Transport Planning & Design Manual

Tunnels

volume 11
Transport Dept. confirmed that only the chapters mentioned above had been published. The others were still not yet published.

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FOREWORD

The Transport Planning and Design Manual consists of eleven volumes and is published primarily as a working document for Transport Department staff. It also provides information and guidance to others involved in the planning and design of transport infrastructure in Hong Kong.

It is intended that the information contained herein will be periodically revised to take account of the most up-to-date knowledge and experience. The inevitable time-lag however, means that certain sections may at a particular time be unavoidably out of date. For this and other reasons, the standards contained in this manual should not be followed rigidly but rather treated as a framework within which professional judgement should be exercised to reach an optimum solution.

The eleven volumes and their component chapters are as follows:

VOLUME 1 TRANSPORT PLANNING

VOLUME 2 HIGHWAY DESIGN CHARACTERISTICS

VOLUME 3 TRAFFIC SIGNS AND ROAD MARKINGS

VOLUME 4 ROAD TRAFFIC SIGNALS
VOLUME 5  ACCIDENT INVESTIGATION AND PREVENTION
Chapters  1. Introduction to Accident Investigation
          2. Traffic Accident Data System
          3. Accident Investigation and Analysis Technique and Procedures
          4. Evaluation of Remedial Measures
          5. Traffic Safety Considerations in Engineering Design
          6. The Role of Publicity in Accident Prevention

VOLUME 6  TRAFFIC AND ENVIRONMENTAL MANAGEMENT
Chapters  1. Introduction  2. One Way Streets & Gyrotary Systems
          5. Vehicle Prohibition  6. Speed Limits

VOLUME 7  PARKING
Chapters  1. Introduction  2. Legislation  3. Parking Inventory
          4. On-street Parking  5. Goods Vehicle Parking
          6. Parking Provision in New Developments
          7. Surface & Multi-Storey Car Parks

VOLUME 8  SURVEY
Chapters  1. General  2. Annual Traffic Census
          5. Public Transport Surveys  6. Home Interview Surveys
          7. Other Surveys

VOLUME 9  PUBLIC TRANSPORT
Chapters  1. Introduction  2. Franchised Buses  3. Public Light Buses
          8. Interchanges

VOLUME 10  SURVEILLANCE
Chapters  1. Introduction  2. Strategic Road Network
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Chapter 1. Introduction  2. Traffic Control & Surveillance
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The current status of a particular Chapter or Section thereof can be obtained from the Standards Section of Transport Department.
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References


4) 'Technical Committee Report on Road Tunnels' - Permanent International Association of Road Congress, XVIth World Road Congress, Vienna, 1979.

5) 'Technical Committee Report on Road Tunnels' - Permanent International Association of Road Congress, XVIIth World Road Congress, Sydney, 1983.

6) 'Technical Committee Report No.5 - Road Tunnels' - Permanent International Association of Road Congresses, XVIII World Road Congress, Brussels, 1987.


11) Road Tunnels (Government) Ordinance Cap. 368, Hong Kong.
1.2 **Purposes**

1.2.1 This Volume aims to outline Transport Department's functional requirements for the provision of tunnel management systems which include traffic control and surveillance, toll collection, ventilation and lighting. The preferred functional requirements of the various facilities are given wherever practicable and should form the basis for the provision of road tunnel management systems.

1.2.2 Information contained in this Volume is intended to be used as guidelines which are subject to a continual process of refinement in the light of future development in technology, changing operational philosophies and expectation from the public. Transport Department should be fully consulted on the provision of management systems in tunnels.
1.3 **Tunnel Area**

1.3.1 The **Tunnel Area** has to be demarcated as required by Section 6 (1) of Cap. 368 on 'Road Tunnels (Government) Ordinance'. This area usually extends at both ends of the tunnel tubes to the first junction with the adjoining road network, where the traffic has the last opportunity to divert. It is based on the "last entry" and "first exit" principle. The tunnel area for non-Government tunnels are defined under individual private tunnel ordinances.

1.3.2 **Tunnel management systems** are provided within the **Tunnel Area**. Normally, the **Tunnel Area** should be determined before detailed design of the tunnel management system proceeds.
1.4 **Tunnel Management Systems**

1.4.1 **General**

1.4.1.1 Reliable tunnel management systems are required for the safe and efficient tunnel operation. The management systems outlined in this Volume include traffic control & surveillance, tunnel control room & operator facilities, toll collection, ventilation and lighting. Operationally, these systems should form an integrated system although the supply of individual systems may come from different sources.

1.4.1.2 The Electrical and Mechanical Services Department (EMSD) should be consulted so that facilities for the maintenance of tunnel equipments are adequate. Also, the Architectural Services Department should be consulted regarding building services.
1.4.2 Objectives

1.4.2.1 Tunnel management systems should be designed to meet the following general objectives:

(a) The environment (e.g. air pollution and lighting level) should be so maintained and controlled to ensure safe operation in both day and night.

(b) Any incident within the tunnel area, whether it be an accident, breakdown or fire etc., should be detected as soon as it occurs. Also, response to any incident should be as quickly as possible for the safety of those directly involved as well as for other motorists trapped in the tunnel. In this way, the chance of secondary incidents would be reduced.

(c) The tunnel management systems should be designed to ensure efficient tunnel operation. Vehicles using the tunnel should suffer minimum delay and the tunnel should be so controlled to provide the maximum traffic capacity.

(d) The tunnel systems should aim to achieve high serviceability, ease of maintenance, and minimum operating cost.

(e) The tunnel should be well protected from any possible risks such as fire and power interruptions.

(f) The tunnel systems should aim to reduce the number of operation staff. In addition, staff costs should be kept to a minimum.

(g) Training mode capability should be provided in the tunnel systems.
1.4.3 Reliability of Power Supply System

1.4.3.1 A reliable power supply system should be provided to support all the equipments in the Tunnel Area. Normally, electricity supply is obtained from two separate feeders from the same or different power companies. A feeder is terminated at each portal of the tunnel respectively. Each incoming feeder usually supplies approximately one half of the equipment load, but both feeders are able to take up the total load if required. If one incoming feeder fails, the remaining feeder will supply the full load of the whole tunnel. In addition to two independent supply feeders, standby diesel generator and uninterruptible power supplies (UPS) should be available.

1.4.3.2 Uninterruptible power supply system should be capable of maintaining supplies to the essential equipment for a minimum of 30 minutes so that the tunnel could be properly closed down. In general, the uninterruptible power supply system should provide supplies to the following equipment:

(a) Emergency lighting;
(b) Essential communication systems;
(c) Computer systems;
(d) Control centre equipment;
(e) Essential control and monitoring systems;
(f) Traffic Control and Surveillance equipment;
(g) Toll collection system.
1.4.4  Fire Fighting Requirements

1.4.4.1 Some Fire Services requirements have been incorporated in the various chapters of Volume II. For the full range of Fire Services installations and requirements, the Fire Services Department (FSD) should be consulted and approval from Fire Services Department is required.

1.4.4.2 In general, fire extinguishers and a fire alarm push button should be housed in the same niches as the emergency telephone. On removal of any extinguisher or activation of the fire alarm push button, a fire alarm will be raised in the control room, and immediately and directly in Fire Services Communication Centre through a direct link simultaneously. Separate direct links are required for tunnel and buildings at both portals. Also, there should be hydrant niches housing hose reels and fire hydrants satisfying Fire Services Department requirements. All fire extinguishers to be provided for Government tunnels should be capable of being maintained by the FSD. The main fire alarm panel in the control room should have facilities, such as separate alarm indication for each input source, so that the source of the fire alarm could be quickly identified.

1.4.4.3 It is essential that the standby diesel generator provided shall back up all FSI equipment and confirm to "Para. 5.8 Part V of Code of Practice for Minimum Fire Service Installations and equipment".
1.5 Contents of Volume 11

1.5.1 General

This volume is divided into 6 chapters. Chapter 1 serves as the introduction while the other chapters focus on the individual management systems for road tunnels. The main systems described in Volume 11 include traffic control & surveillance, tunnel control room & operator facilities, toll collection, ventilation and lighting.

1.5.2 Chapter 2 - Traffic Control & Surveillance

This chapter describes the traffic control and surveillance facilities to be provided in road tunnels. It outlines the basic safety requirements. A brief summary of the operator man-machine interface for the traffic control & surveillance system, which is detailed in Chapter 3, is also included.

1.5.3 Chapter 3 - Tunnel Control Room & Operator Facilities

This Chapter describes the facilities to be provided in both the main and minor control rooms. Also, the provision of communication facilities is described. A list of operator facilities, mainly on traffic control & surveillance aspects, is included.

1.5.4 Chapter 4 - Toll Collection

This chapter is mainly on the requirements of manual toll collection system. It gives the functional requirements of toll booth equipments, toll collection operation and monitoring, as well as central equipment and facilities.

1.5.5 Chapter 5 - Ventilation

This chapter describes the fresh air requirements in a tunnel, the different types of ventilation systems, the ventilation equipment and the different ventilation control systems. Also, it outlines the system reliability and operator man-machine interface for ventilation systems.
1.5.6 Chapter 6 - Lighting

1.5.6.1 This chapter mainly outlines the lighting design considerations, the design of luminaries, and the lighting control system. In addition, requirements on system reliability and operator man-machine interface are included.
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Chapter 2 - Traffic Control & Surveillance
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4) 'Technical Committee Report on Road Tunnels' - Permanent International Association of Road Congress, XVIth World Road Congress, Vienna, 1979.


2.2 Introduction

2.2.1 The tunnel and its approaches should be equipped with the appropriate and necessary traffic control and surveillance facilities for the safe manoeuvre of traffic under all anticipated operating modes of the tunnel. With the help of the traffic surveillance facilities, the operator is kept aware of the true traffic status in the tunnel area at all times. The traffic control facilities are designed to guide the motorists through the tunnel and the tunnel area safely and efficiently. As a whole, the traffic control and surveillance system should be designed to handle all modes of operation anticipated in the tunnel.

2.2.2 The tunnel has different operational modes. With the use of proper traffic control and surveillance facilities, the safe and smooth switching of operational modes can be ensured. In the case of a conventional two-tube tunnel, the normal operation condition is unidirectional traffic flow in each tube. However, the tunnel may be operated with one tube or one lane closed for maintenance purposes or incidence handling. Also, the tunnel may be closed completely because of fire. In addition, a special control mode is required to stop overheight vehicles from entering the tunnel.

2.2.3 Traffic control and surveillance facilities are grouped either under the category of traffic control facilities or traffic surveillance facilities in this chapter. However, it should be noted that some facilities carry both traffic control and surveillance functions and these facilities are categorised under either traffic control or surveillance facilities for the sake of convenience.
2.3 **Traffic Control Facilities**

2.3.1 **General**

2.3.1.1 The tunnel and the approach roads to the tunnel should be equipped with the appropriate fixed and variable signs, traffic lights and traffic lane lights (arrows and crosses) to safely guide motorists through the tunnel and tunnel area. As the tunnel may be operated in different modes i.e. combinations of lane/tube closure situations under different traffic conditions or when it is required for maintenance or incidence recovery purposes, these signs and signals are remotely controlled to suit the prevailing situations.

2.3.1.2 The multitude of signs, signals and their complex combinations and co-ordinations, especially during the change of operating modes makes any attempt to manually operate single signals almost impossible. Usually a number of traffic signalization programmes or plans have to be devised and stored in a traffic control computer for use by well trained operators. Different traffic situations could then be coped with by means of the appropriate traffic signal plan selected by the operator. To change an existing signalization programme the respective traffic signal plan has to be activated by inputting commands, pushing buttons or using light pens etc. The signal plan is then executed after checking on the display or verifying on site. This kind of traffic control system has proved to be a valuable tool for operators, allowing them to smoothly operate, influence and regulate the traffic in a quick, safe and reliable manner.
2.3.2 Traffic Control Signals and Signs

2.3.2.1 Traffic Light Signals

The traffic light signal units are of the conventional type and should have red, amber and green aspects. The switching possibilities of red, red/amber, amber, green and off are required. Traffic light signals could be used at approach roads to stop overheight vehicle and used at tunnel portals to stop vehicles from entering the tunnel. Signal monitoring should be provided to detect bulb failure. Also, a facility should be provided to block the simultaneous display of conflicting green and red signals.

2.3.2.2 Lane Signals inside the tunnel

Lane signals are provided throughout the length of the tunnel. Each signal unit consists of 3 aspects, red cross, downward pointing green arrow and flashing amber. These signal units are usually mounted horizontally over the centre of each lane. Back to back mounting of lane signals is required for bi-directional operation. Motorist should be able to see 2 lane light signals at any time when travelling along the tunnel. The maximum spacing in the straight section of the tunnel should be not more than 200 m.

2.3.2.3 Lane Signals at Approach Roads

Lane signals are to be provided outside the tunnel and are used for control of traffic at the approaches especially during lane closure or tube closure. Normally, these lane signals in glass fibre-optics with a matrix display area of 600mm by 700 mm along the approach roads are adopted. Usually, these signals are mounted on gantries and on concrete structures at the tunnel portals.

2.3.2.4 Pavement Inset Light

Pavement inset lights are used at both tunnel portals for channelisation of traffic during periods when one tube or lane is closed for maintenance or for other reasons. The pavement inset light serves to amplify the directions given by the traffic lane light signals and display continuous guidance lines of yellow light to the drivers.
2.3.2.5 **Variable Traffic Signs**

Apart from standard traffic signs, variable warning signs are needed to give warning messages for special traffic conditions, such as closure of one tube leading to lower speed limit and change of lane. Variable advisory signs are required to advise motorists of any change in the tunnel or route information due to special conditions, such as maintenance or vehicle breakdown leading to tunnel closed or route diversion. Sometimes, lane signals are incorporated into some of the gantry mounted variable advisory signs and used together to provide route information.

2.3.2.6 **Barriers**

Remotely controlled horizontal barriers are used for channelisation of traffic when changing the traffic operation from normal to 2 way operation in one tube. Flashing amber warning lights should be provided on the barrier beam. It is essential that the barriers can also be operated manually without the use of the control equipment. For safety reasons, the use of these automatic barriers has to be very carefully monitored. Site checking and confirmation are required to ensure safety for the approaching vehicles before activating the barriers.
2.3.3 Traffic Signal Plans

2.3.3.1 General

2.3.3.1.1 The combination of operational states of the traffic control equipments, i.e. signs, signals, barriers etc., forms control signal plans. In general, there are three types of traffic signal plans, namely basic traffic signal plan, incident signal plan and emergency signal plan.

2.3.3.2 Basic Traffic Signal Plan

2.3.3.2.1 The basic traffic signal plans are implemented for different modes of operation of the tunnel system, whereas each mode has its own particular traffic pattern. It should be possible, however, to amend each traffic signal plan manually, to suit the required conditions at a particular time. The change of the operational state should be consistent with the sequences which are part of the stored signal plans.

2.3.3.2.2 The traffic signal plan normally comprises of stages of successive sequence. Usually, the signal plan consists of 2 parts. The first part contains switching command from the existing operational state to the neutral state (i.e. tunnel closed state). The second part contains the switching command from the neutral state back to the desired operational state.

2.3.3.2.3 The first step of the signal plan implementation is the proposal of final signal states. Then, the proposed final signal states are implemented when the operator confirms the proposal. The operator could alter the proposed signal plan before implementation proceeds.

2.3.3.2.4 In general, traffic signal plans are devised to ensure that the following basic traffic operation procedures can be conducted safely and efficiently:

(1) Procedure for normal traffic operation,

(2) Procedure for closing one tube for normal maintenance (assuming a 2-tube tunnel) or dealing with major emergency,

(3) Procedure for re-opening one tube to normal operation,
(4) Procedure for closing one lane,
(5) Procedure for re-opening one lane,
(6) Procedure for complete tunnel closure,
(7) Procedure for opening tunnel after complete closure,
(8) Procedure for dealing obstructions with 1 tube bidirectional operation or 2 tube operation,
(9) Procedure for dealing with overheight vehicles, and
(10) Manual operation (fall back mode of operation).

2.3.3.3 Incident Signal Plan

2.3.3.3.1 Incident signal plan proposals should be included for automatic incident detection. The incident signal plans will recommend changes to the operational state of the tunnel. Normally, the incident signal plan is divided into 2 parts. In the tunnel, the first part consists of switching commands to change the related lane signals to flashing amber lights. The second part contains the switching commands to switch the modified lane signals back to the original state.

2.3.3.3.2 On detection of incidence, the desired final signal states of the appropriate incident signal plan will be proposed automatically. Then, the operator can implement the incident signal plan or reject the proposal if it is a false alarm. When the incident is cleared, the operator can execute the second part of the incident plan to restore the original signal states.

2.3.3.4 Emergency Signal Plan

2.3.3.4.1 Special signal plans are required to handle emergency cases which require a quick response to special tunnel situations. These signal plans, for instance, are used to handle overheight vehicle alarm. In this case, the appropriate signals are switched to red to stop the overheight vehicle from entering the tunnel. For these signal plans, there is no signal proposal. All signals and signs will be switched on
immediately when there is an alarm. Another example is to close the tunnel immediately at the portals by activation of the tunnel closed emergency plan.
2.3.4 Individual Signal Control

2.3.4.1 The operator should be able at all times to change the operating state of any individual signal/sign or a group of similar signals/signs simultaneously. The first step of implementing individual signal switching is the proposal of the final signal state. Then, the operator can implement the signal control or stop the implementation if he considers that the proposal is not appropriate.
2.3.5  Others

2.3.5.1 Other traffic control facilities such as Public Address System and Radio Rebroadcast system with break-in facility have been covered in Chapter 3.
2.4 Traffic Surveillance Facilities

2.4.1 General

2.4.1.1 The operator should be adequately informed of the prevailing traffic conditions in the tunnel area at all times. The traffic surveillance system consists of monitoring facilities to enable the operator to detect any traffic anomalies or incidents occurring in the tunnel area.

2.4.1.2 In general, the following traffic surveillance facilities are provided:

- CCTV system
- Automatic incident detection system
- Overheight vehicle detection
- Radar
- Traffic statistics
- Emergency niche equipment
- Emergency telephones
2.4.2 CCTV

2.4.2.1 CCTV cameras should be provided to permit the monitoring of the traffic flows throughout the entire length of the tunnel and the approach roads. The spacing of the cameras should be such as to permit individual vehicles to be clearly identified and to provide continuous coverage of the tunnel area. A practical spacing between CCTV cameras inside the tunnel is about 100 m - 200 m. Cameras normally point in the normal direction of traffic flow. Therefore, the camera provides view of the back of the vehicles and is centrally mounted from the ceiling.

2.4.2.2 Each camera installed within the tunnel section should be provided with a corresponding monitor at the control centre. All monitors should be fitted on the mimic map. Basically, vehicles of the permitted maximum height should be capable of being displayed in full on the appropriate monitor. Also, video recorders with time lapse facility should be available for recording the CCTV picture and for playback purpose.

2.4.2.3 All cameras should be controlled remotely in the control room. The normal control functions include pan, tilt, zoom, focus, iris operation, wiper and screen washer operation, as well as camera on-off.
2.4.3 Automatic Incident Detection

2.4.3.1 An automatic incident detection system relieves the operator from continuously watching the CCTV monitors. The incident detection system should preferably cover the entire tunnel area. It should be able to detect an incident within a maximum period of one minute with good reliability. When an incident is detected, a preprogrammed incident signal plan is proposed to assist the operator to handle the situations. The system should be able to detect incidence by lane or tube.
2.4.4 Overheight Vehicle Detection

2.4.4.1 An automatic overheight vehicle detection system should be installed at suitable locations on the approach roads to the tunnel. In association with the height detector, height limit warning signs, secrete 'traffic signal ahead' warning signs and traffic light signals/lane light signals should be provided. When the detector detects an overheight vehicle, an alarm is activated. At the same time, at the approach road where the detector is activated the associated secret signs and traffic signals/lane signals will be activated to stop the overheight vehicle from entering the tunnel. The system should operate reliably and false triggering of overheight vehicle detection should be avoided.
2.4.5 Radar

2.4.5.1 It is desirable to install radar based speed measuring devices for law enforcement. This radar system is used to activate a camera to take photographs giving the time, speed detected plus the vehicle licence plate clearly legible.
2.4.6 Traffic Statistics

2.4.6.1 Traffic statistics are required. Loop detectors should be installed on the approach roads as well as inside the tunnel. The traffic data on headway, vehicle length and vehicle speed from each vehicle detector station should be available for interrogation upon request. Also, 5 minute interval traffic data on

- traffic flow (per detector station, lane, tube)
- occupancy (per lane, tube)
- vehicle length
- vehicle speed

should be provided on request or printed out automatically at the end of each interval.

2.4.6.2 The traffic data equivalent to 5 minutes intervals should be stored for long term analysis up to one month. The system should be able to provide the daily/hourly reports based on the traffic data stored.
2.4.7 Emergency Niches

2.4.7.1 Emergency niches should be installed at regular intervals (50m – 100m) throughout the tunnel section. A lamp should be provided above each niche to amplify the niche location. When a niche door is open, there should be a corresponding indication on the mimic map in the control room. Further, flashing indication should be shown on the mimic when the telephone inside the niche is activated. Each niche usually contains the following equipment:

(a) emergency telephone,
(b) fire extinguisher,
(c) fire alarm push button,
(d) power point.

2.4.7.2 Also, there should be hydrant niches housing hose reels and hydrants. For the full range of fire services installations and requirements, the Fire Services Department (FSD) should be consulted and approval from FSD is required.
2.4.8 Emergency Telephones

2.4.8.1 Emergency telephones for two-way communication between the tunnel area and the main control room are installed in niches on both sides of each tube. It should be possible to dial to any selected emergency telephone from the control room. When the telephone is selected, the indicator on the niche door should flash.

2.4.8.2 Telephones should also be installed on the approach roads within the tunnel area at regular intervals of not more than 500m depending upon the physical layout of the roads. These telephones on the approach roads should have ringing bells.
2.4.9 Weighbridge

2.4.9.1 Weighbridges should be provided for the checking of overloaded vehicles. There should be provisions to divert the overloaded vehicles away from the tunnel.
2.4.10 Others

2.4.10.1 Other surveillance facilities such as mobile radio for tunnel vehicles are described in Chapter 3.
2.5  Basic Safety Requirements

2.5.1  System Reliability

2.5.1.1  The system must be highly reliable. The essential equipment should be duplicated to ensure a high level of reliability. The system design should employ the concepts of modular structure and graceful degradation such that a single failure will not affect the whole system operation.

2.5.1.2  There should be standby power supply connected to the traffic control and surveillance system. All essential traffic control and surveillance equipment (e.g. central computer system, overheight vehicle detection system, and CCTV system, etc.) should be powered from an uninterrupted power supply system and additionally, a standby short-break diesel generator should be available.
2.5.2 Equipment Monitoring

2.5.2.1 All traffic control and surveillance equipment should be continuously monitored by the central system. Equipment fault detected should raise an audible alarm and cause a fault message printout. The operational status of the equipment should be displayed on the mimic map and should also be available to the operator through the operator interface of the central control and surveillance system.
2.5.3 **Signal interlock**

2.5.3.1 For safety reasons, some traffic control equipment may only be operated in a pre-defined sequence. Unsafe operation of the traffic control equipment should be prohibited. In particular, the system should have blocking facilities to prevent conflicting signals or barrier positions.
2.5.4 Fall Back Provision

2.5.4.1 Fall back mode of operation should be provided to the traffic control and surveillance system. In the normal situation, the system is operated under the computer control mode with full traffic control and surveillance facilities. When the computer control mode fails, the system should fall back to manual control mode safely and it should be possible to perform some basic tunnel operations using this manual control mode. In addition, field equipment should have local control facilities allowing them to be individually controlled on site.
2.6 Operator Man-machine Interface

2.6.1 The main operator man-machine interface for the traffic control and surveillance system is located in the central control room and the minor control room. The facilities of this operator man-machine interface have been described in detail in Chapter 3 and are only briefly mentioned here.

2.6.2 In brief, the operator man-machine interface should have the following facilities:

a) operator console containing all monitoring and control units for the traffic control and surveillance system,

b) colour graphic video display units (VDUs) as the main operator interface to the central control system,

c) mimic map together with the associated CCTV monitors to allow an overall view of the tunnel situation,

d) event logging and report generation facilities,

e) remote manual control console.

2.6.3 Access control to the central control system should be provided. There should be different user access levels for different users, such as the operator, supervisor, software manager, hardware engineer etc. Each user level should have different access privileges to the system. It should be possible to redefine the access privileges for each level of user.
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6) Road Tunnels (Government) Ordinance Cap. 368, Hong Kong.

7) Road Tunnels (Government) Regulations, Hong Kong.


3.2 Control Room

3.2.1 General

3.2.1.1 The control room is the place where all monitoring and control of the entire tunnel operation and related equipment take place, such as traffic control and surveillance, power supply and tunnel lighting, ventilation system, toll collection system, and other services requiring centralised control. The control room layout should be so designed to permit one operator to man the traffic control and surveillance system under normal conditions. The operator is stationed at a purpose-designed control desk into which the majority of control equipment is installed. Most monitoring signals are displayed on the mimic map. If toll collection is involved, the control should be designed for 2-man operation. A separate toll console should be provided for the toll collection system for the second operator to work on the toll collection system. It is essential that all control and surveillance facilities should be centralised and available to the operator at hand. During emergency, additional staff (e.g. Police and Fire Service) are expected to join the operation inside the control room.

3.2.1.2 The entire control centre area should be equipped with computer-room type double flooring and clear room height should not be less than 3m.
### 3.2.2 Mimic Map

#### 3.2.2.1
The mimic map is the most important aid to the operator. It indicates the current traffic configuration applying to the tunnel area. Also, it reports on the prevailing traffic operating conditions and state of the surveillance system at any time. Normally, the mimic map is situated vertically in front of the operator console.

#### 3.2.2.2
The mimic map consists of mosaic tiles which should form a traffic display panel on which there is a schematic mimic representation of the whole tunnel control area. The position of the mimic representation of the tunnel route should be in the central part of the mimic map, surrounded by CCTV monitors. Indicator lamps in various colours and shapes representing the different traffic control equipments are overlaid at relative locations of the mimic map for the tunnel and also revealing the state of the traffic surveillance system. These optical status readouts for the traffic control and surveillance equipments include :-

(a) traffic light signals,
(b) traffic lane signals,
(c) barriers,
(d) pavement inset lights,
(e) overheight vehicle detector indications,
(f) variable traffic signs,
(h) emergency telephones,
(i) traffic flow direction,
(j) incident detector indicator if automatic incident detection is available.
(k) niches,
(l) CCTV cameras.
323 Operator Console

323.1 For the operator console, there is an operator control desk containing all monitoring and control units, required for the tunnel operation and the traffic surveillance and control, which have to be at hand immediately available to the operator. It shall form a control desk from which the regularly required interactions to the system can be initiated by the operator. The following basic facilities should be provided on the operator console:–

(a) control units for the traffic control and surveillance system, lighting and ventilation control systems. In the case of computer-based system, it would probably include the colour graphic terminals;

(b) panel for computer state indication and magnetic card reader for system 'login' in case of computer-based system;

(c) CCTV control panel; 2 nos. CCTV desk monitors; VCR remote control panel; VCR microphone and loudspeaker;

(d) radio control panel; microphone for radio; loudspeaker for radio;

(e) public address control panel; public address loudspeaker;

(f) emergency telephone control panel; emergency telephone handset;

(g) public telephone handset; Telephone with direct line to FSD; telephone with direct line to HKPF;

(h) internal intercom control unit;

(i) any emergency control switches;

(j) a clear writing area for the operator.
3.2.4 Wall Panel Display

3.2.4.1 Normally, remote manual control and indication panels for ventilation, lighting, power supply, environmental controls and alarm announcement panels for fire, ventilation etc. are wall mounted in the central control room. They should be visible to the operator when he is stationed, at the operator console and easily accessible.
3.2.5 Ventilation

3.2.5.1 General

The ventilation of the control room and the control room equipment should be controlled by air conditioning system. The air conditioning system should be designed with such capability that the environmental conditions can be maintained 24 hours a day, 7 days a week, including period of routine and fault maintenance.

3.2.5.2 Environmental conditions

The air conditioning system should ensure that the following environmental conditions are maintained all the time.

(a) Temperature

The nominal ambient air temperature should be 20 degree C plus or minus 2 degree C. The temperature difference between any points should not exceed 3 degree C.

(b) Relative humidity

The relative humidity should remain at 50% plus or minus 5%, without condensation.

(c) Fresh air

Sufficient intake of fresh air should be provided to maintain oxygen content.

Temperature and humidity sensing devices should be provided in the computer and equipment area for continuous monitoring of temperature and humidity. Also, the viewing windows to be provided on the internal partition walls separating the computer area should be suitably sealed and double glazed. Double doors should be provided at the entrances to the control room to serve both as an air lock and fire proof device. The air inside computer room should be slightly pressurised to prevent influx of dust when the doors are open. It is preferable to have automatic fire fighting equipment installed inside the equipment room, which can be activated or deactivated by a key switch at the entrance.
3.2.6 **Viewing Window**

3.2.6.1 Viewing windows should be provided to the control room so that the operator can actually observe the traffic condition at the toll plaza area. All windows on the external walls should be suitably coated to reduce solar heat gain. Also, venetian blinds should be provided as appropriate. Preferably the venetian blinds are electrically operated. Heavy rain should not affect the visibility of the operator from observing the actual traffic conditions.
3.2.7 Lighting

3.2.7.1 Sufficient light illumination should be provided in the control room such that the operator could see the display of indication panels and mimic map clearly and carry out written work. The control desk, toll console and the minor control room should be provided with essential lighting. Additional special local lighting should be provided as appropriate. This will take the form of adjustable spot light mounted on tracks so that they can be adjusted. Separate dimmers should be provided for the normal and additional lighting provided in the control room.
3.2.8 Security of Access

3.2.8.1 All doors should be self-closing. Preferably the external doors should be protected with a security system such as a card operated locking system.
3.2.9 CCTV Monitors

3.2.9.1 The mimic map should house the CCTV monitors. The mimic representation of the tunnel route should be surrounded by CCTV monitors arranged in the same order as the cameras in the tunnel area. The monitors should provide 100% coverage of the tunnel area. Preferably, there should be a CCTV monitor for each CCTV camera.
3.3 Minor Control Room

3.3.1 While there is a control room in the Administration Building located at one portal of the tunnel, another minor control room is situated on the other portal area. This minor control room should have an operator console with the following facilities:

(a) a mosaic mimic map with optical status readouts similar to the one in the main control room. There is a schematic mimic representation of that portion of the tunnel control area where the minor control room is situated. Usually this mimic map is positioned horizontally on the control desk;

(b) controls for some traffic light signals and confirmation of the desired operation of the barriers at this portal. These controls should only be activated on command from the main control room. Preferably buttons are provided on the mosaic mimic map to activate these facilities;

(c) telephone and intercom connected to the main control room;

(d) CCTV monitors and appropriate controls for cameras covering this portal tunnel area;

(e) public address facilities.

3.3.2 The control room has operation priority on the use of public address and CCTV camera control facilities. Operator could use the CCTV camera and public address control facilities in the minor control room only if he is allowed by the control room. Also, first aid facilities and some storage space for traffic signs and other traffic aids should be provided there.
3.4 Communication Provisions

3.4.1 Public Address System

3.4.1.1 Good public address (PA) system should be provided inside the tunnel, on the portals and in the toll plaza areas. This public address system should facilitate transmission of short messages and instructions to the public under critical traffic situations such as congestion, accidents and fire. Also, an audio tape recorder with remote playback control facility should be provided. It should be able to record up to five standard messages up to 5 minutes duration each on a tape or similar device in several languages. It should be possible to play back any selected message automatically on demand.

3.4.1.2 As it is not considered necessary to operate all loudspeakers simultaneously, the area to be covered should be divided into sections for each tube. There should be gooseneck microphone and monitoring loudspeakers with volume controls installed on the operator console. The frequency range of the system should not be less than 300 to 8000 Hz.

3.4.1.3 The public address system should be operated from the control console. The following controls should be provided:

- selection of tube
- selection of the loudspeaker section(s)
- announcement gong control
- 'speak' control
- control for the tape recorded message
- system 'on', 'off' and lamp test control.

3.4.1.4 An announcement signal, such as a two-tone gone is usually mounted when the 'speak' button is depressed. This announcement signal should last no longer than 5 sec. Both the operators in the control room and the minor control room could use the PA system. But only one operator should be able to use the PA system at any time. The operator at the control room has priority in using the PA system.
3.4.2 Radio Facilities

3.4.2.1 A radio communication system should be provided to operate throughout the tunnel. This system should have the following facilities:

(a) Separate radio facilities should be provided for Fire Services, Police and tunnel operation.

(b) Mobile radios should be fitted in all tunnel vehicles.

(c) Foot patrols should be provided with 'Radio Telephone' set to be carried at the waist with the mouth-piece carried at the shoulder (similar to that of Police) to facilitate safe and secure convenience in addition to allowing both hands to direct traffic or positioning of traffic cones.

3.4.2.2 The radio equipment should be weather proof so that they can be operated under all environmental conditions in Hong Kong. Director-General of Telecommunications should be consulted. Also, Director-General of Telecommunications' approval will be required for frequency allocation and specification on transmission power.
3.4.3 Intercom System

3.4.3.1 An intercom system with extensions should be provided to allow communication between the control room and the minor control room with other locations. The intercom system normally comprises a minimum of 11 main extensions, but only the control room and the minor control room can communicate with any other extensions. Collective communication to all extensions should also be possible.
3.4.4 Radio Rebroadcast

3.4.4.1 Public radio rebroadcasting with supervisor break-in facilities should be provided. Director-General of Telecommunications should be consulted on radio frequency and power.
3.4.5 **Telephones**

3.4.5.1 An appropriate telephone system should be provided to facilitate internal communication within the Administration Building in addition to access to the public telephone system.

3.4.5.2 **Direct Lines**

Direct telephone line connections to the Hong Kong Police Force and Fire Services Department should be provided in consultation with the appropriate authorities.
3.5 Operator Facilities

3.5.1 Man-machine Interface

3.5.1.1 The man-machine interface to be provided should be user friendly, easy to learn and use. The main factors to be considered are: -

(a) capability of operator,

(b) distribution of activities among various users and the possible use of access level for distribution control,

(c) minimum training,

(d) simple operation,

(e) human error correction,

(f) safety check,

(g) simple man-machine communication,

(h) use of special purpose keys,

(i) chronological event logging,

(j) avoidance of difficult codes/messages,

(k) system security and level of access for each class of user,

(l) use of special input units such as joysticks, mouse or light pens.

3.5.1.2 A system which does not require the operator to remember specific commands/codes is preferred.
3.5.2 **Colour Graphic VDU**

3.5.2.1 It is highly desirable that colour graphic VDU with light pen is used as the main operational man-machine interface. In this way, it should be possible to present graphically the configuration of the provision of the tunnel traffic control and monitoring facilities on the VDU. And the operator can control interactively the signal equipment without having to remember the names of the equipment. It must be stressed that the communication between the operator and the equipment should be as simple as possible.
3.5.3 Operator Functions

3.5.3.1 General

The system should communicate with the operator in two directions. His commands must be acknowledged by the system. The response time for all simultaneous operator commands must be such that all processes called shall be started within one second of the calls under any conditions. Typical scope of minimum operator functions is given in the following sections.

3.5.3.2 Status reports

(a) Overall system status

- Computer head-standby/on line status for computer-based system
- Time and date
- Major equipment or subsystem status.

(b) Traffic control (signs and signals)

- Current operational plan in operation on area
- Current plan in operation on any sub-area
- Current status of any signal
- Status of any signal controlled from the minor control room
- Status of barriers.
- List of timetables for automatic plan selection.

(c) Vehicle detectors and traffic statistics

- Status of any incident(s) detected if automatic incident detection is employed
- List of any control factors which may be used in treatment of detector information
- Traffic flow values, for all or individual detectors, for all tube and lane combination
- Detector status
- Traffic statistics.
3.5.3.3  Control functions

(a)  Traffic control

Signal plan alteration for area
Signal plan alteration for subarea(s)
Override of individual signal status
Override of individual barriers
Individual signal switching
Switching over of head-standby computers in case of computer-based system

(b)  Detectors and traffic statistics

Request analysis printout, etc.

3.5.3.4  Updating

(a)  Overall system

Assign operator priority levels and access level allocation
Setting of system clock

(b)  Traffic control

Insert new signal plans
Update current signal plans
Add/delete/modify parameters for automatic selection/implementation of signal plans
Update mode of operation/type of individual signals
Add/delete traffic control equipment

3.5.3.5  Alarm analysis and reporting facilities

Provide on demand a list and description of all outstanding alarms. Preferably the alarms are classified into groups.
3.5.3.6 **Chronological event logging**

Chronological logging of every control command issued by the operator, status change, alarms etc. should be provided. Each entry must be time-tagged.
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4.1 References


5) Contract No. HY/85/10, Route 5 - Sha Tin to Tsuen Wan, Shing Mun Section, Toll Collection, Hong Kong Government, 1985.

6) Road Tunnels (Government) Ordinance Cap. 368, Hong Kong.

7) Road Tunnels (Government) Regulations, Hong Kong.
4.2 General

4.2.1 Toll Collection System

4.2.1.1 Since it is Government's stated policy to collect tolls for the passage of vehicles through its tunnels, a toll collection system must be provided in the planning requirements of future tunnels.

4.2.1.2 This chapter describes the functional requirements of manual toll collection systems. It should be noted that the use of autotoll systems is a possible alternative and is under consideration.

4.2.1.3 The toll collection system must be able to control and monitor all toll booths and subsequent revenue accounting together with toll collectors identification and could, if considered necessary, encompass performance monitoring. The system should therefore require dedicated computer systems. The main objective of the system is to safeguard the monies collected from tolls with a minimum of delay to traffic and to provide detailed operational statistics for cash reconciliation. It should provide tunnel management with cash control and the necessary records to protect public revenue. The system should also provide the statistics necessary for operational requirements and resource planning.
4.2.2 Toll Collection System Capacity

4.2.2.1 The toll collection system capacity requirements shall be carefully assessed and the capacity of the toll plaza should match that of the tunnel. The layout of the toll plaza should allow for future expansion to install more toll booths.

4.2.2.2 Assuming a normal four lane, twin tube tunnel there should be provided a minimum of 12 toll booths serving 13 lanes with 16 toll collection consoles which would provide a maximum of 8 lanes to cater for tidal traffic flow. The 6th, 7th and 8th lanes will be reversible and equipment installed here should be interlocked to prevent conflict with bi-directional traffic. To ensure compatibility of equipment, all toll booths should be equipped at the time of opening.

4.2.2.3 For tunnels opening initially with only one tube, consideration must be given to ensure that sufficient booths are available for predicted 2 way traffic figures. Tunnels of unusual layout or design would need special and individual consideration in each application.
4.2.3 Toll Structure

4.2.3.1 The current toll structure provides for 3 different vehicle type classifications. To provide the means to expand the existing classification of vehicles, and for flexibility, provision should be made for the system to have 10 classifications. Although the toll structure philosophy should be to detect vehicles rather than axles, a reliable system based upon the latter would be considered. The system must be able to distinguish cash transactions as well as those made by tickets. Also, differential toll and directional toll should be possible.

4.2.3.2 The toll collection system must be secure, highly reliable and accurate in respect of all toll transactions. It must be designed and constructed so as to provide a very high standard of overall serviceability.
4.3 Toll Booth Equipments

4.3.1 Toll Booth

4.3.1.1 Each toll booth is to be suitably equipped so as to accurately monitor all toll transactions within its lane and to handle and record all information generated in this connection. The toll supervisor console in the control room should have equipment to show the toll collector's identity, controls and other indicators. There should be a toll collector console with a cashier terminal in the toll booth. A "toll paid" sign should be mounted outside the booth to indicate to the motorist the amount he has paid. Overhead classification signs should be mounted on top of each booth facing the Control Room to show the toll supervisor the class of vehicle being registered. A loop, or similar vehicle detector connected with the printer, should be provided in each lane. Traffic lights indicating whether a booth is open or closed are required above each booth. Other equipment necessary will include the actual toll booth structure which should have a finish which can be easily cleaned. The booth should be air conditioned and able to be heated during the winter months. It will require an intercom, suitable chair, security alarm switch, adequate lighting and a fire extinguisher. Four centre booths should be reversible to cater for possible tidal flows. Toll collector console should be equipped with lockable drawers.
4.3.2 **Cashier Terminal**

4.3.2.1 The cashier terminal in the toll booth shall have the following facilities:

(a) Accept not less than 10 classifications and separate keys be provided for each classification.

(b) Indication whether a transaction is in cash or pre-paid coupon.

(c) Vehicle presence detection shall be used (i.e. the form of detector shall not rely on axle counting). Axle detection may, however, be considered as an optional extra, e.g. detection of additional axle(s) or trailer.

(d) Toll operations (including lane opening) will only be enabled when confirmation of valid operator identity is received.

(e) Provide direct control over lane lights above the toll lane, lane barrier and vehicle classification displays.

4.3.2.2 For operation and security considerations:

- the cashier terminal must be able to operate independently. The toll collection operation will continue uninterrupted and with toll collector unaware even in the event of the failure of the central computer.

- local data storage facility in the cashier terminal shall have a capacity to hold data generated for 10 days of continuous operation.

4.3.2.3 In the event of changes in tunnel tolls, the necessary corresponding changes to the cashier terminal, if required, shall be simple to implement requiring only semi-skilled labourers for the site work (e.g. replacement of modules, or plug-in component parts). It shall be possible to effect temporary changes to the whole system within one hour and permanent changes to a lane within one hour.
4.3.3 Construction

(a) Specifications of the typical matrix signals fitted above the toll lanes are shown in Diagrams 4.3.1.3 and 4.3.1.2 of Chapter 4, Volume 3.

(b) Lane width between toll booths shall be not less than 3 m.

(c) The outermost lanes should be able to allow the passage of exceptionally wide vehicles. The minimum width of these extra-wide lanes should be not less than 6.2 m.

(d) Toll booths should be constructed with an easy to clean exterior finish. Interior finish should include a purpose designed desk with two lockable drawers and if the unit is to house electronic equipment, forced ventilation must be provided. Doors should provide a good seal against the ingress of exhaust fumes when closed. Tinted windows should be used in bronze (or similar) anodised frames. A strong comfortable seat should be included in the toll booth specification as should a power point and a heater.

(e) Toll booths should be individually air conditioned and a positive pressure is to be maintained to prevent as far as possible the ingress of exhaust fumes.

(f) To permit toll collection the window of the toll booth adjacent to the toll lane should have an closable aperture measuring 630 mm * 300 mm with its lower edge being 900 mm from ground level.
4.4 Toll Collection Operation and Monitoring

4.4.1 Toll Collection Operation

4.4.1.1 A toll collector coming on duty must be able to identify himself to the system by key or card. Having proved his identity to the system his identification, lane number, lane direction and time of lane opening is recorded. The collector can then raise the barrier and commence collecting tolls. At the end of his period of duty he lowers the barrier, removes his identifier key or card and a record is made in the same manner.

4.4.1.2 These records should be printed on the Control Room printer and other information such as lane open/closed, lane direction, toll collector on duty should be updated on the toll supervisor panel in the control room. Also, a shift report for the toll collector is printed automatically at the end of his duty on the accounting printer when he removes his identifier key or card.

4.4.1.3 As a safety measure against unauthorised use, if a lane barrier is raised when the booth is not operational an alarm should be generated. Also, an alarm should be generated when the barrier is faulty. The barrier status should be shown on the toll supervisor panel.

4.4.1.4 During the period when the lane is in operation, the toll collector registers arriving vehicles on the keyboard by operating a classification button upon the collection of the appropriate toll. The registration is recorded by the lane equipment and repeated on the toll supervisor panel. The supervisory equipment continuously monitors the lane condition and presents on the toll supervisor panel current classification activity for each lane. Concurrently, the current class code number is displayed on the overhead classifier over each active toll booth for the toll supervisor's information. Vehicle classifications on the overhead classifiers are extinguished only by the next classification operation.

4.4.1.5 The toll collection operation in the lanes is monitored by the toll supervisor in the control room with the help of the toll supervisor panel. On the toll supervisor panel, each lane is
represented by signal lights depicting lane status including the toll collectors operational number together with vehicle classifications in real time concurrent with the toll booth classifications. There are indicator lamps operating in conjunction with cancellations, evasions, internal communications and P.A. messages.

4.4.1.6 Lane opening procedure is accomplished by the toll collector successfully identifying himself to the toll collector console. He opens the barrier and then presses the appropriate button to illuminate the overhead booth lane traffic sign.

4.4.1.7 The toll collection process starts when a motorist enters the toll lane. Upon the paying of the correct toll, the toll collector acknowledges receipt by operating the appropriate vehicle class classification button activating the displays. When the motorist drives on after registration of the toll paid, the vehicle activates the loop detector which will cancel the displays and the lane will then be ready for the next motorist to pay his toll.

4.4.1.8 Should a vehicle activates the loop detector before payment of toll is acknowledged, an alarm will sound and the lane will be temporarily put out of service. The supervisor after checking whether the alarm is due to non-payment or late register can put the lane back into service. Such event will be recorded on the printer as an evasion. The number of evasions recorded against each toll collector should also be shown in the daily cash summary report. Should a toll collector make a wrong entry he should be able to cancel the entry by pressing the cancellation button which should alert the toll supervisor at his panel, who can then immediately check whether the correct re-entry has been made. All cancellations should be recorded by the printer. The toll collection system should have the facility to easily accommodate differing toll structures.
4.4.2 Toll Supervisor Console

4.4.2.1 Located in the Control Room is the toll supervisor console which should permit one man operation containing visual display of the lane status, identification of the toll collector, vehicle classification, evasion alarm, cancellation of classification wrongly made and the lane equipment failure. There should also be controls to reset evasion, barrier, cancellation and security alarms.

4.4.2.2 The toll supervisor console shall have a toll supervisor panel which shows the exact status and the current operation on each toll lane. The input should be obtained directly from the source, i.e. toll booth and not the output of the computer.

4.4.2.3 Visual displays for each lane shall include :-

(a) Lane status (open/close)
(b) Identification of toll collector
(c) Vehicle classification
(d) Cancellation alarm (+ audible alarm)
(e) Evasion alarm (+ audible alarm)
(f) Barrier alarm (+ audible alarm)

4.4.2.4 The toll supervisor's console should have a master clock and should display the computer status.

4.4.2.5 Additionally the console should be fitted with two CCTV monitors, with a minimum screen size of 300mm, for the cameras located at the toll plaza area. There should be a control panel for the remote control of these cameras giving pan, tilt, zoom, wash and wipe facilities. Another control panel is required to control the VCR which should be equipped with audio dubbing facilities.

4.4.2.6 A keyboard printer should be provided operating primarily as a logging printer, providing an instantaneous record of all significant events such as opening/closing of a toll lane, signing on/off by a toll collector, shift changes and equipment faults. The toll supervisor would also use this terminal for data retrieval.
4.4.2.7 Communications must be provided and these would include general intercom between the toll supervisor and the toll booths either individually or collectively together with a P.A. system having the same main concept but, in addition, would be able to broadcast pre-recorded message to the toll plaza area.

4.4.2.8 The security alarm provided in each booth should only be audible to the toll supervisor in the control room and should be operated by a concealed foot operated switch in the toll booth.
4.4.3 **CCTV Surveillance**

4.4.3.1 CCTV surveillance requires two strategically mounted cameras giving a view of the toll plaza from opposite sides. The cameras should be able to identify stationary vehicle license plates at the toll booths and provision should be made to enable the cameras to be panned and zoomed in automatically to a booth from which an alarm (cancellation, evasion or security) has just been generated. Automatic video recording of the event is also required.

4.4.3.2 CCTV cameras should be able to clearly view all or any of the overhead classifiers at the toll plaza to enable the toll supervisor to monitor this activity. It is considered that one set of overhead classifiers is sufficient and these should face the Control Room.

4.4.3.3 A control panel should provide the toll supervisor with pan, tilt and zoom control of the CCTV cameras located to view the toll plaza area. Cameras should also have wash/wipe facilities. Another control panel will control the VCR which should be reliable, easy to operate and be provided with time-lapse and audio dubbing facilities. Two VCRs should be provided for video recording and playback by the toll supervisor.

4.4.3.4 Two CCTV monitors, with a minimum screen size of 300mm, should be fitted on the toll supervisor console for the two cameras located at the toll plaza area. It should be possible to playback the VCR on these CCTV monitors.
4.5 Central Computer Equipment and Facilities

4.5.1 Central Computer Equipment

4.5.1.1 The central computer system must be designed to high reliability and the entire system shall be such that there will be no loss of toll data under whatsoever failure circumstance including mains failure and processor failures. The toll collection in a toll lane should not be affected by failure of whatsoever form of the central computer equipment and such failure shall be totally transparent to the toll collector.

4.5.1.2 A keyboard printer shall be provided at the toll supervisor position. This will function as a logging printer as well as providing the toll supervisor access for toll statistics and other information permit at his access level. A medium speed keyboard printer (about 200 lines/min) shall be provided in the Head Shroff's Office in the Tunnel Administration Building. All print-out of the cash details or any information required for cash reconciliation purposes shall only be output on this accounting printer. If magnetic card is used for access control and starting up a toll lane, then card reader and encoder will need to be provided. It should be possible to carry out management functions on the keyboard printer.

4.5.1.3 Computer should be user friendly and easy for control staff to operate. It should require only simple and quick keyboard input to print out shift assignments or reports as requested. The system should have a system of access included into which is a requirement that cash details are available only to the administration staff.
4.5.2 Operation Functions

4.5.2.1 Toll Collection Operation

Validate toll collector/cashier identity

Enable cashier terminal and toll collection

Record transactions

Provide operator and supervisor interventions and operation alarms

Provide shift/sub-shift change information

Provide reports

4.5.2.2 Equipment Fault Monitoring

Line faults

Cashier terminal faults

Barrier fault

Detector faults

Signal fault

Classifier fault

Instation equipment faults

4.5.2.3 Management Function

Revise toll charge rates according to direction, time and class

Incorporate or delete toll class

Assign toll collector identity

Set up shift assignment table

Set up schedule for automatic output of toll collection data

Set up and print tunnel manning scale table together with sub-shift rosta
4.5.3 Statistical Functions - Reports

The system shall maintain in the on-line store at least six months historical data. Historical data shall include toll transactions by lane, by toll collector with date and time stamp, toll collector performance records and shift assignment tables.

4.5.3.1 Daily financial report

(a) Daily cash summary by toll operator. This report should include toll collector's number, sign on/off times of each sub-shift, the lane number, the number of each class of vehicle he has recorded in each sub-shift together with details of evasions and cancellation. Total number of vehicles in each class and total amount of toll revenue - in cash and tickets - he should have collected in each sub-shift and for the whole shift. A grand total of the revenue received from all operators during the 24 hour period should also be included.

(b) This report should be automatically printed daily for a 24 hour period from 0700 of the previous day to 0700.

4.5.3.2 Daily traffic report

(a) Daily traffic report. This report should include the total number of vehicles using the tunnel by direction, by traffic lane and by class on an hourly basis. A grand total of the daily traffic during the 24 hour period should be included. Peak-period information should be available.

(b) These reports should be printed daily for a 24 hour period from 0700 of the previous day to 0700.

4.5.3.3 Shift Report

A shift report for the toll collector should be printed automatically at the end of his sub-shift. This report should include the toll collector's number, the lane number, sign on/off time of the sub-shift, the number of vehicles for each class he has recorded in each sub-shift together with
details of evasions and cancellations. Total revenue for each class and total amount of toll revenue - in cash and tickets - he should have collected for the whole sub-shift should also be included.

4.5.3.4 On demand reports

(a) Traffic report by direction, by lane, by class and total for tunnel for any period of time as specified by the operator on a selected time interval (15 min., 30 min., 60 min.).

(b) Daily cash report by toll lane as specified by the operator on a selected time interval (15 min., 30 min., 60 min.).

(c) Cash record of any toll collector for any given period of time including performance appraisal of operator (e.g. average number of vehicles classified per hour, total evasions, total cancellations and percentage of total number of vehicles classified).

(d) All the daily reports and shift reports could also be printed on demand.
CHAPTER 5 - Ventilation
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1. Technical Committee Report on Road Tunnels, Permanent International Association of Road Congresses, XVIIth World Road Congress, Vienna, 1979

2. Technical Committee on Road Tunnels, Permanent International Association of Road Congresses, XVIIth World Road Congress, Sydney, 1983

3. Technical Committee Report No.5 - Road Tunnels, Permanent International Association of Road Congresses, XVIII World Road Congress, Brussels, 1987, pp. 53-78


5. Contract No. JB22/86, Junk Bay Tunnel Ventilation System, Hong Kong Government


7. 'Code of Practice for Minimum Fire Services Installation and Equipment - Section 5.26 Smoke Extraction System', Fire Services Department
5.2 Introduction

5.2.1 A road tunnel ventilation system can be conceptually segregated into two distinct parts: the electromechanical ventilation equipment with an installed ventilation capacity to deliver the requisite volume of fresh air for the dilution of vitiated air, and the control system that ensures the effective and efficient utilization of the available ventilation capacity. This chapter focuses on the functional requirements and operator facilities of a typical control system for a tunnel ventilation system. In this context, a road tunnel is generalized to mean any section of enclosed road with a non-trivial length, typically ranging from several hundred metres to several kilometres.

5.2.2 In general, the primary objectives of a tunnel ventilation system are as follows:

- to continuously monitor the air quality inside the tunnel and to take such control actions as are necessary to limit the concentration of air pollutants from vehicle exhausts to acceptable levels at all times;

- to control the spread of smoke in the event of a tunnel fire;

5.2.3 The design of a ventilation system usually involves the following steps, in chronological order:

- determination of the fresh air and smoke extraction requirements

- selection of the type of ventilation system to be adopted

- design of the electromechanical ventilation equipment

- design of the ventilation control system
5.3 The Fresh Air and Smoke Extraction Requirements

5.3.1 The pollutants generated from vehicle exhausts essentially consist of carbon monoxide (CO), oxides of nitrogen (NO, NO₂), and smoke. Enough fresh air must be continually introduced, artificially or naturally, to maintain the pollutant concentrations to acceptable levels at all times. The determination of the maximum levels of pollutant concentrations that can be tolerated is normally based on the latest internationally recognized PIARC standard (ref. 1 to 3), and is under the jurisdiction of the Environmental Protection Department.

5.3.2 To maintain pollutant concentrations to acceptable levels, the ventilation system is required to generate enough fresh air per unit time to dilute the tunnel vitiated air under all conceivable traffic conditions. The determination of fresh air requirements is usually based on the latest empirical formulae and parameters recommended by PIARC, which take into account factors such as pollutant concentration thresholds, vehicle emission characteristics, mean traffic density/speed, gradient, altitude, etc. (ref. 1 to 3).

5.3.3 Apart from meeting the fresh air requirements, the ventilation system must also provide adequate smoke extraction in the event of a tunnel fire. General requirements for smoke extraction systems in road tunnels are detailed in the 'Code of Practice for Minimum Fire Service Installations and Equipment, Section 5.26' issued by the Fire Services Department. All smoke extraction proposals are subject to the approval of the Fire Services Department.

5.3.4 Once the fresh air and smoke extraction requirements have been identified, the next step is to determine the capacity and type of the ventilation system to meet these two criteria.
5.4 Types of Ventilation Systems

5.4.1 Depending on the manner in which fresh air is injected and vitiated air is exhausted, tunnel ventilation systems can be classified into one of the following types:

- natural ventilation, where fresh air is drawn in from one tunnel portal and vitiated air is expelled out of the other portal via the piston effect of moving vehicles;

- longitudinal ventilation, where fresh air is drawn in from one tunnel portal and vitiated air is expelled out of the other portal via tunnel longitudinal air velocities introduced artificially;

- transverse ventilation, where fresh air is injected and vitiated air is exhausted through separate perforated ducts installed along the tunnel tube;

- semi-transverse ventilation, where fresh air is injected through a perforated duct installed along the tunnel tube and vitiated air is exhausted through the tunnel portals;

- reversible semi-transverse ventilation, where fresh air is injected through a perforated duct installed along the tunnel tube, with provision for exhaustion of vitiated air through the same duct when operated in reverse mode;

- variations embodying a combination of the above types.

5.4.2 The selection of the type of ventilation system to be adopted for a particular tunnel involves the identification of the most cost-effective system to generate the necessary ventilation capacity dictated by the fresh air and smoke-extraction requirements. This process usually calls for the detailed analysis of the air flow patterns and aerodynamics under different and worst-case scenarios, interpreting the study results and submitting the same to the relevant authorities (viz. EPD, FSD, EMSD and TD) for approval.
5.5 The Electromechanical Ventilation Equipment

5.5.1 Having selected the type of ventilation system to be adopted, the next step is to undertake the design of the electromechanical ventilation equipment. The design determines the type, quantity, locations, power rating and technical characteristics of ventilation fans required to achieve the given fresh-air and smoke-extraction objectives, and is subject to approval by the Electrical and Mechanical Services Department and the Fire Services Department.

5.5.2 Wherever possible, the ventilation equipment should be designed to have spare capacity of not less than the capacity of one fan to allow for the loss of one fan due to fault or overhaul.

5.5.3 Power factor correction equipment should be provided as and when necessary to enable the bulk tariff rate to be charged under the Supply Rule of the respective power company.

5.5.4 The power supply to the ventilation equipment should be designed in such a way that no single power supply fault, such as the loss of a transformer or a feeder, should result in a degradation of the ventilation capacity.

5.5.5 All fans should be reset to the "off" status under power interruptions, so that upon power resumption fans will not be automatically restarted unless commanded to do so by the computer or operator.

5.5.6 The noise generated by fans in operation should be maintained to levels acceptable to the Environmental Protection Department.

5.5.7 All the ventilation equipment handling fire/smoke should be suitable for continuous operation at 250°C for not less than one hour. These should include fans, motors, drivers, dampers, ductwork and duct joints.

5.5.8 The ventilation equipment employed should be proven, durable and accessible for easy maintenance, ready removal and replacement. Adequate maintenance facilities should be provided in consultation with the Electrical and Mechanical Services Department.
5.6 The Ventilation Control System

5.6.1 Objectives

The primary objectives of the ventilation control system are to control and monitor all the ventilation fans and ancillary equipment in a safe, reliable, economical and efficient manner, with or without operator supervision, to ensure the optimum utilization of the available ventilation capacity at all times.

The system should be designed to support the following control modes:

- automatic
- semi-automatic
- smoke extraction
- remote manual
- local

For all control modes, environmental sensors are indispensable as they are the only means to provide a quantitative indication of pollutant concentrations. So far, only carbon monoxide and turbidity sensors have been employed in Hong Kong tunnels. Other sensors, such as those for NO\textsubscript{x}, may also be employed provided that they give reasonably accurate and reliable readings.

5.6.2 Automatic Control Mode

Under the automatic mode, the control system should be able to effect the feedback control of the ventilation fans without operator intervention. By virtue of the level of sophistication usually involved in such control systems, computer-based control is normally required.

On the basis of the continuously monitored CO and turbidity readings, the highest of which in each tube being taken as the reference values, fans are controlled in real-time in such a way as to maintain the CO and turbidity readings below their maximum allowable thresholds. For either CO or turbidity monitoring, a minimum of three sensors located at the two portals and midpoint
of each tube should be provided. For the sake of energy conservation, fans should not be turned on until either the CO or the turbidity level has reached its operator-adjustable minimum threshold. Within an operator-adjustable range of CO and turbidity levels, fan power should be proportional to the pollutant concentration until full power is reached.

Necessary features of the control algorithms are:

(a) Different threshold levels and proportionality factors should apply to uni-directional and bi-directional traffic, and facilities should be provided to allow the acquisition of pertinent traffic information such as traffic direction in each lane in each tunnel tube. Such information could readily be acquired by way of an interface to the Traffic Control & Surveillance System.

(b) Transient Suppression - Transients or spikes in the CO and turbidity readings should be suppressed by software/hardware filtering.

(c) Fan Protection - All protective measures recommended by the fan manufacturer should be incorporated. These would normally include minimum on and off times, maximum number of starts within a period, staggered starting, and fan rotation to equalize run-times.

(d) Safety Interlocks - Safety interlocks should be provided to ensure that all control operations on the electromechanical equipment are fully synchronized to prevent the development of high mechanical/electrical stress or other hazardous conditions.

(e) Air Velocity Monitoring and Control - Tunnel longitudinal air velocities near the portal areas should be constantly monitored. Should the maximum velocity threshold value be exceeded as a result of some fans being in operation, fan power should be appropriately reduced in such a way as to maintain the air velocities to below the threshold value. However, air velocity control should be inhibited if CO or
turbidity readings are high or there is a fire emergency, as air velocity control is subordinate to the control of pollutant concentrations or the spread of smoke. Under such circumstances, an air velocity alarm to alert the operator would suffice.

(f) Malfunctioning Sensor Handling - Owing to the delicate nature of CO and turbidity sensors, it is not uncommon to have some malfunctioning sensors in the system. Therefore, there should be provisions to allow malfunctioning sensors to be detected and taken out of the system by automatic or manual means, to prevent spurious control actions from being issued due to bad sensor data.

5.6.3 Semi-automatic Control Mode

Under the semi-automatic mode, individual fans or groups of fans are controlled at the discretion of the operator in the Control Room through the man-machine interface, with built-in protective measures and safety interlocks as stated in 5.6.2.1 (c) and 5.6.2.1 (d). The semi-automatic operating mode is intended to apply under abnormal conditions such as fire, very high pollutant levels, fan testing, etc. All relevant control parameters should be presented to the operator in a comprehensive and concise manner through the man-machine interface to facilitate decision-making. These include all environmental sensor readings, current states of all electromechanical equipment, traffic flow directions, alarm conditions, etc. It is desirable to keep operator input to a minimum.

5.6.4 Smoke Extraction Mode

The smoke extraction mode overrides all other control modes and is initiated by the operator upon the detection of a fire inside the tunnel. Upon activation of this mode, all fans should normally be returned to the off state pending operator commands. After that, advisory messages and menu-driven input should be provided at the man-machine interface to guide the operator through the proper procedures to turn on all the relevant fans to deal with a particular fire situation. Operator input should be kept to a minimum, and all relevant fans should be started
in the shortest possible time taking account of the necessary safety measures as stated in 5.6.2.1 (c) and 5.6.2.1 (d). Fans have to be started within a maximum time limit to prevent smoke from filling up to a dangerous level. Where fan reversal is involved, there may be a need to employ some form of fan braking mechanism to expedite the reversal process. All smoke extraction procedures are subject to approval by the Fire Services Department.

5.6.5 Remote Manual Control Mode

The remote manual control mode serves as a fallback facility whereby a minimum level of control functions can still be executed in the event of the failure of computer-based control. To minimize the risk of a failure of the fallback facility itself, direct hardwired control is normally entailed. The remote manual control panel should preferably be centrally located in the Control Room, although other convenient locations may be proposed. The panel should be protected against unauthorized access by keyswitch. All fans should be controllable from the panel either in groups or individually. After a pattern of fan operation has been defined by the operator and before any control signal is sent to the field, some form of operator confirmation is required as a safeguard against inadvertent operation.

5.6.6 Local Control Mode

Under this control mode, fans are controlled by way of their respective local control panels. Located near to the fans, these local control panels are not expected to have any safety interlocks and should be provided with local/remote control selector key switches to allow access by authorized personnel only.
5.7 Control System Reliability

5.7.1 Although the ventilation control system is manned, by virtue of the routine nature of its functions, it is expected that the system would operate autonomously and automatically for most of the time, thereby relieving the operator to attend to other non-routine tasks such as incident handling, traffic control and surveillance, etc. It is also necessary to dispense with the need for the operator to keep a close watch on faults in the system. As such, a high degree of reliability is warranted. A number of desirable features to enhance system reliability is as follows:

- The system should be so designed that the automatic control of fans would not be affected in any way by the failure of any single processor (central or remote) in the system, albeit with a momentary interruption.

- All processor/control equipment should be powered from an uninterruptible power supply system to ensure the system's immunity to power system interruptions and disturbances.

- Alternative communication paths or backup communication channels should be provided to guard against the failure of any critical communication channel dedicated for control and monitoring functions.

5.7.2 Apart from the above general requirements, specific reliability standards for tunnel smoke extraction systems exist and are promulgated by the Fire Services Department. Reference should be made to relevant documents issued by the Fire Services Department on this particular subject.
5.8 Operator Man-machine Interface

5.8.1 The operator man-machine interface, located in the Main Control Room, should include the following equipment:

- video display units (VDUs) as the main man-machine interface, complete with input device to allow data entry, cursor control etc.

- logging and report generation devices to produce hard copies for record and reference

- facilities to allow an overview of the ventilation system by way of, say, a mimic display of the real-time status of all fans and associated control gears

- chart recording or trending facilities for CO, visibility and air velocity sensor readings in each tube

- remote manual control console

5.8.2 The man-machine interface should support the following supervisory control and data acquisition functions:

- the continuous scanning of all status and analogue points in the ventilation system, and the display of all alarms and events in the system via VDU and the logging of the same with time and date tags

- the generation of reports on fan operations statistics, alarm/event summary, sensor readings etc. on demand or automatically, and the generation of data archives of such information on an external storage medium

- menu-driven facilities for operator commands and input, with comprehensive input error detection, annunciation and correction

- the dynamic graphical display of all status and measurement information related to all items of equipment in the system

- password, keyswitch or magnetic card facilities to prevent unauthorized access
More detailed descriptions of the supervisory control facilities to be provided are provided in the following sections.

5.8.3 Alarm/event Reporting

All alarms should be displayed in an alarm list with time/date tags and in chronological order. High and low priority alarms should be displayed in different manners (different colours, etc.) to attract the operator's attention to more important alarms. All alarms require acknowledgement by the operator. To minimize operator input, global acknowledgement facilities whereby a whole page of alarms can be acknowledged at one go should be provided. The response time for a high priority alarm, from alarm activation in the field to the display of the corresponding alarm text on the VDU, should normally not exceed three seconds.

All events, such as alarms, status changes, operator commands, etc., should be logged with time/date tags in chronological order.

5.8.4 Report Generation

At least one month's storage of all alarm/events should be provided. Facilities should be provided to enable the report generation of alarm/events for any period during the month.

The following data should be stored as 5-minute interval historical records in the computer database for subsequent retrieval and report generation:

- identities of fans in operation
- % output of fans in operation (if applicable)
- CO, turbidity and air velocity sensor readings

For sensor data, the minimum requirement is to have such data available from three positions in the tunnel, namely the two portals and the mid-point of the tunnel.

Data archives should be stored on disk for at least two months to enable on-line retrieval and report generation. Older records are to be stored off-line on disk or on magnetic tape and facilities should be available to allow the retrieval of such off-line data as and when required.
5.8.5 Operator Commands and Inputs

Operator commands/inputs should be implemented through user-friendly menus, so that the operator need not remember the names and codes of the items of equipment that he wants to control or the parameters he wants to change. To execute a control command, the operator selects the item of equipment in question by cursor pointing, selects the control option and confirms his command. To prevent inadvertent operation, all control commands to the field must be preceded by operator confirmation. The response time for a single command, from operator confirmation to activation in the field, should normally not exceed two seconds.

All relevant parameters and data for each ventilation control mode should be presented in a clear, concise and comprehensive manner to facilitate decision-making and data modifications by the operator.

5.8.6 Dynamic Graphical Display

The status of all field equipment in the ventilation system that is monitored/controlled by the ventilation control system should be displayed on the VDU graphically or in tabular form. Display call-up times, from operator initiation to the display of the full page in question, should normally be within five seconds. Display retrieval should be as simple as selecting a display name from a display menu, without having to remember display names or page numbers.

5.8.7 Access Control

Access control to the man-machine interface should be provided by way of password, keyswitch or magnetic card. Different access rights are assigned to different types of users, such as supervisor, operator, software engineer, hardware engineer, system manager, etc. It should be possible to redefine the access privileges for each type of user.
5.9 Future Refinements

It should be emphasized that the guidelines as set out in this chapter are subject to a continual process of refinement in the light of future developments in the technology of computerized tunnel ventilation control, as well as changing operational philosophies and expectations of the public at large. Therefore, updates to this chapter may be dispatched in future and it is essential that an up-to-date version of the chapter is used when designing for a tunnel ventilation system.
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CHAPTER 6 - Lighting

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References

1. Technical Committee Report on Road Tunnels, Permanent International Association of Road Congresses, XVIth World Road Congress, Vienna, 1979

2. Technical Committee on Road Tunnels, Permanent International Association of Road Congresses, XVIIth World Road Congress, Sydney, 1983

3. Technical Committee Report No.5 - Road Tunnels, Permanent International Association of Road Congresses, XVIII World Road Congress, Brussels, 1987


6.2 Introduction

6.2.1 The primary objectives of a road tunnel lighting system are to provide a controlled reduction of lighting levels to facilitate the driver’s visual adaptation to the tunnel environment as he enters the tunnel, and to provide a reliable and economical source of illumination throughout the tunnel.

6.2.2 This chapter focuses on the functional requirements and operator facilities of a typical tunnel lighting control system for a "long" tunnel. In Hong Kong, a long tunnel ranges from several hundred meters to several kilometers in length.

6.2.3 Lighting levels are measured in terms of luminance levels (in cd/m²), which depend on the illuminance (in lux) received and the nature of the light-reflecting surfaces concerned.

6.2.4 A driver passing through a long tunnel normally encounters several lighting zones as follows, in chronological order:

- Threshold zone, where the lighting level should be such that obstacles in this zone can be seen by a driver still adapted to the external luminance on the approach road. The length of this zone is related to the design speed of the approach and typically ranges from 50 to 80M.

- Transition zone, where a phased reduction of luminance levels takes place to adapt the driver's eyes gradually to the interior lighting of the tunnel. Several lighting stages are employed. The step change in luminance level between two successive stages is usually about 2 or 3 to 1. The length of each lighting stage, being related to the tunnel design speed, typically ranges from 40 to 60M.

- Interior zone, where a minimum and constant level of basic lighting with uniform illuminance is maintained throughout the tunnel tube.
Exit zone, where the lighting level is usually the same as that of the interior zone but may be higher for very long tunnels or some special cases (direct view of the sea, frequent snow etc.). This zone usually extends no more than a few tens of meters from the exit portal.

6.2.5 The design of a tunnel lighting system usually involves the following steps, in chronological order:

- determination of the required luminance levels in the various tunnel lighting zones for day-time and night-time
- design of the luminaires
- design of the lighting control system

More detailed descriptions of these steps are provided in the following paragraphs.
6.3 **Lighting Design Considerations**

6.3.1 The determination of the required luminance levels in various lighting zones should normally follow the latest recommendations of CIE (International Commission on Illumination) or PIARC (Permanent International Association of Road Congresses), subject to approval by the Lighting Division of Highways Department.

6.3.2 Parameters to be considered include design speeds (uni-directional and bi-directional), access zone (approach road) luminance, coefficient of diffuse reflection of various tunnel surfaces (road, wall, ceiling), and the dimensions of the tunnel proper.

6.3.3 As tunnel lighting incurs significant recurrent energy costs, energy conservation should be given due emphasis. Wherever practicable, dark-coloured non-glossy surfaces should be employed for the approach road and portal structures to reduce the access zone luminance. Conversely, light-coloured surfaces should as far as possible be employed for the tunnel road, wall and ceiling to improve the effectiveness of the luminaires. The effects of staining of lightly coloured surfaces within the tunnel proper through prolonged exposure to vehicle exhausts should also be taken into account.
6.4 The Luminaires

The design of luminaires to achieve the required levels of illuminance is a subject under the jurisdiction of the Electrical and Mechanical Services Department. Generally-speaking, a continuous row of twin fluorescent tubes is employed for the interior zone lighting, whilst strategically-located high-pressure sodium lamps are employed for the threshold, transition and exit zone reinforcing lighting. From an operational point of view, the following features are considered essential:

- To facilitate easy cleaning of the luminaires, the housing should be corrosion resistant and sealed from dust and water, and electrical junctions or joints connecting the luminaires should be water-tight.

- The overall power factor of the luminaires should enable the bulk tariff rate to be charged under the Supply Rule of the respective power company.

- Adjacent luminaires for the basic lighting in the interior zone should be electrically connected to separate power supply sources from the power company, if more than one power supply source is available.

- Emergency lighting should be provided throughout the entire tunnel tube. Specifically, one out of five luminaires for the basic lighting should be connected to an uninterruptible power supply (UPS) or a no-break diesel generator.

- The construction of the luminaires should afford easy access for replacement of the electrical components housed therein.

- The luminaires should be arranged in such a way as to avoid flickering or glare.
6.5 The Lighting Control System

6.5.1 Objectives

The primary objective of a tunnel lighting control system is to ensure the efficient and effective utilization of the tunnel luminaires at all times for the safe passage of tunnel users, with or without operator supervision.

The system should be designed to support the following control modes:
- automatic
- remote manual
- local

6.5.2 Photometers

Lighting control under automatic or remote manual control modes makes use of photometer readings at the tunnel portals. Installed near each of the tunnel portals to measure the corresponding access zone luminance, these photometers should give a reliable electrical output proportional to the external luminance under all weather conditions. Sited some distance from the tunnel entrance, they should be oriented in a direction facing the respective tunnel portals.

6.5.3 Automatic Control Mode

Under the automatic control mode, the lighting control system should operate autonomously without operator intervention. By virtue of the level of sophistication normally called for, some form of computer-based control is entailed. On the basis of the photometer reading from each of the portal, the threshold, transition and interior zone lighting is adjusted to give the required luminance levels through staged switching of the relevant luminaires. There should normally be not less than six lighting stages. Stage one is the night time stage where only basic lighting in a dimmed state is provided. Dimming may be achieved through the switching-off of one tube of twin fluorescent luminaires or through electronic means. Stage two is the day-time basic lighting with no
reinforcing lighting, whilst stage three and above involve the switching on of not only the day-time basic lighting but also banks of reinforcing luminaires in proportion to the measured external luminance on the approach road.

Necessary features of the control algorithms are:

(a) Different reinforcing lighting levels should apply to uni-directional and bi-directional traffic at each entrance portal due to the different design speeds of the two modes of operation, and facilities should be available to allow the acquisition of pertinent traffic information such as traffic direction in each lane of each tunnel tube. Such information could be acquired by way of an interface to the Traffic Control & Surveillance System.

(b) Transient Suppression - Transients or spikes in the photometer readings should be suppressed by software/hardware filtering.

(c) Malfunctioning Photometer Handling - Automatic and manual facilities should be available to allow malfunctioning photometers to be detected and "removed" from the control system, as a means to prevent spurious control actions from being issued due to bad sensor data.

(d) Safety Interlocks - Safety interlocks should be provided to ensure that all control actions are fully synchronized to prevent the development of high electrical stress or other hazardous conditions.

6.5.4 Remote Manual Control Mode

The remote manual control mode serves as a fallback facility whereby a minimum level of control functions can still be executed in the event of the failure of automatic control. To minimize the risk of a failure of the fallback facility itself, direct hardwired control is recommended. The remote manual control panel should preferably be centrally located, although other convenient locations may be proposed. Protected against unauthorized access through keyswitch, the panel should allow, as a minimum, the control of each of the above-mentioned lighting stages and the definition of uni-directional/bi-directional traffic in each tube.
6.5.5 Local Control Mode

Under this control mode, the luminaires are controlled through their respective local control panels, which should be accessible by authorized maintenance personnel only. A remote/local control selector switch should be provided in each local control panel to ensure that luminaires under local control are not remotely controllable and vice versa.
6.6 **Operator Man-machine Interface**

The operator man-machine interface, located in the Main Control Room, should include the following equipment:

- Video display units (VDU) to indicate pertinent lighting information in real-time, complete with input device to enable keyboard entry, cursor control, etc.

- chart recording or trending facilities for photometer readings

- logging and report generation devices to produce hard copies for record and reference

- remote manual control console

6.6.1 The man-machine interface should support the following supervisory control and data acquisition functions:

- the continuous scanning of all status and measurement information in the lighting system, the display of all alarms and events in the system, and the logging of the same with time and date tags

- the generation of reports on lighting stage activation, alarm/event summary, photometer readings etc. on demand or automatically, and the generation of data archives of such information on an external storage medium.

- user-friendly operator input facilities, with comprehensive input error detection, annunciation and correction.

- the dynamic display of all status and measurement information related to all items of equipment in the system.

More detailed descriptions of these facilities are provided in the following sections.

6.6.3 **Real-time Display**

The real-time information to be displayed at the operator interface includes the readings of all photometers, status indication of lighting control mode and lighting stage at each portal, status of all lighting circuits, etc.
6.6.4 Alarm/event Reporting

All alarms should be displayed in an alarm list with time/date tags and in chronological order. High and low priority alarms should be displayed in different manners (different colours, etc.) to attract the operator's attention to more important alarms. All alarms require acknowledgement by the operator. The response time for high priority alarm from alarm activation in the field to presentation on the man-machine interface, should normally not exceed three seconds. All alarms and events, including status changes and operator commands, should be logged with time/date tags in chronological order.

6.6.5 Report Generation

At least one month's storage of all alarm/events should be provided. Facilities should be provided to enable the report generation of alarm/events for any period during the month.

The following data should be stored as 5-minute interval historical records in the computer database for subsequent retrieval and report generation:

- lighting stage at each portal
- photometer data at each portal

Data archives should be stored on disk for at least two months to enable on-line retrieval and report generation. Older records are to be stored off-line on disk or on magnetic tape and facilities should be available to allow the retrieval of such off-line data as and when required.

6.6.6 Operator Commands and Inputs

To prevent inadvertent operation, all control commands to the field must be preceded by operator confirmation. The response time for a single command, from operator confirmation to activation in the field, should normally not exceed two seconds.
6.6.7 **Real-time Information Display**

The status of all field equipment in the lighting system that is monitored/controlled by the lighting control system should be displayed graphically or in tabular form on the VDU. Display call-up times, from operator initiation to the display of the full page in question, should normally be within five seconds. Display retrieval should be as simple as selecting a display name from a display menu, without having to remember display names or page numbers.

6.6.8 **Access Control**

Access control to the man-machine interface should be provided by way of password, keyswitch or magnetic card. Different access rights are assigned to different types of users, such as supervisor, operator, software engineer, hardware engineer, system manager, etc. It should be possible to redefine the access privileges for each type of user.
6.7 **System Reliability**

Although the lighting control system is manned, by virtue of the routine nature of its functions, it is expected that the system would operate autonomously and automatically for most of the time, thereby relieving the operator to attend to other non-routine tasks such as incident handling, traffic control and surveillance, etc. It is also necessary to dispense with the need for the operator to keep a close watch on faults in the system. As such, a high degree of reliability is warranted. A number of desirable features to enhance system reliability is as follows:

- The system should be so designed that the automatic lighting control would not be affected in any way by the failure of any single processor (central or remote) in the system, albeit with a momentary interruption.

- All processor/control equipment should be powered from an uninterruptible power supply system to ensure the system's immunity to power system interruptions and disturbances.

- Alternative communication paths or backup communication channels should be provided to guard against the failure of any critical communication channel dedicated for control and monitoring functions.
It should be emphasized that the guidelines as set out in this chapter are subject to a continual process of refinement in the light of future developments in the technology of computerized process control, as well as changing operational philosophies and expectations of the public at large. Therefore, updates to this chapter may be dispatched in future and it is essential that an up-to-date version of the chapter is used when designing for a tunnel lighting control system.