Project Specific Section

Example :

ROCKFALL PROTECTION ALONG SIDDHABABA SECTION OF SIDDHARTHA HIGHWAY

Ch. 28+200 km – Ch. 30+600 km

Table of contents

1 Tunnel data

The 1130 m long Siddhababa Tunnel is located on the H10 road at the foothills of the Himalaya about 30 km north of the Nepali-Indian boarder. It lies in a valley with an approximate north-south orientation and is planned to bypass an area prone to landslides.

The tunnel opening is forecasted for 2023 (design year).

The tunnel:

• will be operated with bidirectional traffic with one lane in each direction,

• is 1'130 m long,

• rises from the southern portal to the northern portal with about 35 m,

• provides 3 bypass tunnels (escape tunnels) towards a parallel road

• is located approx. 210 m above sea level.

The lengths of the bypass tunnels are about 155 m, 129 m and 125 m.

Emergency exits inside the tunnel are provided every 300 m, which means that an emergency exit is 245 m from the southern portal and another 285 m from the northern portal.

The Siddhababa tunnel has to be designed for forecasted traffic for the following years:

− Design year (i.e. tunnel opening year): 2023

− Design year + 20 years: 2043

It was informed by the Customer that the yearly traffic increase of 7% is not to be applied to this project.

According to traffic counts, following data was provided by the Customer:

− Average Annual Daily Traffic (AADT) for both traffic directions: 12'444

− Thereof:

Heavy goods vehicles (trucks, busses, utility vehicles, tractor): 1'474

Passenger cars (car/taxi/motorised three, rickshaw, bullock): 1'886

Motor cycles: 9'084

2 Framework conditions and assumptions of the designer

1) In this project the use of Swiss standards and directives of the Swiss Federal road administration (FEDRO) has been assumed concerning the characteristics of the tunnel facilities in relation to safety and operation.

   In the executive project, in the fabrication of the systems as well as in their installation and commissioning, the general contractor must refer, in order: to the Nepalese laws, to Nepalese and international standards, to directives (Richtlinie) and technical specifications (technische Merkblätter) of the Swiss Federal Road Administration (FEDRO).

2) For electrical installations of buildings, as for low voltage electrical distribution, a generic solution has been defined; in the executive phase the general contractor will have to consider the application of the Nepalese regulations, where present, in this specific field.

3) The project contains the description of the technical solution to be implemented regarding the operating and safety systems; the detail-degree of the description has been harmonized with the project phase and with the procedural situation (choice of a general contractor), therefore no details are provided where it is not considered essential for the outcome of the works. It was therefore assumed that the executive details will be defined with the general contractor, by the client or by a representative of the same, during the execution phase of the project.

4) The installations are designed to be serviced at least once a year by specialized personnel (of the client, of the future manager of the tunnel or of the general contractor). The correct maintenance frequency however depends on the characteristics of the individual installation and will be defined by the supplier (general contractor).

   The operation of the installations is strictly related to a correct and exhaustive periodic maintenance; the lack of adequate maintenance affects the operation of the plants and, ultimately, the safety of tunnel users.

5) The project assumes that tunnel users comply with traffic regulations, such as compliance with speed limits and signage and in particular compliance with the overtaking and stop prohibitions in tunnel. Likewise, the systems have not been designed to withstand shock or impact forces caused by loads projecting beyond the permitted vehicle-shape in tunnel.

6) The systems designed ensure automatic routines to guarantee the safety of the tunnel users. Nevertheless, the project assumes that the gallery is monitored and managed continuously (7 days a week, 24 hours a day) by at least two operators in the control room in the technical building at the south portal of the tunnel. In fact, in case of an event such as a fire in tunnel, only operators present on site and trained, can ensure adequate treatment of emergencies. It has been assumed that these operators will interface with the rescue services, such as the police, firefighters and rescuers, for the operational management of the events.

7) The project assumes that a regulation will be created by the tunnel manager that specifies the minimum operating conditions of the plants under which the tunnel can remain open and therefore, consequently, in correspondence with which plant faults the tunnel must be closed. Operation of the tunnel in the absence of adequate operating conditions of the plants (eg lack of ventilation, lack of fire detection, lack of electricity supply, and similar) exposes users to risk, can favour the occurrence of accidents and prevents the possibility of saving users.

8) The project for the signage system (arrangement of traffic signs, their images, distances, etc.) must be submitted by the client to the competent Nepalese authorities (ministries, police, etc.) for examination and approval before the tunnel is put into operation. In order to avoid late modifications, it would be desirable to obtain this approval before the procurement phase or, at the latest, before the start of the manufacture of the signs and their installation. Without the approval of the signage by the competent authorities, the tunnel shall not be put into service.

9) In the rest of the document indications will be provided on the constitution of the individual elements of the exploitation and safety systems and their housing. However, a general principle is given here, which also applies where details are not provided in this document: all the elements forming the exploitation and safety systems must be installed in cabinets or enclosures that allow protection against rain, dust,

humidity, solar radiation, aggressive atmosphere, etc. Exceptions to this principle are the elements which, due to the function they perform, must be in direct contact with the field (traffic signs, sensors, cables, lamps, etc.).

10) As for the tunnel ventilation, the project contains a mere dimensioning of jet-fans and sensors. It is task of the contractor to define, in the final design phase of the system, the functioning (algorithms) of the ventilation in the normal case (sanitary ventilation) and in the event of a fire (operation of the system in the various fire scenarios in the tunnel). The definition of these algorithms is essential for the safety of tunnel users in the event of a fire.

    Once the ventilation system has been defined and installed, the Customer (or the contractor) must provide for real operational tests, even simulating the event of a fire, involving the emergency services such as fire brigades, police, rescuers, etc.

11) Since it is not possible to have redundant medium voltage power supply, that is coming from two different networks, the loss of this power entails the immediate inability of the tunnel due to the lack of ventilation in case of fire. For this reason, uninterruptable power supplies with batteries have been foreseen to guarantee one hour of operation of the systems (excluding ventilation). This time lapse serves to close the tunnel, which cannot remain open in case of lack of ventilation.

12) In the event of a fire, the tunnel is closed and the traffic piles-up along the road leading to it. Part of the traffic could attempt to reverse using lay-bys along the road. All these conditions make it difficult for rescuers to access the tunnel.

    For this reason, the client will have to check with the emergency services (police, fire brigade) the conditions of viability of the access road, and the related times, in correspondence with the closure of the tunnel in case of fire. If the arrival times of the rescuers are not compatible with the rescue of persons in the tunnel, rescue stations closest to the tunnel should be provided.
    It is also advisable to provide landing places for rescue helicopters at the tunnel portals.

13) Due to the high power-requirement, no reserves were included in the calculation. In the execution phase, and in the phase of agreements with the electricity supplier, the client must evaluate, and have included in the project, the largest possible reserve power margin (desired 30%) compatible with the conditions of the network and the supply.

14) The cellular telephone system is not part of the installations covered by this project. It is in fact to be considered as an extension of the systems of the mobile telephony signal provider, and must be designed, supplied, installed and maintained by him.

    Nevertheless, in view of the importance of such a system both for the users of the tunnel and for the rescue forces, a separate room is provided for the installation of the necessary equipment. The external antennas for the collection of the external signal and the internal antennas for the broadcasting of the signal in tunnel and buildings will be installed by the provider of the mobile telephony.

    This equipment will be powered by the low voltage distribution of the tunnel in the technical rooms, through a connection to reserve switches. Electricity consumption, as well as the space used, should be the subject of a specific agreement between the tunnel owner and the mobile phone provider.

    The mobile phone signal broadcasting system is of great importance for the safety of tunnel users. However, it is also very important during the excavation and construction phases of the tunnel; therefore, it is recommended to start early with the stipulation of agreements with the mobile telephony provider, to ensure good coverage already from the early stages of work.

15) The radio signal transmission system in the tunnel is also an important means of communication for rescuers in the event of an incident, and for maintenance personnel in the performance of their routine duties. The frequencies used in Switzerland were taken into account in the planning.

    Before commissioning, they must be checked with the emergency services (fire brigade, ambulance, police, etc.) and adapted to the frequencies used in Nepal.

16) The closure of the tunnel in case of danger (accident, fire) is a critical event and must be well understood by road users.

    In Nepal Road Standard 2070, no indication was found of the transition times for traffic lights (changeover to red, stop of the traffic-flow). Therefore, two transition tables corresponding to Swiss

regulations were suggested. It is imperative for the implementation phase that the general-contractor checks again with the competent authorities what the image transitions (switching from off/green to red and vice versa) of the traffic lights should be in order for the tunnel closure event to be clearly and unmistakably understood by road users.

17) A **60-month maintenance and warranty period** provided by the plant supplier was included in the costs estimate. In fact, experience shows that, given the complexity of the systems, a similar duration allows to eliminate defects left hidden at the time of testing.

18) Because of the complexity of the plants, it is strongly recommended that the client defines a group of people already by the project phase, who will then join the general contractor in the executive phase. These people will be the future managers and maintenance people of the plants of the tunnel, and the future control room operators. In this way it will be possible to ensure the transmission of know-how concerning the plants and their operation.

3 General concepts and requirements

3.1 Directives and norms considered

Main directives partially considered in the design of the operating and safety systems are the directives of the Swiss Federal road administration[1] (FEDRO):

- FEDRO 13001 Lüftung der Strassentunnel (2008 V2.03)
- FEDRO 13002 Lüftung der Sicherheitsstollen von Strassentunneln (2008 V1.06)
- FEDRO 13004 Branddetektion in Strassentunneln (2007 V2.10)
- FEDRO 13005 Videoanlagen (2012 V1.01)
- FEDRO 13006 Funksysteme in Strassentunneln (2018 V5.00)
- FEDRO 13010 Signalisation der Sicherheitseinrichtungen in Strassentunneln (2011 V2.06)
- FEDRO 13011 Türen und Tore in Strassentunneln (2009 V1.05)
- FEDRO 13015 Beleuchtungsanlagen (2017 V1.11)

The body of technical prescriptions[2] of FEDRO was also considered, even partially in this case.

3.2 Technical and market factors

Operational safety and product quality:

- Choice of devices that guarantee the longest possible service life;
- Additional measures to enable maintenance to be carried out quickly and safely;
- Execution of installations that allow fire resistance where necessary and no-flame propagation, reduced emission of smoke free from corrosive gases.

Uniformity of solutions:

- Simplify and reduce the variety of spare equipment and materials in order to reduce maintenance costs.

Known technologies:

- Use of equipment, control systems and installation technologies, known and already applied with success in other similar projects
- The equipment must be easily replaceable with same or with similar and compatible

products. Availability of spare parts:

- As general rule, chosen products must guarantee the availability of spare parts for a period of at least 10 years.

Presence in Nepal:

- It should be preferred the choice of products with representation (integrators, suppliers, service centres, etc.) in Nepal, if present.

3.3 Choice of materials

As a rule, all the materials chosen must be suitable for the place of installation foreseen for them, especially for the equipment installed in the tunnel (corrosive atmosphere, presence of pollutants).

In the rest of the document specific indications will be given for particular cases.

[1] https://www.astra.admin.ch/astra/de/home/fachleute/dokumente-nationalstrassen/standards/betriebs-sicherheitsausruestungen.html

[2] https://www.astra.admin.ch/astra/de/home/fachleute/dokumente-nationalstrassen/fachdokumente/fachunterstuetzung/fachhandbuch-betriebs-sicherheitsausruestungen.html

3.4 Risk assessment

List of risks related to the project (delays, installation difficulties, etc.).

For each risk, an evaluation is attributed as a product between the probability of its occurrence (from 1 = low to 3 = high) and the size of the damage related to its occurrence (from 1 = low to 3 = high). Where possible, the measures to be taken to address the risk and the responsibilities for them are indicated.

Risk	Probability P	Impact I	Value P x I	Measure	Responsibility (risk owner)
Costs and delays due to project changes while work in progress	2	2	4	Clear definition of functional requirements. Continuous evaluation of ongoing works.	Designer. Direction of works representative of the client.
Budget overrun	1	3	3	Constant cost control	Direction of works representative of the client.
Poor quality of work due to pressure on deadlines (construction duration)	1	3	3	Introduction of contingencies in time estimates. Precise planning of the construction phases.	Designer. Direction of works representative of the client; General contractor
Plants not working as expected after commissioning.	1	3	3	Continuous control of installations during construction phases.	Direction of works representative of the client.

Table 1: Risk assessment

3.5 Environmental conditions

In the technical rooms the temperature is controlled by the HVAC system and no special precautions are required.

For open-air and tunnel installations, a temperature range of 0 ° C to 50 ° C must be considered, with the possibility of condensation forming.

In the case of equipment installed in open-air cabinets, the place of installation must be carefully considered: in the presence of particularly strong exposure to the sun, measures such as forced ventilation and the installation of tropical roofs must be taken.

All the components chosen must be suitable for the place of installation and guarantee a life expectancy, in the installation conditions, of more than 25 years.

3.6 Coding system

A code and labelling system must be adopted that shows the code of every element that must be maintained or that can be a source of data (alarm, measurement, video, voice) or recipient of data (commands).

The system must be based on these principles:

- all the cables must have, on their two ends, a label that identifies the plant they belong to, the point where the end of the label is located and where the other end is installed
- all the elements installed outside of the cabinets must be codified with a code that shows the place of installation, the plant to which it belongs and the identifier of the element itself
- all the elements installed inside cabinets must be labelled according to the identifier that has the same element in the wiring diagrams of the cabinet

- all the visualizations of an element at the level of the tunnel control system (element view, alarm line, etc.) must show the coding of the element itself.

This coding system is necessary to facilitate the understanding of the origin of an alarm or fault and allow a quick treatment of the same by the maintenance staff.

4 Description of the planned measures

4.1 Energy supply

4.1.1 Medium voltage supply

The project starts from the assumption, confirmed by the client, of being able to have a medium voltage power supply (11 kV) by the tunnel portals in the technical buildings (in separate rooms, exclusively reserved for medium voltage).

The medium voltage will be taken from the electricity company to the technical room at the south portal of the tunnel; here it will be transformed into low voltage. Furthermore, starting from this technical room, the electric company will also carry the medium voltage to the technical room at the north portal of the tunnel, using a medium voltage cable laid inside the tunnel in a special duct reserved for it. At the northern location its transformation into low voltage will take place.

The power supply is guaranteed by the local electricity company by connection to the 11 KV transmission line from Hotel Avenue, near Butwal-Palpa area.

Once the requirements of the electricity company are defined, civil works can be evaluated in this project to create an underground conduit where cables can be pulled by the electricity supplier from the last pylon of the medium voltage supply line to the well outside the technical building by the south portal of the tunnel. The division of costs and responsibilities for these works requires an agreement between the client and the electricity supply company.

It is so assumed in the present project that the electricity supply company makes available, in separate rooms in the buildings at the tunnel portals, the power required for the medium voltage tunnel inside specific supply cabinets with the related switches and transformers from medium voltage to low voltage 400 V.

The interface, and supply boundary, is in this way located at the low voltage terminals of the transformers (from the low voltage terminal onwards starts the scope of the present project; medium voltage cables and transformers are excluded from the scope of this project). The costs for the construction of the medium voltage distribution plant are not considered in this project.

This type of interface is foreseen to guarantee the standardization and compatibility of the elements (switches, transformers and cables) installed with those provided by the electricity supplier.

The electrical power of the plants will be supplied by the local electricity company and will be delivered in low voltage at 400V-50Hz for a maximum committed power of 755 kW.

Considering also that the electrical company clearly states that the supply cannot be guaranteed in case of failure of the national network and that there is no redundancy of power supply, the tunnel must be closed for safety reasons during the blackout. The tunnel installations will be designed in such a way as to be energy self-sufficient for enough time (starting from the blackout) to close and empty the tunnel (UPS, uninterruptable power supply network).

The contractor, during the detailed design phase, will plan the low voltage power supply system and connections according to Nepalese standards.

The medium-voltage system requires the Electricity Company to make available to the tunnel control system only the status of the main switches of the medium-voltage supply in the technical rooms and the measurements of the energy consumed for statistical as well as for billing purposes.

4.1.2 Low voltage supply

The power supply of the tunnel equipment will be divided between the two technical rooms near the entrances (north and south) in order to reduce the quantity and cross-section of electrical cables passing through the tunnel.

Each power switch shall be equipped with auxiliary contacts to signal the failure of the switch to the control system via relay contacts.

Each switch must be designed in order to guaranty the over-current discrimination in case of a fault in one point of the installation.

All cables in the tunnel will be routed in the cable ducts positioned in the vault and/or in the cable tracks positioned on the sides of the carriageway. In the technical rooms the cables will be housed in cable ducts located under the floor and reach the electrical cabinets from below. The cables shall be dimensioned in accordance with the laws, standards and ordinances on electricity in force in Nepal.

Cables are also dimensioned on the basis of the maximum permissible voltage drop in the line and coordinated with the line protections on the basis of the minimum short-circuit current at the end of the line.

Cables must be halogen-free, without emission of toxic or corrosive gases, with a reduced emission of non-flammable and self-extinguishing fumes.

Cables installed outdoors must be UV resistant, temperature resistant up to the extreme limits of use in the location, and weatherproof.

Cables for the stand-by electrical network distribution (UPS) are provided with a function stand-by network of 180 minutes, while electric cables for the normal network distribution are provided with a function stand-by network of 5 minutes.

4.1.3 Uninterruptible power supply

The 400/230 V - 50 Hz uninterruptible power supply will be composed of static uninterruptible power supplies (UPS) installed in the technical rooms by south and north portals. UPS will be powered by the normal network.

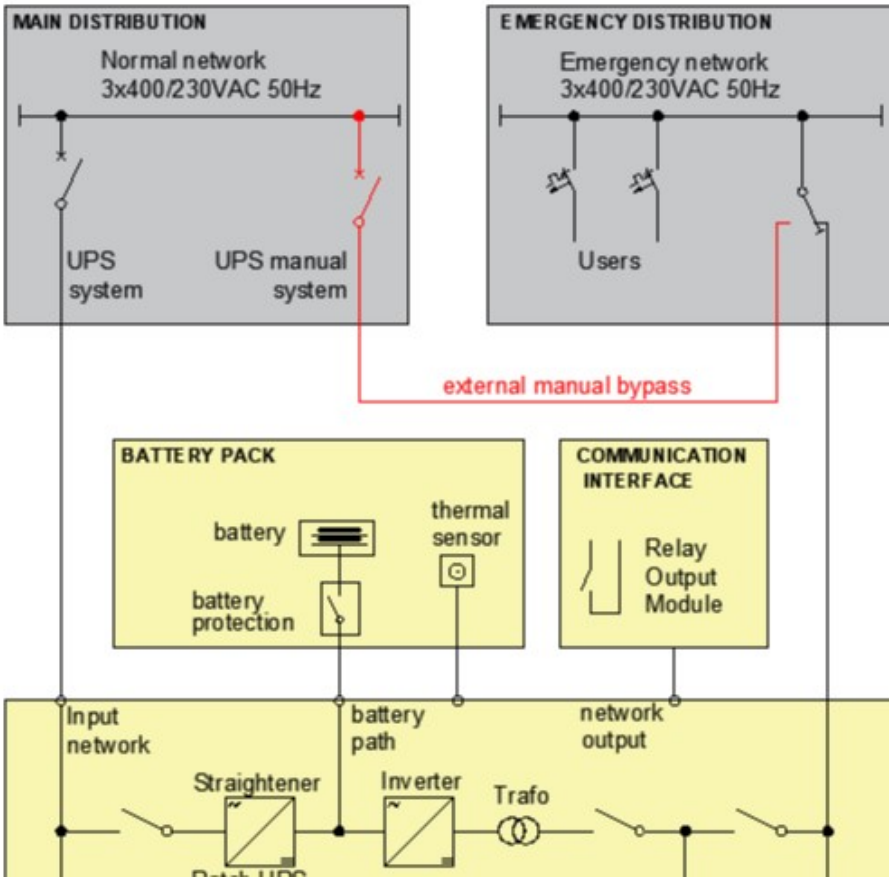
UPS are designed with a set of batteries so that they can power the systems for at least 60 minutes in the event of a loss of normal power. In the event of a normal power failure, the system automatically switches to battery operation.

During UPS maintenance operation, a manual external by-pass will transfer the load from the uninterruptible power supply to the normal power supply.

Supervision of the normal network is via digital network analysers installed in the main cabinets. The supervision of the uninterrupted network is entrusted by the uninterruptible power supply units. All the necessary network parameters shall be transmitted to the tunnel control system via a standard communication protocol.

The uninterruptible power supply will be dimensioned to completely supply the following plants, plus a safety margin of 40%:

- Emergency lighting
- Fire emergency lighting
- Optical guides
- Signage
- Fire detection system
- Radio broadcasting
- Cellular phone network
- Video-surveillance
- Communication network
- Tunnel control system
- Emergency telephone cabinets.



Picture 1: Scheme UPS connections

Picture 2: Batteries and UPS

4.1.4 Estimated electrical powers

The following table shows the electrical powers absorbed from the normal network

Installation	Power input [KW]
Lighting	40
Ventilation	55-530
Signage	1
Tunnel fire detection system	1
Videosurveillance system	3
Communication network	1.5
Tunnel control system	5
Radio diffusion in tunnel	1
Emergency telephone system	0.5
Electrical and lighting system in buildings	12
HVAC system in buildings	10-35
Pumping station	37-125
TOTAL POWER WITHOUT RESERVE	**166 min.** **755 max.**

Table 2: Electrical powers normal network

The low-voltage distribution plant is dimensioned with a coincidence factor of 1.

The following table shows the electrical powers absorbed from the stand-by network

Installation	Power input [KW]
Lighting	10
Signage	1
Tunnel fire detection system	1
Videosurveillance system	3
Communication network	1.5
Tunnel control system	5
Radio diffusion in tunnel	1
Emergency telephone system	0.5
Electrical and lighting system in buildings	3
TOTAL POWER WITHOUT RESERVE	**26**

Table 3: Electrical powers stand-by network

Depending on the loads supplied by the stand-by network, two 40KVA uninterruptible power supply is to be foreseen (one for the north and one for the south technical room). The final dimensioning of the plant will be the responsibility of the contracting company.

4.2 Lighting

4.2.1 General structure of the lighting plant

The lighting system consists of the following sub-systems:

- Crossing lighting: is a band of lamps hung at the vault of the tunnel, with the aim of maintaining the luminance level required inside the tunnel not less than (Nepal Road Standard 2070):
  - 30 lux at night
  - 400-750 lux during day time near the portals and 30 lux at the middle of the tunnel

  The arrangement of the lamps should be so that the carriageway is lit on its entire width (lanes, runway, banquet) and the side walls to a height of 2 m. Above 2 m, no lighting is required except under special circumstances. The cross lighting is installed along the entire length of the tunnel. One lamp in four is connected to the UPS network and provides emergency lighting for 60 minutes in the event of a loss of normal power.
- Reinforcement lighting: these are two bands of lamps, placed by the entrances to the tunnel and having the purpose of connecting the luminance level outside the tunnel with the internal one. A further objective of this subsystem is to avoid the "black hole" effect to motorists entering the tunnel. The length of the tunnel section with the presence of reinforcement lighting depends on the lighting engineering calculations which must be performed by the contractor. The arrangement of the lamps must be such that they only illuminate the road. The adaptation light is installed at the entrances of the tunnels.
- Fire emergency lighting: a set of lamps placed along the tunnel, with the aim of guiding, in the event of a fire, people fleeing vehicles to emergency exits. Every 50 m an element of emergency lighting is provided on the side of the emergency exits. The lights of the emergency lighting are mounted at a height of approx. 0.5 m above the banquet.
- LED optical guide: the optical guide consists of point-sources. The marking points of the optical guide are attached to the left and right of the road along the banquets in the curb or near the road. The optical guide is installed along the entire length of the tunnel. The markings should be visible from both directions of travel.
- Emergency exit lighting: consists of green side lamps and integrated LED flash lights. This sub-system signals the presence of emergency exits to motorists in the event of an event.
- Escape route (or egress route) lighting: it consists of a band of lamps hanging from the tunnels that lead from the tunnel to the external road.
- Street lighting: it is the lighting outside the gallery, composed of street lamps.
- Lighting by rock-shed: it is the lighting of the street inside the rock-shed.

Picture 4: Example of tunnel lighting equipment

4.2.2 Control system and sensors

The lighting control system is part of the tunnel control system (see chapter 4.6.2).

Only specific functions concerning lighting, which must be carried out in the tunnel control system, are described here.

The tunnel control system must show to the operators the alarms (faults) as well as the status of the lighting system.

The following operating logic is provided for each sub-installation:

Cross-lighting

- light intensity shall be regulated on 4 levels: emergency (25%), night (50%), day (75%), maximum lighting (100%);
- external luminance probes allow the automatic adjustment of the 4 levels;
- day/night change must take place through a threshold value managed with data from the external luminance probes. In the event of a fault of a probe, the day/night change can be managed by means of the other probe. In the event of a fault of two probes, the day/night change can be managed by means of the ephemeris of the tunnel location.

Reinforcement-lighting

- light intensity is regulated on 4 levels
- external luminance probes allow the automatic adjustment of the 4 levels;
- day/night change must take place through a threshold value managed with data from the external luminance probes. In the event of a fault of a probe, the day/night change can be managed by means of the other probe. In the event of a fault of two probes, the day/night change can be managed by means of the ephemeris of the tunnel location.

Fire emergency lighting

- switched off under normal conditions;
- lit in case of fire.

Optical guide

- light intensity is regulated on 3 levels, night (25%), day (75%), event (100%);

Other

- emergency exit light shall be always on;
- light bands and flashes: bands always on, flashes on in case of fire;
- one in four lamps in the escape route lighting are always on.

Luminance probes are powered by the normal network and are installed about 70 m from the respective north and south portals. The exact positioning must be defined by the general contractor based on careful inspections. The luminance measurement of each portal is transmitted to the tunnel control system via an analogue signals or field-bus.

Before the final design of the lighting system by the contractor, the characteristic luminance values must be measured on site at the tunnel portals, on the basis of which to carry out the lighting engineering dimensioning of the system.

4.2.3 Crossing lighting

For the crossing lighting, the use of LED technology is mandatory. This technology is now very widespread in the world, allows to have an excellent light output/power ratio (very low power consumption), has an excellent performance over time and has a very long life-span. The lamps are

fixed to the gallery vault by means of two brackets. Through this system it is possible to modify the position of the lamp on the vertical axis, on the transversal axis and the rotation on the longitudinal axis. Horizontal brackets are also applied to the vertical brackets, allowing the installation of a channel for the laying of power and control cables.

Lamps and power supply

The lamps are divided into four groups: North, North Emergency, South and South Emergency and have a distance between each lamp of about 12m. One lamp every four is connected to the stand-by network. This solution allows these lighting values to be achieved:

lighting	level of brightness
Max	100%
Daytime	75%
Night	50%
Emergency	25%

The dorsal power cable of each group starts from the adjacent central unit and ends in the junction box adjacent to the first lamp, after which there is a cable that connects all the other lamps in the group. For each lamp the phases (F1-F2-F3) will be alternated in order to share the load. The cables will be laid on the cable duct. The junction box terminals is used to supply the lamps. The branch cable is flexible. Each lamp has a single-phase power supply and must provide for its adjustment and control (e.g. using DALI). Cable characteristics

For the normal network, cables with 5-minute isolation must be used, while for the stand-by network, cables with 180-minute isolation and 30-minute functionality must be used. All fire-resistant cables will have "B2ca-s1a, d1, d1, a1" characteristics according to European standard EN 50575 - CPR EU 305/2011.

The general contractor is responsible for checking and laying cables that guarantee the required operation.

Lamp features:

- technology LED;
- a lifespan of at least 80,000 hours; ○ bright colour = 4'500K;
- Minimum luminous efficiency: 100lm/W;
- a failure of the illuminating cover must not lead to the replacement of the complete lamp; ○ IP65
- corrosion-resistant stainless-steel housing.

The lamps are fixed to the gallery vault by means of two brackets (mounting system). The minimum characteristics:

- bracket with vertical upright with adequate length and with the possibility of fixing brackets for the cable duct and fixing plates at a time. The plates allow the adjustment of the inclination to allow the adaptation to any surface.
- horizontal brackets for fixing the cable duct and in stainless steel; ○ each fixing point is protected against self-loosening;
- each mounting system is calculated for a load capacity corresponding to a static load of at least 1kN (100 kg per lamp);
- each mounting system allows easy adaptation to the irregularities and inclination of the supporting surface (reinforced concrete);
- all metal elements are sandblasted;
- for the separation of the different materials, in particular of the supports with the lamps, there are Teflon washers with knurled edges that guarantee electrochemical insulation of different metals, also preventing the lamp from moving;
- the material of all the components, including the bolts, and metal bushings for fixing the supports, must be adequate for installation in tunnel.

Electric power estimation

Power supply from technical room north:

- Lighting circuit F1 = 1.5 KW (cosphi =0.9)

- Lighting circuit F2 = 1.5 KW (cosphi =0.9)
- Lighting circuit F3 = 1.5 KW (cosphi =0.9)

Total = 4.5 KW

Power supply from technical room south:

- Lighting circuit F1 = 1.5 KW (cosphi =0.9)
- Lighting circuit F2 = 1.5 KW (cosphi =0.9)
- Lighting circuit F3 = 1.5 KW (cosphi =0.9)

Total = 4.5 KW

Power supply from technical room north, UPS:

- Lighting circuit F1 = 0.5 KW (cosphi =0.9)
- Lighting circuit F2 = 0.5 KW (cosphi =0.9)
- Lighting circuit F3 = 0.5 KW (cosphi =0.9)

Total = 1.5 KW

Power supply from technical room south, UPS:

- Lighting circuit F1 = 0.5 KW (cosphi =0.9)
- Lighting circuit F2 = 0.5 KW (cosphi =0.9)
- Lighting circuit F3 = 0.5 KW (cosphi =0.9)

Total = 1.5 KW

4.2.4 Reinforcement lighting

The use of LED technology is mandatory for the implementation of reinforcement lighting. This technology is now very widespread in the world, allows to have an excellent light output/power ratio (very low power consumption), has an excellent performance over time and has a very long-life span. The lamps are fixed on the side tunnel walls by means of two brackets. Through this system it is possible to modify the position of the lamp on the vertical axis, on the transversal axis and the rotation on the longitudinal axis.

Lamps and power supply

The lamps are divided into two groups: North and South and have a distance of about 2m between each other. Reinforcement lighting and is provided for about the first 100m from the entrance of the two portals. The precise lenght of the stretch with reinforcement lighting will be defined in the executive design by the contractor based on lighting engineering calculations.

The dorsal power cable of each group starts from the adjacent central unit and ends in the junction box adjacent to the first lamp, after which there is a cable that connects all the other lamps in the group. For each lamp the phases (F1-F2-F3) will be alternated in order to share the load. The cables will be laid on the cable duct. The junction box terminals is used to supply the lamps. The branch cable is flexible. Each lamp has a single-phase power supply and must provide for its adjustment and control (e.g. DALI).

Cable characteristics

For the normal network, cables with 5-minute isolation must be used, while for the stand-by network, cables with 180-minute isolation and 30-minute functionality must be used. All fire-resistant cables will have "B2ca-s1a, d1, d1, a1" characteristics according to European standard EN 50575 - CPR EU 305/2011. The contractor is responsible for checking and laying cables that guarantee the required operation.

Lamp features:

- technology LED;
- lifespan of at least 80,000 hours;
- bright colour = 4'500K;
- minimum luminous efficiency: 100lm/W;
- a failure of the illuminating cover must not lead to the replacement of the complete lamp;
- IP65 protection degree
- corrosion-resistant stainless-steel housing.

The lamps are fixed on the side tunnel walls by means of two brackets (mounting system). The minimum characteristics are:

- bracket with vertical upright with adequate length and with the possibility of fixing brackets for the cable duct and fixing plates at a time. The plates allow the adjustment of the inclination to allow the adaptation to any surface.
- each fixing point is protected against self-loosening;
- each mounting system is calculated for a load capacity corresponding to a static load of at least 1kN (100 kg per lamp);
- each mounting system allows easy adaptation to the irregularities and inclination of the supporting surface (reinforced concrete);
- all metal elements are sandblasted;
- for the separation of the different materials, in particular of the supports with the lamps, there are Teflon washers with knurled edges that guarantee electrochemical insulation, also preventing the lamp from moving;
- the material of all the components, including the bolts, and metal bushings for fixing the supports, must be adequate for installation in tunnel.

- Lighting circuit F1 = 3 KW (cosphi =0.9) ○ Lighting circuit F2 = 3 KW (cosphi =0.9) ○ Lighting circuit F3 = 3 KW (cosphi =0.9)

Total = 9 KW

Power supply from technical room south:

- Lighting circuit F1 = 3 KW (cosphi =0.9) ○ Lighting circuit F2 = 3 KW (cosphi =0.9) ○ Lighting circuit F3 = 3 KW (cosphi =0.9)

Totale = 9 KW

4.2.5 Fire emergency lighting

Emergency lighting is necessary to guide road users in the event of a strong presence of smoke (due to a fire) that significantly reduces visibility. The lamps of the fire emergency lighting are placed on the northbound lane where the emergency exits are provided. The power supply is divided into two groups, one starting from the north technical room and one starting from the south technical room. Each lamp has a junction box (IP65 and E30). From the junction box to the lamp there is a power cable (fire resistant for 180 minutes and having characteristics "B2ca-s1a, d1, a1" according to European standard EN 50575 - CPR EU 305/2011). The branch in the box must be provided by dividing the load over the three phases. Here is an example of fire emergency lighting:

Picture 3: Example of fire emergency lighting

Lamp features:

- LED technology;
- instantaneous power on with 100% power; ○ Luminous flux >1'000 lm;
- a failure of the illuminating cover must not lead to the replacement of the complete lamp;

- pipes (against flame propagation) are to be installed on the side wall from the cable duct to the lamp to protect the connection cable.
- the visible luminous surface must not exceed 50 cm^2; ○ resistant to heat, splashes and dirt;
- lighting bodies are laid every 50 m and at a height of 50 cm from the banquet;
- the material of all the components, including the bolts, and metal bushings for fixing the supports, must be adequate for installation in tunnel.

4.2.6 Optical guide

LED modules will be installed to mark the direction of travel for road users. The installation is planned on both sides of the pavements. For about the first 100m at the entrance to the tunnel in both directions, where the reinforcement lighting is present, the distance between the modules will be 25m, while in the remaining part of the tunnel it will be 50m. Each side of the tunnel must have its own supply line and will be controlled by a control unit installed in the technical room north. The edge of the pavement must be provided with a groove milled to allow the laying of power cables. The milling for the laying of the power cable must be 1cm wide and at least 3cm deep. After laying the cable and connecting it to the modules, a protective sleeve covering the groove must be laid.
Here is an example of LED optical guide:

Picture 4: Example of LED optical guide

Module features:

- LED technology;
- IP68 protection degree;
- Life-span of at least 100,000 hours; ○ bright color = 4'500K;
- luminous intensities ≥ 25 cd and ≤ 100cd (maximum);
- a failure of the illuminating cover shall not lead to the replacement of the complete lamp; ○ driveway resistance 5 tons.

4.2.7 Emergency exits lighting

Two green light bands shall be installed by each emergency exit to mark the entrance to the escape route in the event of fire/emergency. A lamp shall also be installed above the door. The lamps are composed of a vertical green bar on the whole height and 3 flashing LED lamps distributed on each side. The green bars must always remain on; in case of an event the LED lamps on the sides must flash to draw the attention of road users and signal the escape route despite the presence of smoke. The lamps are connected to the UPS network.
Here is an example of standard illumination of an emergency exit:

Picture 5: example of illumination of emergency exits

LED lamp features:

- LED technology;
- life span of at least 80,000 hours; ○ Bright colour = 4'500K;
- ○ A failure of the luminaire shall not lead to the replacement of the complete lamp; ○ IP65 protection degree;
- corrosion-resistant stainless steel-housing;
- pipes (against flame propagation) are to be installed on the side wall from the cable duct to the lamp;
- fire resistant cable and having characteristics "B2ca-s1a, d1, a1" according to European standard EN 50575 - CPR EU 305/2011, cable from the backbone for each luminaire.

Mounting system of the lamp above the exit:

The minimum characteristics are:

- slots for direct wall mounting.
- each fixing point is protected against self-loosening;
- each mounting system is calculated for a load capacity corresponding to a static load of at least 1kN (100 kg per lamp);
- all metal elements are sandblasted;
- for the separation of the different materials, in particular of the supports with the lamps, there are teflon washers with knurled edges that guarantee electrochemical insulation, also preventing the lamp from moving;
- the material of all the components, including the bolts, and metal bushings for fixing the supports, must be adequate for installation in tunnel.

Green bands and LED flashes features:

Lamp features:

- LED technology;
- Service life of at least 80,000 hours; ○ Bright colour = 4'500K;
- A failure of the luminaire shall not result in the replacement of the complete lamp;
- IP65 protection degree;
- corrosion-resistant stainless-steel housing, RAL 6035;
- the middle of the luminous bands is foreseen at 1 m from the sidewalk, vertically mounted; ○ Plexi-glass of the vertical band, opaque and green in colour;

- pipes (against the propagation of the flame) are installed on the side wall from the cable duct to the lighting cover;
- cable deriving from the backbone fire resistant cable and having characteristics "B2ca-s1a, d1, a1" according to European standard EN 50575 - CPR EU 305/2011, for each lamp.

Mounting system and fixing of light bands and flashes:

- slots for direct wall mounting.
- each fixing point is protected against self-loosening;
- each mounting system is calculated for a load capacity corresponding to a static load of at least 1kN (100 kg per lamp);
- all metal elements are sandblasted;
- for the separation of the different materials, in particular of the supports with the lamps, there are Teflon washers with knurled edges that guarantee electrochemical insulation, also preventing the lamp from moving;
- the material of all the components, including the bolts, and metal bushings for fixing the supports, must be adequate for installation in tunnel.

4.2.8 Lighting of escape routes

Escape routes shall be illuminated. The lighting consists of internal lights along the entire length of the escape route and external lights by the entrance and the light bands and flashes at the entrance. Each escape route is provided with a normal power supply line and an emergency (UPS) power supply line. The connection is made from the nearest technical room. For each cable there is an IP65 junction box (in the case of the emergency power cable also E30) which must allow the junction of at least 4 connections. The junction boxes will be positioned on the side wall of the tunnel, above the cable duct. The following lamps are connected to the normal network:

- internal lamps (2 every 3)
- internal lamps (1 every 3);
- external lamp above the entrance;

Interior lighting

The escape routes are to be illuminated along their entire length by means of lamps with LED technology. The lamps are connected to both the normal and stand-by networks. The lighting of each cross passageway is designed to achieve an average brightness of 20 lux in the central area of the escape route, measured at a height of 80 cm above the ground and a minimum of 1 lux in every other place.

Lamps connected to the stand-by network provide an average brightness of 1 lux in the central zone of the escape routes, measured at a height directly on the ground. The lamps are automatically switched on after the tunnel door has been opened.

Lamp features:

- LED technology;
- life span of at least 80,000 hours; o bright colour = 4'500K;
- a failure of the illuminating cover must not lead to the replacement of the complete lamp; o IP65 protection degree;
- corrosion-resistant stainless-steel housing;
- pipes (against flame propagation) are to be installed on the side wall from the cable duct to the lighting cover;
- cable derived cable deriving from the backbone fire resistant cable and having characteristics "B2ca-s1a, d1, a1" according to European standard EN 50575 - CPR EU 305/2011, for each lamp.

Mounting and fixing system:

The lamps are fixed to the escape route by means of two brackets (mounting system). The minimum characteristics are:

- bracket with vertical upright with appropriate length and with the possibility of fixing brackets for the cable duct and fixing plates at a time. The plates allow the adjustment of the inclination to

allow the adaptation to any surface.

- horizontal brackets for fixing the cable duct and in stainless steel;
- each fixing point is protected against self-loosening;
- each mounting system is calculated for a load capacity corresponding to a static load of at least 1kN (100 kg per lamp);
- each mounting system allows easy adaptation to irregularities and to the inclination of the supporting surface (reinforced concrete);
- all metal elements are sandblasted;
- for the separation of the different materials, in particular of the supports with the lamps, there are Teflon washers with knurled edges that guarantee electrochemical insulation, also preventing the lamp from moving;
- the material of all the components, including the bolts, and metal bushings for fixing the supports, must be adequate for installation in tunnel.

Electric power estimation

The estimate of the total power absorbed by the total normal network of luminaires (power supply from technical room north/south):

- Lighting circuit F1 = 1.5 KW (cosphi =0.9)
- Lighting circuit F2 = 1.5 KW (cosphi =0.9)
- Lighting circuit F3 = 1.5 KW (cosphi =0.9)

Total = 4.5 KW

4.2.9 Street lighting

At the north portal and at the south portal, 6 luminaires will be installed, 3 on each side. The power supply is provided by the nearest technical room with cable type FE05C 5x10mmq through a series connection. Electric power estimation

The estimate of the total power absorbed by the total normal network of luminaires (power supply from technical room north/south):

- Lighting circuit 1= 1 KW (cosphi =0.9)
- Lighting circuit 2 = 1 KW (cosphi =0.9)

Total = 2 KW

4.2.10 Lighting by rock-shed

The pedestrian walkway will be illuminated along its entire length by means of luminaires with LED technology lamps. The luminaires will be connected both to the normal electrical network and to the stand-by electrical network. The lighting is designed to reach an average brightness of 20 lux in the central area, measured at a height of 80 cm above the ground according to the international directive on street lighting. The luminaires connected to the stand-by electrical network provide an average brightness of 1 lux in the central zone of the route, measured at a height directly on the ground. The lamps are automatically switched on in the evening by means of a twilight sensor.

Lamp characteristics:

- LED technology;
- service life of at least 80,000 hours;
- bright colour = 4'500K;
- a failure of the illuminating cover must not result in the replacement of the complete lamp.

Characteristics of luminaires:

- IP65 protection degree;
- stainless steel or corrosion-resistant thermoplastic housing;
- pipes are to be installed on the side wall from the cable duct to the luminaire;
- cable deriving from the backbone fire resistant cable and having characteristics "B2ca-s1a, d1, a1" according to European standard EN 50575 - CPR EU 305/2011, for each luminaire.

Mounting and fixing system:

The luminaires will be fixed to the ceiling/wall of the escape route by means of two brackets (mounting system). The minimum characteristics:

- bracket with vertical upright with adequate length and with the possibility of fixing brackets for the cable duct and fixing plates to the ceiling / wall. The plates allow the adjustment of the inclination to allow the adaptation to any surface.
- horizontal brackets for fixing the cable duct and in stainless steel;
- each fixing point is protected against self-loosening;
- each mounting system is calculated for a load capacity corresponding to a static load of at least 1kN (100 kg per lamp);
- each mounting system allows easy adaptation to the irregularities and inclination of the supporting surface (reinforced concrete);
- all metal elements are sandblasted;
- the material of all the components, including the bolts, and metal bushings for fixing the supports, must be adequate for the place of installation.

Electric power estimation

The estimate of the total power absorbed from the normal network (power supply from technical room north/south):

- Lighting circuit F1 = 1.5 KW (cosphi =0.9)
- Lighting circuit F2 = 1.5 KW (cosphi =0.9)
- Lighting circuit F3 = 1.5 KW (cosphi =0.9)

Total = 4.5 KW

4.3 Ventilation

The ventilation system is described in the reference A2.

The document contains the dimensioning of jet-fans and sensors. Regarding to traffic in reference year, this is irrelevant as the dimensioning case was the fire operation, and it was judged that the resulting fresh-air supply during normal operation was more than adequate in all traffic density conditions.

It will be the task of the contractor to define, in the final design phase of the system, the functioning of the ventilation in the normal case (sanitary ventilation) and in the event of a fire (operation of the system in the various fire scenarios in the tunnel).

4.4 Signage

4.4.1 Traffic and signalling

The implementation of the tunnel is accompanied by a larger-scale traffic and signalling concept that makes it possible to manage traffic flows as efficiently as possible, in normal conditions and in the event of tunnel closure.

The tunnel consists of a two-lane tube (1 lane per direction). Under normal traffic conditions, traffic flows to the left of the roadway in a northerly direction (Tansen) and to the right in a southerly direction (Butwal).

4.4.2 Traffic principles

With the future tunnel, the current H10 road becomes the pedestrian/bicycle way on the section concerned. With a clear space gauge of **3.5 m x 5.0 m**, it allows the mixed circulation of numerous bicycles and pedestrians as well as the passage of emergency vehicles in case of need (to be coordinated with the intervention of a security guard).

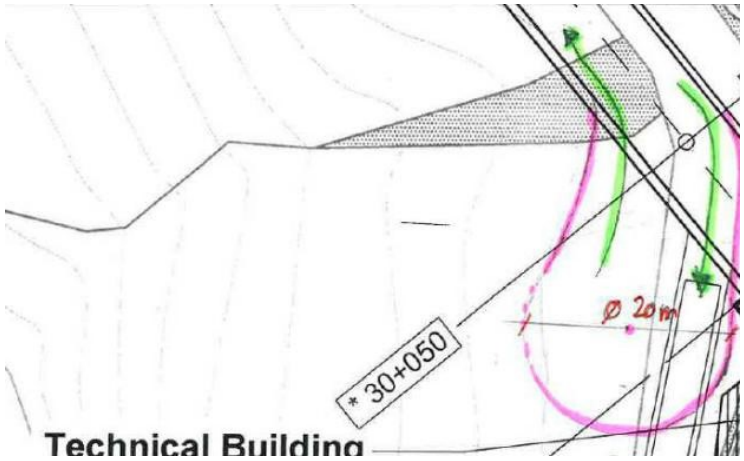
The pedestrian/bicycle path is the collector of the tunnel's pedestrian bypasses (emergency exits).

In the event of tunnel closure (accident, fire, maintenance), the road route via the H10 between Butwal and Tansen is no longer possible. The alternative road route is via the H01 and Rahabas Jhadewa Sadak, via Rupse (see Reference A9). This alternative route is very long (about 4h30) compared to the H10 (1h25 today). The alternative route should therefore only be used in the event of prolonged tunnel closure.

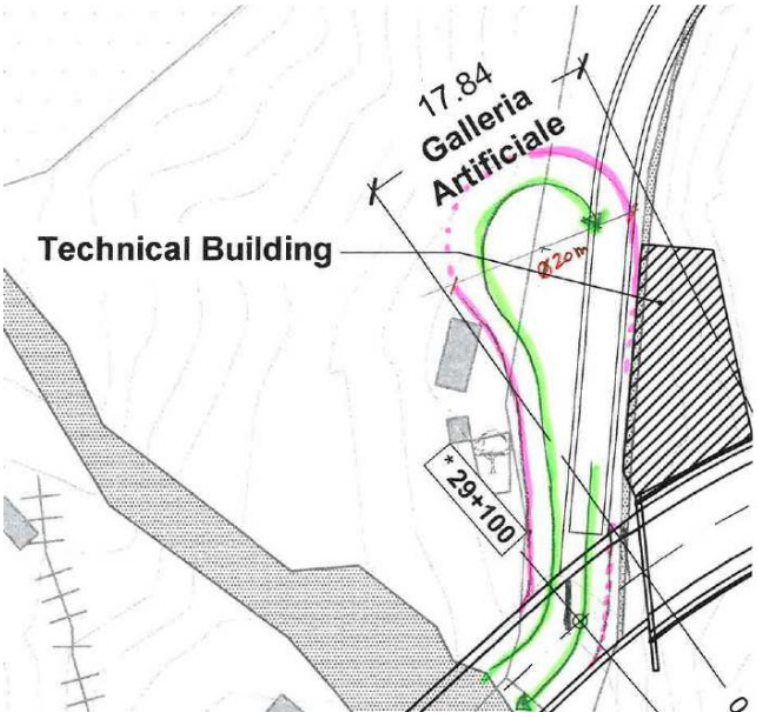
Variable traffic signs will be installed between Butwal and Tansen to inform and direct users to the alternative route (see Reference A10).

The closure of the tunnel will result in vehicle queues on the H10. In order to allow users to turn back, turnaround spaces must be provided at both gates. The radius of curvature must be large enough to allow a truck or bus to turn (min. 20 m in diameter) - see illustrations below.

Depending on the context (slope, slope, ground conditions), an adaptation of the turning back zone will be necessary.



Picture 6: North portal



Picture 7: South portal

Emergency vehicles will be accessible to the tunnel via the H10. A helicopter landing site can be considered near the tunnel to ensure a very fast response time, as road access can be disrupted by the lines of cars or turning back.

4.4.3 Control system of the Signage

An operating condition (OC) is a specific status for all variable signs in the area managed by the traffic control system.

For the operation of the tunnel, a few OCs will be needed; they will be stored in the traffic control system which is part of the tunnel control system (chapter 3.6.2). Here we must point out the fact that the signage must have a very reliable control system.

The OCs constitute "states". Only the logically possible transitions (based on the indications of the traffic specialist and the current Nepali legislation) between these states must be able to be carried out in the system. Using the tunnel control system, operators in the control room must be able to select the desired states of the tunnel signage and to command its activation.

Each OC contain the status of every single variable traffic sign. When an OC is loaded, all traffic signs assume the new status defined in the OC. Not every OC can be loaded at any time, the relations between the OCs is described in the so-called interlock matrix.

The interlock matrix, as well as the list of possible OCs for the tunnel signage, will have to be defined in the execution phase by the traffic specialist of the project team of the general contractor.

In case of failure of a traffic sign, operators in the control room must be informed trough the SCADA system. The system will not lock any OC because of a defected sign; the operator must decide, if a requested OC can be applied even in case of faulty signs.

The traffic control system must exclude the possibility to activate a combination of signs which is not foreseen by the interlock matrix or contradictory (for example: green at the same time by two traffic lights allowing traffic flow in opposite directions). To archive this request, measures must be taken on different levels (SCADA, PLC). In particular, the display of contradictory signs must be prevented (such as green light and red light at the same time on a traffic light).

Given the relevance in legal and insurance terms (for example in case of an accident) all the commands entered for the signage and all the transitions made by the same must be traced in a log (command, status of each sign, operator who has sent the command, date, hour, etc.).

Because of their distance from the technical rooms to the north and south portals of the tunnel, the VDS1, VDS 2, VDS 6 and VDS 7 signs will be equipped with photovoltaic panels or wind micro-turbines. These signs will have their own local control with microprocessor (PLC, RTU) connected to the tunnel control system through the data network on mobile telephony.

4.4.4 Traffic signs

Fixed and variable signs must be placed on the tunnel access road to inform users of the accessibility status of the tunnel and to regulate traffic through the tunnel.

The schemas in References A9 and A10 illustrate the traffic signs that should be placed in order to properly inform users and allow drivers' behaviour to be adapted. These signs refer to the Nepalese Traffic signs manual (August 97) and the number of the corresponding sign is mentioned.

Before entering the tunnel, prohibition signs should be placed to inform pedestrians and cyclists that they must use the current road and not the tunnel.

For motor vehicles, a no-overtaking sign and a speed limit of 60 km/h should also be placed near the entrance (as soon as the marking of the double white line on the roadway begins).

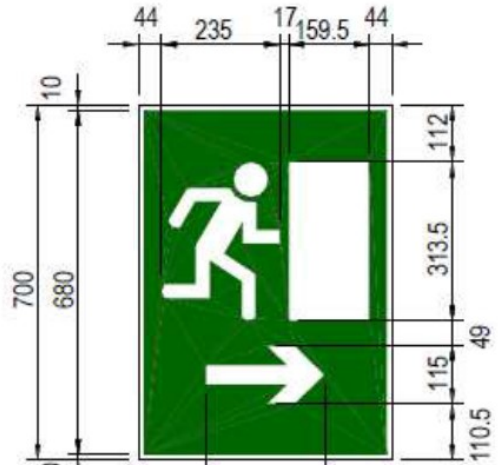
In order to limit the damage that could be caused by a very high vehicle (gauge of more than 4.50 m), a prohibition sign must be placed before the entrance and a gauge can be installed, either at the two tunnel entrances (possible at the level of the gates - see example below), or upstream on the H10.

Depending on local usage, it may be appropriate to mark a pedestrian crossing before the tunnel entrances, in order to provide relative safety for pedestrians who will have to join the pedestrian/bicycle path.

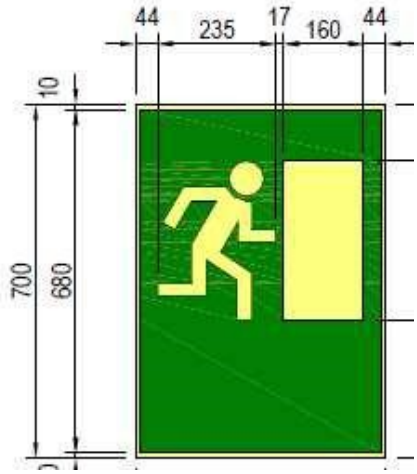
4.4.5 Emergency exits and safety signs

For the arrangement of the emergency exits and safety signs in the tunnel, see the document A1. For multilingual signals, the languages to be considered (in addition to Nepalese and English) must be defined by the general contractor in agreement with the client.

Within the tunnel, emergency exits shall be marked with appropriate signs (colour RAL 6029, dimensions in mm):

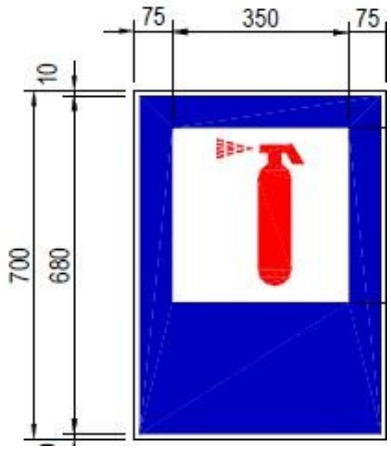


The following signage shall be affixed to the emergency exits' access doors (colour RAL 6029, internal yellow, dimensions in mm):

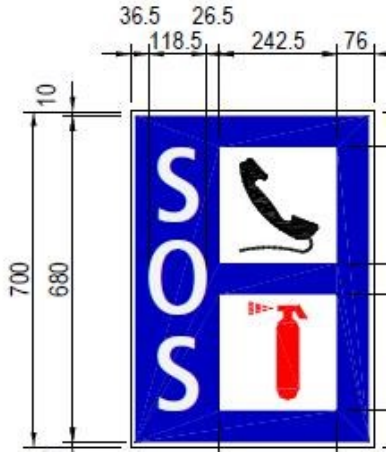


In the SOS niches in the gallery, a multi-lingual sign must be affixed to indicate that the location is unsafe:

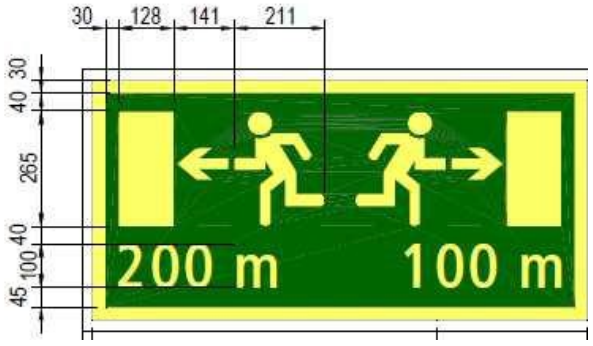
The presence of fire extinguishers must be indicated by a special illuminated signal (dimension in mm):



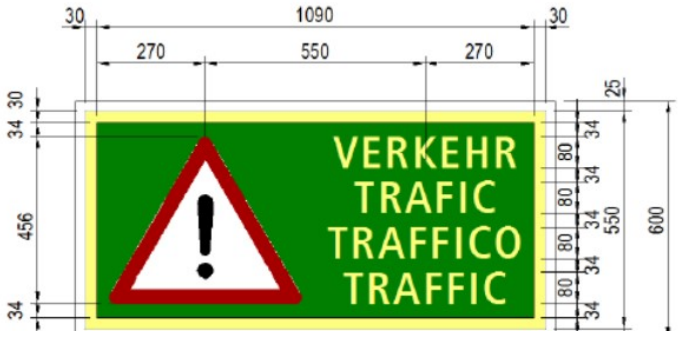
The presence of emergency phone combined with fire extinguishers must be indicated by a special illuminated signal (dimension in mm):



Signs indicating the distance to the nearest emergency exits in both directions shall be installed at regular intervals throughout the tunnel. These signs shall have residual lighting. The dimensions are expressed in mm:



The exit doors from the cross passages to the outside road shall be marked with signs indicating the presence of traffic.



4.4.6 Traffic barriers

At both tunnel-entrances a movable barrier must be installed. Aim of these barriers is closing the access to the tunnel in case of dangers in it.

The barriers are controlled from the control room; operators must be able to check the situation via the video surveillance to be sure that barriers can be closed safely.

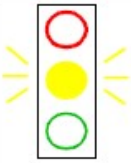
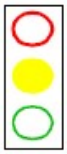
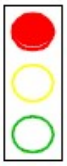
Depending on the final layout of the reversing places at both gates, the barrier must be provided in such a way as not to disturb the vehicles. If possible, barriers should be provided on both lanes to prevent users from using the lane in the wrong direction.

4.4.7 Signs transitions

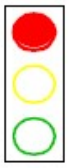
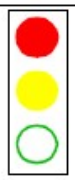
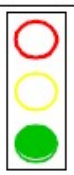
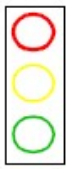
Traffic lights: traffic lights are mounted at the sides of the tunnel portals

From "OFF" to "RED" → In accordance with Nepalese law

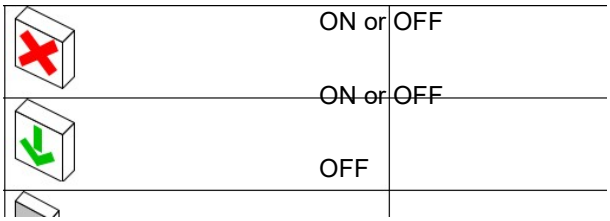
In the absence of legal regulations under Nepalese law (to be verified again by the general contractor after obtaining the contract) the following table can be considered.

	Status	Duration	Frequency
	All lights off.		
	Yellow blinking	6 sec	1 sec ON 0.5 sec OFF
	Yellow on	6 sec	-
	RED on		

From "RED" to "OFF" → In accordance with Nepalese law
In the absence of legal regulations under Nepalese law (to be verified again by the general contractor after obtaining the contract) the following table can be considered.

	Status	Duration	Frequency
	RED on		
	RED and YELLOW on	6 sec	1 sec ON 0.5 sec OFF
	GREEN ON	2 min	
	All lights OFF		

Traffic guides: traffic guides are the signs mounted on the ceiling inside the tunnel.



Each status can be assumed directly, starting from any other status.

4.4.8 Traffic detection and counting

To allow the management of signage and ventilation it is necessary to detect the traffic conditions.

For this reason, 6 detection points are planned, 3 per direction, based on inductive coils embedded in the road surface. These positions will be at the portals of the tunnel and at the centre of it.

Each detection-station must be able to detect:

- vehicle speed (km/h)
- number of vehicles (vehicles per minute, vehicles per hour)
- type of vehicles (at least the following: motorcycle, car, light truck, heavy truck, lorry with trailer, bus)
- vehicle direction (possible presence of vehicles in contravention)
- degree of occupation of the lane (percentage)
- presence of stationary vehicles.

These data must be detected by specific detection stations connected to the tunnel control system. The data collected must be able to be displayed in the SCADA both on-line ("live" display) and as historical archives (display of data through curves and histograms in freely definable time windows).

4.5 Surveillance systems

4.5.1 Tunnel fire detection system

4.5.1.1 Description of the tunnel fire detection system

This system will be responsible for the detection of fires in the tunnel. This is a system separate from the fire detection system provided in buildings.

Fire detection in the tunnel will be based on two separate technologies, both controlled by the detection system:

- detection of the increase in temperature, by means of a fibr*E* optic sensor cable
- detection of the presence of smoke, by means of point-sensors installed.

Sensors with a maintenance interval <1 year are not allowed;

The checks and calibrations of the sensors that must be carried out periodically must be communicated by the supplier at the time of the offer, in order to be able to guarantee the function of the sensors with the necessary maintenance.

Operating interruptions must be eliminated within 72 hours.

Easy assembly/disassembly of the components in the tunnel should be preferred.

In case of fault or damage, simple replacement must be guaranteed without the use of special tools. The cleaning of the construction elements, if necessary, is only possible in conjunction with the ordinary cleaning of the tunnel.

4.5.1.2 Description of the elements of the tunnel fire detection system

4.5.1.2.1 Fibre optic sensor cable

As a fire detection cable or linear probe, a fibre optic probe must be used. The technology chosen must be state of the art.

The cable used must withstand the aggressive environment of the traffic compartment and possible mechanical stress during maintenance work (tunnel cleaning).

- temperature measurement range: -30 ° C to 85 ° C
- measurement resolution: 10 m

If the cable is interrupted, the measurement must continue and be ensured by the side still connected, i.e. on the entire cable between the fire control unit and the breaking point.

The linear probe fixings to the vault must be made of stainless steel and must withstand the aggressive environment of the traffic compartment and possible mechanical stress during normal functioning (vibrations due to the passage of vehicles) and during maintenance work. The minimum bending radii, the maximum distance between supports, the tensile strength during laying and the resistance to mechanical stress during operation and maintenance (e.g. tunnel washing) must also be considered. The linear probe must be placed 8-9 centimetres from the vault so as not to be in contact with the concrete surface. Appropriate spring-type fasteners must be used that do not exert an excessive pressure on the probe itself, in order not to damage the probe or cause disturbances to its operation. The section of the probe which goes from the fire control unit in the technical room to the end of the tunnel will be laid in a cable duct and must be adequately protected mechanically, for example, with a pipe.

4.5.1.2.2 Smoke detectors

Diffused light smoke detectors with continuous measurement must be installed, connected as a ring or as a star. Fog, including salt fog, should not be detected as smoke and changes in temperature or humidity should not cause measurement errors. The duration for calculating the average value and the delay of the alarm activation must be centrally parameterized in the SCADA tunnel control system. It is planned to install 10 smoke sensors (see reference A3).

Requested features for smoke detectors are:

- measurement range: 0 ÷ 3 E / m;
- measurement resolution: 1 mE / m;
- IP 66 protection degree;

The detector used must withstand the aggressive environment of the traffic compartment and possible mechanical stress during normal functioning and maintenance work.

4.5.1.2.3 Fire control units and smoke control units

The units of analysis and evaluation of the temperatures measured in the traffic compartment must be composed of components of well-known suppliers, widely used and easily available, and must have a user interface (minimal display panel, LEDs, etc.). The technical characteristics must in any case satisfy the purpose for which they are foreseen and what is described in the present document as far as operation and construction are concerned.

The control units must guarantee:

- processing of data detected by the probes
- reporting of the exact point of an event and of the fire-sector concerned;
- management of several (>20) fire sectors
- indication of the current average temperatures of each fire sector (for the fire control unit)
- indication of the current average values of each probe (for the smoke control unit)
- inhibition of measurement in one or more fire sectors (for the fire control unit)
- inhibition of the measurement of the presence of smoke in one or more smoke detectors (for the smoke control unit)
- transmission to the PLC Fire of detected data.

The communication between the PLC Fire and the fire control unit and the smoke control unit must be on fieldbus.

4.5.1.3 Description of the functionality of the tunnel fire detection system

The tunnel will be divided into 11 fire alarm sectors (see Reference A3). The tunnel fire detection system must provide:

- independent management of each individual fire sector;
- data acquisition from the tunnel (temperature, air opacity);
- detection for each fire sector of temperature variations with relative position where this variation takes place. In particular, the maximum values and speed with which these are reached (gradient) are to be shown and recorded in the SCADA tunnel control system
- display of the data collected in the SCADA tunnel control system
- visualization of the system status in the SCADA tunnel control system
- transmission of commands from the SCADA tunnel control system to the tunnel fire detection system (such as: start data recording, inhibit of one or more sector)
- analysis of the data collected, determination of the fire sector affected by the fire event and transmission of the data to the SCADA tunnel control system to show measures and alarms
- receiving notification of fire presence from the SCADA tunnel control system (fire-alarm declared by an operator at the SCADA-client level)
- system calibration, so that it can be adapted to the specifics of the tunnel (e.g.: different thresholds by tunnel portals, etc.).

In case of operation in normal situation the fire detection system is required

- reading of sensor values;
- saving data in a ring buffer;
- applying algorithms for the verification of the presence of fire events.

In the case of operation in the presence of a fire, the same functionalities as in the normal case are required, but with the addition of the data recording.

In order to always guarantee the greatest possible accuracy of the measurements, it must be possible to calibrate the system to compensate for any drifts of the measurements over time. These interventions must be possible without the need to intervene in the traffic compartment and there must not be more than one operation per year.

The fire detection system data must be archived. The storage of this data must be done in the SCADA tunnel control system

Data from the last 30 minutes (configurable time) must always be available, while the oldest data can be overwritten.

In case of a fire it is necessary to guarantee the availability of all data starting from 30 minutes before and up to 30 minutes after the time of the event; these data and cannot be overwritten. The data must be stored with a resolution of 1 second and must be marked with the date, time, minutes and seconds. In case of multiple events the data must be stored in a separate file for each event.

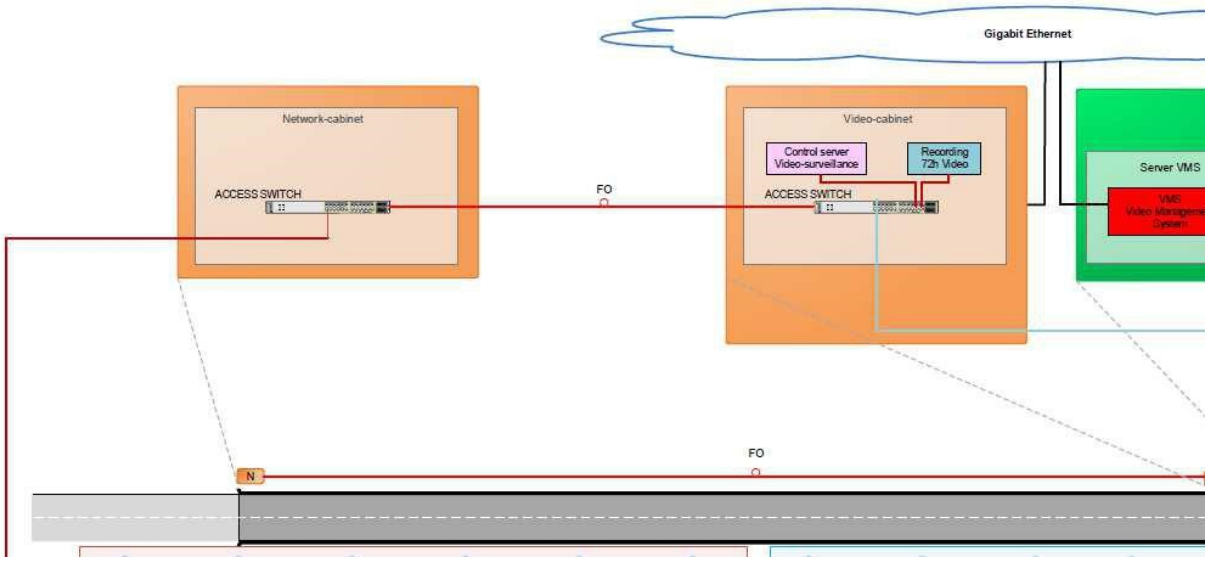
The data must be stored in a format that allows the graphic representation and the export such as .xls, .csv or .xml.

4.5.2 Video-surveillance system

4.5.2.1 Description

The structure of the video surveillance system foresees 10 IP cameras in tunnel and 2 IP cameras outside the tunnel, a server with an application that manages video-images and a recording server (for 72 hours). The cameras will be connected via cable cat.7 to the access-switches installed in the north and south technical rooms, inside cabinets. The connection between the access-switches and the video control server will be over single-mode fibre optic connection. The control server, as well as the cameras will be connected to the tunnel's communication network. The Video Management System (VMS) will be installed in the technical room at the south portal of the tunnel and will allow the users in the control room to direct the images on the 6 displays there installed.

The diagram in the figure shows the new video surveillance system:



Picture 8: structure of the video-surveillance system

4.5.2.2 Video-surveillance control server and software

The graphic interface of the control system of the video-surveillance must be accessible via web-browsing. The control system will have the task of interacting with the tunnel control system (cap. 4.6.2) sending alarms, warnings and the general state of the video surveillance system, including the status of the cameras (alarm / disturbance). The video-surveillance control system will receive the automatic reactions from the tunnel control system to start the recording of events. Remote control of the cameras via the interface is possible on the video-surveillance control system. Activation of video-images on the 6 display in the control room, on the other hand, are handled by the VMS.

Control System technical features

- Popular branded server products with wide distribution in Nepal and good assistance in Nepal
- Products released for at least 1 year from the date of submission of the offer and for which there is no foreseen replacement in the following 5 years from the date scheduled for the final installation on site
- At least 50% reserve in terms of computing power, working memory, non-volatile memory

- Console for system administration (keyboard, mouse, 16:9 display of at least 21")
- Video software product renowned and widespread on the Nepalese market, in a stable version (versions released for less than a year from the start of application development date are to be avoided)
- Server operating system in English, stable, released for at least 1 year from the date of submission of the offer and for which there is no foreseen replacement in the following 5 years from the date scheduled for the final installation on site
- Remote accessibility (web-browsing server)
- Complete software documentation
- User interface is to be agreed with the Customer during the executive design phase.

4.5.2.3 Recording system

The recording system digitally stores the video streams of all the cameras and consists of a permanent recording (circular buffer) and an event recording (on event-recording, according to the matrix of the automatic reactions).

The permanent recording stores the video streams continuously and with a reduced image rate which can be configures from 1 image per second up to 25 images per second and is available up to a maximum of 72 hours. Files are created separately for each camera and must retain hourly information.

The on-event recording system processes and records the images of 3 cameras near the event (incident, call by an emergency phone, etc.) and creates one or more event files that will not be deleted automatically. These files contain images from a configurable (from 10 to 60 minutes) time prior to the event to a configurable (from 10 to 60 minutes) time after the event, at recording rate of 25 images per second. The automatic reactions matrix is the basis for defining the relationship between an event and the cameras to be recorded. The format of the recordings must be in known and widespread video-format and the video stream encoded in a freely available format. In addition, in order to watch recorded videos, it must also be possible to view up to 4 video streams in real time on the control system.

Recording System technical features

- Popular branded server products with wide distribution in Nepal and good assistance in Nepal
- Products released for at least 1 year from the date of submission of the offer and for which there is no foreseen replacement in the following 5 years from the date scheduled for the final installation on site
- At least 50% reserve in terms of computing power, working memory, non-volatile memory
- Console for system administration shared with the video-surveillance control server
- Software product renowned and widespread on the Nepalese market, in a stable version (versions released for less than a year from the start of application development date are to be avoided)
- Operating system in English, stable, released for at least 1 year from the date of submission of the offer and for which there is no foreseen replacement in the following 5 years from the date scheduled for the final installation on site
- Possibility of contemporary reading and writing
- Web-interface for configuring the recordings
- Complete software documentation.

4.5.2.4 Cameras in the tunnel

The 10 internal IP cameras must have the following minimum characteristics:

- Fixed color camera, with mechanical removal of the IR filter
- Sensor: ≥ 1/3"
- Sensitivity: min 0.3 lux (colors) - 0.1 lux (B/W)

- Wide dynamic range
- Video compression: H.264
- Resolution: HD720p
- Transmission speed: up to 25 fps
- Multistreaming (minimum 2 independent video streams) configurable independently (Unicast / Multicast)
- Minimum protocols supported: TCP / IP, UDP / IP, HTTP, RTSP, RTCP, RTP / UDP, RTP / TCP, SNTP, mDNS, UPnP, SMTP, SOCK, IGMP, DHCP, FTP, DDNS, SSL v2 / v3, SSH
- Power supply: 12VDC / PoE
- Lens: VARIO (5-15mm)
- Web-server integrated on the camera for configuration
- Case: Stainless steel gr.II, with integrated heating (with power splitter)
- Mounting brackets: stainless steel, mounting in tunnel-roof.

4.5.2.5 Cameras outside the tunnel

The 2 external IP cameras must have the following minimum characteristics:

- Fixed color camera day&night, with mechanical removal of the IR filter
- Sensor: ≥ 1/3"
- Sensitivity: min 0.3 lux (colors) - 0.1 lux (B/W)
- Wide dynamic range
- Video compression: H.264
- Resolution: HD720p
- Transmission speed: up to 25 fps
- Multistreaming (minimum 2 independent video streams) configurable independently (Unicast / Multicast)
- Minimum protocols supported: TCP / IP, UDP / IP, HTTP, RTSP, RTCP, RTP / UDP, RTP / TCP, SNTP, mDNS, UPnP, SMTP, SOCK, IGMP, DHCP, FTP, DDNS, SSL v2 / v3, SSH
- Power supply: 12VDC / PoE
- Lens: VARIO (5-15mm)
- Web-server integrated on the camera for configuration
- Case: Stainless steel, with integrated heating (with power splitter). If necessary, an external sunshade device must be added to the case for external cameras in order to avoid reflections of light
- Mounting brackets: stainless steel, mounting on poles.

4.5.2.6 Video-streams

The cameras must be able to provide a minimum of two configurable video streams independently (Unicast / Multicast) as follows:

Stream 1: main stream used for live view

- Video compression: H.264
- Resolution: HD720p
- Transmission speed: 25 fps
- Multicast stream

- RTSP protocol enabled.

Stream 2: stream used for recording on the recording system and on display in the control room

- Video compression: H.264
- Resolution: HD720p
- Transmission speed: 25 fps
- Unicast stream
- RTSP protocol enabled.

4.6 Communication network and Tunnel control system

4.6.1 Communication network

4.6.1.1 Description of the communication network

To allow the monitoring and control of the tunnel facilities through the transport of data, voice and images, a communication network is required.

The communication network will be based on Gigabit Ethernet technology; all connections must allow a speed of 10 gigabit per second on the main backbone between the technical rooms by the tunnel portals and 1 gigabit within the technical rooms.

The connection topology of the main backbone between the technical rooms by the tunnel portals is a ring, in order to assure a redundancy in case of interruption of the cable. The communication ring must extend over two different cables so that the interruption of a single cable does not affect the operation of the ring (see chapter 4.7.2).

4.6.1.2 Description of the elements of the communication network

4.6.1.2.1 Main switches

Main switches are the switches in the two technical rooms of the tunnel and in the control room (see reference A7).

Hardware

- Switches of renowned brands with wide distribution in Nepal and good assistance in Nepal
- Products released for at least 1 year from the date of submission of the offer and for which there is no foreseen replacement in the following 5 years from the date scheduled for the final installation on site
- Redundant power supply
- Low heat and noise emissions
- At least 50% reserve in terms of computing power, working memory, non-volatile memory
- At least 30% reserve in terms of connections (RJ45, fibre optic)
- Support for ring network topology
- Suitable for the installation location (temperature, humidity, vibration, air quality).

Software

- Complete documentation of the software and of the configuration.

4.6.1.2.2 Secondary switches

The secondary switches are all the switches needed to transmit data, video and voice and not classified as "main switches" in the reference A7.

- Switches of renowned brands with wide distribution in Nepal and good assistance in Nepal
- Low heat and noise emissions
- At least 50% reserve in terms of computing power, working memory, non-volatile memory

- At least 30% reserve in terms of connections (RJ45)
- Support for ring network topology, where necessary
- Industrial design suitable for the installation location (temperature, humidity, vibration, air quality). Software
- Complete documentation of the software and of the configuration.

4.6.1.2.3 Network management system (NMS)

Hardware

- Dedicated hardware (no hardware sharing with the SCADA servers) of renowned brands with wide distribution in Nepal and good assistance in Nepal
- Products released for at least 1 year from the date of submission of the offer and for which there is no foreseen replacement in the following 5 years from the date scheduled for the final installation on site
- Low heat and noise emissions
- At least 50% reserve in terms of computing power, working memory, non-volatile memory
- Console (keyboard, video, mouse).

Software

- Operating system in English, stable, issued for at least 1 year and for which there is no foreseen replacement in the following 5 years from the date scheduled for final installation on site
- Network management environment, in a stable version (versions released for less than a year from the start of application development are to be avoided)
- Interface to the SCADA server for the communication of the status of the network and of alarms
- Complete documentation of the software.

4.6.2 Tunnel control system

4.6.2.1 Description of the control system

The tunnel facilities will be controlled by a system based on a SCADA server interfaced with PLC in control of the processes of the different plants.

The tunnel control system must collect and present to the operators in the control room all the conditions present in the installations, in particular diagnostic conditions (presence of faults and defects) and information on the operation (states, measures, etc.).

The tunnel control system must also show alarm conditions related to safety events.

The annex A7 shows the architecture planned for the tunnel control system.

4.6.2.2 Description of the elements of the control system

4.6.2.2.1 SCADA Client

Hardware

- PC-based workstations of renowned brands with wide distribution in Nepal and good assistance in Nepal
- For each PC, 2 flat panel displays 16:9 Full HD at least 24"
- PC hardware with low heat and noise emissions, installed far from workstations (e.g. in technical rooms on the same floor of the control room, connected by KVM extender) so as not to disturb operators in the control room
- At least 50% reserve in terms of computing power, working memory, non-volatile memory

- For each PC: extended keyboard, mouse.

Software

- Operating system in English, stable, released for at least 1 year from the date of submission of the offer and for which there is no foreseen replacement in the following 5 years from the date scheduled for the final installation on site
- Renowned SCADA product widely available on the Nepalese market, in a stable version (versions released for less than a year from the start of application development are to be avoided)
- Complete documentation of the software.

4.6.2.2.2 SCADA Server

Hardware

- Popular branded server products with wide distribution in Nepal and good assistance in Nepal
- Products released for at least 1 year from the date of submission of the offer and for which there is no foreseen replacement in the following 5 years from the date scheduled for the final installation on site
- Redundant hardware execution: primary server and hot-stand-by server
- At least 50% reserve in terms of computing power, working memory, non-volatile memory
- Console for system administration (keyboard, mouse, 16:9 display of at least 21").

Software

- SCADA product renowned and widespread on the Nepalese market, in a stable version (versions released for less than a year from the start of application development date are to be avoided) and perfectly compatible with the installed SCADA product
- Server operating system in English, stable, released for at least 1 year from the date of submission of the offer and for which there is no foreseen replacement in the following 5 years from the date scheduled for the final installation on site
- Remote accessibility (web-browsing server)
- Complete software documentation.

4.6.2.2.3 PLC

PLC distributed in the cabinets of the individual systems; each PLC must be related to a single technology (it is forbidden to manage multiple technologies, such as lighting and signage, with the same PLC). The PLCs can be connected to remote terminal units (RTU) for remote data collection.

Hardware

- PLC products of renowned brand with wide distribution in Nepal and good assistance in Nepal
- One only series, one only model (the proliferation of the variety of hardware must be avoided)
- At least 50% reserve in terms of computing power, working memory, non-volatile memory, addressable I/O periphery.
- Products issued for at least one year from the date of submission of the offer and for which there is no foreseen replacement in the 3 years following the date of the final installation on site.

Software

- Modular programming according to IEC 61131, with exhaustive comments
- Non-volatile memory resident programming
- Complete documentation of the software (contact lists, comments, etc.).

4.6.2.2.4 Communication bus between SCADA and PLC

- Fieldbus with wide diffusion and good assistance in Nepal or Ethernet
- Product natively supported by both SCADA and PLCs

- Redundant topology (ring).

4.6.2.2.5 Operator panel

Hardware

- Products of renowned brand with wide distribution in Nepal and good assistance in Nepal
- One only series, one only model (the proliferation of the variety of hardware must be avoided)
- At least 50% reserve in terms of computing power, working memory and non-volatile memory.
- Diagonal of at least 10", touch-screen colour panel
- Products issued for at least one year from the date of submission of the offer and for which there is no foreseen replacement in the 3 years following the date of the final installation on site
- Connection to operator panels via fieldbus or Ethernet.

Software

- Modular programming according to IEC 61131, with exhaustive comments
- Non-volatile memory resident programming
- Complete documentation of the software.

4.6.2.3 Description of the functionality of the control system

The control system must allow operators to continuously monitor and control the systems. For this reason, a redundant execution of the SCADA server has been foreseen.

If the SCADA server, although running redundantly, is unavailable, it must be possible for operators to perform the basic functions for the safety of tunnel users at the operator panel level:

- Command the lighting
- Command the signage (closing of the tunnel, fire-scenario)
- Control the ventilation (fire-scenario).

The SCADA server must primarily present the operators with the actual situation of the tunnel facilities. Separate visualization, by plant, as well as an overall summary view, are required. The resolution of the HMI is left free and must be adapted to the complexity of the images to be shown (display without scrolling, easy comprehension) and present good ergonomics (choice of colours, size of images and characters).

Therefore, at SCADA level, a visualization of the tunnel status and a presentation of the data will be carried out. Settings and control operations on board the SCADA are possible, but they do not have to concern functionality related to the safety of tunnel users, such as the reaction to a fire.

The SCADA server will allow the management (surveillance and command) of the following systems:

- Energy supply
- Lighting
- Ventilation
- Signage
- Fire detection
- Auxiliaries

The Auxiliaries plant is a fictitious installation, not corresponding to a real installation. This system collects single signals (contacts) from a set of installations in the tunnel for which it is not convenient to dedicate a PLC to each technology:

- Emergency call stations (status of the call lever and contact of fire extinguishers, general status, summary alarms)

- Air conditioning of the technical rooms of the tunnel and of the control centre (general status, summary alarms)
- Fire detections in building (general status, fire alarms)
- Pumping stations (general status, summary alarms, levels, flow rates)

In the pages of each system, the status of the equipment must be shown (in operation, stationary, in alarm, inhibited, etc.) and the configuration of the individual equipment must be possible (thresholds, hysteresis, etc.).

The HMI of the SCADA will also have to clearly show the presence of alarms. There are two types of alarms and two priorities:

- Technical alarms: failure situations or technical problem on the plants
  - Priority 1: urgent intervention (7/24) by maintenance staff
  - Priority 2: not urgent intervention by the maintenance staff
- Operative alarms: danger situations for tunnel users
  - Priority 1: urgent intervention (7/24) by the police and/or firefighters
  - Priority 2: intervention by the police and/or firefighters not necessary, but it is required that the police get to know the situation

Examples:

- Energy supply loss: technical alarm with priority 1
- Fault to a camera: technical alarm with priority 2
- Tunnel fire: operational alarm with priority 1
- Column formation in tunnel: operational alarm with priority 2.

The activation of an alarm will cause an acoustic and luminous warning (e.g. coloured lamp, a different colour for each priority) at the SCADA client workstations, which will be suppressed with the acknowledge of the alarm by the operator in the SCADA client, and sends, if configured, an alarm message via SMS, phone call or email, to the maintenance staff.

The SCADA system will have to maintain a log, visible within the HMI (separate page), reporting in chronological sequence of all events of the system, with all the necessary detail information (time, date, user name, etc.):

- Login / logout with user details
- Sending command (with the username of the user who sent it)
- Alarm activation / deactivation
- Acknowledgment of an alarm (with the name of the user who has acknowledged it)
- Main measurements (temperatures, air speed, luminance at portals, number of vehicles per minute, etc.).

The system will have to allow to reconstruct, in a simple and precise way, the sequences of all the actions (without exclusion) resulting from the occurrence of a security event, such as (but not only) a fire:

- Temperatures before the fire
- Reaction of the systems to the fire
- Ventilation, activation of the corresponding scenario and fan reaction
- Lighting, switching on of the corresponding scenario and system reaction
- Signage, activation of tunnel closure and signs' reaction.

The SCADA system must allow the sending of commands by the operators; every command must always request a confirmation from the operator before the sending takes place. The result of sending the command (executed / not executed) must always be shown to the operator.

At the SCADA level the log data of at least 13 months for the whole system must be saved. At the end of the 13 months the oldest month must be saved in a separate file to allow the export by the operators on other support, if necessary.

4.6.2.3.2 Functions of PLC

At the PLC level will reside the functions of

- reading the plant status (reading of the analog and digital inputs),
- processing the status read (with sending data to SCADA if required for the visualization),
- and writing in the plants (activation of analog or digital outputs) based on processing performed and/or of the data received from the SCADA.

Basically, the process control functions (lighting, ventilation, etc.) must be maintained at the PLC level. Functions concerning the safety of road users will have to reside only at the PLC level.

The PLC processing cycle- time must be reduced and made constant (stabilization of the cycle time).

4.6.2.3.3 Functions of the operator panel

The operator panels have the following two purposes:

- allow a low-level control acting locally (on site)
- act as a back-up of the SCADA display if the latter should be lost.

All operations requiring the on-site presence of the operator (for example, for safety reasons, having to make sure of the physical possibility of executing a command) must only be possible by acting at the level of the operator panels.

For the operator panels, a resolution appropriate to the images shown on them is required. On the operator panels the alarms (active, acknowledged or not) present in the part of the system supervised by them must be shown.

4.6.2.4 Automatic safety reactions

All the tunnel facilities must be managed by the SCADA and the PLCs in such a way that certain automatic security reactions are always ensured.

These reactions are shown in A8 (matrix of automatic safety reactions).

The matrix contains reactions:

- automatic (with orange background), which do not require any intervention by the operator

- manual (with a pink background), which require the consent of the operator. This means that, upon the occurrence of the event (column), the operator is asked to confirm before executing the relative reaction

Since the safety of tunnel users will depend on these reactions, they must be implemented in a simple (avoiding complex software routines), effective (avoiding the introduction of delays in the application of actions) and easily testable/maintainable manner.

In the matrix there is then an exception (cells with a green background), consisting of a command sent by the operator to the SCADA client: the operator can select one of the 11 planned fire sectors, and declare (command window) the presence of a fire in that sector. The tunnel control system will then ensure that the tunnel plants react according what defined in the matrix. This command is required if the operator becomes aware of the presence of a fire before the tunnel installations have detected it (for example through video-surveillance, or because a call has been made by a motorist in the tunnel).

4.6.2.5 Plants with own control system

The following installations have their own server or dedicated control system, which is not integrated into the SCADA:

- video surveillance
- emergency telephone stations
- communication network
- radio.

It is foreseen the reading in the control system of contacts from these systems (general status, summary alarms, etc.) through the PLCs of the "Auxiliaries" plant.

4.6.3 Control room layout

The control room has two work stations, equipped as follows:

- SCADA client place (mouse, keyboard and 2 display)

- client place of the video system (mouse, keyboard and 1 display) from which it is possible to see the images of the cameras on the display and to direct the images on the 6 wall displays of the control room

- optical signalling system for the presence of alarms (coloured lamps)

- acoustic warning system for the presence of alarms (gong, siren, or similar)

- a telephone.

Between the two workstations there are (equipment shared by the operators):

- a client for the emergency phone system, which displays the system status and calls (mouse, keyboard and 1 display)

- a client for the radio system, which displays the status of the system and allows the use of the radio (mouse, keyboard, microphone, speaker and 1 display)

These work places are laid on one or more tables. Each operator has an ergonomic chair which is adjustable in height and inclination.

The installation of hardware that emits heat or noise in the control room must be avoided: the servers and PCs can be installed remotely in technical rooms at the same floor of the control room and made accessible to operators by means of a KVM connection.

On the wall in front of the operators, there are 6 displays of the video system, on which the images of all the available cameras can be freely routed through the client places of the video system.

In the control room is also foreseen a shared colour laser printer for printing images from the SCADA (system views, event logs, etc.) and from the other systems in the control room (video surveillance, radio, etc.).

The lighting conditions of the control room must allow the operators to easily use the systems (avoid dark areas, direct reflections, direct lighting, etc.).

There must also be natural lighting with a view towards the outside of the building.

4.6.4 Radio diffusion in tunnel

The tunnel will be equipped with a Radio system that will be responsible for the transmission of the radio signals throughout the tunnel.

The project will transmit inside the tunnel the radio signals existing outside of the tunnel. The bands considered are the following three:

- FM - Frequency Modulation: for a maximum of 4 radio channels (range from 87 to 107 MHz).
- VHF - Very High Frequency: typically used for fire brigade, rescue services and ambulance, tunnel maintenance's men (range from 160 to 180 MHz).
- UHF - Ultra High Frequency: reserved for Police in the 400 MHz band.

Note: the DAB+ technology will not be considered in this project because not yet broadcasted on the Nepali territory.

Standards

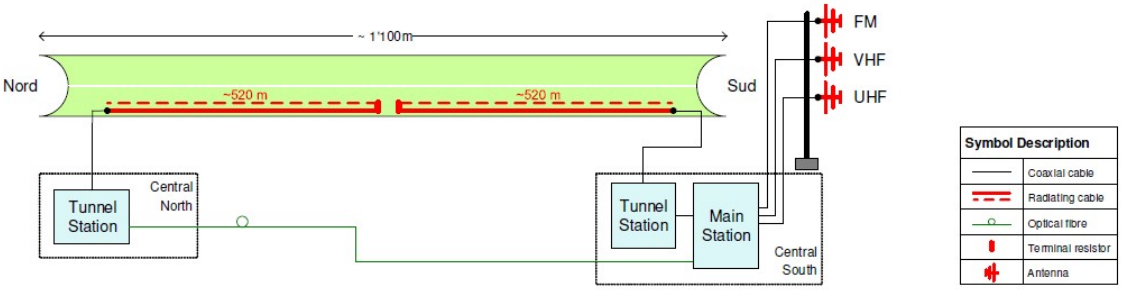
The Radio system shall comply with the following recommendations and regulations:

- IEC (International Electrotechnical Commission).
- IEE (Institution of Electrical Engineers).

Important remark: all metal equipment installed in the tunnel (clips, box, etc) must be stainless steel 1.4571 or higher and all cables must be halogen free.

Technical solution

The tunnel has a technical building at each portal. The Main Station is the heart of the radio system and is installed in the technical building by the technical building by tunnel south portal. The external frequencies are captured through the antennas, located outside the building, filtered and converted into optical signals and transmitted on the secondary technical building by the north portal of the tunnel. On each technical building a radio tunnel station will distribute the signals inside the tunnel through a radiating cable. Here a simple schematic of the chosen solution:



Picture 9: radio diffusion in tunnel

Radiating cable

The radiating cable is used for both one-way and two-way communication systems and because of its broadband capability, a single radiating cable can handle multiple communication systems simultaneously. The cable will be installed inside the tunnel under the vault of the tunnel. The cable will be secured with special clips.

Here an example of a standard radiating cable:

Picture 10: radiating cable

Clips

As mentioned, the radiating cable will be fixed on the vault of the tunnel. This will be done with special plastic clips every meter. For security reasons, for example in case of fire, every ten meter will be installed a stainless-steel clip.

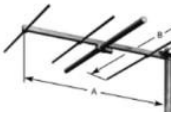
Here an example of a plastic clips:

Here an example of a stainless-steel clips:

Antennas

The antennas are externally mounted on a dedicated pole and connected to the radio system through coaxial cables.

Here an example of a FM antenna:



Here an example of a VHF antenna:

Here an example of a UHF antenna:

Dispatching position for Police announcements - Option

As an option, the system should allow the police to broadcast into the tunnel messages instead of FM programs. Drivers can so listen on the radio the advertisements broadcasted by the police. The police operator has the possibility to choose a varied type of message or to speak "live".

GSM

The GSM frequencies will not be considered because they are not part of the radio system - see also chapter 2 paragraph 14).

4.6.5 Emergency telephone system

This installation allows the tunnel's users to call the operators in the dispatching/maintenance centre in case of emergencies or need of help.

Along the tunnel, alternately on the right and left side and at a distance of 150 meters, there are 9 niches with an emergency telephone (SOS). In each niche a SOS cabinet should be installed.

Each SOS cabinet should have:

- 1 SOS telephone
- 2 fire extinguishers, with switches to detect their removal
- RTU of the tunnel control system to collect I/O signals
- lighting for the users.

Moreover, each portal of the tunnel is provided with the installation of an additional SOS cabinet, as the ones in tunnel.

The removal of an extinguisher from its seat is potentially related to a fire risk and has to be tracked and communicated to the tunnel control system in order to grant consistent reactions by other installations in the tunnel.

In the tunnel technical rooms at south portal all the necessary equipment for treating the SOS calls and redirect them to the control room are installed; they are, mainly, a telephone exchange and a call

recorder. By the cabinet, the telephone call will take place by means of a lever or of a button; the user will speak through an intercom grille. The actuation of the lever or of the button must be easy even for people with little force.

The SOS cabinets and the tunnel technical rooms at south portal are be connected via the fibre-optic infrastructure of the tunnel. The connection topology is a ring, in order to assure a redundancy in case of interruption of the cable. The communication ring must extend over two different cables so that the interruption of a single cable does not affect the operation of the ring (see chapter 4.7.2).

The SOS calls will be received in the control room by the operators using a receiving station with: telephone, graphic display with layout of the tunnel showing where the call is taking place, direct connection to the SOS cabinets, direct connection to the nearest Police station. SOS calls can be diverted to the Police station by the operators.

The execution of the cabinets must comply to the aggressive atmosphere of the gallery; the material must be steel. In particular, an IP rating of at least 55 must be guaranteed. The opening of the cabinet by the user for picking up a fire extinguisher must be simple, clearly indicated, easy even for people with little force.

The cabinets installed on the portals must be protected from sun and rain by means of a small canopy.

The colour of the cabinets must be orange, well visible even in low light conditions or in the presence of smoke.

Each cabinet must be clearly marked with a unique code that identifies its location (reference for the caller).

Picture 11: example of a SOS-cabinet

4.7 Cabling system

4.7.1 Earthing and lightning protection system

Goal of the earthing system is to avoid dangerous potential differences between the different parts of a tunnel or between those and the neutral ground.

Technical buildings will have an earth electrode with a determined impedance ZE given by property of the concrete reinforcement steel, of the earth rod and of the ground in proximity of the building. The impedance ZE will determine the potential of the buildings related to the 0-potential of the neutral earth.

4.7.1.1 General concepts

A flat galvanized copper conductor must be placed in every electrical pipe battery outside and inside the tunnel and be made accessible in every cable drawing pit. Important metallic parts placed along the tunnel and the motorway (guard rail, field cabinets, lighting columns, portal frames, etc.) must be connected to this conductor.

The pipe for the water supply of the tunnel, if metallic, must be connected to the earthing system of the tunnel.

The technical rooms will have a flat galvanized copper conductor posed in their foundations. One access point to the earthing system must be provided in every technical room.

Cable sheaths and armours of optic-fibre or copper cables must be earthed at every joint and on both sides.

Concrete reinforcement steel bars shall not be welded together.

All metallic parts of the SOS-niches will be connected to the equipment earthing conductor of the tunnel.

The earthing rod in every technical room must be connected at least to the concrete reinforcement steel.

The equipotential interconnections must be made with an insulated copper wire disposed inside every group of pipes. The earthing of metallic parts must be done by means of a bare copper wire.

All needed action to avoid direct or indirect line surges must be taken. These include:

- For High-Voltage: install lightning protection at every transition from overhead electric line to cable line.
- For Low-Voltage: for all cables leaving the tunnel, install over-voltage protection on the metallic conductor.

4.7.2 Fibre-optic infrastructure

The FO network ensures the transmission of data between different management and control systems. The main parts of the optical fibre system are:

- FO cables;

- FO distribution elements (19" drawers, boxes and connectors).

All optical equipment must be single-mode. The main equipment containing the FO distribution elements will be installed in the two technical rooms (south and north), in the emergency phone cabinets.

The two technical rooms will be connected by two 48 core FO backbones that will be arranged in a ring and laid in the two cable ducts at the sides of the tunnel, in order to obtain a "mechanical" redundancy and thus increase the level of safety.

The backbone cables must have the following characteristics:

- Singlemode cable 9/15µm;

- The cable must be suitable for installation in cable ducts and PE pipes;

- armoured rodent resistant fibre optic cable,

- FR/LSOH sheaths (fire retardant / low smoke emission and halogen free);

- Glass armor;

- Must not contain metals.

- Maintain insulation for 180 minutes;

- Maintain function for 30 minutes;

4.7.3 Universal structured wiring

Structured voice and data cabling using Ethernet or fibre optic technology forms the communication infrastructure in the buildings.

A set of passive components will be laid on site: cables, connectors, sockets, change-over switches, etc., properly installed and prepared to interconnect active devices (computers, telephones, printers, monitors, etc.).

Only halogen-free cables with limited fire propagation and low smoke emissions should be used.

Specifications:

- Twisted pair, at least category 6

- Type S/FTP

- Ethernet 10GBase-T

- AWG 22 or AWG 23.

Each circuit must be labelled and once installation is complete, all technical measures must be taken to ensure the completeness and functionality of each connection.

4.7.4 Cable shelves and pipe infrastructure

In the technical rooms the cables will be housed in cable ducts installed under the floor and reach the electrical cabinets from below.

All cables in the tunnel shall be installed in the cable ducts located in the vault and/or in the cable routes provided on the sides of the carriageway.

The electrical cables for the distribution of the stand-by electrical network (UPS) will be provided with a functional maintenance of 180 minutes, while the electrical cables for the normal distribution of the electrical network will be provided with a functional maintenance of 5 minutes. All cables must be halogen-free, without emission of toxic or flammable or corrosive gases, with a reduced emission of non-flammable and self-extinguishing gases having characteristics "B2ca-s1a, d1, a1" (performances requirements from European standard EN 50575 - CPR EU 305/2011 and IEC 60331 series International Electrotechnical Commission).

In the technical rooms and in tunnel, technical compartments will be made on the walls to contain cable ascents and serve the electrical components at a time. The cable ascents will be mechanically protected by PE pipes and metal sheets.

The characteristics of the covers just be as follows:

- Galvanized steel

The characteristics of the tubes will be:

- Internal Ø 120 mm

- Polyethylene

- Halogen-free

- Not fire propagating

The characteristics of the fasteners of the tubes will be:

- Brackets or profiles in Galvanized steel

- suitable fastening material compatible with the materials used, avoiding contact corrosion (or bimetallic corrosion).

The jet fans will be powered by cable lines that must withstand fire for a minimum of 120 minutes at 250°C. Cable ducts and support brackets shall be made of stainless-steel cat. 1.4571.

4.8 Secondary installations

4.8.1 Electrical and lighting system in buildings

Electrical sockets

At least one 230 VAC socket must be provided for each room, and there must also be a socket at each work station. Exceptions are service sockets located inside the cabinets of the individual systems, which must be commensurate with the needs of the system itself. The sockets must be divided into sockets to the normal network and to the emergency network; the latter must be at least 25% of the former and must be marked with a different colour (e.g. orange).

The definitive position and quantity of the sockets and data will be evaluated by the contractor on the basis of a final layout.

On the ground floor of the two technical buildings, the supply backbone lines of the various plants will lay on cable trays located under the floor that can be inspected to facilitate entry into the various distribution cabinets.

In rooms not equipped with a technical floor, the lines will hang mainly to the ceiling by means of metal cable ducts suspended to the ceiling/wall data and signal. Descents will be carried out at planned points by metal or PVC pipes fixed to the wall or, if possible, in under track execution.

Lighting

The average lighting for offices and work areas with video terminals is 500 lux, while in the technical rooms, ceiling lighting with a minimum intensity of 300lux is required. 10% of the lights must be connected to the UPS network. The room lighting must be switched on and off by means of a switch located near the entrance doors.

In the escape routes in buildings a minimum lighting of 20 lux is required (located in the middle of the window, 80 cm from the floor).

The lighting system will be made of lamps installed to the ceiling, made of highly impact-resistant material, equipped with anti-glare devices and suitable for the place of installation.

Lighting in the rooms will be provided by energy-saving, and easy-to-maintain lamps.

4.8.2 Chain hoists

Technical building by south portal

A 1 ton hoist will be installed in the central to the south portal, on the first floor, and will be used for transporting the different equipment between the ground floor and the first floor of the building. The hoist rail will be fixed to the ceiling. The movement will be on 2 axes, horizontally on the track and vertically. After the installation, the free space under the hoist (from the lowest point to the hook) must have a height greater than 2.2 m.

Features:

- Manual chain hoist;
- Minimum lifting capacity 1.0 t;
- Axes of displacement 2 (advancement and lifting);
- Advancement length:> 6 m;
- Lifting length:> 7 m;
- Degree of protection for the motor: IP 54;
- Chain according to the DIN 50049 standard;
- Hook according to DIN 15404, certificates of conformity according to the standard DIN 50049;
- Container for the plastic chain;

- Hot galvanized steel (sizing carried out by the contractor) beams (according to the SN EN ISO 1461 standard) and painted in the same colour as the bridge of the hoist.

Technical building by north portal

A 1 ton hoist will be installed in the central to the north portal, on the ground floor, and will be used for transporting the different equipment between the ground floor and the basement of the building. The hoist rail will be fixed to the ceiling. The movement will be on 2 axes, horizontally on the track and vertically. After the installation, the free space under the hoist (lowest point / hook) must have a height greater than 2.2 m.

Features:

- Manual chain hoist;
- Minimum lifting capacity 1.0 t;
- Axes of displacement 2 (advancement and lifting);
- Advancement length:> 2 m;
- Lifting length:> 7 m;
- Degree of protection for the motor: IP 54;
- Chain according to the DIN 50049 standard;
- Hook according to DIN 15404, certificates of conformity according to the standard DIN 50049;
- Container for the plastic chain;
- Hot galvanized steel (sizing carried out by the contractor) beams (according to the SN EN ISO 1461 standard) and painted in the same colour as the bridge of the hoist.

4.8.3 Fire barriers

The fire barriers build the fire resistance in the case of the crossings through walls; they are products that must be EI certified according to the specific standards in conditions similar to those of use and must be applied in the quantities and with the construction methods described in the certification itself.

Fire and smoke barrier must be installed at cable and pipe crossings between fire compartments using products suitable for the purpose (for example for crossing from low voltage room and MV/LV transformation room):

May be used:

1) Fire-resistant foam for
- Combined and single sealing
- Single cables, cable bundles and cable tracks
- Metallic Pipes
- Gas-tight
- Water and vapor resistant
- Suitable for fire compartment

2) Closure with fireproof panels
- Ideal for large openings
- Smoke-tight
- Suitable for fire compartment

Every barrier must be labelled with and identification code.

4.8.4 Telephone system in rooms and buildings

4.8.4.1 Description of the telephone system

A fixed telephone system must be created that allows:

- communication (internal dialling) between the technical rooms of the tunnel, the control room, the workshop, the office, the meeting room, etc.

- communication (external dialling) to the outside with connection to the national telephone network.

The telephone system must use the Phone over IP technology and the structured universal wiring for the connection of the devices.

4.8.4.2 Description of the elements of the telephone system

4.8.4.2.1 Telephone switchboard

Telephone switchboard, either hardware or software (virtual), for telephony over IP capable of:

- connect the internal telephone system to the external national telephone network

- manage an internal telephone numbering

- provide, for external access, a different number for each telephone of the internal network. A solution with the following characteristics is required:

- Popular branded products with wide distribution in Nepal and good assistance in Nepal
- Products released for at least 1 year from the date of submission of the offer and for which there is no foreseen replacement in the following 5 years from the date scheduled for the final installation on site
- At least 50% reserve in terms of dialling numbers, computing power, working memory, non-volatile memory
- Dedicated console for system administration
- Remote accessibility (web-browsing server)
- Complete documentation of the software and of the configuration.

4.8.4.2.2 Telephones

A telephone connected to the fixed network must be installed in every room that sees the presence, permanent or occasional, of people of the staff or has no coverage of the mobile network.

The precise number, type and location of the telephones will be defined during the execution phase of the works, in agreement with the client.

There are two types of phones:

- fixed phones

- cordless phones

General features of telephone devices will be:

- Devices of renowned brands with wide distribution in Nepal and good assistance in Nepal
- High charge duration (for cordless)
- Complete documentation of the software and of the configuration
- robustness, impact resistance
- suitable to the installation place.

5 References

A1. Synoptic plan of exploitation and safety equipment

A2. Report 695013-D-A-E-T-002-C00 "Ventilation – Technical Report"

A3. Synoptic plan of the ventilation system

A4. Layout of the EES in the technical building at the south portal

A5. Layout of the EES in the technical building at the north portal

A6. Tunnel-sections with EES layout

A7. Tunnel control system architecture

A8. Automatic reactions matrix

A9. Traffic Pattern

A10. Signage plan