workstation is designed for managing emergency scenarios. This station is named « emergency station ». The workstation is composed of personal computer and is designed to allow the following functions:

- Same function as previous workstations,

- Telephony software to manage emergency calls from intercom terminals,

- Voice command software for radio broadcasting,

- Access control management

Printers

Two black and white laser printers are dedicated to printing the events and alarms report. Two color ink jet printers allow the screens or windows hard copies.

Communication functions

Two Ethernet networks perform the communication functions. The first one interconnects servers, workstations, and printers. The data transfer uses TCP/IP protocol at 1000Mbits/s. Each device can access to the network through a Gigabit Ethernet adapter card in star topology inside the control room.

The second one interconnects servers and main programmable logic controllers. The data transfer uses TCP/IP protocol at 1000Mbits/s. This network is made up from double ring configured in redundancy. Each device can access to the network by adapter cards and is plugged on medium by transceivers. In case of one network failure, data communication will be performed on the available network. This switch is executed automatically and allows SCS functionalities in degraded availability mode.

User levels

To control and to manage the site from the control room workstations, five operating accesses are defined:

- Visualization Operator,

- Command Operator,

- Tunnels Manager,

- Maintenance operator,

- System Engineer.

The Visualization Operator access is the default access of the control room workstations. It enables only to display any supervision view. No control can be achieved with this level.

The Command Operator access enables to display any supervision view, to send commands and set points to the whole site equipment, according to the control mode of the equipment. Neither configuration nor parameterization can be achieved with this level.

The Tunnels Manager access extends the Tunnel Operator access to the Tunnel management views.

The Maintenance access extends the Tunnel Operator access to pre-set the thresholds of the alarms, defining the time slopes, adjusting the filters, and display actuators counters.

The System Engineer access is the specific access which enables configuration, programming and parameterization of the servers and supervisory system.

Any user level can be reached from any workstation.

Operating modes

The system equipment can be controlled according to the following operation modes:

- Automatic: Under operators' parameters through main PLCs control,

- Operator: Under operator's workstation control,

- Local: Under operator's local control or field control.

In automatic mode, the system programmable logic controllers perform sequences. No order can be directly given from workstation's screens to one machine. Nevertheless, an operator could adjust set points from control room workstations.

In Operator mode, orders can be sent from the operator's workstations. Nevertheless, the system programmable logic controllers perform sequences. This Operator mode includes machine individual orders or sequence Operator orders.

In local mode, orders are sent directly from the local control boards. Only Basic protection interlocks are still active. No order can be given from operator's workstations. This mode is generally used with great care and for maintenance under local operator's responsibilities. In this mode, the selected machine is unavailable for the automatic or Operator mode. The local mode must be able to run out the SCS availability.

The transient modes will be programmed such as the machine will stay in the same running status in case of transition from automatic to operator mode.

These operating modes are exclusives. Supervision of all equipment is always available whatever the operation mode is running except in Operator mode if the SCS is unavailable.

For each operating mode, safety requirements (personal or equipment damages) is out of SCS capability. All safety requirements will be done by the system supplier's equipment. Nevertheless, interlocks will be handled from the SCS and will be programmed in each system PLC.

The precedent description details general principles, please refer to the detailed functional analysis of each system for further information.

Application views organization

Several screens enable the operation of the whole site. They are organized in several groups of mimics. Each group is in charge of operating a specific function. The main groups are listed below:

- Welcome view with login.

- Access level's view,

- SCS system status (current state of the SCS equipment)

- Overall view of the installation

- Detailed supervision views (arranged by system),

- Alarms and status messages, including the time tagged events,

- Trending and historic functions,

- Help view, system maintenance view,

- Utilities views (data storage, time setting, etc.).

The hierarchy and the general format of each group will be described in the MMI detailed functional analysis.

Equipment displayed on the screens is symbolized using a simplified representation. The equipment status is color animated (e.g.: run, stop, close, open, etc.) or symbols animated (e.g.: AUTO = automatic, OPER = Operator, etc.).

If equipment can be operated from the screen, its identification will be a dialogue box symbolizing a push button. When clicking on this identification box, the operator will be asked to select the operation to be performed and next an action on specific confirmation touch valid the order. Cancellation will always be presented.

Analogue values are shown as numerical values with their physical units. The decimal number depends on the measurement ranges.

Reference language

The reference language for the project design, documentation, system software packages, application software and reports is the English language. Nevertheless, in the application software, mimic views are able to display texts either in English or in Arabic language. A specific function key will switch from one language to the other.

2.1.3.2 LEVEL ONE

Overview

Level 1 is composed of 2 redundant Master PLCs located in the following stations:

- Technical building East,

- Technical building West,

Each Master PLC is connected to level 2 by redundant fiber ring at 10Gbits/s speed and connected to level 0 by a redundant fiber link using TCP/IP communication at 1 Gbps speed (could be PROFINET or equivalent technology). Level 2 redundant 10G fiber network is dedicated to the Master PLCs whilst level 0 edge fiber ring network is connecting all RIOs to the Master PLCs and also provides IP connected devices to the main control stations in the technical buildings.

Each main PLC is redundant thus in case of one processor fails, data computing will be performed on the redundant processor. This switching is automatically performed and allows SCS functionalities to continue uninterrupted operation with switching speed over dedicated fiber cores for program synchronization. The system will remain functioning in degraded mode even if 3 out of 4 Master PLCs fail since each PLC CPU can run all tunnel functionalities.

In the most degraded network mode, 2 failures can occur simultaneously from any of the two Ethernet networks, any of the main PLC processor, and any of the two PROFINET networks related to this main PLC. Restoring the full availability of the SCS after such combined failures is achieved without operation break following a specific maintenance procedure.

The primary function of the main PLCs is to collect and concentrate system data information and generate automatic mode of the global systems. These functions are mainly integrated through communication with remote RIO or through Modbus serial links with specific systems.

Master PLC Common Functions

- PLC operating system (stop, initialization, run).

- Ethernet communication management (link to level 2).

- PROFINET or MODBUS communication management (link to level 0).

- Data communication and logic controllers' redundancy.

- Data interface with level 2.

- Data acquisition from level 0.

- Systems automated scenarios (please refer to next sections for each system).

Sub-system control functions:

- Ventilation plant and synchronizing north tunnel ventilation,

- DRUPS system

- MV and LV stations,

- Lighting control system,

- Ventilation system

- Dewatering equipment,

- HVAC equipment,

- CCTV equipment,

- Fire-fighting equipment,

- Radio equipment,
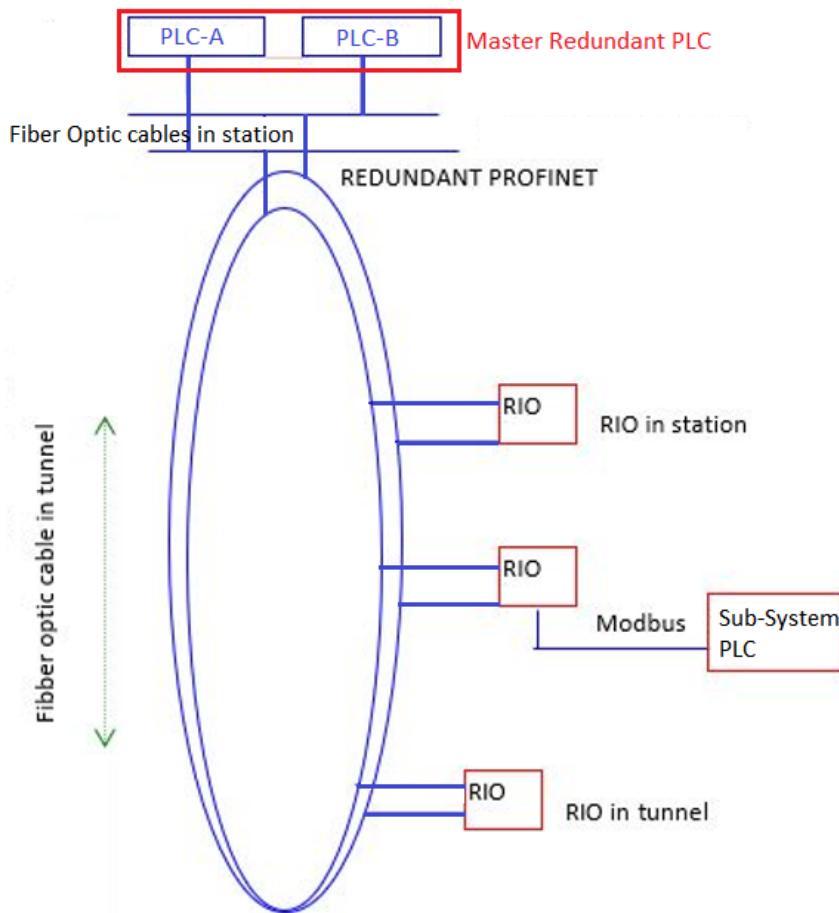
- Emergency Telephone equipment,
- Fire-detection (LHD and service building fire alarm)
- Traffic control (counters and traffic signs)
- AID (Automatic incident detection)

2.1.3.3 LEVEL ZERO

The level 0 is an extension of the level 1 and is mainly composed of:

- Redundant PROFINET networks,

- RIOs (with optional CPU for degraded mode of operation)

- MODBUS Link with systems and sub-systems.

Figure 5 presents the level 0 topology for one main PLC.

Figure 5 Main PLC topology

The redundant PROFINET network connects every RIO scattered in the site. Each PROFINET network is redundant thus in case of one network failure, data communication will be performed on the available network. This switching is automatically performed and allows SCS functionalities in degraded availability mode.

RIO is dedicated to interfacing the field components directly such as sensors and actuators. It's working for converting electric signals to digital or analogue values and vice-versa. RIO provides data acquisition to main PLCs. In case of RIO failure, only the equipment under RIO control is unavailable.
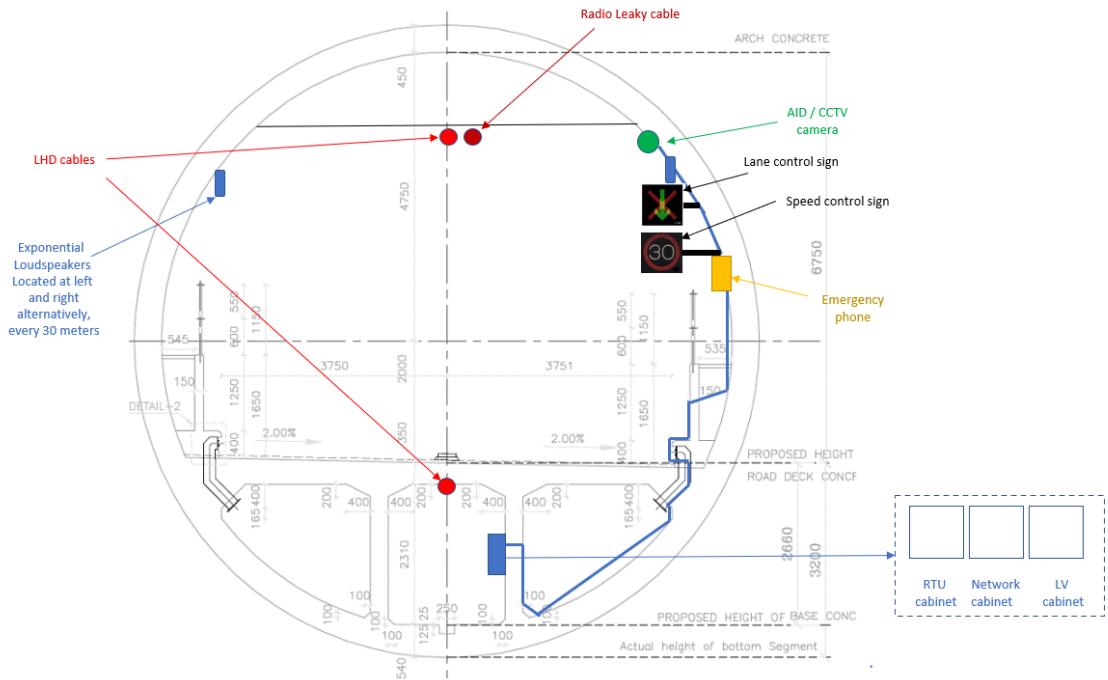
Systems or sub-systems can also work under own specific programmable logic controller. In this case, it will be MODBUS linked and systems are connected to the main PLC through the PROFINET communication between RIO and the Master PLC.

When Modbus protocol is used, it employs serial binary data interchange based on RS485 interface standard.

The level 0 is in charge of gathering local information of the following systems and sub-systems:

- Telephone, public address and general announcement,
- Dewatering,
- Fire detection (tunnels, galleries, technical rooms),
- Power supply,
- Radio,
- Close Circuit Television,
- Diesel generators,
- Firefighting,
- HVAC,
- Traffic control (LCS, gauge system, barrier, flashing light, measures stations)
- Ventilation and starters,
- Lighting control
- Emergency signage system.
- Weather station.

The following diagram illustrates the location of each of the equipment connected to the control architecture:

Figure 6 ITS sub-systems localization

Please refer to section (3-ITS Systems) and related MEP design documents for more details concerning each system and sub-system.

2.1.3.4   MEP Sub-system integration

The objective of the following sections is to overview the general functionalities in reference to system functional analysis (generally written by system vendors). The following sections can't replace it. And in addition, for each system, for the MMI and networks, a detailed functional analysis will be written by SCS vendor and would be completing the present document.

The table below provides an overview of the communication protocols used for different systems and sub-systems.

System	Equipment	Location	Type
Telephone system	1 PABX (Modbus TCP) Emergency telephones (Modbus TCP)		Modbus in station alarms to Master PLC
CCTV	Ethernet connections to emergency cabinet network switch		Ethernet in RIO in tunnel
Traffic control	2 Measure stations Over-height detection/barriers/lights		Modbus TCP in tunnel RIO in tunnel
Linear heat detection in tunnel and service gallery	Modbus TCP Slave rack (hardwire)		Modbus in station RIO in tunnel
Public Address	Hardwire alarm inputs.		RIO in tunnel

	Audio interface (to Radio system)		
Access control in service buildings	OPC to Master PLC Hardwire		OPC in station RIO in station
Lighting	DALI controllers		RIO in tunnel
AID System	Modbus TCP to Master PLC		Modbus TCP in station
Ventilation control system	Analog signals from sensors		RIO in tunnel
Radio	1 Radio cabinet Audio link		Modbus in station Public Address IP Matrix
DRUPS	1 synchronizing system PLC and x generators micro controllers		Modbus in station
Fire fighting	firefighting stations Water Mist		RIO in station RIO in station
HVAC	HVAC system PLCs		Modbus in station
Ventilation and fan starters	Ventilation systems sensors (Analog) and drivers are Modbus linked		RIO in station RIO in station
Dewatering	x Dewatering stations (Modbus)		RIO in station
Fire detection in service buildings	Master rack (Modbus)		Modbus in station
Power supply	Power supply system UPS links.		RIO in station Modbus in station

Table 2 : Sub-system connectivity

2.2   Telecommunication Network

The Telecommunication Networks that will be implemented in the Ahmed Hamdy-1 tunnel, Toll Areas and existing Control Centre connectivity, aim to provide a solid and robust infrastructure for transmission of information between the Control Centre, programmable logic controllers (PLC), remote terminal units (RTU) and field devices installed inside the tunnel and ancillary buildings, Toll Areas, and Control Centre (video cameras, phones, PA racks, etc.). Thus, direct communication channels are created between all equipment installed on the tunnel, Toll Areas, and the Control Centre systems.

2.2.1   Application of reference standards

The TIA-758-B Customer-Owned Outside Plant Telecommunications Infrastructure Standard will be followed for all infrastructure cabling. This Standard specifies minimum requirements for customer-owned telecommunications facilities in a campus environment. This standard specifies the cabling, pathways, and spaces to support the cabling.

The ANSI/TIA-942-B specification references private and public domain data center requirements for data center infrastructure elements such as Network architecture, Electrical design, Mechanical systems, System redundancy for electrical, mechanical and telecommunication, Fire safety, Physical security, and Efficiency.

2.2.2 Functional requirements of the system

To allow information exchange between the different elements installed all along the tunnel and ancillary buildings, Toll Areas and Control Centre telecommunication networks will meet two fundamental principles:

- Robustness of the network, so that there are redundant access paths to each of the nodes that comprise it. This ensures that the failure of one of the communications equipment does not prevent access to other network elements.
- High bandwidth to allow the correct transmission of all information between the field devices and the Control Centre.

The telecommunication networks will be a last generation network. This kind of system is based on a functional multiservice network for the transport of video, data, and voice upon a single infrastructure. This network will be based on IP technology with the possibility to offer different services according to the QoS needed.

The main characteristics of the network design are:

- WAN TCP/IP communications network
- IP structure using levels for multiservice.
- High availability, redundancy, and fault tolerance:
  - o Design of double networks using both sides of the tunnel
  - o Deployment of different physical paths for the main and redundant cabling.
  - o Use of a ring topology
- Security:
  - o Avoid unauthorized access.
  - o Deploy independent traffics for different subsystems and services.
  - o Encoding of the transmitted data
  - o Authentication of all users and services that try to access to the network.
  - o Different levels of access for different functional categories of the possible users
  - o Isolation of the users and services non authorized, using independent networks and Demilitarized Zones (DMZ)
  - o Isolation of services using VLAN technology
  - o Filtration of the information received from external voice and data transmission networks to the tunnel.
- Management: a management system tool will be used in order to allow direct, dynamic, and efficient configuration. This tool will also supervise the alarm activation and the performance of the system:
- Quality of Service
- Data and message transmission:
  - o Transmission of acquired data from the tunnels section to the Control Centre
  - o Transmission of the messages to be visualized and management commands to all the users' aid equipment.
- Flexibility and scalability with an increase of the performance and the stability
- The projected solution will be dimensioned with expansion capacity.

2.2.3 System architecture
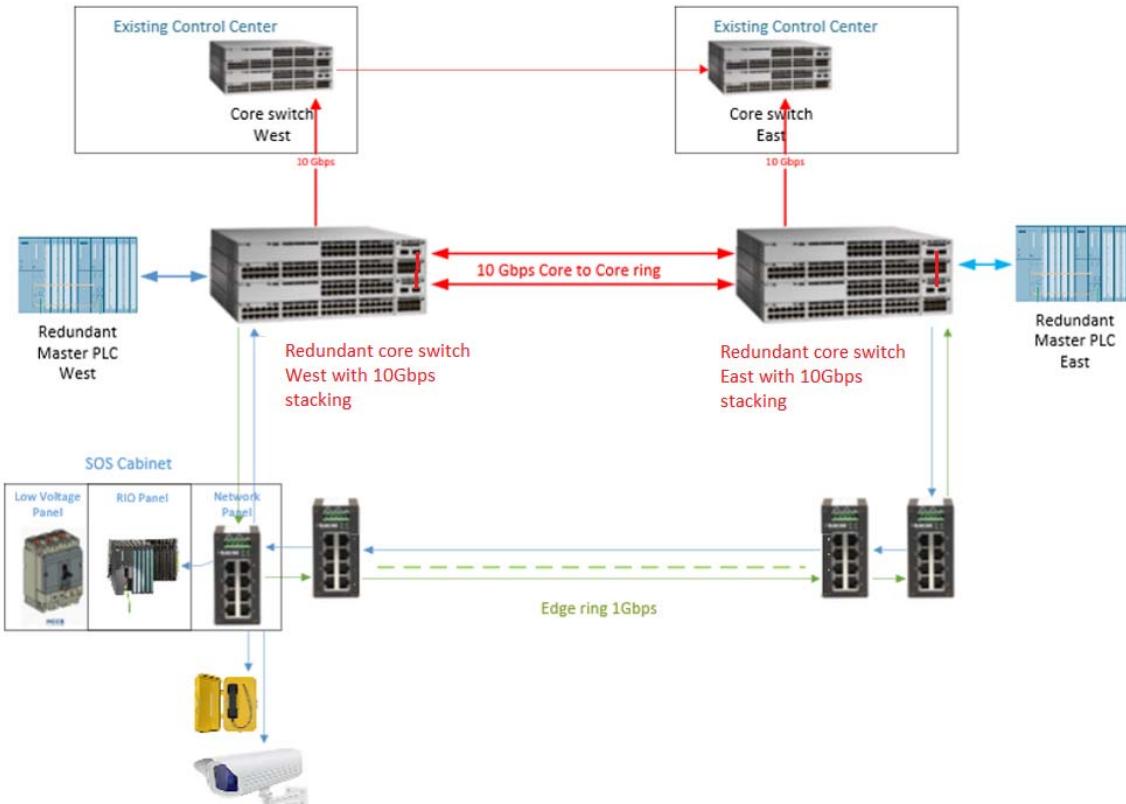
The telecommunication networks of the AH-1 tunnel deploy a three-layered structure:

- Backbone Network: 10 Gbps links. This level deploys single-mode optical fiber in ring topology and IP Ethernet technology. This layer links the East and West Technical Building and the Control Centers for both tunnels.

- Access Network: 1 Gbps links. This level is based on single-mode fiber optic build in ring topology. This Network deploys rings for the connection of on-field equipment to the network using IP-Ethernet technology.

The telecommunication networks topology shown in Figure 7 is designed to have the following benefits:

- Redundant core network which grants proper and efficient performance
- Highly structured solution with clear functions scheduling for each level of the network. This simplifies its implementation and management.
- Industrial grade edge switches installed in a communication cabinet located beside the RTU control cabinet and Low voltage cabinet.
- This topology allows the use of the same VLAN IDs for same services. This simplifies its implementation and management Network switches will have at least the minimum connections needed plus a twenty-five percentage extra.

Figure 7 Network architecture and integration with existing AHT-2

2.2.4 Interfaces with other systems

The Telecommunication Networks system will have an interface with the following systems:

- Closed Circuit Television (CCTV) system.
- Automatic Incident Detection (AID) system
- Roadside Emergency Phone System
- Private Radio Communication System
- Public Address system
- Fire linear Detection system
- Access Control and Intrusion Detection system
- Fire Detection system inside technical rooms

- Control Architecture
- Centralized Management System
- Ancillary Electrical Switchboards
- Ancillary Civil works
- Low Voltage system
- Medium Voltage
- HVAC system
- Lighting control system
- Fire protection
- Water Mist Control system
- Ventilation and gas detectors Control system
- Videowall system

2.3 Power, Communication and Control cabinets

The inside master emergency station will have a low voltage and a communications cabinet which will be used for housing various auxiliary equipment for other systems, such as: Remote IO Units, Terminal Blocks, Switches, Circuit Breakers, Power Supplies, Converters, etc.

2.3.1 Reference Standards

Cables:

- EN 133100: Frameworks for telecommunications networks.
- EN 50085: Specification for cable conduction in electrical and communications cabinets. Mounted on any surface.
- EN 50086: Specification for conduit systems for cable management. Conduit systems buried underground.

Equipment:

- EN 20324: DEGREES OF PROTECTION PROVIDED BY ENCLOSURES (IP CODE)

- IEC 61000: Electromagnetic compatibility (EMC)

- RoHS 2002/95/EC and 2011/65/EU

- EN 50018: Electrical switchboard for low voltage

- BS 7671: Requirements for Electrical Installations

2.3.2 Technical Specifications

2.3.2.1 Mechanical Specifications

Emergency Phone Cabinet dimensions:

- Width: 300 mm
- Height: 800 mm
- Deep: 300 mm

Communications Cabinet dimensions:

- Width: 800 mm
- Height: 800 mm
- Deep: 300 mm

Low Voltage Cabinet dimensions:

- Width: 800 mm
- Height: 800 mm
- Deep: 300 mm

Cabinets Frame:

- Material: Stainless steel, anti-vandalism, and anti-spray
- Thickness:
  - Flat surface: 2 mm
  - Corners: 4 mm
- Strength value:
  - Tensile strength (Kg/cm2): 625
  - Transverse strength (Kg/cm2): 1100
  - Impact strength (Kg/cm2): 30
- Tightness: IP65 (Ingress Protection Marking)

Doors:

- Hinges: Stainless steel
- Joints: Synthetic rubber 20 mm
- Grid: Stainless steel
- Lock: High security

Finishing:

- Painting: Polyurethane RAL-2004/ 40µm

2.3.2.2 Electrical Specifications

The Electrical secondary switchboards for ITS equipment are used to connect the power supply wires of the ITS devices. Secondary switchboards will be placed in the Roadside emergency phone's cabinet of the tunnel and in the technical rooms in front of the tunnel shafts.

Technical Specifications

The electrical secondary switchboards must meet the following technical requirements:

- Isolator switch:
  - 4-poles (as showed in drawings)
  - IN=40 A
  - Endurance:
    - Electrical: 20.000 cycles
    - Mechanical: 50.000 cycle
  - Short-circuit resistance: 20 x In during 1 s
  - Visible position of the switch
  - Compliant with EN 60668.1 and 60947.3
  - Terminal for 50 mm2 wire and 40 A In
- Up to 15 automatic thermal magnetic RCD:
  - Thermal magnetic block:
    - Poles and nominal current as per contractor detailed design.
    - Voltage: 230/400 VCA
    - C curve: 5 to 10 In
    - Switching power: 6 kA (EN 60898)
  - RCD:
    - Type: A class
    - IN< 25A
    - Sensitivity: 30 mA
    - Poles and nominal current as per contractor detailed design

- ▪ Voltage: 230 /415
- ▪ Terminal for 25 mm2 wire
- ▪ Test system
- ▪ Red mechanic indicator
- o C curve
- o 2 or 4 poles
- o IN=6 A
- o PDC=6kA
- o Type A RCD
- o Sensitivity: 30 mA
- Including mounting board, strip, DIN rail, and any other element for its fully operation and connection.
- Plastic protection covers compliant with IEC 695.2.1 and EN C 20-455
- Grounding terminal
- Complaint with IEC 439-1, EN 60439-1 and EN 60439-2
- The switchboard must keep a 30 % of its capacity for future enlargement of the supported devices.

2.4 Control Building equipment Specifications

The scope of work will include the complete installation of the Centralized management elements detailed in present specification. The supply shall include:

2.4.1 Server room equipment

2.4.1.1 Hardware Server for virtualization

for central management software for all systems including at least 3 rackmount servers with:
- Dual Intel Xeon CPU with at least 8 cores
- Memory
  - 128 GB of RAM, SDRAM DDR
  - Expandable up to 768 GB
  - Advanced error-correcting code (ECC)
- Storage
  - 3 discs of 2TB 10.000 RPM, SAS or SSD
  - Expandable up to 32 TB
  - RAID integrated disk controller
  - Hot Pluggable
- Interfaces
  - Two Gigabit Ethernet card sockets
  - Two Gigabit Ethernet adapters
  - One 10/100 Ethernet for management
  - I/O serial ports
  - 2 x 3.0 USB ports
  - VGA / HDMI video ports
  - CD-ROM reader
- Operative systems supported on virtualization: Microsoft Windows, Ubuntu, Red Hat, SUSE LINUX, etc.
- Redundant Power Supply Unit 2 x 750 W
- 19" rack mount

2.4.1.2   Network shared storage

The Data Storage System will consist of a large data storage environment in hard drive and iSCSI technology. These hard drives will be stored in a Disk array that includes SAN iSCSI network configuration features as a RAID strategy and state checks.

The Disk Array will be based in a virtualized modular storage architecture that will dynamically manage the disk activity to avoid inactivity. The Disk array will have the following elements:

- Modular chassis
- Disk controller
- Disk drives of different sizes and performance

The disk array incorporates multiple redundant paths from the controllers of the cabin to the drives, to provide increased data availability.

This system will allow to:

- Restore lost or corrupted files from security copies.
- Eliminate redundant data from security copies in order to maximize capacity.

Technical Specifications

The Storage Disk array must meet the following technical specifications:

- Supported interfaces: DAS, SAN iSCSI, SAN FC, etc.
- Support for OS: Windows, Linux, Unix, VMware, etc.
- Double SAN iSCSI interfaces with Gigabit Ethernet
- RAID compatibility: RAID 5 and RAID 6
- Management interfaces: SNMP, Telnet, HTTP, web SSL
- Virtualization technology for the array management.

Controller

- Electrical requirements:
    - o Voltage: 100-240 Vac
    - o 2 Battery: Li-ion
    - o Dual redundant Power supply unit
- Hardware:
    - o 19" rack standard
    - o Disk-drives: 48 TB, 3.5"
    - o Memory: 16 GB system RAM
    - o Includes front and rear cooling.
    - o At least 2 x 10Gbps network interfaces.

2.4.1.3   Server 19-inch rack with KVM

Rack with depth 1000mm at least including:
- height 42 U
- Integrated PDU
- Switch KVM with input for keyboard, mouse and monitor.
    - o Compatible with Windows, and Linux
    - o High VGA resolution 1920 x 1080 at least
    - o Ports with LED diagnosis
    - o OSD ("On Screen Display")
    - o Password Security

- o Identify and select computers by name.
- o Assembly: 1 U rack 19 "
- o Accessories
  - ▪ Monitor TFT 15 "
  - ▪ Keyboard with touch pad

2.4.1.4 NTP Server

The NTP server will provide the time reference to all the systems installed at the tunnel. The NTP server will consist of a GPS antenna and a server dedicated to manage the NTP protocol packets.

Technical Specifications

The NTP server will have, at least, the following main specifications:

NTP server

- • Internal time base:
  - o OCXO or TCXO oscillator. (Ageing max: 2.10-9)
  - o March reserve: 2 h. Configuration parameters stay on flash memory
  - o 100ns precision for GPS synchronization
- • Safety:
  - o 64-bit RSA MD5 certificate, HTTPS; SSH, SNMP v3
- • Network protocols:
  - o NTP v4
  - o SNTP v4
  - o HTTPS
  - o SNMP v3
  - o IPv6 (DHCP compatible)
  - o FTP
- • Hardware specification:
  - o IP 31
  - o MTBF: 110 000 h
  - o Size: 1 U, 19" Rack
  - o PSU: 230 VAC/50-60 Hz (redundancy)
  - o Max consumption 20 VA
- • Web Configuration
- • Synchronization inputs:
  - o 1st: GPS/ GLONASS / NMEA + PPS
  - o 2nd: AFNOR NFS / NTPv4 Ethernet
  - o 3rd (backup): Frequency 10 MHz
- • Output:
  - o NTP V4/SNMP in RJ45
- • GPS compatibility: GPS/GLONASS

GPS antenna

- • Weight: 6.4 oz. (180g)
- • Dimensions: 2.48-inch dia. x 1.6-inch ht. (63mm dia. x 40.5 mm ht.)
- • Connector: TNC
- • Mounting: 0.75-inch threaded mount
- • Operating Temp: -40°C to + 85°C
- • Storage Temp: -40°C to + 100°C
- • Humidity: 20% to 95% R.H.
- • Frequency: L1 (1575) MHz

- Impedance: 50 OHMS
- Polarization: RHCP
- VSWR: 2.0 max
- Axial Ratio: 90° : 3.0 dB min. 20° : 6.0 dB min
- Gain: 28.0 dB min

The antenna should include its connecting cable, cable tube protection and the fastening elements.

2.4.1.5 Network Switches

The server room will also have a network rack housing the redundant core switches with the following specifications to achieve the following connectivity:

- dual connection 10Gbps with existing AHT-2 core switches.
- dual link 10Gbps for connection to the other AHT-1 core (core to core ring)
- dual link 1 Gbps for connection to redundant fiber ring connecting all edge switches in the tunnel

Redundant Backbone switches Pair (Layer 3)
- Eight (8) ports 10 GbE XFP
- Eight (8) ports 1 GbE SFP
- Thirty-Two (32) ports 10/100/1000Base-Tx
- Layer 3
- Installation options: 19" rack
- Support:
  - o VLAN ID Assignation
  - o ACL Security Assignation
  - o QoS policy assignation
  - o Port authentication assignation
  - o DNS resolution for RADIUS
  - o Protection and Intrusion detection mechanisms o Multicast capacity
  - o DHCP
  - o Spanning Tree
  - o Rapid Spanning Tree
  - o QoS mechanisms

Edge switches (Layer 2)

The edge switches will be installed in the network cabinets all over the length of the tunnel.

- Two (2) 1 Gb Ethernet
- 8, 16, 24 according to detailed design
- Layer 2
- DIN rail
- Power supply DIN rail
- Support:
  - o Protection and Intrusion detection mechanisms
  - o Multicast capacity
  - o Rapid Spanning Tree
  - o SNMP

2.5 Master PLC and RIO Specifications

Redundant Master CPU Bundle with the following specifications:

- A powerful processor:
  The CPU achieves command execution times as low as 7.5 ns per binary command.

- 32 MB RAM (16 MB for programs, 16 MB for data):
  Load memory for user programs and configuration data for the automation system; Fast main memory for subroutines of the user program that are relevant to the process.

- Memory card:
  For expanding the integrated load memory. In addition to the program itself, the information contained in the load memory also includes configuration data for the PLC, which is why it takes up twice as much space in the memory.

- Flexible expansion options:
  Up to 16384 digital and 16384 analog inputs/outputs.

- Multi-point interface MPI:
  The MPI enables the creation of a simple network with up to 32 nodes and a data transfer rate of 187.5 kbit/s. The CPU can establish up to 64 connections to nodes on the communication bus (C bus) and the MPI.

- PROFIBUS DP interface:
  The PROFIBUS DP interface allows a redundant, distributed automation configuration offering high speed and ease of use. From the user's point of view, the distributed I/Os are treated like centralized I/Os (same configuring, addressing and programming).

- PROFINET interface with 2 ports (switch):
  Support of system redundancy and MRP (Media Redundancy Protocol)

- Mode selector:
  Designed as a toggle switch.

- Diagnostics buffer:
  The last 120 alarm and interrupt events are stored in a ring buffer for diagnostic purposes.

- Real-time clock:
  Diagnostics reports from the CPU are provided with the date and time.

- Backup battery for keeping program and data memory in case of power disconnected.

Remote Terminal Units

Modular cabinet design with common backplane to accommodate Power Supply Units, Interface Modules, CPU, IO Modules digital and analogue and communication modules.
The RTU CPU is snapped directly onto the DIN rail and features:

- A powerful processor:
  The CPU achieves command execution times as low as 25 ns per binary instruction.

- Extensive work memory:
  200 KB for program, 1 MB for data

- SIMATIC Memory Cards as load memory;
  permit additional functions such as firmware update, data log and archives

- Bit-modular expandability for maximum flexibility;
  up to 64 I/O modules (I/O, technology, and communications modules) in any combination. Station width up to 1 m.

- PROFINET IO IRT interface with 3 integrated switch ports:
  - o   Port 1 and 2 via Bus Adapter
  - o   Port 3 via integrated RJ45 socket

- Integrated communication functions:
  - o   PG/OP communication
  - o   PROFINET IO
  - o   Open IE communication (TCP, ISO-on-TCP and UDP)
  - o   OPC UA server/client (data access)
  - o   Web server
  - o   S7 communication
  - o   S7 routing
  - o   Data record routing

- Maintenance-free data backup without battery

- Diagnostics displays for errors (Error), operation (RUN/Stop), maintenance (MT), power supply (PWR) and one link LED per port

- Optional labeling using light gray or yellow labeling strips. There is a choice of 2 materials:
  - o   Foil and roll with 500 strips, for thermal transfer roll printer
  - o   Paper (280 g/m^2), DIN A4 sheets with 100 strips each, for laser printer

- Different PROFINET connection types by means of Bus Adapter
  - o   In standard applications with moderate mechanical and EMC loads, SIMATIC Bus Adapters with an RJ45 interface can be used, e.g. Bus Adapter BA 2xRJ45.
  - o   For machines and systems in which higher mechanical and/or EMC loads act on the devices, a SIMATIC Bus Adapter with connection via Fast Connect (FC) is recommended.
  - o   The use of SIMATIC Bus Adapters with a fiber-optic cable connection (SCRJ, LC) is not possible with CPU 1510SP-1 PN.

- Modular IO interfaces including digital inputs, digital outputs, relay outputs, analogue inputs, analogue outputs, serial Modbus interfaces to be selected according to each panel single line diagram as part of the contractor detailed design.

2.6   Control room equipment

2.6.1   Video wall controller

The Video wall controller allows processing and visualization of images and graphical applications hosted by the controller or the communications network as well as video signals, external RGB/DVI, etc.

The functionalities of the controller software for the video wall (TFT monitors) are:

- Easily access form any operator post. All operators can eliminate, add, move or modify signals and information in real-time.
- Allows representing a schematic diagram of the screens and the displayed information: including all the information and signals present in the video wall (data, RGB signals and video).
- Any position or layout change is displayed in the video wall controllers.
- Intuitive graphical interface that allows eliminating signs or information, add new information sources, move, or modify the existing ones simultaneously in real-time.
- Drag & Drop display. The user will be able to add a new source simply selecting from the list of Possible Sources and dropping them into the layout area.
- Once is placed, windows will be able to be moved freely on the layout.
- The controller will be able to receive the following signals:
  - RGB/DVI/HDMI graphical signals
  - Video IP signals (MPEG 2/4 – H264)
  - Any type of Windows or Unix application
  - Screen view of any terminals of the LAN

The controller will be software-based running in a general-purpose server equipped with special multiple-output graphical cards.

Technical Specifications

The controller will meet, at least, the following minimum requirements:

- Central Unit at least:
  - Rack-mounted 1U for workstation rack setup
  - Intel Xeon 4C CPU 2.5 GHz at least
  - 8 MB of cache level 2
  - Memory: 16 GB DDR3 SDRAM scalable to 32 GB
  - Hard Drive: 2 x 2 TB SATA
  - 2 x LAN Ethernet 10/100/1000
  - Dual Power supply unit
- Graphical output:
  - Up to 32 Video Signals
  - 24-bit color
  - Output resolution from 1920x1080 to 2048x1536

2.6.2 Video wall TFT-LED Monitor 55"

TFT-LED Monitors will configure a visualization system (video wall) to provide general overview of the tunnel state. The visualization system will consist of 8 additional TFT-LED monitors of 55" and the overall video wall for both AHT-1 and AHT-2 should be reorganized in order to provide efficient visibility of the 2 tunnels.

Technical Specifications

The monitors will have, at least, the following main characteristics:

- TFT-LED technology
- Resolution: 1920 x 1080
- Format: 16:9
- Screen size: 55"
- Response time: 0.8 ms
- Contrast: 2000:1
- Visualization angle: 170º (±85º H and V)
- Horizontal frequency: 31,5 – 91,1 KHz
- Vertical frequency: 50 – 85 Hz
- Input:

- o   Ethernet RJ-45
- o   RGB – VGA analogic (640x480) to UXGA (1600 x1200)
- o   480P – 1080I in HD15
- o   HDMI
- Plug and Play: VESA DDC2 Bi
- with thin edge suitable for mounting in conjunction with existing video wall

2.6.3   Operator workstations

The workstation will serve the operator to visualize the tunnel status and send commands in order to take the actions needed at each time. This workstation will host the client applications in order to control the centralized equipment.

Technical Specifications

The workstation will have, at least, the following main characteristics:

- Rack-mounted 1U for workstation rack setup
- Intel Xeon 4C CPU 2.5 GHz at least
- 8 MB of cache level 2
- Memory: 16 GB DDR3 SDRAM scalable to 32 GB
- Hard Drive: 2 x 2 TB SATA
- Disk drive: CD/DVD read/writer.
- 2 PCIe slots:
    - o   Graphical Processing Unit (2 GB)
    - o   Supports for 3 screens.
    - o   Display resolution: 1920x1200
- Internal audio
- Peripheral: mouse and keyboard
- Network: Gigabit Ethernet interface card
- I/O interfaces:
    - o   4 USB 2.0
    - o   2 USB 3.0
    - o   2 series ports
    - o   1 parallel port
    - o   2 10/100/1000 Base-T RJ-45
    - o   1 VGA/HDMI/DP
    - o   Input Output audio
- 3 x LED 22"
- PSU unit
- All the needed SW licenses, OS included.

2.6.4   Desktop Phones

VoIP phone providing operators a mean to communicate with the maintenance staff and the tunnel users.

Technical Specifications

The phone will have, at least, the following main characteristics:

- Functionalities:
    - o   Voice mail
    - o   Graphic display
    - o   Call record
    - o   5 lines of IP voice

- o Call identification
- o Line keys
- o Programmed keys
- o Display keys
- Interfaces:
  - o 2 Ethernet 10/100Base-TX
  - o HCP compatibility
  - o Audio codecs: G.711, G.722, G.729ab, ADPCM
- Required standards:
  - o IEEE 802.1Q (VLAN)
  - o IEEE 802.1p
  - o Type of Service (ToS)
  - o IEEE 802.3
- PoE capability

3   ITS Sub-Systems

The following sections cover the ITS sub-systems as follows:

1. Traffic Management System

2. Closed Circuit Television

3. Automatic Incident Detection

4. Telephone System

5. Public Address System

6. Tunnel Ventilation Control System

7. Emergency Signage System

8. Fire alarm and Linear Heat Detection System

9. Road Weather Information System

10. Private Radio Communication System

11. Access Control System

Each System description will include the following sections:

- Application of refence standards

- Functional requirements

- System Architecture

- Interface with other systems

3.1 Traffic Management System

3.1.1 Application of reference Standards

The European Directive 2004/54/EC in its Article 2.15.2 states: "inside all tunnels longer than 3 000 meters, with a Control Centre and a traffic volume higher than 2 000 vehicles per lane, equipment to stop vehicles in the event of an emergency is recommended at intervals not exceeding 1 000 meters. This equipment shall consist of traffic signals and possibly additional means, such as loudspeakers, variable message signs and barriers".

On the other hand, the NFPA 502 in its Article 7.5.2 states: "Road tunnels longer than 240m shall be provided with means to stop traffic from entering the direct approaches to the tunnel, to control traffic within the tunnel, and to clear traffic downstream of the fire site following activation of a fire alarm within the tunnel".

All VMS traffic signs should comply with the EN-12966 standard.

EN 12966-1 Vertical Road signs—Part 1: Variable message signs standard defines several parameters regarding the spacing, sign dimensions, luminance classes, character heights and times required for driver at different speeds.

EN 12368 standard for all traffic signs luminance uniformity, light intensity, chromatic areas,

3.1.2 Functional requirements of the Traffic Management system

The Traffic control system and indicator is a set of equipment dedicated for the safety of the tunnel operations. The main following functions are:

- Tunnels access control: gauge system, barriers and flashing lights,

- Traffic counting sensors (measurement stations).

- Lane control and speed control signals (LCS).

The gauge system detects over-height vehicles from photocells located within the two gantries at the entrance of each tunnel. The SCS interface with the gauge system is based on digital wiring information from station RIO.

Each barrier closes the entrance of one traffic lane and has a red blinking light above it. The SCS interface with the barriers is based on digital wiring information from station RIO.

Traffic loops are located at the entrance, the middle, and the exit of each tunnel. It generates traffic counting, traffic flow rates and an estimated vehicle average speed. This information is used for qualifying the traffic status such as fluid, congested or stoppage status. The SCS interface with the measure stations is based on Modbus serial links from RIO located in tunnel emergency station.

The LCS informs the drivers on the available lanes and directs the vehicles in case of closing lane. The LCS are made of 3 displays: "go" green light, "do not use" red cross and "keep away" change lane arrow. They are located at the entrance and along each tunnel. The SCS interface with the LCS is based on digital wiring information from tunnel RIO.

The (Speed control sign) is located at the entrance and along each tunnel to remind the drivers of the speed limit for the tunnel and also to reduce the speed at certain events.

For each tunnel, the Operator will define the LCS map in the Control room and this map will be applied after validation either instantly or in light wave following the vehicle average speed.

The SCS provides the following functionalities:

- Monitoring of traffic control systems,

- Alarms logging and events recorder,

- Automatic, operator and local controls of the barriers,

- Automatic, operator and local controls of the LCS,

- Automatic, operator controls of the gauge system,

- Connecting the measurement stations on serial Modbus links,

- Recording the Data traffic loops trends,

- Generation of traffic status from the vehicle average speed,

- Helps the operators to define the new LCS map for each tunnel,

- Automatic or manual controls in case of major events.

In case of major events in the tunnel such as traffic jam, vehicle on a lay-by, excessive temperature in the tunnel, sandy winds, accident, fire, maintenance work under traffic or programmed lane closure the SCS helps the operators in the operations.

3.1.3   System Architecture inside the tunnel

The Variable Message Sign System inside the tunnel will include the following signs:

- Variable Message Signs. These signs will enable the operators at Local Control Center to broadcast custom and predefined messages to all the drivers in the tunnel, depending on the traffic circumstances.

- Lane Control Signs. These signs will indicate to all the drivers the current status of the lane. The Operators will be able to open or close the road lanes remotely using these signs.

- Speed Control Signs. These signs will inform about the speed limit of each lane. Speed values will be managed by operators depending of the traffic circumstances and scenario.

The general criteria to locate the equipment inside the tunnel is:

- The distance between two consecutive variable message signs will be no more than 800 meters, in compliance with the European Directive.

- For each lane two signs will be installed: one Speed Control Sign and one Lane Control Sign. The distance between these set of Speed Control Sign and Lane Control Sign will be approximately 250 meters, in compliance with the European Directive and as per EN 12966-1 Vertical Road signs— Part 1. Lane Control Signs and Speed Control Signs will be installed in independent structural metallic supports on the side walls.

Additionally, the following criteria has been considered for equipment location:

- The signs will be located at a sufficient distance to avoid being hidden by any installed equipment

- To reduce the required communication and power cable length and to facilitate its deployment, the location of all Variable Message Sign will take into account the position of the emergency stations.

Considering these criteria, the variable message signs to be installed and its location inside the tunnel is shown in the diagram below. The VMS large display will only be installed at the entrance gantry and will not be installed in the middle of the tunnel due to the limited height. The Lane control and speed control will be located at the entrance plus 4 locations along the length of the tunnel as shown in Figure 8.
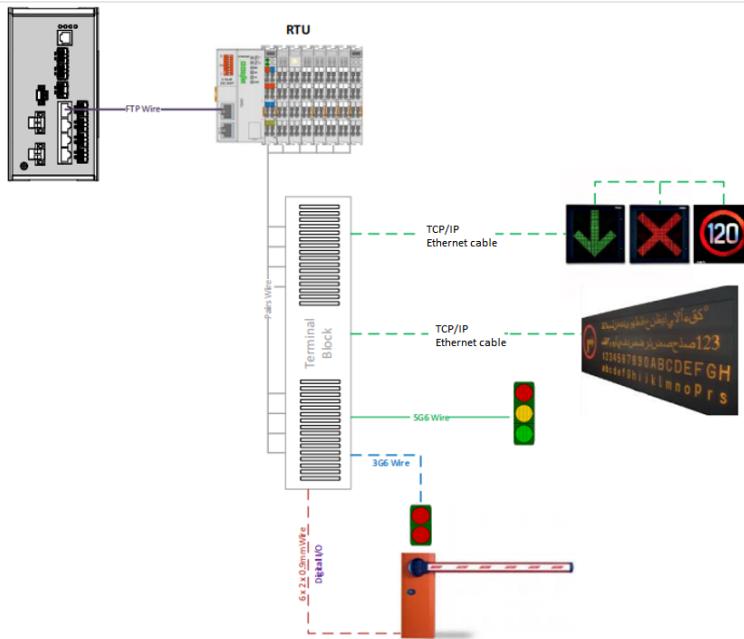
Figure 8 VMS distribution in Tunnel

Figure 9 shows the way this equipment will be connected to the communication network, and how it will be fed. As mentioned previously, the location criteria of the signs will depend on the location of the Emergency cabinets that include the RIO and network switches with the aim of reducing the length of the required power and communication wires.

3.1.4 Tunnel Access Control system

The Tunnel Access Control System will enable traffic management at the entrance of the tunnel. It will also inform all vehicles located near the tunnel portals about the status of the tunnel.

This system will be connected to the communications network so it will be possible to update and control the VMS, traffic signs and barriers in real time, according to the particular circumstances of the tunnel.

Figure 9 VMS and Tunnel access control connectivity

3.1.5 Functional requirements of the Tunnel Access control system

The main functions of the Tunnel Access Control System can be summarized as follows:

- Remote control of all system devices:

    a. Variable Message Signs

    b. Traffic Lights

    c. Automatic Barriers

- Inform clearly in real time all vehicles about the different possible circumstances:

a. Meteorological events

b. Accidents or other kind of traffic issues

c. Infrastructure damages

d. Tunnel Lane closure

e. Speed limits variations

f. Traffic status

g. Over-height control warning

h. Operation & Maintenance works

i. Alternative routes

- Indicate further actions that should be taken if an accident occurs.

- Close the tunnel if is required depending on the circumstances.

The management of all the access control elements will be dynamic and it will be possible to control it from the Control Centre as they will be connected through the Communications network. The operators will be able to manage the traffic and close the tunnel using the automatic barriers, the Variable Message Signs or Traffic Lights.

3.1.6 Tunnel Access Control System Architecture

The Tunnel Access Control system will consist of:

- Variable Message Signs. These signs will enable the operators to communicate with all drivers in the tunnel by sending messages depending on the traffic circumstances.

- Traffic Lights. The traffic lights will allow the operator to manage the flow of traffic.

- Automatic Barriers. The automatic barriers will allow the operator to close the tunnel.

The location of the Tunnel Access Control System equipment will be at the tunnel entrance (West) and will include:

a. Variable message signs: they will be installed at the end of the toll area, just 250 meters before the box section.

b. Traffic Lights: two sections of traffic lights will be installed outside the tunnel. One traffic light per lane will be installed per section. The distance between the Variable Message Sign and the first section of traffic lights will be 50 meters and the distance between the two sections of traffic lights will be 100 meters.

c. Automatic Barriers: the barriers will be located at a distance no longer than 50 meters from the tunnel entry portals. Each barrier will be equipped with red-red LED traffic lights and a horn. In this case the barriers will be installed at the entrance, at the beginning of the box area.

3.1.7 Technical Specifications

<u>VMS General specifications: (EN 12966)</u>

- Beam Width: B4

- Color coordinates: Class C2
- Luminance Ratio: R3
- Luminance: Class L3
- Dimming: 8 levels / automatic
- MTBF: 50.000 hours at least

Mechanical Characteristics:

- Material: Aluminum or Stainless Steel
- IP Degree: IP54
- Temperature Class: T2 (IEC 60079)

Communication:

- Connection: RS-485 or RJ-45
- Protocol: Standard communication protocols could be (NTCIP over TCP/IP or Modbus over serial link RS-485 or MQTT over TCP/IP

Lane control and Speed control signs

- Resolution: 50 x 50 pixels
- Height x Width: 500 x 500 mm
- Maximum Pixel Pitch: 10 mm
- Pixel Color: RGB full Color

Main entrance LED signs

- Resolution: 450 x 100 pixels
- Height x Width: 4500 x 1000 mm
- Maximum Pixel Pitch: 10 mm
- Pixel Color: Full Color
- A pair of ringbolts shall provide an extra fixation to ceiling independent of the beam.

Traffic sign at the tunnel entrance

General**:**

- Lens Diameter: 200 mm at the barrier, 300 mm on the entrance gantry
- Box protected and stabilized against UV radiation.
- Fuse equipped.
- Operating Temperature: from -40ºC to 70ºC
- Protection Degree: IP66 (Ingress Protection Marking)
- Rust-proof
- MTBF: 100.000 hours

Optical Performances

- Narrow Aperture (N class)
- The light shall shine like a bright circular shape.
- The luminance uniformity shall comply with EN 12368 standard.
- The light intensity shall comply with the second level of the class 1 from the EN 12368 standard.
- The colors red, green shall comply with the chromatic areas of the EN 12368 standard.
- LED background: black
- Ghosting effect not exceeding the values for the class 1 of the EN 12368 standard.

Support structures for all VMS signs

Compliant with the mentioned characteristics and the general required procedures at the latest versions of the following standards:

- EN 10025 - Hot rolled products of structural steels.
- EN 1993 - Design of steel structures
- Stainless steel at least S304 at least with 4mm thickness
- Loads should be calculated and submitted prior to manufacturing.

Tunnel access gate barrier

At each tunnel entrance there will be 2 barriers installed on both sides with each one having the following specifications:

- Barrier arm 4 meters
- Arm made of aluminum alloy or carbon fiber.
- Opening speed 1 to 2 seconds
- Electromechanical motor with speed control
- Safety loop sensor to prevent hitting a passing vehicle.
- LED light alarm while moving
- Protection class IP54 at least

3.1.8 Interface with other ITS Systems

The main interfaces of the Traffic Management system are:

- Traffic Detection and Classification system (CCTV)
- Telecommunication Network system
- Centralized management system

Traffic Detection and Classification System (CCTV)

The Traffic Detection and Classification System (CCTV) will inform the Traffic Management System in order to change the state of the signs and traffic lights to achieve a safe state of the tunnel for the drivers.

Telecommunication Network System

Traffic Management system will need the Telecommunication Networks to transmit its information. Traffic Management will provide to the Telecommunication Networks its communications need, such as bandwidth, locations, others.

Telecommunication Network will provide the following:

- 10/100/1000Base-Tx ports

Centralized Management system

Centralized Management System will provide the RTUs to connect the Traffic Management devices. Traffic Management will provide its needs, such as capacity, functionalities, others. Centralized Management System will provide NTP server to allow all systems to have the same time reference.

3.2   Closed Circuit Television System

For surveillance of traffic conditions, detection, and verification of incidents inside the tunnel it will be necessary to install a surveillance system using video cameras. The Closed Circuit Television System (CCTV) is an important part of the ITS field equipment and in order to accomplish its security functions it is required to monitor, control, and manage all the installed cameras. The Closed Circuit Television System is one of the main systems required for a rapid detection of incidents outside and inside the tunnel.

The Closed Circuit Television system allows the operators who are working at the Control Centre to remotely visualize the real time situation inside and outside the tunnel and therefore increase the security. In case of an event detection by another system the CCTV will immediately verify the alarm and evaluate the risk of the vent.

In addition, CCTV will help the operator to provide a quicker response to the event and to analyze the registered video afterwards. During the CCTV system design, the system architecture and equipment specification will be according to the latest technology.

3.2.1   Application of reference Standards

The European Directive 2004/54/EC in its Article 2.14.1 states: "video monitoring systems and a system able to automatically detect traffic incidents (such as stopping vehicles) and/or fires shall be installed in all tunnels with a Control Centre".

The NFPA 502 in its Article 7.3.1.2 states: "Closed-circuit television systems (CCTVs) with or without traffic-flow indication devices shall be permitted to identify fires in tunnels with 24-hour supervision. Ancillary spaces within tunnels (pump stations, utility rooms, cross passages, ventilation structures) and other areas shall be supervised by automatic fire alarm systems".

All cameras should be compliant with the following standards:

- CENELEC - EN 50132-5-2: Alarm systems - CCTV surveillance systems for use in security applications - Part 5-2: IP Video Transmission Protocols

- EN61000-3-3, -6-1, -6-2: Limitations of Voltage charges, voltage fluctuations and flicker; Electromagnetic compatibility.

- EN 50130-4: Electromagnetic Compatibility for Alarm and Fire Alarm System.

- SMPTE 274M-2008 standard for camera performance.

- RoHS 2002/95/EC and 2011/65/EU

3.2.2   CCTV Functional requirements

The main functions of this system are listed below:

- Surveillance of the traffic conditions inside the tunnel.

- Surveillance of evacuation stairs, lower-level gallery.

- Monitoring of Emergency Phones and doors to technical rooms.

- Detection and verification of incidents. Video surveillance is one of the key elements in which the accident management is performed.

- Analysis and surveillance of other alarms detected and raised by other systems in the tunnel.

- Camera control and alarms management

- Interchange of video data with existing Control Centers.

- Data collection of the installations and systems performance.

- Data collection of the events in order to analyze them afterwards.

In addition to the general functions the CCTV system allows the operators to control all the images provided to:

- Monitor the traffic inside the tunnel in order to help the installation management.

- Monitor the meteorological conditions in order to help them to analyze the current conditions and warn all drivers.

- Help the ongoing maintenance works in order to reduce the risk of the onsite workers.

- Systems surveillance inside the tunnel in order to facilitate systems damage detection.

- Facilitate damage and accidents detection in order to reduce the time needed to solve the problem.

- Facilitate the verification of alarms risen by other systems.

- Help to restore the initial conditions after the accident has been sort out.

3.2.3   CCTV System Architecture

There are different possible architectures for the CCTV design. It depends on the way the video and the images are transmitted to the Control Centre, the length of the tunnel and the number of specific places to monitor. It is important to distinguish between the design inside the tunnel with its accesses and the design outside the tunnel.

The design criteria followed inside Ahmed Hamdy tunnel will be:

- Cover all way inside the tunnel tube.

- Locate all the cameras as close as possible to the Roadside Emergency Phones to first facilitate the connection of these cameras to the telecommunication network and second, to cover the surveillance of these emergency stations.

- The distance between cameras will not be longer than 80 meters in order to optimize the operator view and allow AID in case video technology is used.

- In case the location of any camera is too close to any other system (Pipes, VMS, LCS, speed signs, etc.) it will be moved 10 to 30 meters ahead or back, depending on its situation.

The location of the fixed cameras and dome cameras will provide 100% visual coverage of the tunnel without any shadow area. As a general rule all fixed cameras will be installed as close as possible to the top of the tunnel, which is the highest part of the tunnel, and the distance between them as it has already been mentioned will be no longer than 80 meters.

The fixed cameras will always be oriented in the same direction as traffic flow in normal operation conditions. However, there will be two exceptions in the tube as it is important to install fixed cameras on the opposite direction at the tunnel entrance and exit.

The mounts and accessories to install the fixed cameras will meet the criteria regarding the location of the other system's elements and the minimum height available for tall vehicles.
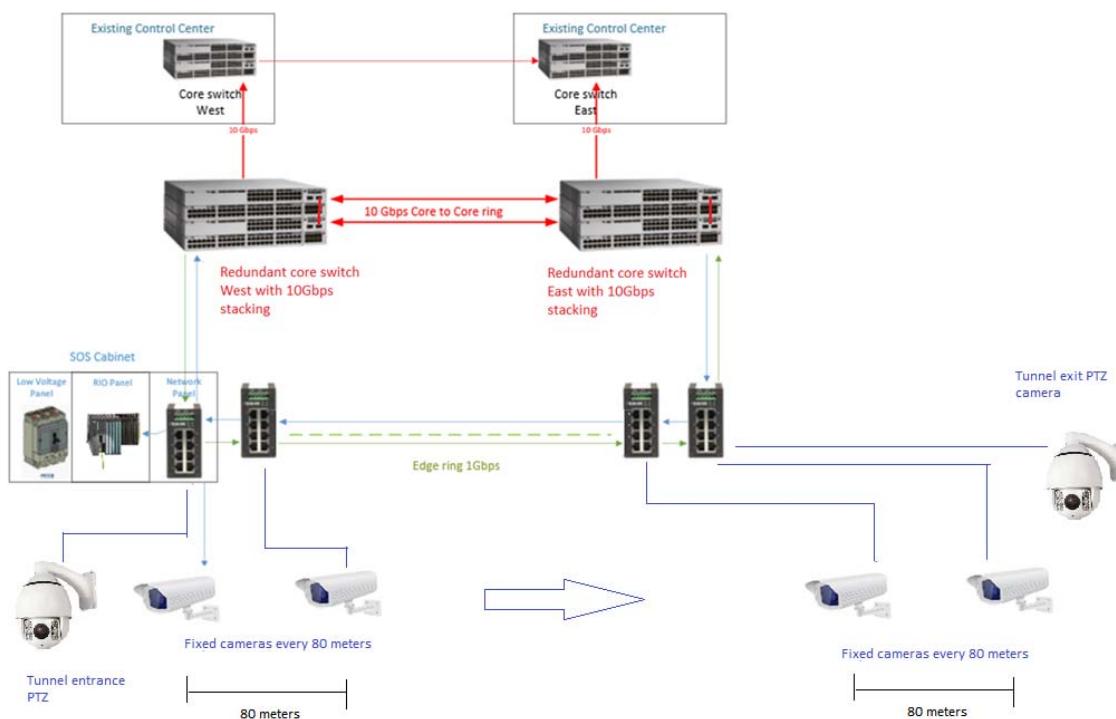
Apart from tunnel tubes, there are other areas which need to be covered. The criteria will be:

- Inside technical rooms outside and inside the tunnel one camera will be installed to monitor the rooms and control the entrances.

- The accesses to the tunnel entrance will be covered with (2) Dome cameras. They will be installed in the U section.

- Inside the lower gallery level, a mini dome will be installed every 200 meters to cover the control and network cabinets and secure the cables and verify fire events.

All the cameras (fixed and dome) installed inside and outside the tunnel will be IP cameras. Therefore, CCTV system will be based on an IP network. Inside the tunnel each camera will be connected to the closest network switch in order to connect to closest switch of the Communication Network (located at the emergency control and network cabinet), unless the distance between them is longer than 90 meters.

It is required that the supplier provides the detailed coverage plan showing the actual visible areas according to the exact location of each camera as part of the detailed design that will be submitted by the contractor and accepted by the customer prior to delivery.

3.2.4 Technical Specifications

All cameras should comply with the mentioned standards in section 3.2.1 plus the following minimum requirements:

- Resolution at least 1920x1080 Full HD

- Intelligent Dynamic Noise Reduction

- ONVIF compliant

- PoE standard: IEEE 802.3af (802.3at Type 1)

- Video compression H.265 to minimize network load and storage capacity.

- Multiple configurable streams over H.265 and M- JPEG

- Varifocal lens 5-50mm to adjust the camera field of view.

- Corridor lens to minimize the walls in the camera field of view.

- Protection class at least IP66

- Wide Dynamic Range 120dB

For the entrance and exit areas the PTZ cameras will have to comply with the following:

- Pan Range: 360º cont.

- Tilt Angle: 18º above horizon

- Pre-position speed Pan 400º/s, Tilt 300º/s

- At least 30x optical zoom no less than 100 mm focal lens

3.2.5   Interface with other ITS Systems

The main interfaces of the CCTV system are:

- Automatic Incident Detection system

- Telecommunication Network system

- Centralized management system

Automatic Incident Detection System

The interface between the Automatic Incident Detection System and the CCTV is very close because the AID System needs the CCTV cameras to confirm the detected events.

Telecommunication Network System

Closed Circuit Television system will need the Telecommunication Networks to transmit its information. CCTV will provide to the Telecommunication Networks its communications need, such as bandwidth, locations, others.

Telecommunication Network will provide the following:

- 10/100/1000Base-Tx ports

Centralized Management system

Centralized Management System will provide the servers and workstations to install the CCTV software. CCTV will provide its needs, such as capacity, functionalities, others.

Centralized Management System will provide Storage Disk arrays to store all data required from the systems. CCTV will provide its needs, such as storage capacity, others.

Centralized Management System will provide NTP server to allow all systems to have the same time reference.

Video wall design of the existing control center will be redesigned to accommodate both tunnel CCTV streams.

3.3 Automatic Incident Detection System (AID)

The Automatic Incident Detection System (AID) inside the tunnel is based on the CCTV video analysis or other equivalent technologies such as Radar systems. The objective is to know and identify if there is any kind of incident and in addition it will be able to measure the traffic density.

3.3.1 Application of reference Standards

The European Directive 2004/54/EC in its Article 2.14.1 states: "video monitoring systems and a system able to automatically detect traffic incidents (such as stopping vehicles) and/or fires shall be installed in all tunnels with a Control Centre".

The NFPA 502 in its Article 7.3.1.2 states: "Closed-circuit television systems (CCTVs) with or without traffic-flow indication devices shall be permitted to identify fires in tunnels with 24-hour supervision. Ancillary spaces within tunnels (pump stations, utility rooms, cross passages, ventilation structures) and other areas shall be supervised by automatic fire alarm systems".

3.3.2 AID Functional Requirements

This system is the best complementary system to the traditional Roadside Emergency Phones and CCTV systems and allows the detection of events that would not be able to be detected by other systems like the electromagnetic loops. For instance, vehicles crossing the tunnel very slowly, vehicles stopped anywhere inside the tunnel, objects that have fallen anywhere inside the tunnel, pedestrians, etc.

The Automatic Incident Detection System has the following functions:

- The AID system will automatically and immediately raise an alarm of any event or incident inside the tunnel. This alarm will can be raised before any operator detects the incident.

- The AID system allows a fast analysis of the situation in order to help make any decision.

- The system will not raise different alarms which belong to the same incident.

- The alarms activated can be divided in the following groups:
  - Main Alarms:
    - Stopped vehicle inside the tunnel either in the lanes or on the sides.
    - Queue forming detection.
    - Vehicle driving in opposite direction.
    - Vehicles driving slowly inside the tunnel.
    - Slow moving traffic and congestions
    - Pedestrians walking inside the tunnel.
    - Objects that have fallen inside the tunnel that might be risky.
    - Poor visibility due to smoke or fog
  - Technical alarms:
    - CCTV camera signal lost
    - Low video quality
    - Failures with the communication system connection

In addition, the Incident detection system will be able to provide traffic statistics and data. This information will be:

- Traffic data per lane:
    - o Traffic speed
    - o Traffic density in some areas
- Traffic data per vehicle:
    - o Vehicles speed average
    - o Inter-vehicle distance average

3.3.3 AID System Architecture

The AID processing can be onboard of the cameras, or a central AID processor located at the server room and processing all the received video streams from the IP cameras. The AID server will then relay the events to the centralized SCADA system over OPC interface.

In case of providing AID enabled cameras the central video management software will have a rich Analytics modules dedicated for traffic applications and providing all the above-mentioned functional requirements (3.3.2) and will have to comply with the below specifications.

3.3.4 Technical Specifications

- Incident detection rate: > 95%
- False alarm rate: < 10%
- Fast detection: < 5 s
- Pre-alarm and Post-alarm recording with adjustable length.
- Alarm search by time, type of alarm, location, and ad-hoc filtering
- Management and recoding of operator actions, acknowledge and reject (could be achieved in AID software or directly in SCADA view)

3.3.5 Interface with other ITS Systems

The Automatic Incident Detection System has interfaces with:

- CCTV system
- Telecommunication Network system
- Centralized Management System

CCTV System

The interface between the Automatic Incident Detection System and the CCTV is very close because the AID System needs the CCTV cameras to work if video detection is selected or will need the CCTV cameras to verify each incident in case Radar technology is selected.

Telecommunication Networks System

AID system will need the Telecommunication Networks to transmit its information. AID will provide to Telecommunication Networks its communications need, such as bandwidth, locations, others.

Telecommunication Networks will provide the following:

- 10/100/1000Base-Tx ports

Centralized Management System

Centralized Management System will provide the servers and workstations to install the AID software. AID will meet the requirements, such as capacity, functionalities, others.

Centralized Management System will provide Storage Disk arrays to store all data required from the systems. AID will meet the requirements, such as storage capacity, others.

Centralized Management System will provide the racks, in the technical rooms, to install the AID equipment, such as AID modules, others. AID will meet the requirements, such as ventilation, space, others.

Centralized Management System will provide NTP server to allow all systems to have the same time reference.

3.4 Emergency Telephone system

The aim of the telephone system is to provide the following main functions:

- Service telephone system for the tunnel personnel,

- Emergency telephone system for tunnel users.

The Roadside Emergency Phone System has become one of the most important and useful systems in road tunnels environment. This system provides direct communication between the tunnel user and the Control Centre, which is vital in dangerous situations.

3.4.1 Application of reference Standards

The European Directive 2004/54/EC in its Article 2.10.3 states: "Emergency stations shall be provided near the portals and inside the tunnel at intervals which for new tunnels shall not exceed 150 meters and which in existing tunnels shall not exceed 250 meters".

Besides, the NFPA 502 in its annex A, Article A.7.4 states: "Areas of refuge or assembly, if available, should be provided with reliable two-way voice communications to the emergency response authority."

According to this article, it will be necessary to install emergency phones inside the Ahmed Hamdy tunnel giving two-way communication coverage to the road tunnel.

All telephony devices should also comply with the following:

- IETF RFC 3261. SIP Session Initiation Protocol. Network Working Group. IETF. June 2002
- IEC 61000-6 Electromagnetic compatibility (EMC) -- Part 6-1: Generic standards - Immunity for residential, commercial, and light-industrial environments

3.4.2 Telephone System Functional Requirements

The service telephone system provides communication between any service telephone device scattered among the whole site (offices, workshop, storage room, control room, technical room, etc ...).

The emergency telephone system provides communication between tunnel users through SOS phone devices network and the emergency central station located in the control room. The phone network is made of telephone devices located along tunnels in each emergency station.

One IP PABX (Private Automatic Branch exchange) located at technical building West perform and manage the communication phone functionalities.

The interface with the telephone system is mainly based on one Redundant Modbus link from IP PABX to main PLC.

The Roadside Emergency Phone System in Ahmed Hamdy 1 Tunnel will offer these functions:

- Voice communication between tunnel users and tunnel operator

- Emergency phones tests

- Voice recording

- Graphic interface for the Roadside Emergency System

The functions for the user are listed below:

- Emergency call: as a response to the raising of the handset, an oral communication between the emergency phone and the control center is established.

- Once the handset is raised the telephone system will auto-dial the operator extension.
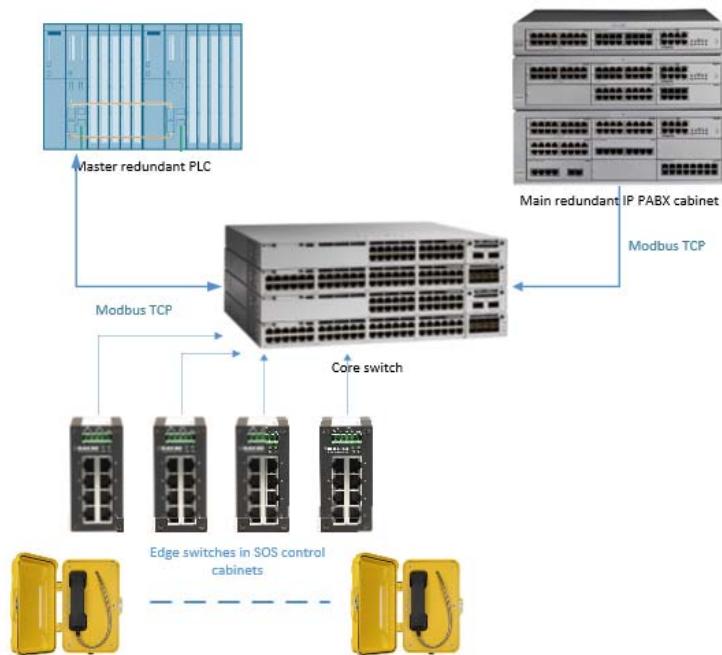
- Wait Message: when the call is established and the user is waiting for the operator to respond, an audible message is generated by the speakers of the phone. This message is configurable.

- Fail Message: if the communication fails and the call cannot be processed, an audible tone is generated by the speakers of the phone.

3.4.3 Telephone System Architecture

The main IP PABX should have hot standby call processor modules and both of them should have direct Ethernet connection to the core switch. All system events and alarms should be sent to the Master PLC as a Modbus TCP link and also to be sent to the central network management software as SNMP traps.

The emergency telephone sets will be connected to the nearest industrial edge switch inside the emergency cabinets distributed over the tunnel length and located every 160 meters.

Figure 10 overviews the telephone system.

Figure 10 Telephone system

3.4.4 Technical Specifications

Emergency telephones

- Network interface:
  - Signal type : 1 x 10Base-T, 100Base-TX
  - Operation mode: full/half duplex
  - Protocols: TCP, UDP, IGMP, RTP, ICMP, Telnet and SIP
  - Signal connector: 1 RJ-45
- Electrical interface:
  - Impedance of the speaker: ≥ 4 Ω
  - Output speaker power: 5 W RMS
  - Microphone type: Dynamic or Electret

- o   Open door alarm: Usually open contact
- o   Call push button: Usually open contact
- Remote management
  - o   SNMP protocol support for alarm trips
  - o   Modbus TCP support for direct reporting to SCADA system over TCP/IP
  - o   Remote management and firmware update through central device management software
  - o   Support for auto-attendant software
  - o   Configuration of autodial or auto-answer
- Power supply:
  - o   AC or DC power supply
  - o   Internal back-up battery is required.
- Operating environment:
  - o   Temperature: -40 ºC – 75 ºC
  - o   Humidity: 0 % - 95 %

Emergency Phone Cabinet dimensions:

- Width: 300 mm
- Height: 800 mm
- Deep: 300 mm

IP PABX / SIP server

The IP PABX meets the following requirements:

- Call requirements:
  - o   Black list management
  - o   CDR (Call Detail Records)
  - o   Call Forwarding
  - o   Call queuing
  - o   Call routing
  - o   Call transference
  - o   LDAP integration
  - o   Voice mail
  - o   Trunking
  - o   Audio recording management
- Contact center: contact management functionalities
- Audio encoding:
  - o   G.711 mu-law, a-law
  - o   G.723.1
  - o   G.729A/B
  - o   GSM-EFR, FR
- VoIP supported protocols:
  - o   SIP
  - o   H.323
- Hardware equipment:
  - o   Power supply unit
  - o   4 x 10/100/1000 Base-T Interface card
- It will include all licenses necessary for the correct performance of the system (emergency SOS phones and desktop telephones in the control room)

Emergency SOS phones management

IP PABX will allow the following minimum functionalities for the communication with the SOS phones:

- SOS phones emergency/maintenance calls attention
- SOS phones remote activation
- SOS phones status monitoring. Alarms reception and display
- SOS phones tests. Maintenance tasks: maintenance tests, audio tests, etc.
- SOS system data base management
- System events register.
- Incident reports handling
- SOS phones audio volume configuration
- Indication when SOS phones are busy, calling or fault.

Emergency Telephone attendant station

Software based running on high performance workstation with at least:

- Rackmounted 1U for workstation rack setup
- Intel Xeon 4C CPU 2.5 GHz at least
- 8 MB of cache level 2
- Memory: 16 GB DDR3 SDRAM scalable to 32 GB
- Hard Drive: 2 x 2 TB SATA

The workstation should be connected with a professional desktop dispatch microphone and should allow

- the operator to respond and transfer received emergency call.
- show the status of all emergency phones and
- allows the operator to register his actions taken during the call receiving.

The event log should keep the time and identity of each received call, the actions taken and when the call was closed.

3.4.5 Interface with other ITS Systems

The Roadside emergency phone system has an interface with six systems: Communication Networks, Emergency Signage System, Control Architecture, Centralized Management System, and Audio Recording Management System.

Communication Networks

In general, the location of the switches depends directly on the location of the emergency phones because the switch will be located in a cabinet next to the emergency phone.

The connection of the emergency phone to the nearest switch will provide the following two functions:

- Phone calls between the roadside emergency phones and the Control Centre by connecting the emergency phones to the IP PABX at the Control Centre

- The monitoring of the state of the roadside emergency phones on the Centralized Management System.

Emergency Signage System

Inside the tunnel illuminated signs indicating the exact location of the emergency phones. Photo luminescent signs indicating the distance to the emergency phones will be installed in the road level and the escape corridor.

Control Architecture

To receive open door alarms, the open-door sensor will be connected to the remote terminal unit by a one pair cable Ø 1 mm.

Centralized Management System

The Centralized Management System will integrate the Emergency Phone control interface, which will act as a graphic user interface of the system state and functionality.

In general, the functions of the Emergency Phone interface will be the following:

- Call attending
- Call remote activation.
- Alarms reception and supervision
- Maintenance tests
- System events registration
- Volume setting

Audio Recording Management System

Every voice communication between the Control Centre and the Emergency Phones will be recorded by the PABX IP software in the Control Centre and will be available in the storage system.

3.5 Public Address System

The Public Address System will enable the broadcast of pre-recorded or original voice messages from the Local Control Center to tunnel users.

3.5.1 Application of reference Standards

The European Directive 2004/54/EC in the article 2.16.3 mentions, "Shelters and other facilities where evacuating tunnel users must wait before they can reach the outside shall be equipped with loudspeakers for the provision of information to users." According to that statement a Public Address system will be necessary to be defined for the Ahmed Hamdy Tunnel.

The Contractor shall supply equipment of a well-proven design, observing local laws and standards:

• IEC 60849 Sound Systems for Emergency Purposes

• IEC 60331 Tests for electric cables under fire conditions

• IEC 60754 Tests on gases evolved during combustion of materials from cables.

• IEC 1034 Measurement of smoke density of cables burning under defined conditions.

3.5.2 PA Functional Requirements of the System

The Functional Requirements of the Public Address System are listed below:

• Dispatch specific instructions to all the users everywhere inside the tunnel, service gallery, exterior access stairs and tunnel portals.

• Dispatch of announcements to zones and/or groups.

• Different types of messages:

  o Pre-recorded messages

  o Broadcast announcements in real time

• Selection of number of repetitions and time period of the messages

• In an emergency situation the messages will be modulated and sent by the commercial FM signal, so all the drivers inside the tunnel will be able to listen these messages using their radios inside their cars

• Volume adjustment

• Broadcast announcements recording

3.5.3 Public Address System Architecture

The system will be composed of the following equipment:

• Loudspeakers inside the tunnel (connected in a staggered pattern to give redundancy to the zones), and at the surrounding area of tunnels portals. It is important to consider that "staggered" refers to the connection as the loudspeakers are located in the same side of the tunnel.

• Amplifiers connected to the loudspeakers.

• Audio matrix with output cards enabling the communication with the management system at Control Centre West via fiber communication

• Microphonic desk, which will enable the broadcast of customized or pre-recorded messages from the Control Centre West and the East (Back-up Control Centre)

- Noise level probes to be installed in the tunnel to give feedback to the main controller to adjust gain on the amplifiers in the corresponding zones.

Exponential loudspeaker

Digital amplifier 360 W
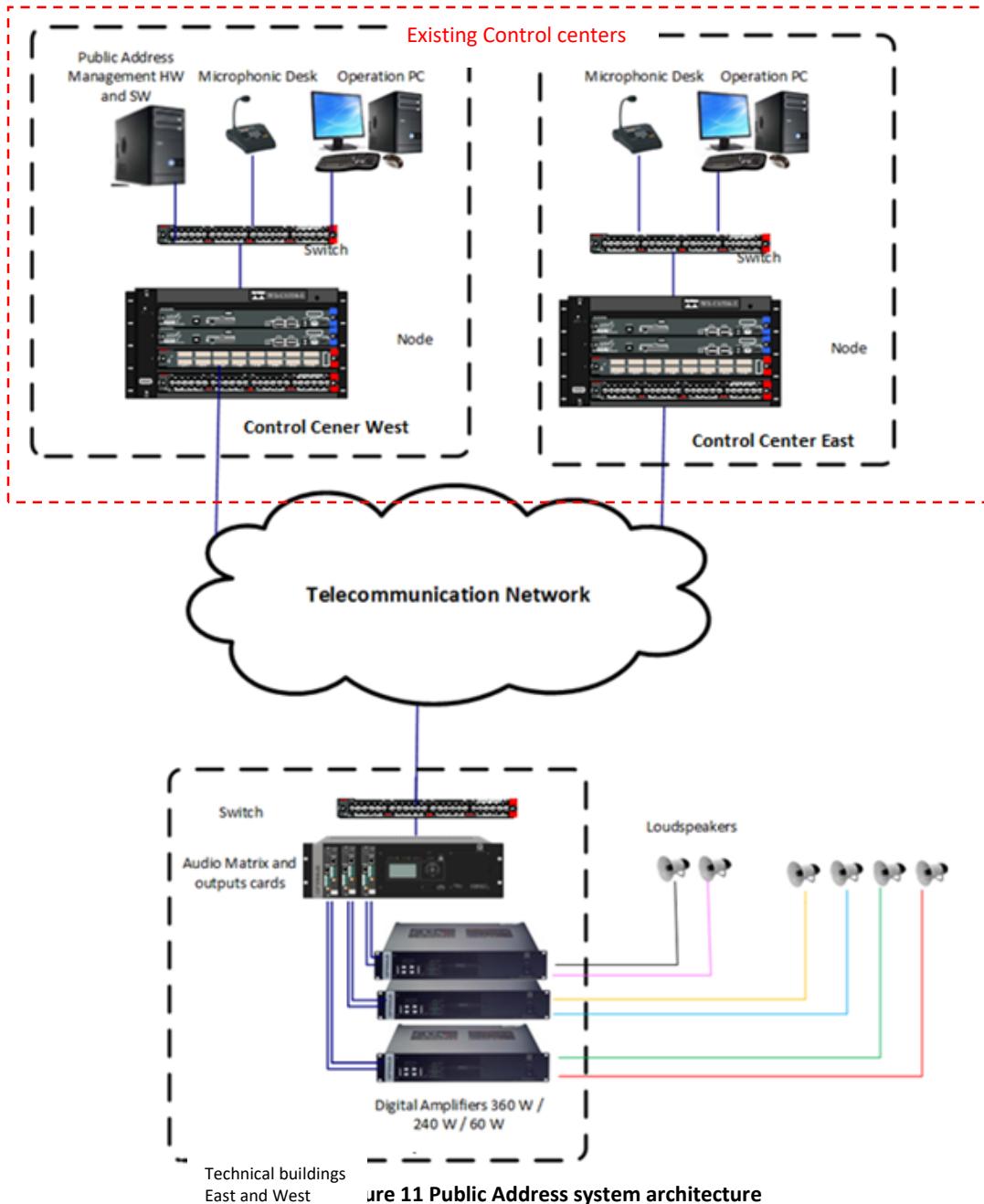
Microphonic desk

Audio Matrix

The simplified system architecture is shown in Figure 11:

Figure 11 Public Address system architecture
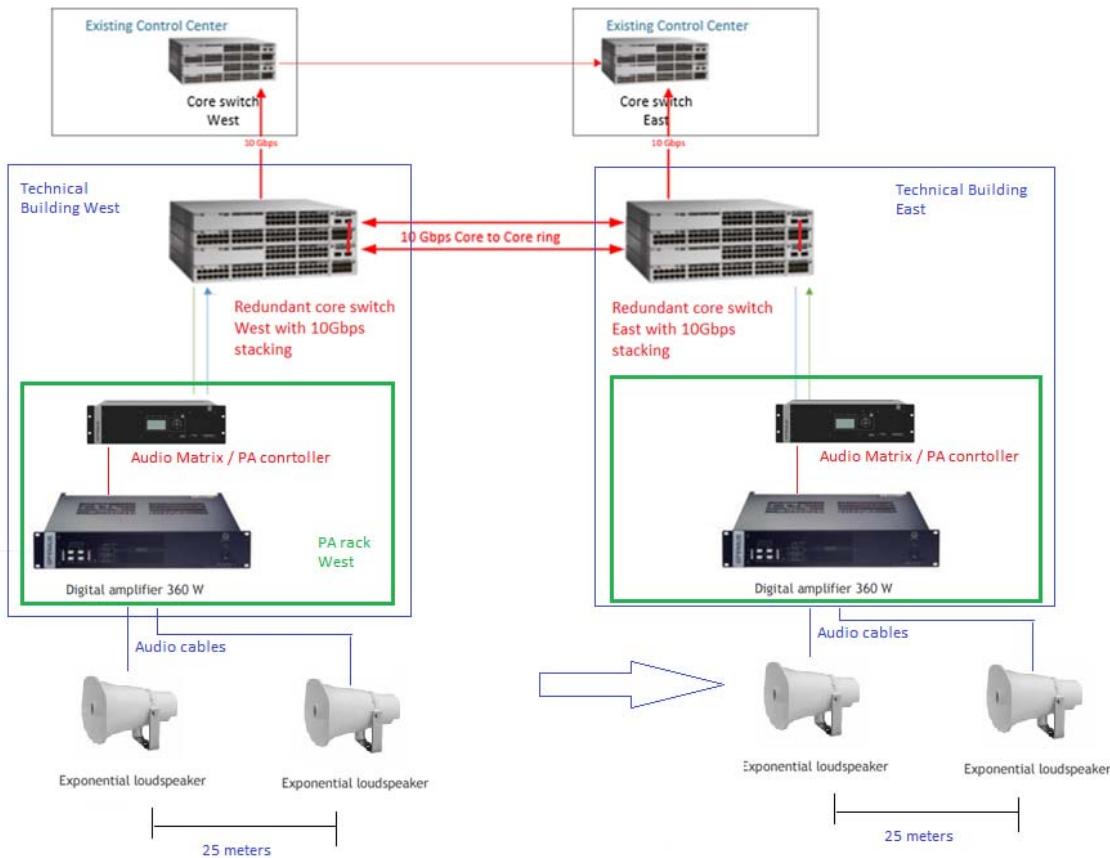
The location of the exponential loudspeakers will fulfil the following criteria:

- Every 25 meters along the tunnel on the external side (cut and cover section) installed on the exterior sidewall (the right side taking as a reference the traffic direction)

The distance between the loudspeakers is defined by the sound level that the Public Address System has to provide to every place inside the tunnel. The most significant parameters that define the sound level are:

- Sound Pressure Level (SPL): the difference between the SPL and the noise level has to be higher than 25 dB in closed areas and 10 dB in open spaces.

- Speech Transmission Index (STI): the Public Address System will guarantee a STI bigger than 0.3 in all the areas of the tunnel.

3.5.4 Technical Specifications

A- Exponential speaker inside the tunnel

- Stainless steel brackets and hardware (screws, bolts), and powder-coated horn ensure superb weatherproofing and corrosion-resistance.

- Shock-resistant aluminum oval horn.

- Panel-mounted input impedance selector on high impedance models facilitates input impedance matching.

- Unobtrusive off-white color (corresponding to RAL 9010).

- Compliance with IP65.

The exponential loudspeaker must meet the following requirements:

Rated Input:	10 W, 15 W, 30 W

Rated Line Voltage:	100 V line
Impedance:	330 Ω (30 W)
Sound Pressure Level:	113 dB (1W, 1m at 500 to 2,500 Hz peak level)
Frequency Response:	250 – 10,000 Hz

B- Ceiling Speakers in the technical buildings

The ceiling speaker must meet the following requirements:

- Loudspeaker   5"
- Power (RMS)   6 W
- Maximum Power   9 W
- Impedance   1k7 3k3 and 10k Ω
- Frequency response   100 ~ 15.000 Hz
- Sensitivity   92 dB (1 W, 1m)

C- Digital Amplifiers

The digital amplifiers must meet the following requirements:

- Power Supply: 230 Vac, 50 – 0 Hz
- Channels: according to the contractor acoustic study
- Power: according to the contractor acoustic study
- Inputs: Auxiliary 0 dB, 10 Kohm, asymmetrical
- Frequency response: 80 ~ 16.000Hz (+1dB, -3dB)
- THD: Below 0.5% at 1/3 of power
- SNR: > 80 dB

D- Digital Audio IP Matrix

Main Characteristics:

- Surveillance functionalities

    o Speakers Line (Open and Short circuit)
    o Amplifiers: To check whether amplifiers are ON and also if there is any problem for audio broadcasting: Cable unplugged, volumes at 0, power transistors burnt.
    o Internal cards surveillance and status report.

- Redundancy

    o The IP connection is fully redundant with 2 connectors working as primary and secondary, with immediate commutation and surveillance of the link status of both.

- Include one 4 GB micro SD card that is used as pre-recorded message storage unit. This provides the functions of DVA (Digital Voice Announcer) to the local zones.
- The mainframe backbone is equipped with a 16 channels bus for all the different audio interconnections.

- It has space for up to 8 different Supervisory cards. The number of cards can be increased, by using the expansion connector (included in the mainframe), as the Compact mainframe are stackable. So several mainframes (up to 10) can be linked together, allowing reach up to 110 supervisory cards.
- The mainframe itself, without adding extra cards, includes all the necessary connections, surveillance system and front panel indicators to fulfil with EN54-16 (EU standard for Fire Evacuation):

  - o Fire Trigger Input (supervision for Short/Open cable)
  - o Fire Mode Notification (used for Fire Mute, and different functions)
  - o Real Time Clock
  - o Alarms and Events logs files (with Time Stamp)
  - o Alarms visual and acoustic indication in the front panel

- Al the system information and alarms are transmitted to the network (by using the IP connection) so the different control software can get info about the system.
- Connection with External Systems:

  - o VoIP
  - o XML Commands
  - o TCP socket connection
  - o DLLs
  - o Dry Contacts (IN or Out): with the surveillance of the contact status. One IN and one OUT contact included in the basic mainframe.

The digital audio IP matrix must meet the following requirements:

- Capacity: 8 cards
- Audio channels: 16
- Communication system: IP layer 3 & layer 2 network
- Connections: ETH A / ETH B (redundant system)
- Outputs: Fail relay (NO/NC)

E- **Audio Copper Wire**

Two wire cable for PA. It must be halogen free, flame and fire retardant. A line of loudspeakers will be installed for every amplifier.

The only connections to the public address distribution line to the loudspeakers shall be done in the distribution boxes and the speakers themselves.

Technical Specifications

Different cable core diameters should be calculated for each loop, Copper wire 2 x 2,5 mm2 , 2 x 4 mm2 , 2 x 6 mm2 , 2 x 10 mm2 and 2 x 16 mm2 with the following minimum specifications:

- Voltage: 0.6 / 1 kV

- Halogen free: (IEC-60.754.1)

- No corrosivity: (IEC 60754.2, NFC-20453)

- Low smoke emission (Transmittance greater than 90% s/ EN 50268) IEC 61.0343

- Cu wire: Class 5

- Isolation: XLPE

- Max working temperature: 90 ºC

- Constructive characteristics: EN-21123.4

F- Distribution Box

Made from halogen free fiberglass reinforced polyester compound, these boxes allow a service tap-off from the main through cable without the need to strip or cut the main cable.

The only connections to the public address distribution line to the loudspeakers shall be done in the distribution boxes and the speakers themselves.

Technical Specifications

The Distribution Box must meet the following requirements:

- Fire resistance:

  o NF C 32-070: temp. 920°C – temperature increases.

  o NF EN 50362:   temp. 850°C – temperature increases.

- Service terminals:

  o 2 to 5 insulation-piercing, stainless steel connectors, fitted into a ceramic base. The whole arrangement is fitted to the wall by means of a stainless-steel plate.

  o 2 to 5 insulation-piercing only under EN 50362

- Protection class: IP66 according to NF EN 60529

- Shock resistance: IK09 according to NF EN 50102

- Fire smoke class: M1F0

- Self-extinguishing material: UL94-V0

G- Microphonic desk

The Microphone desk must have an Ethernet network connection.

It must support broadcast announcements through an Ethernet network, in real time, in addition to control data and equipment configuration.

Technical Specifications

- Double Ethernet connection for installations with redundant network

- Dispatch of announcements to zones and/or groups.

- Evacuation announcement activation key.

- Pre-evacuation announcement activation key.

- Activation of general-purpose pre-recorded messages.

- Announcements with or without a pre-announcement tone (Gong).

- Supports the connection of a music source.

- Alarm LED indicator.

- Display of system alarms.

- Monitor loudspeaker.

H- **Public Address System management software**

This software must manage the units of the Public Address control systems. It will be installed in a virtualized server.

Technical Specifications

The Public Address system management software must meet the following requirements:

- Live or pre-recorded messages.
- Selection/editing of zones and groups of zones.
- Graphic interface with plans and presentation of units on them.
- Assignment of priority levels, musical programs, prerecorded announcements.
- Control and dynamic assignment of announcement volume.
- Digital announcement recording (WAV, MP3, WMA, etc.)
- Time programming.
- User profiles.
- System parameters and unit status on-screen supervision.
- Events log and alarm files.

3.5.5 Interface with other ITS systems

The Public Address System will have an interface with the Communications Networks, Radio Communication System, Centralized Management System and Audio Recording Management System.

Communication Networks

Every digital audio IP matrix will be connected by 2 UTP cat 6 cable (because of the redundancy) to the nearest switch in the technical area in order to provide the communication to the Public Address Management Software.

Radio Communication System

The SOS messages sent by the Public Address system will be modulated and inserted into FM frequency band for broadcasting inside the tunnel, so all drivers will listen to these messages in their cars.

In the master station the following will be installed:

- FM modulator which will be in charge of joining the SOS messages with the commercial FM frequencies.
- Additional digital 60 W amplifier that will be connected to the FM modulator.
- An additional audio matrix with output card which will be connected to the digital amplifier.

Centralized Management System

The Centralized Management System will have a specific graphic interface for Public Address System that will allow at least the following functionalities:

- Public Address Area selection
- Pre-recorded messages selection
- Selection of number of repetitions
- Selection of time period of messages
- Alarm indication
- Public Address state
- Sector error
- Amplifiers state and error
- Communication error
- Microphonic desk error
- Control unit error
- Loudspeaker errors per speaker

Audio Recording Management System
Every announcement emitted from the microphonic desk will be recorded by the Audio Recording Management System in the Control Centre and will be available in the storage system.

3.6 Tunnel Ventilation Control System

The aim of the Tunnel Ventilation Control System is to adjust the ventilation system according to the measures acquired by the environmental equipment installed throughout the tunnel. The system will provide the measures of:

- Visibility inside the tunnel: it is vital to maintain good visibility inside the tunnel. Low visibility because of gas emission or environmental causes may affect the driving abilities of the tunnel users.
- Gas emission: an excessive CO, NO2 or CH4 gas emission can harm human beings due to its toxicity.
- Longitudinal air speed: it is important to monitor the longitudinal air speed, especially in fire situations.

It is important to consider that the ground sensors for each gas will be located in the external side of the tunnel at a corresponding height according to the gas requirements. In this way, as the Methane is a light gas, the detection sensor in this case will be installed at the top of the tunnel. In case of the rest of the sensors, a medium height in the external side of the tunnel will be enough.

3.6.1 Application of reference Standards

The European Directive 2004/54/EC in its Article 2.12 states: "The design, construction, and operation of the ventilation system shall take into account the control of pollutants emitted by road vehicles, under normal and peak traffic flow". This article also mentions that "the longitudinal air velocity shall be monitored constantly and the steering process of the ventilation system (dampers, fans, etc.) adjusted accordingly".
According to that article, it is necessary to install environmental detectors for the characterization of the environmental conditions inside the tunnel. The centralized management software will monitor the measures of this equipment in real time. These measures will be displayed into the Control Centre in order to inform the Operators about the condition of the tunnel ventilation system.

3.6.2 Tunnel Ventilation Functional Requirements

The tunnel Ventilation Control System will offer the following functionalities to the Centralized management software:
- Provides 100% coverage inside tunnel tubes.
- Monitoring in real time the measure of:
  - CO Gas emission
  - NO2 Gas emission
  - Visibility inside the tunnel
  - Air speed
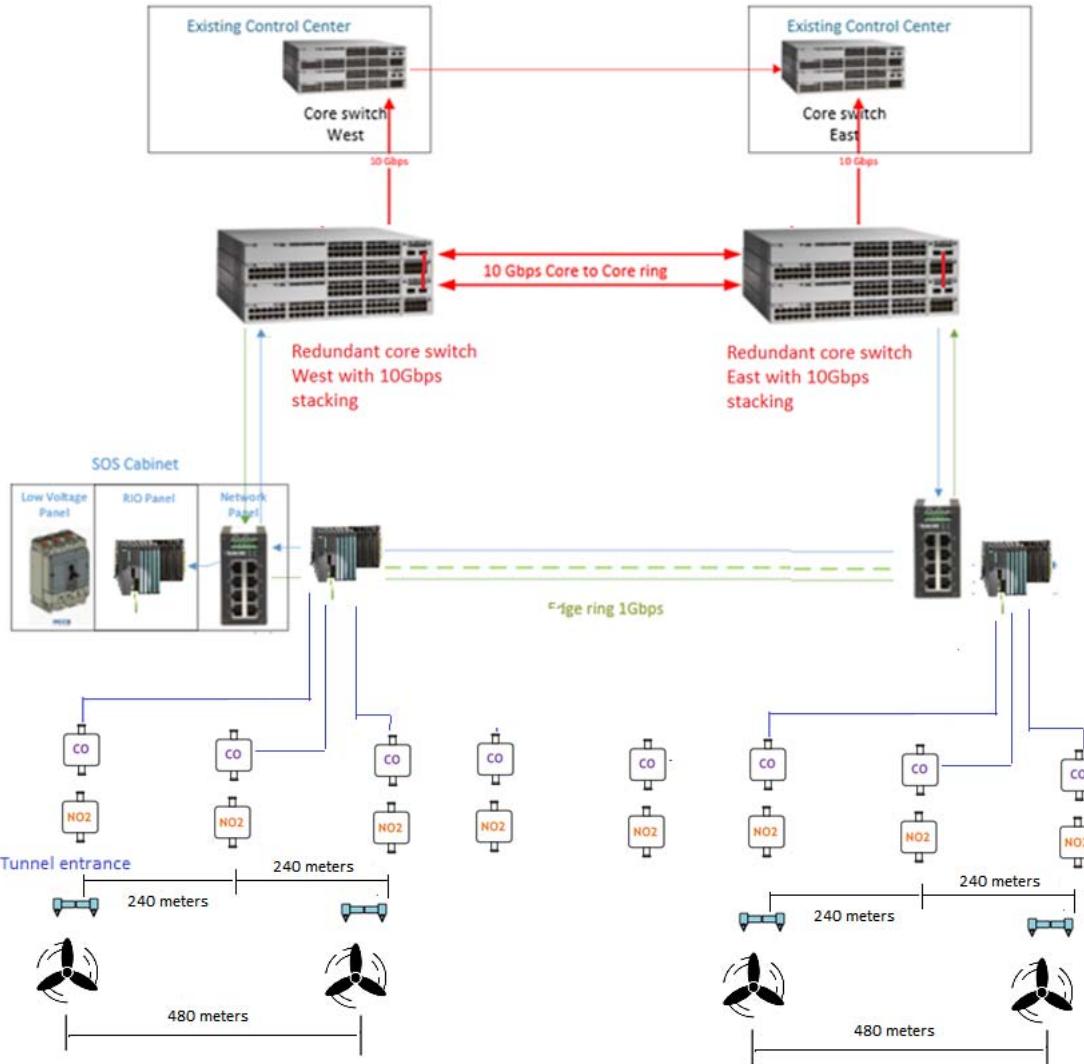
All these detectors will have 4-20 mA analogue outputs that will be wired to the centralized management system through RIO in the nearest control and SOS cabinet.
The process for automatic control of ventilators, running in the master PLC of the centralized management system, will process the measurements and command the system as it is defined in the ventilation algorithm.

3.6.3 Ventilation Control System Architecture

The Tunnel Ventilation Control System will consist of the equipment listed below:
- CO Detector, which detects the amount of CO gas in the air inside the tunnel every 240 meters
- NO2 Detector, which detects the amount of NO2 gas in the air inside the tunnel every 240 meters
- Opacity Sensor, which analyses the visibility inside the tunnel every 480 meters.
- Anemometer, which detects the longitudinal air speed every 480 meters.

The CO detectors will be located every 240 meters along the tunnel and near the emergency stations on the right sidewall of the tunnel. The CO detectors will be located separately from the NO2 detectors.
The required detectors have electrochemical technology, which means the electrochemical sensors generate specific changes of electric current if there is CO present.

The NO2 detectors will be located every 240 meters along the tunnel and near the emergency stations on the right sidewall of the tunnel.
The required detectors have electrochemical technology, which means the electrochemical sensors generate specific changes of electric current if there is NO2 presence.

The opacity sensors will be located every 480 meters along the tunnel and near the emergency stations on the right sidewall of the tunnel.

The required opacity sensor has the light diffusion principle, which means, the sensor generates a visible light towards a mirror and then it returns to the sensor. The intensity of its reflection will determine the accurate measure of visibility.

The anemometers will be located near the entrance and exit portals. In the middle part of the tunnel anemometers will be located every 240 m. The anemometers will be installed on the top of the tunnel, and they will be separated from the tunnel wall at least 0.5 m.

The technology required for the anemometers is propeller type: the wind speed and the direction of the wind is detected by the rotation of the propeller. They are usually used in the tunnel environment because of their robustness and accuracy.

3.6.4   Technical Specifications

The technical specification for the CO detectors is:
* Measuring range: from 0 to 300 ppm (parts per million)
* Technology: Electrochemical
* 0.5 ppm resolution
* Error probability: < 2%
* Response time: T90<40 sec
* Protection index superior or equal to IP65
* 4-20 mA analogue outputs
* Installation from ground: 150-200 cm

The technical specification for the NO2 detectors is:
* Measuring range: from 0 to 10 ppm (parts per million)
* Technology: Electrochemical
* 0.1 ppm resolution
* Error probability: < 2%
* Response time: T90<35 sec
* Protection index superior or equal to IP65
* 4-20 mA analogue outputs
* Installation from ground: 100 cm

The technical specification for the opacity sensors is:
* Measuring range: (0 to 15)/km
* Technology: Light diffusion principle (Optic)
* Resolution: 0.01/km
* Repeat accuracy: ±2 % at 15/km
* Response time: 5 … 600 s freely adjustable
* Protection index superior or equal to IP65
* 4-20 mA analogue outputs

The technical specification for the anemometers is:
* Measuring range: 0.1… 20 m/sec
* Technology: Propeller
* Application range: -30ºC / +60ºC
* < 5% error
* Protection index superior or equal to IP65
* 4-20 mA analogue outputs

3.6.5   Interface with other ITS Systems

The Tunnel ventilation Control system interfaces will be the following:

Ventilation system

> The system will be connected to Ventilation system via communications network to activate defined ventilation procedures according to contamination values measured by ventilation control equipment.

Control Architecture

> The system will be connected to the Remote Terminal Units of Control Architecture for remote monitoring from the centralized management system.

Telecommunication Networks will provide the following:

- 10/100/1000Base-Tx ports

Centralized Management System

> All detectors will have 4-20 mA analogue outputs that will be connected to the centralized management system, specifically to the nearest remote terminal unit by pair cable. This connection allows that all the obtained measures are represented in the centralized management software. Power supply for each equipment will be provided by the same data cable.

3.7 Emergency Signage System

The Emergency Signage System allows the users to know the exact location of evacuation exits and emergency equipment, which is vital in critical situations in order to improve the security of the tunnel. The Emergency Signage System will be deployed in the tunnel and in the control center.

3.7.1 Application of reference Standards

The European Directive 2004/54/EC in its Article 2.12 states: "Specific signs shall be used for all safety facilities provided for tunnel users". Also, in the American NFPA in the article 11.6 mentions, "Lighting shall be provided to highlight special emergency features including but not limited to fire alarm boxes, extinguishers and telephones, and special feature instructional signage."

3.7.2 Functional Requirements of the System

The Emergency Signage System in the Ahmed Hamdy Tunnel will provide the users the indication of the equipment listed below:

- Evacuation exits.
- Roadside emergency phones
- Portable Extinguishers
- Fire Hose Connections

3.7.3 System Architecture
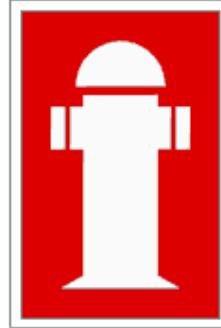
The signaling devices that will be installed in the tunnel consist of the equipment listed below:

- Illuminated signs.
- Fire Hose Connections
    - o Emergency stations (Roadside emergency phone and portable extinguisher)
    - o Evacuation exit
- Photo Luminescent signs
    - o Distance to the emergency station
    - o Distance to evacuation Exit
    - o Location of evacuation exit

For all illuminated signs, they are transparent photo luminescent sign installed inside the illuminated sign, so the sign is still visible in case of no light and Luminance is according to DIN 67510

Illuminated sign for fire hose connections in Tunnel
The illuminated signs for fire hydrants will be located on the external side of the wall. These types of signs will be placed next to and on top of every fire hydrant.
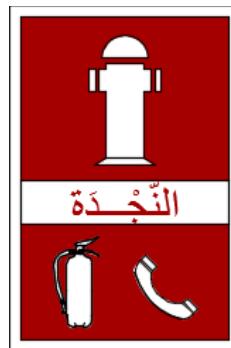
Figure 12 Pictogram for illuminated sign of fire hydrant

Illuminated sign for emergency stations and fire hydrants in Tunnel

The illuminated signs for emergency stations and fire hydrants will be located on the external side of the tunnel. These types of signs will be placed next to and on top of every emergency station.

Figure 13 Pictogram for illuminated sign of Emergency Station and Fire Hydrant

Distance to the emergency station photoluminescent sign in the Tunnel

This sign indicates the distance to the emergency stations that will be placed 30 meters away from every emergency station on the external side of the tunnel.

Features:

- Luminance according to DIN 67510
- Aluminum thickness: 1 mm
- Measurements 1000 x 400 mm

Figure 14 Pictogram for photo luminescent sign of distance to emergency station

3.7.4 Technical Specifications

The illuminated sign must meet the following requirements:

- Protection type: IP65(Ingress Protection Marking)
- Dimension: 750 x 500 mm
- LED Life expectancy: 50,000 hours
- 220 V AC feeder
- Stainless steel cable gland. IP67
- Stainless steel framework or aluminum 5mm thick.
- LEDs Bar surrounding with reflective surface for uniform lighting.
- Polycarbonate for light diffusion, B Class, self-extinguishing.
- Surface painting with Photoluminescent self-adhesive material

The photo luminescent sign for distance to the emergency station or evacuation exit must meet the following requirements:

- The aluminum made sign of 1.5mm, including the mounting material for aesthetic coating.
- Photo luminescent: strontium aluminate
- Evacuation pictograph with left and right arrows, showing the distance.
- Emergency station pictograph with the SOS word with an arrow indicating the location of the station, as well as its distance.
- 1000 x 400 mm dimensions
- Complies with EN 23035-4 Type A , based on the emitted light intensity:

	Category of photoluminescent signals	
	Type A	type B
Luminance at 10 min	$\geq 210 \text{mcd/m}^2$	$\geq 40 \text{mcd/m}^2$
Luminance at 60 min	$\geq 29 \text{mcd/m}^2$	$\geq 5.6 \text{mcd/m}^2$
Fading time (min)	$\geq 3000 \text{min}$	$\geq 800 \text{min}$

3.7.5 Interface with other ITS Systems

The Emergency Signage System has interface with the Roadside Emergency Phones System, Fire Protection System, Control Architecture and Centralized Management System.

Emergency Phone System

The Emergency signs will be located inside the tunnel depending on the location of the emergency telephones. The signs will be in the exact same location for illuminated signs in road tunnel and every 30 meters for the photoluminescent signs.

Fire Protection System

The Emergency signs are located inside the tunnel depending on the location of the hydrants and the extinguishers. The signs will be in the exact same location for illuminated signs.

Control Architecture

In order to receive the illuminated sign state, the power source will have a connection to the digital input module of the remote terminal unit.

Centralized Management System

The Centralized Management System will have a graphic interface for monitoring the state of the illuminated signs.

3.8 Fire alarm and Linear Heat Detection System

The environmental conditions inside a road tunnel make standard fire detectors a non-viable option for fire detection all along the tunnel.

Multipoint temperature measurement linear systems are an alternative for fire detection inside road tunnels.

These kinds of linear systems have a great ability to work in hostile environments, high reliability in fire detection and location, sensitivity to temperature changes in short periods of time and low maintenance requirements. This last factor is very important in the context of road tunnels, where maintenance works have to be reduced.

The fire linear detection will be installed for detecting fire in the following locations:

- Road tunnel
- Lower-level gallery under the road

3.8.1 Application of Reference standards

The NFPA 502 in its Article 7.3.1.2 states: "At least two systems to detect, identify, or locate a fire in a tunnel, including one manual means, shall be provided".

In the case of the Ahmed Hamdy Road tunnel, a fire linear detection system in combination with a set of manual pull fire alarm boxes will be considered.

Standards

- Directive 2004/54/EC of the European Parliament and of the Council on Minimum Safety Requirements for Tunnels in the Trans-European Road Network
- NFPA 502 Standards for Road Tunnels, Bridges and Other Limited Access Highways
- Technical Reports by the European Thematic Network Fire in Tunnels: Fire Safe Design for Road Tunnels and Rail Tunnels
- NFPA 72 National Fire Alarm Code
- IEC 60331 Tests for electric cables under fire conditions
- IEC 60332 Tests on electric and optical fiber cables under fire conditions
- IEC 60754 Tests on gases evolved during combustion of materials from cables.
- IEC 1034 Measurement of smoke density of cables burning under defined conditions.
- NFPA 70 National Electric Code - Article 760 Fire Alarms.
- NFPA 72 National Fire Alarm and Signaling Code.
- EN 54 part 1 Fire detection and alarm systems - Introduction.
- EN 54 part 2 Fire detection and alarm systems - Control and indicating equipment.
- EN 54 part 3 Fire detection and alarm systems - Fire alarm devices - Sounders.
- EN 54 part 4 Fire detection and alarm systems - Power supply equipment.
- EN 54 part 5 Fire detection and alarm systems - Heat detectors - Point detectors.
- EN 54 part 7 Fire detection and alarm systems - Smoke detectors - Point detectors using scattered light, transmitted light or ionization.
- EN 54 part 10 Fire detection and alarm systems - Flame detectors - Point detectors.
- EN 54 part 11 Fire detection and alarm systems - Manual call points.
- EN 54 part 12 Fire detection and alarm systems - Smoke detectors - Line detectors using an optical light beam.
- EN 54 part 13 Fire detection and alarm systems -Compatibility assessment of system components.
- EN 54 part 16 Fire detection and alarm systems -Voice alarm control and indicating equipment.
- EN 54 part 17 Fire detection and alarm systems -short circuit isolators.
- EN 54 part 18 Fire detection and alarm systems -Input/output devices.

- EN 54 part 21 Fire detection and alarm systems -Alarm transmission and fault warning routing equipment.
- EN 54 part 23 Fire detection and alarm systems -Fire alarm devices - Visual alarm devices.
- EN 54 part 24 Fire detection and alarm systems -Components of voice alarm systems - Loudspeakers.

3.8.2 LHD System Functional requirements

An automatic linear fire-detection system will be installed all along the tunnel ceiling. This system will enable the detection of fast changes in temperature inside the tunnel, also being capable of precisely locating the origin of these changes.

The system will have the following main functionalities:

- Accuracy in fire location of fire < 15 meters (the article 7.3.1.3.4 of the NFPA 502 requires less than 15 meters)
- Configurable alarm thresholds:

  - Maximum temperature alarm (usually 58 ºC)
  - Temperature gradient (usually between 6 and 12 ºC)
  - Temperature difference over the mean temperature at a section (commonly 15 ºC)
  - Individual alarm threshold for each detection area
  - Maximum response time < 10 sec
  - Alarms in case of cable breaks

- Information about the length or the magnitude of the fire
- Indications about the direction of propagation of the fire

3.8.3 LHD System architecture

The system will consist of:

- A linear detection cable installed at the top part all along the tunnel and the ceiling of gallery under the road.
- Linear detection cable control units

The architecture designed will provide system redundancy in case of a cable break or a failure in a linear heat detection unit.

The fire detection system will be integrated in the Centralized Management System of the tunnel through a direct connection to the Communications Network (Ethernet IP interface) by a Modbus TCP/IP.

Linear Heat Detection Zoning

The Zones of the Fire Linear Detection system inside the tunnel will be determined by zones of the Water Mist System. The activation of a fire alarm in a zone of the Linear Heat Detection System will activate the same zone of the Water Mist System.

The Zones of the Fire Linear Detection system inside the emergency galleries will be delimited by the position of the Cameras in the emergency galleries.
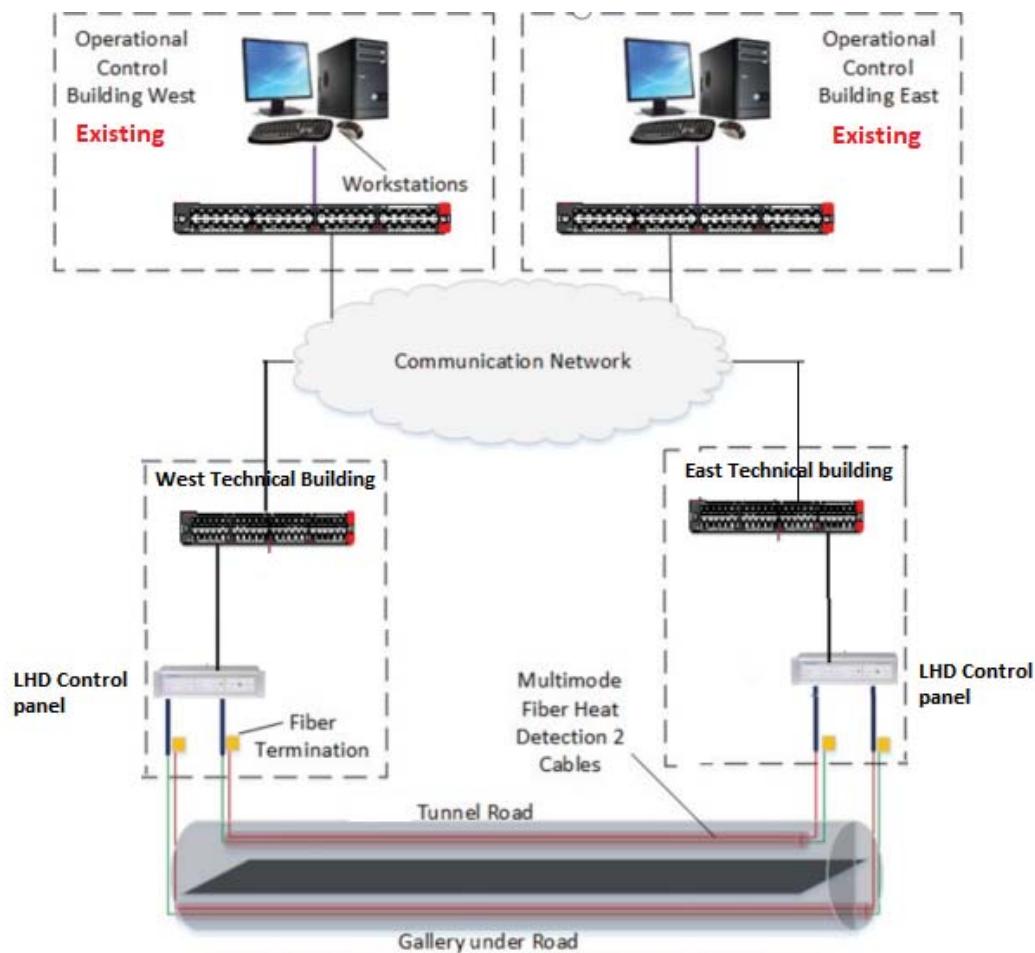
The Fire Linear Detection system architecture is shown in Figure 15.

The system will be based on a linear detection cable for fire and temperature changes detection. This cable will be installed all along each tube near the top part of the tunnel and the emergency gallery, centered between the lanes.

The Linear Detection Cable Control units will be connected to the sensor cable by:

- Connection Boxes installed near the top part of the tunnel and the gallery.

- Connection Wire Shielded Fire resistant wire for connection between Connection Boxes and Control Units.

The fire detection system will be integrated in the Centralized Management System of the tunnel through a direct connection to the Communications Network (Ethernet IP interface).


Figure 15 Linear Fire Detection Architecture

3.8.3.1 Fire Detection System Inside Technical Rooms

The scope of work will include the complete installation of the Fire Detection System Inside Technical Rooms elements detailed in present specification.

The supply shall include:

- Fire Detection Control Panels, including all the auxiliary elements and tools for its correct installation.
- Communications Module, including all the auxiliary elements and tools for its correct installation.
- Manual Fire Alarm Point, including all the auxiliary elements and tools for its correct installation.
- Photoelectric Smoke Detector, including all the auxiliary elements and tools for its correct installation.
- Heat Detector, including all the auxiliary elements and tools for its correct installation.
- Gas Inflammable and Oxygen Detector, including all the auxiliary elements and tools for its correct installation.
- Hydrocarbon Detector, including all the auxiliary elements and tools for its correct installation.
- Fire Alarm Horn, including all the auxiliary elements and tools for its correct installation.
- Fire Detection Loop Wire 2 x 2.5 mm2, including all the auxiliary elements and tools for its correct installation.

The supply shall include the testing, commissioning, and integration of the system, which is described in the technical specification document.

3.8.4   Technical Specification

3.8.4.1   LHD cable

The Multimode Fiber Optic Detection Cable detects hot gases and radiant heat using linear temperature measurement. It is based on Optical Time Domain Reflectometer (OTDR) technology, it injects a series of optical pulses into the fiber under test and extracts, from the same end of the fiber, light that is scattered or reflected from points along the fiber. The detection of fire will be the result of finding variations in the reflection along the fiber in consequence of the heat.

Optical fiber characteristics:
Fiber type: Graded index 125 µm

Mechanical characteristics:
- Cable sheath material: Electro conductive Polyethylene (PE)
- Number of fibers: at least 2
- Max. tensile strength long-/short term   1100 N / 2000 N
- Min. bending radius without tensile loading   40 mm
- Min. bending radius with tensile loading   80 mm Impact resistance
- Max. distance between fixations   1m

-Temperature range:

Operating temperature, continuous	-25 ºC to +85 ºC
Installation temperature	-5 ºC to +50 ºC
Short term temperature	-50 ºC to +150ºC

-Additional characteristics
Fire load 0.31 MJ/m
Fire performance: Halogen free, non-corrosive and no toxic fumes
Resistance to oil, petrol, acid and leach

3.8.4.2   Linear Heat detection control unit

The Linear Heat detection control unit is a fiber-optic linear heat detection system, which monitors a maximum range of 8 km (up to 2 fiber channels with 4 km length each). The system creates an exact temperature profile while measuring the temperatures along the optical fiber in minimum measurement cycles of 10 seconds and with a maximum spatial resolution of 8 m.
The Fiber Optic Detection Cable is based on a laser beam sent through a fiber- optic cable. The fiber-optic cable

scatters a small part of the laser radiation at any point, back to the source. The backscatter is measured by the controller.

The near-infrared electromagnetic LED laser light radiation emitted is scattered in different ways by the fiber-optic cable:

- Rayleigh scattering
- Stokes scattering
- Anti-Stokes scattering
-

The Rayleigh scattered light has the same wavelength as the laser beam, whereas the Stokes scattering has a slightly higher and the anti-Stokes scattering a slightly lower wavelength. The two Stokes scattering types are also referred to as Raman scattering. While Stokes scattering is not so temperature-dependent, anti-Stokes scattering is affected by the thermal energy of the fiber-optic cable's local temperature. The intensity increases with the temperature. The temperature of the fiber-optic cable is calculated from the intensity ratio between Stokes and anti-Stokes scattering.

The Fiber Optic Detection Cable will allow different alarm and pre-alarm criteria at least:
- Surpassing a defined maximum temperature.
- Experiencing a rapid temperature increase.
- Deviating too far from the average temperature of a zone.

Controller Specifications

Transmitter:

- The Transmitter contains the laser and its control.

Receiver:

- The Receiver contains the entire optical system including coupler and optical receiver.
- Coupling of the laser light generated in the transmitter to the sensor cable.
- Converting the back scatter light returned from the sensor fiber from an optical into a electrical signal.
- Amplification and filtering of electrical signals.

Digital controller:

- The digital module controls the entire device and the measurement process.
- It calculates, based on the received measurement data, the temperature profile along the sensor cable.
- Integrated inputs for resetting, external alarm transmission or monitoring functions.
- Integrated outputs enable alarm and malfunction reporting to a fire detection center.

Ethernet interface for Modbus TCP/IP Protocol

3.8.5 Interfaces with other systems

The Fire Linear Detection System will have interfaces with the Communications   Network and Centralized Management Software.

Communications Network

The cable control units will be connected to the centralized management system through the Ethernet Communications Network of the tunnel, for alarms transmission to the Operational Control Buildings.

Centralized Management Software

Interface with the Centralized Management Software: the system will communicate with the Centralized Management Software at the Operational Control Buildings, for remote data and alarms monitoring. The following information will be displayed:

- Fire Alarm by area

- Fail Alarm by area.

- Average temperature by area

- Control unit fail alarm.

CCTV

The Zones of the Fire Linear Detection system inside the emergency galleries will be delimited by the position of the Cameras.

Access control system

Fire alarm dry contact needs to be connected to each access control panel in order to release the doors locks in case of fire event.

Water Mist System

The Zones of the Fire Linear Detection system inside the tunnel will be determined by zones of the Water Mist System. The activation of a fire alarm in a zone of the Linear Heat Detection System will activate the same zone of the Water Mist System.

3.9   Road Weather Information System

Weather and environmental conditions on the road such as rain, fog, wind, or reduced visibility generate degraded states in traffic flow. Under such conditions, the probability of accidents happening increases.

With the aim of ensuring safer driving and the reduction of the number of accidents due to bad weather and environmental conditions, it is highly recommended to know in real time the climatological state of the road and its surroundings. With the purpose of monitoring meteorological conditions outside the tunnel, a Road Weather Information System will be necessary, capable of detecting and measuring atmospheric agents.

3.9.1   Application of Reference standards

Neither the European Directive 2004/54/EC, nor the NFPA 502 explicitly mention the Road Weather Information system. Therefore, the system design will take into account as a design basis other Egyptian standards.

In the case of the Ahmed Hamdy tunnel, the definition of two weather stations, located next to the tunnel portals, will be considered for weather and road state monitoring.

3.9.2   RWIS Functional requirements

The primary function of the Road Weather Information System (RWIS) is to measure and monitor road weather conditions with the use of different sensors outside the tunnel. RWIS assists the Client and other agencies in determining road conditions. This information can be shared with drivers or used internally to assist in scheduling maintenance. RWISs collect atmospheric, pavement surface, and sub-surface information to provide the most accurate weather information available.

The weather stations will be capable of measuring:

o Temperature

o Relative Humidity

o Wind Speed

o Wind Direction

o Visibility

o Rainfall

o Pavement Conditions

The system will gather all the weather-related data and will send it on demand to the centralized management system for statistical studies and calculations. The integration period for these calculations will be usually configured to 1, 5 or 15 minutes.

The weather stations will be capable of warning about weather conditions that could severely affect the state of the road. In this case, the station will immediately notify the Centralized Management System. The information will be shared with road users via VMS displays and will be used to initiate traffic control scenarios.

RWISs should be used with an information dissemination source such as VMS or Speed Control Signs to reach the road users and reduce weather related traffic accidents.
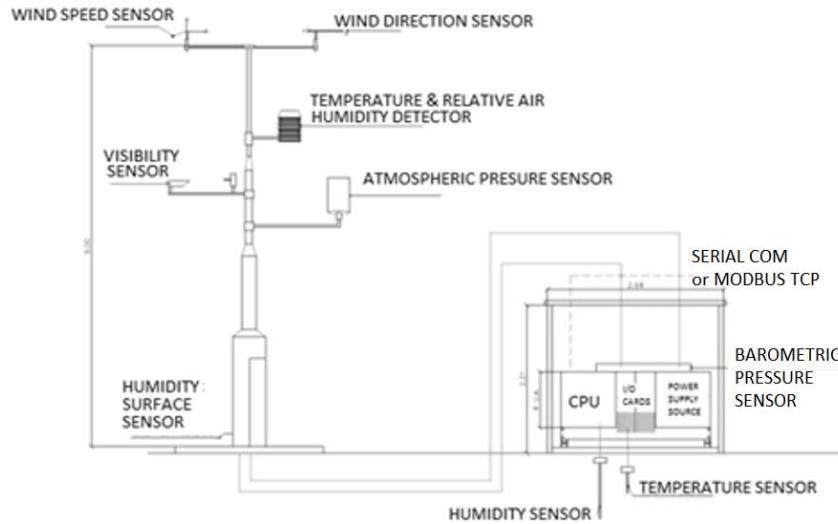
3.9.3   RWIS System architecture

The Road Weather Station will consist of a combination of sensors that gather and transmit pavement, temperature, wind speed, visibility, and humidity data. These sensors are controlled by a field Remote Processing Unit (RPU), which sends the sensor data to the centralized management system.

The Road Weather Information System will be equipped with:

- Barometer

- Anemometer for measuring wind speed and direction

- Rain gauge for rainfall volume and intensity measurement

- Road sensors for measuring:

    o   Temperature

    o   Dry, wet, or wet with liquids road surface

    o   Water of the road surface

- Visibility sensor

- Humidity and temperature sensor

Each weather station will be connected by means of a serial communications interface to the nearest Remote Terminal Unit of the tunnel Control Architecture, or by an Ethernet/IP interface to the Communications Network. This connection will allow remote monitoring from the Control Centre.

Figure 16 Weather station architecture

Embedded road sensor

This is a multiparameter sensor that provides a series of measures on the state of the road. There are two technologies, depending on the measuring principle:

- Active Technology: measures the prevailing physicochemical conditions existing in the aqueous medium on the sensor surface using a Peltier element to heat and cool the sample, providing the actual value of the freezing point.

- Passive technology: measures the prevailing physicochemical conditions in existing aqueous medium on the sensor surface and calculates the freezing point algorithmically function at least of the following parameters:

Concentration of salt (chemical agent), presence or absence of water on the roadway and temperature measurements of surface and subsurface. Interfaces with other systems.

According to environment conditions related with this project, the passive technology principle should be the preferred technology as the best way to evaluate the state of the road.

For its proper operation it is necessary to connect it to a processing unit which has local information of atmospheric parameters supplied by other sensors.

3.9.4   Interface with other ITS Systems

The Road Weather Information System interfaces will be the following:

Control Architecture

The system will be connected to the Remote Terminal Units of Control Architecture for remote monitoring from the centralized management system.

Telecommunication Networks will provide the following:

- 10/100/1000Base-Tx ports

Centralized Management Software

The system will communicate with the Centralized Management Software at the local Control Centre of the tunnel for remote weather-related data and alarms monitoring.

3.10 Access Control System

With the aim of restricting and monitoring the access to technical rooms inside the tunnel premises, an access control system will be defined for the Ahmed Hamdy tunnels. Each door entrance to technical locations will be remotely controlled. Moreover, when required, manholes and technical cabinets will be also controlled to know instantly when the door has been opened.

The system will be managed from the local Control Centre through the access control centralized management software as all detectors will be connected to the communication network.

The Access Control System allows the operators who are working at the Control Centre to remotely notice if someone enters any tunnel area or technical building and therefore increase the security. In case of an event detection by Control Access System, the CCTV will immediately allow to verify the alarm and evaluate the risk of the event. In addition, CCTV will help the operator to provide a quicker response to the event and to analyze the registered video afterwards.

It is important to take into account that the Access Control System will be used as well in the toll areas, and the control center as can be seen in the Figure 17.

3.10.1 Application of reference Standards

Neither the European Directive 2004/54/EC, nor the NFPA 502 explicitly mention the Road Weather Information system. Therefore, the system design will consider as a design basis the designer expertise and the national standards.

3.10.2 Access control system Functional requirements

The system will enable the access management to restricted areas. It will be possible to enable or disable access to selected areas depending on the:

- User profile
- Area
- Day
- Hour

Various levels of access rights to different areas. Record of all the accesses, alarms, commands and other events. It will be possible to make inquiries about the recorded accesses. Remote management of access permission to a determined area.

3.10.3 Access control System architecture

The access control system will be remotely managed from the Control Centre. In this center, the Access Control System management software will be installed.

The architecture for the Access Control System will be distributed, this is, the control of the various control points (doors and gates) will be held locally. This architecture provides high availability to the system, allowing the system to continue operating properly even though failure or loss of communication with the Control Centre.

The access control system will consist of the following equipment:

- Digital card readers, which will be connected to the CPU double door controllers for the transmission of user identification. This will be the interface of the user with the system.
- Electromagnetic locks, which will be the element installed on the door that will enable or disable door aperture. There is no specific requirement related to the doors materials.
- Opening detectors magnetic type for door state monitoring (opened or closed).

- CPU double door controllers: will be the equipment in charge of managing the access control equipment installed on the controlled doors and communicating with the access control system management software.
- Access Control System management software.
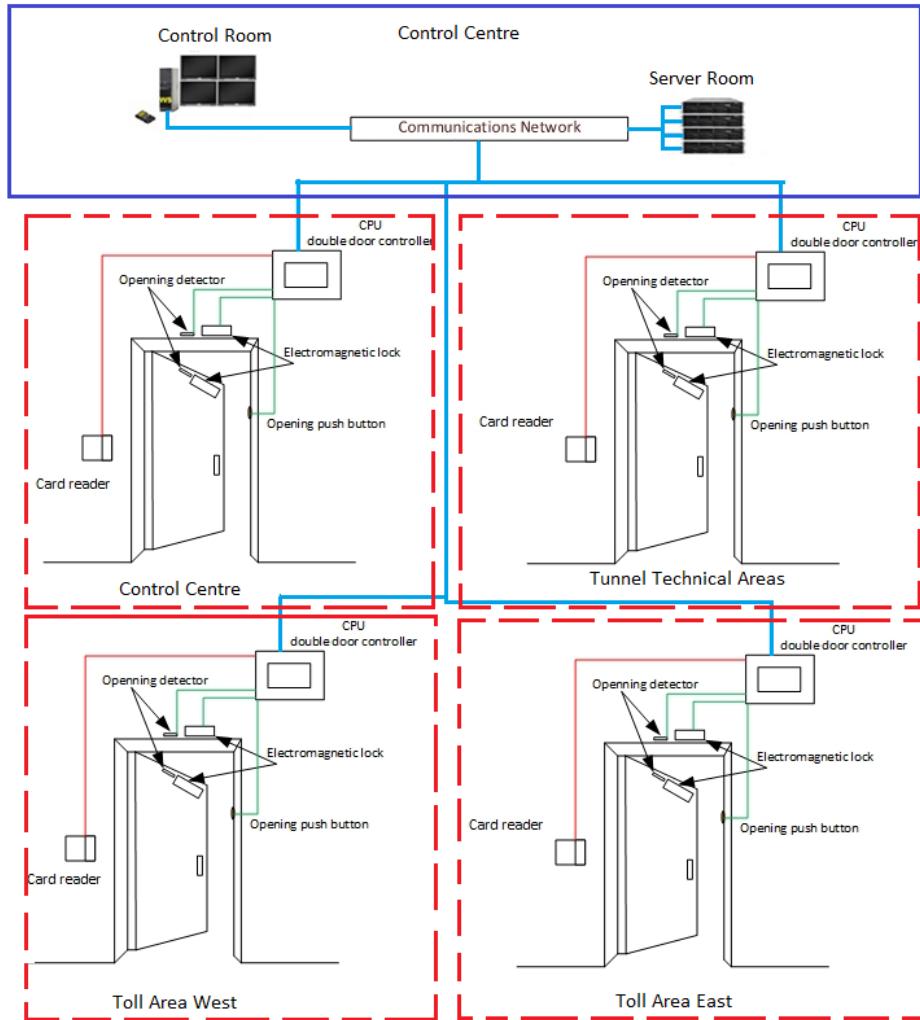
Figure 17 Overview of Access control system

3.10.4 Technical Specifications

The electromagnetic lock must meet the following requirements:
- Electromagnetic lock and the monitoring device that checks the state of the door.
- Body of 75 mm of height for left and right door opening
- Equipped with adjustable nail that allows a tolerance of 4 mm between the slip and the nail.
- Holding force: 3000N a magnet
- Power supply: 12-24 VDC
- Power Tolerance: +/- 10%
- Operating temperature: -10 up to 55ºC
- Suitable for control of movement of persons

- Integration in any security installation
- Equipped with locking position signaling and LED indication
- LED is located behind a protective lens.

The opening detector must meet the following requirements:
- Type of detection: magnetic field measurement
- Housing material: aluminum
- Withstand electric shocks up to 2400 volts.
- Closed circuit with active magnet
- Switched contact for N.C. operation.
- Protection: IP68
- Installation distance between parts: 20 mm
- Maximum operating temperature: 50ºC

The digital card reader must meet the following requirements:
- Proximity HID reader
- Stand-by current: ≤30 mA
- Reading range: 50 to 100 mm
- Response time: 0.1 sec
- Power supply: 12-24 VCC
- ISO 14443A compatible
- Temperature range: -10ºC ...+60º C.
- Protection: IP65
- Operating humidity: 0-95%

The exit push button must meet the following requirements:
- Exit button associated with access control.
- Dimensions approximately: 80 x 80 mm
- Wired to readers for deactivating the alarm process.
- Deactivating door lock when the button is pushed.
- Wall mounted.

The CPU double door controller must meet the following requirements:
- Power supply: 12 VDC
- User capacity: 20.000 users
- Opening methods: Card, card + pin, multi-cards, first card, etc.
- Operating temperature: 0ºC up to 50 ºC
- Enclosed in IP65 housing.
- Internal power supply that supports a battery of 2 Ah in "floating mode".
- Electrical connection to 220 Vac (50 / 60Hz) network using standard cable grounding.
- Bus connectivity via RS232 or RS485 to USB or TCP / IP
- 2 reader ports – RS-485 or Ethernet
- Keypad: multiplexed with card data
- Alarm inputs: 8 supervised, general purpose alarm inputs with programmable circuit type
- Communication: RS485 or TCP/IP communication to all modules
- Card type: multiple reader and card formats for maximum flexibility and security options.

The access control system management software will be installed in the local Control Centre of the tunnel and will provide the following functionalities:

- Remote configuration of card readers
- User profile definition: access rights assignment for every card
- Card programming: identification code and user profile assignment
- System and card configuration storage.

With the aim of maintaining a record of all the actions developed with the access control system management software, this application will communicate with the Centralized Management software of the tunnel.

The access control software must be able to run in a virtualized server environment.

3.10.5 Interface with other ITS Systems

The Access Control System will have interfaces with the following systems:

Control Architecture

The CPU double door controllers will be connected to the Ethernet communications network of the tunnel.

Telecommunication Networks will provide the following:

- 10/100/1000Base-Tx ports

Fire alarm

Each access control panel should have an alarm input connected to the fire alarm system to release all doors in case of fire event. The alarm input should be a dry contact.

Centralized Management System

The access control system management software will communicate will the Centralized Management Software at the local Control Centre of the tunnel for remote data and alarms monitoring.

Centralized Management System will provide the servers and workstations to install the access control software. Access control system will provide its needs, such as capacity, functionalities, others.

Centralized Management System will provide Storage Disk arrays to store all data required from the systems. Access Control system will provide its needs, such as storage capacity, others.

Centralized Management System will provide NTP server to allow all systems to have the same time reference.

3.11 Private Radio Communications System

The Private Radio Communications System will allow the operators, maintenance staff and external emergency services (Police, firefighters, Emergency Medical Services etc) to communicate via the UHF private radio channels that will be retransmitted inside the tunnel.

This system will also provide radio coverage for a selected number of FM commercial radio channels, and it will be possible to interrupt these channels with emergency messages broadcasted by an operator through the Public Address system.

3.11.1 Application of reference Standards

The European Directive 2004/54/EC in its Article 2.16 states: "Radio re-broadcasting equipment for emergency service shall be installed in all tunnels longer than 1.000 meters with a traffic volume higher than 2.000 vehicles per lane. Where there is a Control Centre, it must be possible to interrupt radio rebroadcasting of channels intended for tunnel users, in order to give emergency messages".

3.11.2 Radio System Functional requirements

With the aim of extending the outdoors radio communication services inside the tunnel, the Private Radio Communication system will be able to retransmit existing UHF carriers from the 380 – 470 MHz band (TETRA is assumed as the existing service for emergency services and tunnel operator). This system won't provide a private radio network, but it will provide radio coverage inside the tunnel for the defined frequencies of an existing UHF radio network. In this way, it is highly important that:

- Frequencies should be provided by the owner of the existing networks.
- Licenses should be provided by the owner of the existing networks.
- The devices should be as well aligned with these characteristics.

With this system, security inside the tunnel will be improved and in the event of an emergency situation, emergency services will have an efficient communication system which will allow the coordination of all the services involved.

The mobile phone coverage must be provided by an external operator. Nevertheless, the radiant system (radiating cable) of the Private Radio Communications system will be able to operate in the GSM band (Low band < 1000 MHz), but full coverage and passive compatibility is not assured for this band. GSM equipment is out of the scope of this system, and it must be provided by the mobile phone operators (adaptations of the radiating cable included).

The communication services which will be included in this system will be:
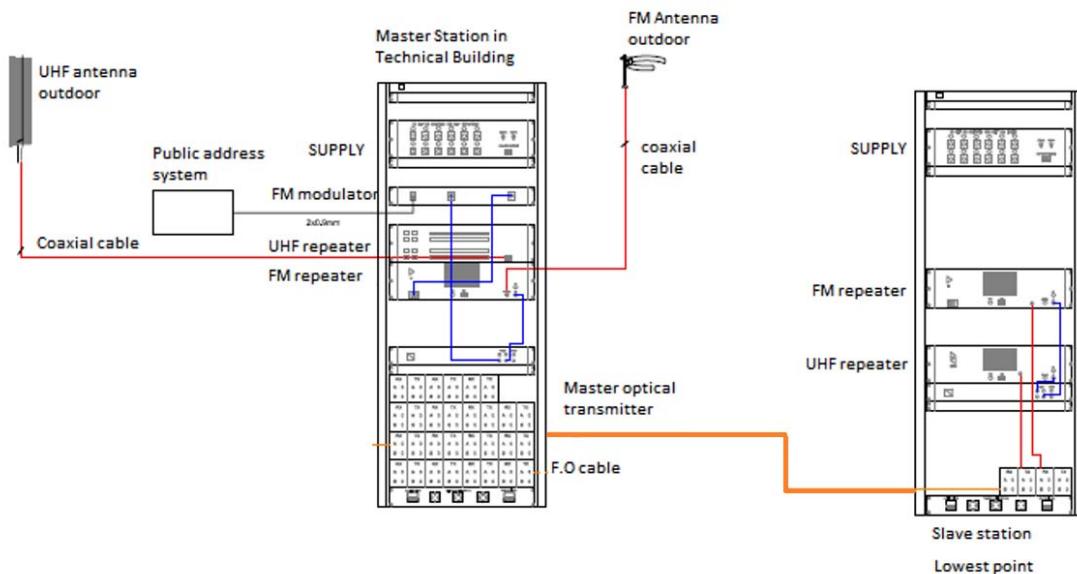
- Commercial channels for Radio broadcasting
- UHF communication system for Police, Firefighters, Emergency Medical Services etc.

Only channels with good coverage and radio conditions will be able to be retransmitted inside the tunnel. In the same way, the quality and the level of the signal is very important because if the signal is degraded outside the tunnel, the quality of the signal retransmitted inside will be even worse and then, the communication quality will not be acceptable. This criterion has to be considered as well for the FM commercial channels.

3.11.3 System Architecture

In Ahmed Hamdy-1 tunnel the system will need one Master Station located outside the tunnel and one Slave Station inside the tunnel. Both stations will be connected through Optical Fiber links, and the slave station will feed the radiating cable installed along the tunnel starting from the lowest point transmitting the signal on the leaky cable in both directions.

The Master Station will be installed outside the tunnel in the Technical Building West. The Slave Station will be installed inside the technical area in the lowest point in the middle of the tunnel. The coverage inside the tunnel will be assured without any shadow area. The links between the Master Station and the Slaves will be based on single mode fiber optic.

Figure 18 Radio System Architecture

The calculations made guarantee the slave stations is enough to cover the tunnel. It is required to have module redundancy on the slave station. In case of failure in any of the modules of the slave station the station will still guarantee full coverage inside the tunnel.

The location of the Stations is as it is shown in the diagram below:

- Master Station: Located in the Technical Building West

- Slave Station: Located in the lowest point in the middle of the tunnel.

3.11.4 Technical Specifications

3.11.4.1 Master Radio Station

Digital channel/band selective FM repeater
- Channel frequency: 87.5 – 108 MHz (up to 24 channels)
- Output power/carrier: +40 dBm
- Impedance: 50 Ohm
- Third order intercept: +54 dBm
- Spurious emission: < -36 dBm
- Remote control: IP-based
- Power requirements: 230VAC 50Hz

FM Modulator
- Frequency Range: 87.5-108 MHz
- RF Power: 1 watt before combining.

- Connector: N-type 50 Ohm
- Harmonics / Spurious: >68 dBc / >95 dBc
- VSWR fold back: Above 2.1
- Frequency selection: Internal switches or menu system

Digital channel and band selective repeater for Public Safety (UHF repeater)
- Channel frequency: Any TETRA channel, options 60kHz (high selectivity), 90kHz (low delay) 380-470 MHz
- Output power/carrier: +40 dBm
- Impedance: 50 Ohm
- Third order intercept: +68 dBm
- Spurious emission: < -36 dBm
- Remote control: IP-based
- Power requirements: 230VAC 50Hz or 110VAC 60Hz or -48 VDC

Multiband Coupler (RF Combiner)
- Frequency ranges: 86 – 108 MHz and 380 – 470 MHz
- Insertion loss: <0.5 dB for both bands
- Impedance: 50 Ohm
- Isolation: >35 dB
- VSWR: < 1.4

Optical Fiber System
- Frequency Range: 68-960MHz
- Gain Flatness: Typical 2 dB (p-p)
- Nominal RF input power: +10 dBm composite power
- Maximum Absolute RF input power: +23 dBm composite power
- Number of optical modules: 1-6
- Power Requirements: 230/115 VAC, 50/60 Hz, 24/-48 VDC
- Local Maintenance Terminal: RS232
- Ethernet connector: RJ45

3.11.4.2 Repeater Radio Station

FM Bidirectional Amplifier:
- Channel frequency: 87.5 – 108 MHz (up to 24 channels)
- Output power/carrier: +40 dBm
- Impedance: 50 Ohm
- Remote control: Ethernet
- Power requirements: 230VAC 50Hz or 110VAC 60Hz or -48 VDC
- IP protection: IP65
- Local Maintenance ports: RS232
- RF Ports: N type female

UHF Bidirectional Amplifier:
- Channel frequency: Any TETRA channel, options 60kHz (high selectivity), 90kHz (low delay) 380-470 MHz
- Output power/carrier: +40 dBm
- Impedance: 50 Ohm

- IP3: >+68 dBm
- Remote control: Ethernet
- Power requirements: 230VAC 50Hz or 110VAC 60Hz or -48 VDC
- IP protection: IP65
- Local Maintenance ports: RS232
- RF Ports: N type female

Multiband Coupler (RF Combiner)
- Frequency ranges: 86 – 108 MHz and 380 – 470 MHz
- Insertion loss: <0.5 dB for both bands
- Impedance: 50 Ohm
- Isolation: >35 dB
- VSWR: < 1.4

3.11.5 Interface with other ITS Systems

The main interfaces of the Radio communication system are:

- Public Address System
- Network Communication System
- Control Network and SCADA

Public Address System

The Radio Communications System will work together with the Public Address system. The SOS messages sent by the Public Address system can be modulated and sent through the commercial FM signal, so all drivers inside the tunnel will be able to listen to these messages using their radios inside their cars. The SOS messages can either be sent by the Operators from the control room or can be played automatically in case of incident.

The Private Radio Communication System will provide an FM modulator in the Master Station which will be in charge of joining the SOS messages with the commercial FM frequencies. Along with the modulator there will be other equipment associated with each radio communication station and it will be in charge of the interconnection of both systems.

The Public Address System will be able to connect to the FM modulator of the Master station in order to send SOS messages in case of an incident. The input of the FM modulator will be a low impedance output from a Public Address amplifier.

Network Communication System

The Radio Communications System is based on a master-slave station layout. This structure is supported by a reliable connection between both master and slave devices. Network Communication System will provide two single mode Fiber Optic links for each slave station to fulfil the Radio Communication System needs.

The following equipment has Fiber Optic communication requirements on the Installation Building:

- Master Station: 2 Fiber Optic ports

The following equipment has Fiber Optic communication requirements on the Cross Passages:

- Slave Station: 2 Fiber Optic ports

Apart from these all the Stations involved in the radio communication system can be remotely controlled by the Operators. Therefore, Radio Communication equipment needs to be connected to the Network Communication system to get remote control and monitoring from the Control Centre.

The following equipment has Ethernet communication requirements on the Technical Building:

- Digital channel and band selective repeater for Public Safety: 1 Ethernet 10/100 port
- Digital channel/band selective FM repeater: 1 Ethernet 10/100 port
- FM Transmitter: 1 Ethernet 10/100 port
- Master Station (Optical Master Unit): 1 Ethernet 10/100 port

The following equipment has Ethernet communication requirements on the Cross Passage 4:

- Band selective fiber optic repeater: 1 Ethernet 10/100 port
- Band selective fiber optic FM repeater: 1 Ethernet 10/100 port

The following equipment has Ethernet communication requirements on the:

- Band selective fiber optic repeater: 1 Ethernet 10/100 port
- Band selective fiber optic FM repeater: 1 Ethernet 10/100 port

4   Bill of Materials

The below items represent our initial estimation for budget purpose however a more detailed bill of material will be generated upon the BOQ approval and the development of the initial design drawings.

Item	Description	QTY
1	**AHT-1 Technical building equipment**	
	Server room equipment	
1.1	Hardware Server for virtualization for central management software for all systems including at least 3 rackmount servers with latest Xeon CPU with at least 8 cores, 128GB RAM and RAID SSD storage at least 3 x 2TB including Server virtualization license and Windows Server OS license	Bundle
1.2	Network shared storage sever as shared storage for the virtualization server and for video storage for all cameras and for audio recording of emergency calls and announcements with the minimum storage of 48 TB at least with storage controller having at least 2 x 10Gbps interfaces.	1
1.3	Server 19-inch rack with depth 1000mm at least including PDU and KVM console with keyboard and LCD display for server management	1
1.4	NTP Server including appliance, GPS antenna and NTP server software	1
	Main data and voice communication equipment	
1.5	IP PABX with redundant call processor and SIP license for at least 11 emergency phones and in building distributed 16 desk phones and control room emergency phone attendant station	1
1.6	Redundant core switch (stacked pair) with 32 ports 10/100/1000 Base-T and 8 ports 1Gbps and 8 ports 10 Gbps SFP fiber uplinks.	2
	Master PLC	
1.7	Redundant Industrial grade Master PLC with synchronization module including dual Ethernet communication processors and sync cable	2
1.8	Technical building RTU cabinet including: Remote Terminal Unit (RTU) + CPU + Ethernet controller + field bus controller + power supplies + bus end terminal including: High availability dual PROFINET modules. IO modules according to final contractor design including: • DI modules 16 inputs. • DO modules 16 outputs. • Relay modules 4 relays. • Serial COM interface RS-485 Modbus RTU.	2
1.9	Industrial media converter / switch supporting Redundant Ring Protocol to PROFINET	8
1.10	Industrial Power supply 24VDC - 10 Amp	4
	Control room equipment	
1.11	Videowall Controller to extend existing video wall system to accommodate the new 32 cameras for AHT-1	1
1.12	Video wall TFT-LED Monitor 55" with thin edge suitable for mounting in conjunction with existing video wall	4

1.13	Workstation equipped with 3 monitors for SCADA tunnel management operator interface and maintenance interface	2
1.14	Emergency phone attendant station including PC, and desktop microphone	1
1.15	Technical building administration office IP desk phones	16
	Control room software	
1.16	Centralized Management Software (SCADA) license + Programming for all subsystems	1
1.17	Public Address System management software (server and client) and should include the call station software, PC and desk microphone	2
1.18	Emergency phone management software	1
1.19	Access Control System management software application (server and client)	2
1.20	CCTV management software license per camera	63
1.21	AID management software license per camera	34
	Network and Low voltage panels for technical rooms including fire tank, ventilation room, pump room	
1.22	Stainless steel cabinet 800 mm x 800 mm with mounting plates and accessories and secure locks to accommodate 3 types of equipment at each SOS station (RTU control cabinet, Network cabinet, Low voltage cabinet)	12
	Low voltage cabinet	

1.23	Low Voltage switchboards must meet the following technical requirements:
	- Isolator switch:
	  4-poles (as showed in drawings)
	  IN=40 A
	- Endurance:
	  Electrical: 20.000 cycles
	  Mechanical: 50.000 cycle
	- Short-circuit resistance: 20 x In during 1 s
	- Compliant with EN 60668.1 and 60947.3
	- Terminal for 50 mm2 wire and 40 A In
	- Up to 15 automatic thermal magnetic RCD Type A
		6

	Switch cabinet	
1.24	Switch 1 Gb (Layer 2) 2x1GbE SFP + 8x10/100 RJ-45 DIN rail	6
1.25	DIN rail mount patch panel 8 ports RJ-45 couplers	6
1.26	Panel mount ODF junction box for edge ring junctions and splitting of 2 single mode fiber interfaces for switch in and out ports	6
1.27	Industrial Power supply 24VDC	6

2	AHT-1 SOS Stations	
	Road level telephones	
2.1	Roadside Emergency Phone cabinet with SIP protocol support including cabinet and handset with Ethernet interface to local switch in SOS station at gallery level. Should include all needed accessories, power supply, patch cords and cable glands	11
	Service gallery telephones	
2.2	Emergency Phone wall mount set with keypad with support for SIP protocol support including cabinet and handset with Ethernet interface to local switch in SOS station at gallery level. Should include all needed accessories, power supply, patch cords and cable glands	11
	Technical buildings and Firefighting building	
2.3	Emergency Phone wall mount set with keypad with support for SIP protocol support including cabinet and handset with Ethernet interface to local switch in SOS station at gallery level. Should include all needed accessories, power supply, patch cords and cable glands	25
	Service gallery level	
2.4	Stainless steel cabinet 800 mm x 800 mm with mounting plates and accessories and secure locks to accommodate 3 types of equipment at each SOS station (RTU control cabinet, Network cabinet, Low voltage cabinet)	33
	RTU Control cabinet	
2.5	Remote Terminal Unit (RTU) + CPU + Ethernet controller + field bus controller + power supplies + bus end terminal including: High availability dual PROFINET modules IO modules according to final contractor design including: • DI modules 16 inputs • DO modules 16 outputs • Relay modules 4 relays Serial COM interface RS-485 Modbus RTU	11
2.6	Industrial media converter / switch supporting Redundant Ring Protocol to PROFINET	22
2.7	Industrial Power supply 24VDC with power according to the number of IO cards in each cabinet	11
	Switch cabinet	
2.8	Switch 1 Gb (Layer 2) 2x1GbE SFP + 8x10/100 RJ-45 DIN rail	11
2.9	DIN rail mount patch panel 8 ports RJ-45 couplers	11
2.10	Panel mount ODF junction box for edge ring junctions and splitting of 2 single mode fiber interfaces for switch in and out ports	11
2.11	Industrial Power supply 24VDC	11
	Low voltage cabinet	

2.12	Low Voltage switchboards must meet the following technical requirements: - Isolator switch: 4-poles (as showed in drawings) IN=40 A - Endurance: Electrical: 20.000 cycles Mechanical: 50.000 cycle - Short-circuit resistance: 20 x In during 1 s - Compliant with EN 60668.1 and 60947.3 - Terminal for 50 mm2 wire and 40 A In - Up to 15 automatic thermal magnetic RCD Type A	11
2.13	Cabinet should have external IP54 rated LED indicators	

3	AHT-1 TUNNEL Traffic Management	
	Variable Message Sign system	**1**
3.1	Lane Control Sign LED technology 500 x 500 mm	14
3.2	Speed Control Sign LED technology 500 x 500 mm	7
3.3	Supporting Structural beam for LCS or SCS	21
	Tunnel Access Control system	**1**
3.4	Automatic mechanical barrier 6 meters long	4
3.5	Traffic Lights Red - Green - 200 mm	1
3.6	Traffic Lights Red - Yellow - Green - 300 mm	4
	External Variable Message Sign and traffic light	
3.7	Variable Message Sign LED technology 2 Lines of 16 characters and 1 Graphic Zone of 64 x 64 pixel	1
3.8	Supporting Structural beam for VMS	1
3.9	Infrared height sensor including transmitter and receiver	1
3.10	Over-Height System Control Module	1
	Speed detection and violation system	
3.11	License plate recognition camera 5MP with integrated IR illuminator suitable for overhead implementation at 6 meters height on entrance gantry capable of detecting license plates in 2 lanes based on integrated analytics	2
3.12	Supporting Structural beam for LPR camera	2
	Professional services	**1**
3.13	TMS and Tunnel Access control Integration, management software, Commissioning and Testing	1
3.14	License plate recognition management software with speed violation detection based on speed section control and customizable reports	1

4	AHT-1 TUNNEL CCTV and AID	
	CCTV cameras for tunnel road	
4.1	High Definition IP Fixed Bullet Camera with built-in video analytics with advanced edge processing to detect tunnel incidents such as sopped vehicles, wrong direction driving, fallen objects, pedestrians on the road and any additional features the bidder may propose will be evaluated	21
4.2	High-Definition fixed Dome Camera, including material and accessories for mounting overlooking the emergency phone cabinet'	11
4.3	High Definition PTZ Camera, including material and accessories for mounting at the tunnel entrance and exit	2
4.4	Supporting Structural beam for surveillance and AID camera	34
	Technical Building cameras East and West	
4.5	High-Definition fixed Dome Camera, including material and accessories for mounting overlooking the emergency phone cabinet	12
4.6	High-Definition IP Fixed Bullet Camera 2.8mm lens	17
	Fire fighting building and pump room and ventilation room	
4.7	High-Definition IP Fixed Bullet Camera with built-in video analytics	3
	Professional services	
4.8	CCTV and AID system Integration, management software, Commissioning and Testing	1

5	AHT-1 Public Address system	
	Public Address speakers inside the tunnel	
5.1	Exponential loudspeaker 30 Watts	55
5.2	Fire Resistant Distribution box for copper wire	55
5.3	Copper wire 2 x 2,5 mm2 RZ1-K(AS+) per meter	2000
5.4	Copper wire 2 x 4 mm2 RZ1-K(AS+) per meter	7500
5.5	Copper wire 2 x 6 mm2 RZ1-K(AS+) per meter	5000
5.6	Copper wire 2 x 10 mm2 RZ1-K(AS+) per meter	6500
	Public Address cabinets in technical buildings	
5.7	**Public Address system**	
5.8	Digital Amplifiers 500 W	10
5.9	Digital Audio IP Matrix including all accessories, audio interfaces, network controller and cables	2
5.10	Rack 19-inch 35U spacing with PDU and internal cabling	4
5.11	Output supervisory card for connection between audio matrix and amplifier	44
5.12	Power Source 24 V 2.5 Amp	2
	Professional services	

5.13	**Public Address System Integration, Commissioning and Testing should include:** Undertake Initial Site Configuration Undertake Initial Site Testing Acoustic Testing Once Basic Systems is Operational Detailed System Configuration to Achieve the Required Audio Quality	1
	EXTERNAL INSTALLATIONS	
5.14	Exponential loudspeaker 30 Watts	4
5.15	Fire Resistant Distribution box for copper wire	4
5.16	Copper wire 2 x 2,5 mm2 RZ1-K(AS+) per meter	800

6	**AHT-1 Tunnel Ventilation Control system**	1
	Opacity, air speed and gas detectors in tunnel	
6.1	Optical Opacity Sensor range from 0 to 0,015 m-1 every 480 meters	4
6.2	CO Detector range from 0 to 500 ppm every 240 meters in road level and service gallery	8
6.3	NO2 Detector range from 0 to 1 ppm every 240 meters in road level and service gallery	8
6.4	Anemometer range from 0 to 20 m/seg every 480 meters	4
	Professional services	
6.5	Tunnel Ventilation Control System Integration, Commissioning and Testing	1
	Road Weather Information system	
6.6	Road Weather Station equipped with different sensors to measure road weather conditions	1
6.7	Outdoor Rack Cabinet including all required accessories, power supply and cables	1

7	**AHT-1 Emergency signage system**	
	Emergency Signage inside the tunnel	
7.1	Photo luminescent sign distance to emergency exit 1000 x 400 mm located beside the emergency phones	11
7.2	Photo luminescent sign distance to the emergency station 1000 x 400 mm on the side wall after getting to the escape side path	11
7.3	Electroluminescent light strip for evacuation exit 1000 mm x 200 mm showing the location of the stairs to the side escape path	11
7.4	Electroluminescent light driver and controller connected to the nearest RTU panel	11
7.5	Illuminated sign for emergency stations 750 x 500 mm	11
7.6	Illuminated sign for fire hydrants 750 x 500 mm	11
	Emergency Signage inside technical rooms	
7.7	Electroluminescent light strip for evacuation exit 400 mm x 200 mm showing the location of the exit doors	20
	Professional services	
7.8	Emergency signage system Integration, management software, Commissioning and Testing	1

8	**AHT-1 Linear Heat detection system**	
	LHD cable for tunnel road and service gallery	
8.1	LHD cable for road level: Thermoplastic (metal free) LSOH sensor cable containing twin Acrylate 62.5/125µm fibers having 2 fiber cores	2000
8.2	LHD cable for service gallery level: Thermoplastic (metal free) LSOH sensor cable containing twin Acrylate 62.5/125µm fibers having 2 fiber cores	2000
8.3	Cable Mount Kit (for tunnel ceiling) Includes clamps, base, screws & plugs	4000
8.4	Manual Addressable Double Action (Push - Pull) (MCP) Fire Alarm Point	30
	LHD Control Panel in service gallery	
8.5	Sensor control unit in rackmount form factor with 2 ports for one core in road level and one core in service gallery for connecting one core from the road ceiling cable and one core from the service gallery ceiling cable	2
8.6	LHD panel communication interface for Modbus TCP and Modbus RTU with RS-485 interface	2
	Professional services	
8.7	LHD system Integration, management software, Commissioning and Testing	1
9	**AHT-1 Access control system**	
	Access Control system	
9.1	Electromagnetic lock	23
9.2	Opening detector	23
9.3	Card reader according to ISO 14443 A/B standard	23
9.4	CPU double door controller	14
9.5	Exit push button	23
9.6	Access Control system Integration, Commissioning and Testing	1
	Fire Detection system inside technical rooms	1
9.7	Fire Detection Panel with power supply and network interface	4
9.8	Communications Modbus Interface	2
9.9	Inputs/Outputs supervision Module	23
9.10	Manual Fire Alarm Point	23
9.11	Ionic-Optical smoke detector	50
9.12	Thermovelocimetric detector	10
9.13	Oxygen Deficiency Detector	6
9.14	Fire Alarm horn	23
9.15	Fire Detection system Integration, Commissioning and Testing	1

10	**AHT-1 Private Radio system**	
	Private Radio Communication system in tunnel	
10.1	Radiating Wire 1 1/4"	1650
10.2	Radiating Cable ½"	90

10.3	Metallic Click clamps for wall mounting of radiating cable 1 ¼"	1650
10.4	Coaxial Cable 7/8"	125
10.5	Coaxial Cable ½"	110
10.6	Transition Coaxial cable - Radiating cable	9
10.7	50 Ohms Load	5
10.8	Splitter	6
10.9	Asymmetric splitter	2
10.10	Repeater Radio Station including optical amplifiers for UHF and FM band, combiner with 4 RF outputs	1
	TECHNICAL AREAS	
10.11	Master Radio Station including amplifiers for UHF and FM band, combiner and optical master unit	1
10.12	UHF Antenna	1
10.13	Omnidirectional FM Antenna	1
10.14	Antenna supporting mast 3 meters height	2
	Professional services	
10.15	Radio communications System Integration Commissioning and Testing	1

11	AHT-1 CABLES	
	Control and communication cables and accessories in tunnel	
11.1	2-Pair cable Ø0,91 mm EATST	3,500
11.2	4-Pair cable Ø0,91 mm EATST	900
11.3	6-Pair cable Ø0,91 mm EATST	1,100
11.4	8-Pair cable Ø0,91 mm EATST	500
11.5	12-Pair cable Ø0,91 mm EATST	1,600
11.6	24-Pair cable Ø0,91 mm EATST	375
11.7	24-Singlemode fiber optic cable	9,000
11.8	12-Singlemode fiber optic cable	550
11.9	12-Fibre Optic Wall-mounted distribution cabinet	11
11.10	Junction box for connection of a fiber optic cable to a 12-fiber optic cable with splicing accessories	11
11.11	4-pair UTP Cat 6 cable	4,400
11.12	Galvanized iron in heat tray 200 x 60 mm	3,930
	TECHNICAL AREAS	
11.13	2-Pair cable Ø0,91 mm EATST	440
11.14	4-Pair cable Ø0,91 mm EATST	260
11.15	12-Pair cable Ø0,91 mm EATST	200
11.16	16-Pair cable Ø0,91 mm EATST	700
11.17	20-Pair cable Ø0,91 mm EATST	440
11.18	24-Pair cable Ø0,91 mm EATST	3,000
11.19	24-Singlemode fiber optic cable	600
11.20	42-RU rack (LHD, Core switch, Master PLC, Distribution switch) both East and West	8
11.21	24-Fibre Optic rack 19" Fiber Distribution Frame (FDF)	8
11.22	24 UTP ports patch panel	8

11.23	4-pair UTP Cat 6 cable	3,500

5 APPENDICES

5.1 DICTIONARY

Anemometer: Equipment installed in the tunnels and allows air velocity measurement.

Application software: Specific software programming and configuring within SCADA.

Carbon monoxide detector: Equipment installed in the tunnels and allows carbon monoxide analysis.

Close Circuit Television (CCTV): Video supervision of traffic zones by operators, the system is mainly composed on matrix panel, network cameras, monitors and matrix keyboards.

Dewatering system: Drainage and pumping stations.

Elevator: Lifting equipment for personnel & equipment vertical transportation installations.

Emergency station: Tunnel rooms closed and ventilated located in tunnels approximately every 200m (emergency recess).

Emergency telephone system (SOS): Telephone posts located in each emergency station of the tunnel.

Entrance access control: Equipment located in the entrances of the tunnel such as flashing lights and barriers.

Equipment: System components such as for SCS: supervisory, main PLCs, RIO, networks...

Fire detection: Detection equipment such as sensor cables, heat and smoke detectors, manual call point.

Fire fighting: Fire equipment located in stations such as tanks, booster pumps and other equipment such as water pipe network, fire hydrants and extinguishers.

Gauge control: Equipment vehicle over height control such as arrow, flashing lights, plastic bars and highly vehicle stop and cells.

Guide signs: Equipment fixed on tunnel walls and indicates any direction such as emergency way, telephone, etc.

Heating Ventilation air-conditioning (HVAC): air-conditioning and ventilation system.

Lane control signals (LCS): Traffic lane conditions red cross, green and yellow arrows located in the tunnels approximately every 200 to 400 m.

Lighting system: External and internal lighting circuits.

Package: system or sub-system out of SCS scope and links through Modbus serial link.

Power supply system: Medium and low voltage power supplies for tunnels.

Radio communication system: Radio frequencies management for operation and maintenance staff.

Road signal: Refer to VMS.

RS485: A recommended standard of the Electronic Industries Association (EIA) for multipoint systems.

RS232: EIA interface standard between DTE and DCE for serial binary data interchange.

Smoke recorder: Equipment installed in the tunnels and allows air analysis.

SOS central post: Located in the control center room, the central post manages and controls the SOS posts network.

Supervisory Control System (SCS): Equipment such as: workstations, servers, main PLCs, RIO, Ethernet and Profibus networks.

System or sub-system: Tunnel works components such as ventilation, lighting, power supply, etc..

Telephone system: Emergency and service telephone posts located throughout both tunnels and technical stations.

Traffic control: Management of lanes lights (LCS), entrance lights, control lane barriers, gauge control and measurement stations.

Traffic detection: Traffic flow control equipment and functions such as inductive loop, traffic count, and traffic flow rate, average vehicle speed.

Variable Message Signs (VMS): Speed messages or other variable messages written in Arabic and English languages installed above traffic lanes.

Ventilation system: Forced ventilation in tunnels, technical rooms and galleries.