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1 Introduction

This volume covers intelligent transport systems (ITS) with a specific focus on the impact that ITS deployment has on road civil infrastructure provision. It outlines basic design requirements to be considered by planners and designers in the delivery of ITS for rural and urban road infrastructure and tunnels.

Intelligent transport systems are information and communication technologies applied to road infrastructure and vehicles in order to improve road safety, efficiency as well as reduce impact on the environment of transportation systems.

In this version: Additional requirements regarding clearance areas around equipment added to Section 16.3.

1.1 Background

There has been a significant increase in transportation demand as a result of economic development, urbanisation and in particular, the growing trend of ‘just-in-time’ delivery of goods and services. This demand inevitably results in congested motorways. Traffic congestion contributes to air and noise pollution, reduces business productivity and competitiveness, and degrades the transportation network.

The traditional response to traffic congestion has been building more motorways. Yet, construction to handle increasing traffic loads is becoming more expensive. Financial, environmental, safety, and other policy and community considerations make expanding the size of the transportation systems difficult, socially unacceptable and unsustainable. It is increasingly accepted that construction of more motorways is no longer feasible in many areas as the primary solution to traffic congestion: ‘we cannot build our way out of congestion’.

Intelligent transport systems (ITS) have proven to be an innovative alternative to traditional measures for addressing transportation problems and needs.

ITS alone though cannot solve all the transportation problems. Nor can any one technology solve the growing demand for, and changing patterns of travel. ITS applications do not reduce the demand for mobility and accessibility nor increase highway capacity. But ITS can provide transportation agencies with extra levers with which to manage transportation challenges and maximise the safety and efficiency of existing infrastructure.

ITS application requirements may impact many facets of planning and design including earthworks, hydraulics, structures, traffic engineering and environmental disciplines and early deployment of ITS can assist in traffic management during project construction. Therefore, mainstreaming of ITS into the planning, program and project development processes is critical in order to build and sustain support for ITS investments.

ITS applications vary from simple traffic control and traveller information systems, to the rapidly evolving automatic incident detection applications and vehicle-to-infrastructure cooperative systems.
1.2 Early project involvement

Early consultation should be made with the Queensland Department of Transport and Main Roads’ Intelligent Transport Systems and Electrical (ITS&E) and Network Operations and Performance (NO&P) business units for projects where ITS deployments are planned, or likely in future.

2 Intelligent Transport Systems design

2.1 Intelligent Transport Systems functional design

An ITS functional design needs be undertaken to set the requirements on which the detailed design is based. The ITS functional design for any new ITS capacity should include:

- the identification of the primary and secondary (if required) Transport and Main Roads monitoring entities(s); that is, the Brisbane Metropolitan Transport Management Centre (BMTMC), Busways Operations Centre (BOC), North Coast Hinterland Traffic Management Centre (NCHD TMC), South Coast Hinterland Traffic Management Centre (SCHD TMC) or external monitoring party

- integration with the Principal’s existing Transport and Main Roads systems – the contractor shall confirm the versions of the respective Transport and Main Roads systems that are applicable to the given project with the departmental Project Representative

- selection of technology which is fit for purpose

- procurement of commercially off-the shelf (COTS) system components; that is, not based on proprietary standards

- value for money solutions

- product whole-of-life considerations for ongoing administration, maintenance and management if the ITS is delivered

- security requirements in accordance to Industry and Principal’s specific security standards / policies

- the design allows for high availability (applicable only for safety critical functions)

- Crime Prevention to Environmental Design (CPTED) principles in the design, and

- equipment which is physically and technologically robust and reliable.

The overall ITS functional design shall be submitted to the departmental Project Representative for review and approval, at least 14 working days prior to any detailed design being undertaken.

2.2 Supporting infrastructure

It is important that road designers approach provision of ITS supporting infrastructure from a holistic point of view. This includes consideration of project-related ITS applications which may be outside immediate project boundaries.

ITS design must take into account road geometry, landscape design, drainage systems, road structures, other road furniture such as static signs, lighting, services such as electricity and public utility plant and supplies. Likewise, these services must consider ITS requirements. This will allow addressing conflicts that may arise regarding ITS equipment space allowances, conduit routes and
sighting distances with other road services. Site and maintenance access are critical aspects of all ITS designs.

ITS design must be guided by provisions outlined in this manual, the *Manual of Uniform Traffic Control Devices* (Queensland) (MUTCD), *Traffic and Road Use Management Manual* (TRUM) and relevant Australian Standards.

The final design may require a compromise in other services so as to accommodate the ITS necessary to meet traffic management imperatives as mentioned in *Volume 1 – Legislation* of this manual.

ITS equipment requires power and reliable communications links to operate efficiently. Civil infrastructure must allow for the conveyance of ITS electrical and communications cabling. Designs must allow for ducts, pits, conduits, trays, ladders, antennas, cabinets and wall or structure penetrations as necessary. Wherever practicable, ITS devices and supporting infrastructure (including pits and conduits) should be located in the outer verges.

Designers may also need to consider that ITS deployment may be on a temporary and/or ‘early works’ basis to overcome issues during construction. Consideration for possible future road operations requirements (such as road widening, hard shoulder running and/or separation for differential speed limits) must be made in the ITS design. While provision of ITS applications may not be required immediately, land acquisition and civil works should be undertaken to allow these to occur easily in future.

### 2.3 Functional safety

Designers must note that it is essential as part of ITS design that preliminary hazard analysis be done with input from the department’s ITS and Electrical, Network Operations and Performance, and Traffic Engineering and Data units, and that functional safety requirements are evaluated in accordance with AS 61508 *Functional safety of electrical / electronic / programmable electronic safety-related systems* Set.

### 2.4 Main Intelligent Transport Systems

The key motivators for providing ITS include:

- improving road safety
- improving road network efficiency
- improving transport system efficiency, and
- reducing environmental impacts of the transport system.

These outcomes demand deployment and integration of a number of systems and subsystems including:

- road condition or road use data collection systems
- traveller information systems
- traffic management / control systems
- incident management systems
- heavy vehicle management systems, and
- public transport priority / emergency vehicle pre-emption systems.
These systems depend on many different technologies and devices including: vehicle detectors, message signs, display monitors, closed circuit television (CCTV) and telecommunications networks. The specifics of these and other devices and their supporting infrastructure are discussed in the remainder of this volume.

3 Vehicle Detection Stations

3.1 Introduction

Vehicle Detector Stations (VDS) are a critical element of the road data collection systems and provide raw vehicular data required by ITS applications. Each detector station may involve a number of sensors, enabling the collection of basic aggregate measures such as occupancy, volume, and speed. These sensors may be embedded within the road surface or mounted roadside on poles or structures. VDS should be placed periodically along a roadway to allow fast detection of congestion and incidents, and to provide an accurate picture of flow along the entirety of the road.

VDS are also used in ramp metering applications described in more detail later. Ramp Metering Systems (RMS) optimally use vehicle detection, both on the mainline and on the ramp, to meter access to congested motorways. Congestion management systems use vehicle detection data to evaluate and display appropriate messages on Variable Message Signs (VMS) and Variable Speed Limit Signs (VSL). For information relevant to detection in traffic signalling, refer to the Road Planning and Design Manual (RPDM) (2nd edition) Volume 3 – Guide to Road Design, Part 4 – Intersections and Crossings – General.

In permanent applications, sensors may be installed within the road surface (in-pavement) or mounted on the roadside.

3.1.1 In-pavement vehicle detectors

There are various types of sensors that are installed on or embedded in the pavement used for detecting vehicles. These include:

- piezoelectric sensors
- pneumatic tubes
- magnetic sensors / probes, and
- inductive loops.

Piezoelectric sensors generate a voltage when subjected to a mechanical force. The voltage developed is proportional to the force applied. This makes such sensors suitable for weigh-in-motion and vehicle axle based classification applications.

Pneumatic tubes are normally used in temporary installations, due to the ease in installation requirements. These sensors are installed directly on the road pavement surface. Due to the direct exposure to vehicle traffic, these sensors have a short lifespan, depending on the types and volumes of vehicles involved.

Magnetic sensors indicate vehicle presence by detecting disturbance of a magnetic field caused by the vehicle passing over them. The sensors are suitable for vehicle speed, classification by length and counting applications. Some sensors transmit vehicular data wirelessly to roadside equipment. Some of these sensors are beginning to rival inductive loops in terms of application.
Inductive loops are by far the most commonly used primary means of collecting vehicular data for ITS applications. They are widely considered both reliable and accurate. Inductive loop sensors are embedded in the road pavement and are either preformed or cut into the pavement. Preformed loops are made to order in the factory and installed on site prior to laying pavement. Inductive loops are not usually compatible with chip-sealed roads. Special considerations are required for concrete pavements. Further information is provided in the *TRUM Volume 4 – ITS and Electrical Technology Manual, Part 5 – Configuration and Placement of Vehicle Detection Sensors*.

### 3.1.2 Roadside mounted vehicle detectors

Newer alternatives in off-pavement (non-invasive) sensors include:

- video imaging
- Doppler radar
- microwave ranging
- audio and ultrasonic sensing, and
- photoelectric sensors.

Video detection relies on change in contrast of the image being captured to detect vehicle presence or movement. Video detection is susceptible to harsh weather conditions. Rain and fog, for instance, affect visibility and hence proper video detection.

Doppler radars use microwave signals to sense vehicles moving towards or away from the radar and are able to detect vehicle speed. True-presence radar measure distance to a target (range) which may be moving or stopped and can be used to detect vehicle presence.

Acoustic vehicle sensors may be active or passive. Active acoustic sensors are gantry mounted and use sound waves they generate onto trafficked lanes in order to determine vehicle presence. They are used for vehicle counting and classification purposes. Passive sensors detect noise generated by tyres or winds generated by passing vehicles and are used for traffic flow and speed monitoring. Evaluations to date have indicated unacceptable performance.

Photoelectric sensors, laser or infrared sensors detect presence or absence of light that the sensors generate across or above trafficked lanes and are used to detect vehicle presence, over-height vehicles, speed and in vehicle classification.

The reliability and accuracy of all these sensors depends on the application and environment in which they are used. Non-invasive sensors provide some advantages in the areas of installation and maintenance. These activities may be performed without the need for lane closures. These sensors may also be configured easily for changes in location or detection zones via configuration software.

However, these sensors are also more prone to vandalism and damage due to their high visibility. They also add to additional furniture on the roadside.
3.2 Physical components

- Vehicle detecting sensors (usually inductive loop sensors)
- Vehicle detector electronics
- Controller cabinet
- Conduits required for power and communications, and
- Maintenance access.

Often, vehicle detectors are installed as part of a broader ITS application. In these instances, the sensors may interface to the ITS controller, communications and power.

3.3 Typical layout

The following sketch, Figure 3.3 illustrates a typical VDS installation in a motorway application. Further information is contained in the TRUM Volume 4, Part 5.

Figure 3.3 - Vehicle Detection Stations layout in a motorway application
3.4 Implementation considerations

3.4.1 Loop installation

Cut-in loops are installed in the asphalt after paving operation. If open graded asphalt is used, the loops need to be installed in the dense grade asphalt before the final overlay. Preformed loops require installation before concreting or paving operation.

- **Limitations**: Inductive loop tail length, from the field to the cabinet where the detector unit is housed, must not exceed 200 metres.
- **Lane closure**: Lane closure is necessary when installing inductive loops or other in-pavement sensors. Traffic control deployment to facilitate their placement is required.
- **Future widening consideration**: Future roadway widening should be considered when positioning detector equipment, sensors, and associated underground infrastructure.
- **Placement and line marking**: Exact loop coordinates (eastings and northings) need to be established as part of the design and subsequent line marking. Loops, especially preformed loops, may be rendered ineffectual, depending on application, if line markings do not take into account the exact loop positions.
- **Reinforcing steel**: Concrete pavement reinforcement can affect operation of detector loops. The minimum distance between the loop and reinforcement that allows proper loop operation needs to be verified with the loop manufacturer.
- **Pavement type** can also affect the operating performance, installation and maintenance of loops, for example, asphalt, concrete, chipseal.

3.4.2 Location and frequency

Vehicle detector stations shall be located at each motorway interchange to allow detection of both mainline and on / off ramp traffic. At an interchange, the VDS may be integrated into a ramp metering system (RMS), or some other ITS application. Preferably, detection devices should be located in situations that have minimal vehicle weaving movements. Shorter separation should be used for bridges and tunnels.

In a motorway application, VDS placement is dictated by the needs of the system. Further details are provided in *TRUM Volume 4, Part 5* and the managed motorways ITS placement guidelines (pending publication – contact the department’s Network Operations and Performance unit).

3.4.3 Detector type for required application

The detection technology should be suitable for the required application. Technology adopted must best offer accuracy and reliability under the road conditions expected.

3.4.4 Automatic vehicle location / identification

In-pavement sensors may be used in conjunction with vehicles that have specially fitted transmitters in order to derive location of the vehicle. This may be for the purposes of real-time passenger information system or public transport priority scheme implementation. These detectors should be placed strategically at entrances, exit points and other points along the route of the target traffic. On-board computers with GPS, as well as GSM / GPRS / 3G connectivity, sometimes called transport personal computers, are increasingly being used for this purpose. In future, this technology may reduce or eliminate the need for in-pavement sensors for these applications.
3.4.5 Real estate

Field cabinets must be installed to allow easy and safe access for maintenance and should ideally be located on the outside verge. Direct access to power and communications links should also be considered. Limitations exist in positioning field cabinets away from the sensors. When long structures are involved, special consideration must be given to accommodate installing field cabinets on the structures. Refer also to Section 16.

3.4.6 Rural vehicle detection: minimal intervention

A rural vehicle detection station design should require minimal maintenance and user intervention. Pavement depth should be verified if in-pavement sensor technologies are under consideration in low depth seals.

3.4.7 Urban vehicle detection: future planning

Strategic planning of VDS designs in urban areas may prove most useful when provisioning for future expansion. This includes both the detection devices and the real estate required for these devices. The roadways design should include real estate for poles, cabinets and other roadside furniture, in order to reduce future expansion / relocation costs.

3.4.8 Detection on structures

Sensors or detectors shall in no way violate the structural integrity of the members or road furniture on which they are mounted.

In-pavement sensing may not be possible at a bridge and roadside detection needs to be considered. Stick-on detector loops may only be used for temporary applications (typically up to one week total duration). Detectors may be placed on bridge approaches to help minimise the restrictions that apply at bridge structures. Maintenance access shall be considered in the final location of devices.

Any existing pole or structure used for the mounting of sensors or detectors shall be inspected by a structural Registered Professional Engineer of Queensland (RPEQ). Any design using an existing pole or structure shall ensure the combined sensors or detector installation configuration is certified by a structural RPEQ for such characteristics including structural wind and mechanical loadings.

4 Vehicle counters / classifiers

4.1 Introduction

Vehicle counters / classifiers collect and record traffic volume and vehicle classification data. Classification may even be an additional feature of the vehicle detection systems described previously.

Classification may be done on the basis of speed, vehicle length and/or number of axles. Austroads 12-bin classification bases classification on the number of axles and distance between axles or axle groups and has been widely adopted. The system accommodates vehicles and vehicle combinations with up to sixteen axles. Data capture may include lane of travel of each vehicle, accumulated counts by lane, date, time of day and classification. Four-bin classification is based on vehicle length. Road agencies in Australia and New Zealand are moving towards harmonising vehicle lengths for the various bins.
Vehicle counters / classifiers may rely on pneumatic tubes, detector loops, piezos, laser, infrared or radar technology. The latter three are non-intrusive and do not require sensors in the pavement. Pneumatic tubes are normally used for temporary applications.

### 4.2 Physical components

Vehicle counters / classifiers components may include:

- a data logging device capable of collecting, processing, storing and transmitting vehicular data
- axle sensors to detect vehicles, vehicle speed, axle counts and axle spacings – the sensors may be pneumatic tubes, loops, or piezoelectric sensors
- communications interface to allow local / remote connectivity
- field cabinet and all necessary interconnecting cables and miscellaneous materials to make an operational system, and/or
- maintenance access.

### 4.3 Implementation considerations

Where classifiers are not installed on existing roads, they should be provided during the planning phase of respective road projects. This will enable effective data collection which will further inform project decisions.

A conduit system should be designed for the connection of power and telecommunications to vehicle count / classifier site.

For motorways, classifiers should be placed on both carriageways midway between all interchanges. Off-pavement classifiers such as the infrared based units may suffer from occlusion during periods of heavy traffic and accuracy may degrade as a result. Roadside equipment may need realignment periodically since it is less immune to vibrations.

### 5 Closed Circuit Television systems cameras

#### 5.1 Introduction

Closed Circuit Television (CCTV) systems provide a means by which road agencies may effectively monitor the road network, detect and respond to incidents. Figure 5.1 shows a camera arrangement typically adopted for roadside CCTV coverage. The main components in the field site on a roadway include an ITS field cabinet, camera pole and base and the camera and mount.

Real-time CCTV coverage allows Traffic Management Centre operational staff to immediately identify incidents as they occur as the time with which an incident is detected / verified affects the time with which it is responded to and effectively managed to minimise the amount of disruption to the traffic flows as a result.

Refer to MRTS225 *Imaging* specification for details on the design, supply, installation, testing and commissioning, performance, documentation, training and maintenance requirements of imaging infrastructure / services for ITS network applications.
Typical incident verification includes:

- confirming that an incident has occurred
- determining the exact location and direction of travel, and
- obtaining and assessing the nature and as many additional details about the incident as possible.

Operators are able to verify the incident, carry out an initial assessment of the incident severity and estimate the resources needed to respond to the incident (for example, emergency vehicles).

CCTV technologies are increasingly being used for automatic incident detection (AID), especially in tunnel environments. The video image processing system can prompt the traffic management centre operator via tunnel operational management systems, should an incident be detected. AID may address incidents such as smoke presence, stationary vehicle, unauthorised pedestrian crossings, fallen debris, any vehicle travelling in the wrong direction, tailgating or sudden speed changes in the monitored zone. AID reduces reliance on traffic management operators for incident detection. This is important to promote reliable and fast incident detection.

IP cameras have found use in applications such as posting of motorway traffic video images on the internet as part of a traveller information service. In this application, cameras give travellers the privilege of viewing road network conditions at points of interest before embarking on their journeys. Bandwidth considerations and privacy issues may require that such images be of low resolution. Webcams may also be used to verify images displayed by electronic road condition signs, or at sites with low bandwidth and/or slowly / infrequently changing images.

Video images can also be used to assist in maintenance operations.

CCTV capability within tunnels is typically integrated into the local plant, control and management systems to provide greater situational awareness to the operators. For example, the fire, life and safety system may be integrated with the CCTV system, such that operators are provided with a visual
alarm when a critical system, such as the deluge or egress pressurisation system, has been alarmed or activated.

5.2 Physical components

The equipment required to implement a closed circuit television or web camera subsystem includes:

- cameras mounted on existing structures such as overpasses, fixed and swing poles, or the rooftops adjacent to the corridor to be monitored – ideally, the cameras should be capable of vertical and rotational movement with zoom capabilities (pan, tilt, zoom, or PTZ which is not a requirement in most web camera applications)
- controller cabinet
- conduits for power and communications
- maintenance access, and
- lightning protection.

5.3 Typical layout

Usually, CCTV cameras are mounted on a pole or a fixed structure. If a tilt pole is used, an area on the outer verge is needed to tilt the pole safely without affecting traffic. Refer also to Section 16.

A typical layout for CCTV in a motorway application is shown in Figure 5.3.

Figure 5.2 - Closed Circuit Television layout in a motorway application
5.4 Implementation considerations

5.4.1 Location

Cameras are typically installed off the travelled portion of the roadway such that all segments of the motorway system are within view. As a minimum, there should be CCTV coverage for traffic through the carriageway (including underpasses), emergency stopping bays, entry and exit ramps and associated intersections.

Finding a good CCTV location requires extensive investigation of the proposed camera locations. For example, the CCTV camera should be located and aimed to minimise direct exposure towards the rising and setting sun. Furthermore, the CCTV camera should not be mounted or pointed at roadway lighting luminaries. If the CCTV camera mounting height is similar to roadway luminaries, the luminaries may be equipped with light cut-off shields to prevent the camera from looking directly at the luminaries. Effects of existing or proposed signage, structures, vegetation (including future growth) and road geometry need to be considered.

Cameras should be located such that each camera can view the entire carriageway(s) through to the chainage of the next upstream and downstream camera. In all cases, the maximum separation shall be 1000 m.

Web cameras should be positioned so as to give a broad view of traffic on the road network but not allow facial recognition of road users or vehicle number plates.

Refer to MRTS225 \textit{Imaging} for the general location of cameras which are monitored by other road agencies such as the Busway Operations Centre (BOC).

5.4.2 Structural mounting of Closed Circuit Television

Any existing pole or structure used for the mounting of sensors or detectors shall be inspected by a structural RPEQ. Any design utilising an existing pole or structure shall ensure the combined sensors or detector installation configuration is certified by a structural RPEQ for such characteristics including wind and mechanical loadings.

5.4.3 Pole type

There are a number of different mounting methods and poles available for CCTV cameras:

- Fixed pole mounting requires both the provision of bucket trucks for maintenance, and the availability of access for the truck without blocking traffic flow.

- A swing pole removes the need for a bucket truck for maintenance. The pole can be swung down to allow access to the camera. Orientation of the swing direction must be such that safety is maximised and ideally should not require road or lane closure, that is, the swing pole arc shall not impinge into any traffic envelope when it is swung down for camera maintenance or installation purposes, and

- Mounting on a building or fixed structure (such as bridge, busway station / stops or tunnel) must allow safe access for maintenance personnel and their vehicles.
5.4.4 Vibration

Vibrations limit the extent of a CCTV camera's view. A number of factors contribute to vibration:

- mounting height (specifically, the height of mounting on pole)
- mounting configuration, and/or
- wind exposure and the amount sail area of the camera and mounting arrangement.

It should be noted that the amount in which the camera is zoomed-in will amplify or attenuate the apparent vibration effects. Where available, cameras with image stability control compensation or equivalent internal image processing functionality shall be used.

Camera poles must meet dimensions specified in the respective Transport and Main Roads drawings and secure mountings must be used for fixing cameras.

5.4.5 Public misconception

The installation of CCTV cameras may often be considered negatively by the public. This is often due to the misconception of the camera's purpose such as law enforcement, invasion of privacy and so on and may require public consultation / education. However, in some cases Queensland Police Service (QPS) officers may formally request video footage from the department's CCTV system for incidents that may have occurred, that is, assaults or other illegal activities conducted on public property such as at busway stations, bus stops or any other public infrastructure owned by Transport and Main Roads which has CCTV coverage.

5.4.6 Communications limitations

Video data typically requires high-bandwidth communications. Communications limitations and the cost to overcome these limitations can be difficult to resolve. The camera should be positioned within range of higher-speed network connections, wherever possible. Extension of the Transport and Main Roads ITS telecommunications network should be considered in all projects.

Web or IP camera images, as in the examples stated previously, need to be updated at regular intervals and the communications link should be suited to the particular application.

However, they typically have lower resolution and refresh rates (and therefore lower bandwidth requirements) than live CCTV and may be considered for special applications in lieu of CCTV.

5.4.7 Closed Circuit Television network security

All CCTV cameras and associated network-enabled equipment shall allow for operations, administration and maintenance access functions to be securely performed through the application of credential-based authentication, that is, username and password access accounts. The username and password credentials shall comply with the States’ information security standard (IS18).

All CCTV cameras and associated network enabled equipment shall also be deployed with the latest version of firmware provided by the respective product vendor or manufacturer.

5.4.8 Closed Circuit Television network design

All additional CCTV system capacity shall be seamlessly integrated into the existing ITS communications network and CCTV infrastructure and comply with the requirements of MRTS245 ITS Telecommunications Network (ITS TN) and MRST225 Imaging respectively.
6 Road weather monitoring

6.1 Introduction

Road weather monitoring stations (RWS) supply valuable information regarding the state of road weather conditions and are an important element of improving traveller safety.

Road weather stations monitor conditions such as pavement temperature, precipitation rate, wind speed and wind direction. This information may be transmitted to a Traffic Management Centre (TMC) and/or a suitable warning message displayed on selected VMS. Speed limits may be varied accordingly in response to precipitation, wind speeds or other conditions as monitored by the environmental sensors.

6.2 Physical components

- Road weather detector, with in or off-pavement components
- Mounting pole
- Field cabinet
- Conduits for power and communications as necessary, and
- Maintenance access.

6.3 Typical layout

An area is required on the outer verge for the pole and field cabinet. Given the traveller safety aspect of RWS, the field equipment should be protected by barriers. If tilt / swing poles are used, space is required to allow the pole to tilt safely such that the swing arc does not encroach into any pedestrian or roadway traffic envelope. Safe vehicular and pedestrian access for maintenance is required, preferably from a service road.

When monitoring road flooding conditions, the sensors would more likely be installed on the bridge columns. It is desirable to install such sensors with a stilling tube on the downstream side of the water flow. This would provide protection for the sensors from moving debris. Consideration should be given to a robust conduit system to route power and/or communications cables to the sensor from the field cabinet. It is necessary to install the field cabinet in a location where it would not be subject to flooding to protect any devices from water damage.

6.4 Implementation considerations

If possible, field equipment should be integrated with other roadside features, for example, landscaping, signs, structures and so on.

Location should best promote measurement of the weather condition(s) of interest.

Communication facilities and infrastructure need to be assessed while appraising the eventual location of the monitoring station. Full redundancy of sensors and supporting infrastructure may need to be considered depending on the functional safety requirements of the weather monitoring system. Cameras may also be considered to enable verification at all times of day / night.

7 Help telephones

Further information is contained in TRUM Volume 1 – Guide to Traffic Management, Part 9 – Traffic Operations, Section 5.1.6-1: Help phones (roadside emergency phones). Wherever practicable, emergency stopping bays must be provided for help phones.
7.1 **Purpose**

Motorists involved in an accident or stranded with a disabled vehicle may require help or assistance. Help phones play an important role in improving traveller safety and security. They provide a means of establishing direct communication with traffic management centre operators. For example, travellers may request for tow trucks or emergency services via a call centre. If the motorist suffers personal injury, medical personnel may be dispatched quickly and efficiently to the scene, increasing the motorist's chance of survival. In the event of a disabled vehicle blocking lanes of traffic, a tow truck can be dispatched to the scene to assist in the repair or removal of the disabled vehicle. In both instances, quick and efficient dispatch of resources is critical to reducing congestion and improving public safety.

In urban / motorway environment, help phone locations must be provided with CCTV surveillance.

7.2 **Physical components**

Help phones usually require:

- telephone suited for roadside environment
- mounting pole / structure
- access to telecommunications network (Transport and Main Roads or leased), and
- emergency stopping bays, in which a vehicle can safely stop.

Additionally, the help phone may benefit from lighting (can be solar powered if mains power is impracticable). Lighting is highly desirable as it enhances safety of users especially in unlit and rural road environments.

7.3 **Typical layout**

Requirements for help telephones are detailed in TRUM Volume 1, Part 9 Section 5.1.6-1: *Help phones (roadside emergency phones)*. Concerning the placement of field equipment and the supply of maintenance access, refer to Section 16.

Sufficient land must be allocated to accommodate the following help phone configurations:

- Local widening should be considered in tunnels for stopping bays.
- Wherever practicable, for carriageways containing three or more lanes, help phones should be placed in the medians to avoid the need for motorists to cross multiple lanes. Stopping bays and/or localised widening must be provided to enable safe parking and pedestrian access to use help phones without protruding into any traffic lane.
- Wherever practicable, for carriageways containing two lanes and a hard shoulder, or intended for future three lanes, provision should be made for help phones in the median. Stopping bays and/or localised widening must be provided to enable safe parking and pedestrian access to use help phones without protruding into a running lane.
- Wherever practicable, help phones shall be aligned to within 50 m across both carriageway directions. There shall be one or two median phones depending on access from both carriageways.

Road crossing conduits for both power and communications cables must be provided between the median and the outer verge of the roadway. A typical layout of help phones is illustrated in Figure 7.3.
Figure 7.3 - Help phone layout in a motorway application

7.4 Implementation considerations

7.4.1 Installation

Installation of a help phone facility on an existing roadway may be more difficult than greenfield installations because the space available may not be adequate to provide protection for motorists using the help phone.

Footings need to be installed in new locations. Existing phones may need to be relocated in accordance with the requirements of sequencing of road construction works. A wide carriageway would require three or four help phones aligned to no more than 50 m from each other as measured longitudinally.

Colocation of help phones with other ITS devices where possible makes installation and maintenance more cost effective.

Consideration must be given both to the location and frequency of help-phone installation.

7.4.2 Frequency

Spacing between help phones should be such that travellers may access the help phone safely, with relative ease and within reasonable time. In urban situations, help phones should be placed every 200 m to 1 km, with closer spacing used in areas of heavy traffic. In rural situations, spacing of 2 km to 5 km may be adequate, depending on the circumstances. Placement frequency within tunnels is discussed in Section 15.

7.4.3 Safety and access

The help phone should be located in a protected area where the motorist may safely access the help phone without the threat of personal injury. Emergency stopping bays are required if shoulders are less than 3 m wide. This may involve widening certain parts of roadway / tunnel. Lighting and CCTV coverage around the help phone would also improve safety and security.

Help phone provision shall conform with requirements of the Disability Discrimination Act 1992 (DDA). People with a disability shall be afforded equal access to phones.

7.4.4 Communications

Unless otherwise specified, a conduit system will need to be designed for connection of the phones to the ITS network as necessary. All communication cabling shall be in accordance with MRTS234 Communications Cables. All pits and conduits shall be in accordance with MRTS91 Conduits and Pits.
8 Variable Message Signs

8.1 Introduction

Variable Message Signs (VMS) are an essential element of traveller information systems and are used to provide advance information to motorists. The information provided to motorists by a VMS should assist them in making informed choices about routes and travel modes.

VMS may also be placed at the beginning of steep slopes or at tunnel entrances to draw attention when safe passage may be compromised.

VMS messages are advisory rather than regulatory in nature and relate typically to:

- accidents / incidents
- congestion
- roadwork
- weather-related conditions
- special events
- road safety messages, and/or
- general transportation messages.

Figure 8.1 shows a VMS mounted roadside and typical message.

*Figure 8.1 - Variable Message Sign*

8.2 Physical components

A VMS implementation may consist of:

- a sign enclosure
- maintenance gantry
- support structure and footings
- equipment enclosures
- field cabinets and footings
- VMS display
• power supply
• communications
• electrical systems
• control systems, and/or
• maintenance access.

8.3 Typical layout

VMS location factors are essential to obtain maximum visibility and observance. The sign location must be suitable to the design features and alignment of the roadway. The location must also conform to TRUM and MUTCD requirements, VMS implementation standards and safety factors concerning fixed obstacles near the roadway. Figure 8.3 illustrates examples of a motorway application of VMS.

An area is required on the verge for the sign column / gantry and field cabinets. Safe access for maintenance personnel is required. Refer to Section 16.

Figure 8.3 - Variable Message Signs layout in a motorway application
8.4 Implementation considerations

The following issues should be addressed in the implementation of a VMS.

8.4.1 Size of sign

The size of the sign will typically depend on the speed of traffic on the adjacent roadway. This information is shown in Table 8.4.1.

Table 8.4.1 - Character size in relation to speed and sighting distance

<table>
<thead>
<tr>
<th>Type</th>
<th>Speed (km/h)</th>
<th>Min sight dist.</th>
<th>Min character height</th>
<th>Border width</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>&lt; 60</td>
<td>100 m</td>
<td>150 mm</td>
<td>125 mm</td>
</tr>
<tr>
<td>B</td>
<td>60 &lt; 90</td>
<td>160 m</td>
<td>330 mm</td>
<td>185 mm</td>
</tr>
<tr>
<td>C</td>
<td>&gt; 90</td>
<td>250 m</td>
<td>400 mm</td>
<td>220 mm</td>
</tr>
</tbody>
</table>

Other considerations such as sight distance and consistency along the route may also influence on the size of the sign.

8.4.2 Sign location

VMS may be placed roadside or overhead. Ideal sign locations are determined by a number of factors and are detailed in TRUM Volume 2 – Guide to Road Safety. Some of these factors include:

- minimum distance between signs
- distance before decision point
- frequency of signage
- lateral location and height, and
- aiming the sign.

All VMS locations should conform to the requirements of the MUTCD, the RPDM (2nd Edition) Volume 3, Part 3 – Geometric Design in relation to sight distance, and TRUM Volume 2.

8.4.3 Cabinet, pole and footings

For the design and positioning of the cabinet and pole, refer to Section 16. The mounting method should permit adjustment in the vertical plane of the VMS enclosure about its horizontal axis for ±5°. A suitably sized cabinet can be integrated at the base of the VMS structure. VMS mounting structures must comply with the requirements of the relevant Australian standards regarding wind loadings for the installed location.

8.4.4 Variable Message Signs services

Given the significant electrical load, connection to mains power and a telecommunications link should be provided to VMS sites.

8.4.5 Public consultation

In areas that are likely to be sensitive to the visual impact of VMS installation, public consultation may be required.
9 Changeable Message Signs systems

9.1 Introduction

Changeable Message Signs (CMS) offer the ability to activate or alter signs at different times or in different conditions.

Only a limited number of pre-determined messages can be displayed on a single CMS; these messages are usually short and simple. MUTCD approved signs (for example speed limit signs) can also be displayed.

Some CMS applications may provide travellers with information to assist them in making informed choices about routes and travel modes; for example, indicating to expect delays ahead.

CMS come in a variety of different forms such as:

- The simplest form of CMS is a sign that becomes active when lights are flashing. This may be used, for example, in a Ramp Metering System (RMS), where motorway entry becomes restricted at different times of the day.
- Revolving drum signs contain a small number of simple messages; the message displayed changes as the drum inside revolves, and
- In situations where it is desirable for MUTCD approved signs to change in value (for example, speed limit changes in peak-hour traffic), a tri-vision CMS can be used. A tri-vision CMS contains a number of revolving triangular prisms, allowing three different sign values to be displayed.

9.2 Physical components

A CMS implementation may consist of:

- support structure and footings
- equipment enclosures
- field cabinets and footings
- Changeable Message Sign
- power supply
- telecommunications, and/or
- maintenance access.

9.3 Typical layout

Figure 9.3 illustrates a motorway application of CMS.
Figure 9.3 - Changeable Message Signs layout in a motorway application
9.4 Implementation considerations

9.4.1 Decision time

Some CMS applications are designed to provide motorists with information to assist them in making informed choices about routes and travel modes. Longitudinal placement should allow travellers adequate decision time before reaching the critical decision point (such as the turn-off to an alternative route). Refer to the RPDM (2nd edition) Volume 3, Part 2 – Design Considerations.

9.4.2 Sign design

Changeable message signs can display a variety of different messages. Consideration will need to be made as to the message length and the size of the sign and lettering in accordance with the MUTCD requirements.

9.4.3 Power supply

CMS applications require a power source. In remote situations, where the installation of power services may be costly, alternative power sources (such as solar power) may be desirable, providing that the risk of theft, vandalism or failure is low. Due to their nature, CMS typically have low power consumption and are well suited for solar power applications.

The default message displayed on the sign in the event of a communications, power or sign control failure should also be considered.

9.4.4 Real estate

An area is required on the verge for the sign column and field cabinets. Safe access for maintenance should be provided. For more information, refer to Section 16.

10 Road condition information signs

Road condition information signs (RCIS) are a variant of CMS and/or VMS. They are placed at strategic locations on the road network and show the state of passage of road segments of interest to the motorist. These roads may be subject to occasional flooding or load restrictions.

Each sign may consist of a number of variable message signs or modules with each module showing whether a section of the road is open, closed or subject to conditional access such as load limits that may be imposed due to environmental conditions.

Operators should be able to update the status of the road segment remotely from the Traffic Management Centre. The message signs may be monochrome or multi-coloured. A network access sign example is shown in Figure 10.
10.1 Physical components

A RCIS implementation may consist of:

- a sign face complete with variable message signs
- support structure and footings
- field cabinets and footings
- power supply including solar power
- communications
- electrical systems
- control systems, and/or
- maintenance access.

10.2 Typical layout

As with VMS, location factors are essential to obtain maximum visibility and observance. The sign location must be suitable to the design features and alignment of the roadway.

An area is required on the verge for the sign assembly and field cabinets. Safe access for maintenance personnel is required.

10.3 Implementation considerations

Installation of RCIS must comply with requirements of the MUTCD and Transport and Main Roads standards on road furniture. The following issues should be addressed in the implementation of a RCIS.

10.3.1 Size of sign

The message sign module character sizes will depend on the speed of traffic on the adjacent roadway. The character sizes given for VMS in Table 8.4.1 also applies to RCIS. In addition, the sign shall also comply with the requirements of the MUTCD.
10.3.2  Sign location

The RCIS location must conform to MUTCD requirements and safety factors concerning fixed obstacles near the roadway and the RPDM (2nd edition) Volume 3, Part 3.

The sign must be strategically located before a decision point, ahead of the road segments where road closures or load restrictions are a common occurrence.

10.3.3  Number of modules per sign

Consideration must be given on the maximum number of message modules each sign should have in order to avoid driver information overload.

Consideration for information overlap should be made for signs placed consecutively along the decision points.

10.3.4  Legal implications

The information provided by RCIS is advisory but may have legal consequences to the road agency. The default message display, if any, in the event of loss of communication with the Traffic Management Centre needs to be considered. A fail-safe situation will be to blank-off the sign display in the event of loss of communication with the TMC or other problems affecting the displayed message.

10.3.5  Functional safety

The signs need to meet the functional safety requirements of AS 61508 Functional safety of electrical / electronic / programmable electronic safety-related systems Set.

11  Variable speed limit / Lane control signs

Speed limits may be changed in line with weather or other traffic conditions. Speed limits may also be varied to allow maintenance activities or as a way of easing congestion in adaptive speed control systems. Periodic speed limit changes are required in school zones. These ITS applications have increased the need for active variable speed limit signs (VSLs).

Speed zone establishment is done in line with provisions of the MUTCD (AS 1742 Manual of Uniform Traffic Control Devices Part 4 Speed Controls).

A VSL may have dual function in that it may be a VSL as well as being a lane control sign (LCS). A lane control sign is used to indicate if a traffic lane is open / closed / closing to approaching traffic. Figure 11 shows a typical VSL / LCS configuration in a motorway.
**Figure 11 - Variable speed limit / lane control signs application**

- **VSLS/LCS** at entrance ramp
- **VMS at beginning of speed zone**
- **Vehicle detector loops**
- **Ramp**
11.1 Physical components

A VSL / LCS installation may consist of

- a sign enclosure
- support structure and footings
- maintenance and access for signs and installation
- field cabinet housing group controller as necessary and other equipment
- power supply
- communications.

11.2 Typical layout

VSL / LCS shall be mounted over the running lanes; VSLS shall be located on both sides of the carriageway. Provision of VSLS on gantries should be allowed for in any carriageway having (or expected to have) six or more lanes in a given direction. This must include any widening necessary to allow installation of gantry footings.

VSL / LCS display regulatory information and high visibility of the signs is essential. Sign design and layout must agree with provisions of MUTCD and TRUM. Supplementary static signage is required in conjunction with the end of the variable speed limit zone.

Placement of VSLS in a variable speed zone is detailed in TRUM Volume 1, Part 10 – Traffic Control and Communication Devices, Section 5.7-1. The median design should allow for gantries if VSLS and/or LCS are to be implemented.

A VSLS should be placed at each on-ramp where a variable speed zone exists on the adjoining motorway. Ramps with complex operation shall be considered for VSL / LCS application.

Placement of VSLS, VSL / LCS, VMS, VDS and other signs must be coordinated. It is beneficial if the reason for speed limit change is explained to motorists through use of VMS. Default speed signs should be installed on both the on-ramps and off-ramps in case of system failure of the variable speed limit signs on the mainline.

In giving consideration for possible future road widening, design allowance for hard shoulder running and/or segregation of lanes with differential speed limits should be made.

11.3 Lateral location and height

VSLS must be installed on the roadside; whereas VSL / LCS must be located above a lane. For arterial installations, overhead mounting depicted in Figure 11.3 is generally preferred. The minimum overhead clearance (from the road surface) should be 6.1 m.
11.4 **Size**

VSLS and VSL / LCS design requirements are similar to speed restriction signs (R4-1 series) except that the numerals are white within an illuminated red annulus on a black background. Size of the numerals will depend on the maximum approach speed of traffic on the roadway. Signs may be square, sized at the respective R4-1 sign width.

Part of the red annulus shall be flashed to signify a reduced / changed speed limit.

11.5 **Cabinet, pole and footings**

For the design and positioning of the cabinet and pole, refer to Section 16. VSLS and VSL / LCS installations must comply with requirements of Transport and Main Roads standards on road furniture.

11.6 **Variable speed limit / Lane control signs services**

Mains power and a communications link should be provided to VSLS and VSL / LCS sites. Colocation of VSLS and VSL / LCS with some ITS devices such as CCTV where possible, makes implementation more cost effective. Conduit systems should be designed for the connection of power and communications.

11.7 **Functional safety**

VSLS and VSL / LCS must meet the functional safety requirements including the safety integrity level (SIL) as defined in AS 61508 *Functional safety of electrical / electronic / programmable electronic safety-related systems* Set.

11.8 **Operational issues**

The VSLS and/or VSL / LCS must operate as described in *TRUM Volume 1, Part 10*, Section 5.7-1. Permanent VSL / LCS in construction and maintenance areas on motorways must be operated in accordance with AS 1742: *Manual of Uniform Traffic Control Devices*.

12 **Ramp Metering Systems**

12.1 **Introduction**

Traffic congestion occurs when travel demand exceeds capacity. Such congestion is a common occurrence on parts of the motorway network. Ramp metering aims to limit the number of vehicles entering the motorway from entrance ramps at specific periods of time so that motorway flow can be maintained. Excess demand is forced to wait at the entrance ramp.
Ramp metering uses three-aspect (red, amber and green) traffic signals at motorway on-ramps to control the rate of vehicles entering the motorway. The signals can be set for different metering rates to optimise motorway flow and minimise congestion.

Designers should consult with Transport and Main Roads’ Network Operations and Performance unit on the placement of loops on complex ramps. For further details on ramp metering, refer to TRUM Volume 4, Part 5 and TRUM Volume 1, Part 9, Section 8: Systems and procedures for smart motorways.

12.2 Physical components

Ramps are becoming more complex in design and operation. Further vehicle detection and infrastructure may be required than described following; however, a ramp metering system typically consists of various components. These are outlined in Sections 12.2.1 to 12.2.7.

12.2.1 Ramp metering signal lantern and controller

The lantern is typically located on both sides of the ramp or above the ramp carriageway. Each ramp metering installation typically has one nearby weatherproof control cabinet, which houses the controller and other communication equipment (for example, modem).

12.2.2 Advance warning signage

Advance warning CMS or static signs with flashing beacons may be used to indicate that ramp metering is active. For maximum benefit, the locations of these signs may be some distance away from the motorway ramp to allow traffic to divert in case the motorway is congested.

12.2.3 Presence detector

The presence detector (usually a loop detector) is located upstream of the stop bar. The presence detector notifies the controller that a vehicle is approaching the stop bar.

12.2.4 Passage detector

The passage detector is located downstream of the stop bar. The passage detector notifies the controller that a vehicle has passed through the stop bar.

12.2.5 Queue detector

The queue detector (vehicle detector) is located on the ramp, upstream of the presence detector. The queue detector is intended to manage spill over onto the surface street network. Once ramp queues begin to spill onto the surface street, the metering rate may be relaxed to allow the queue to dissipate.

12.2.6 Mainline detectors

Mainline detectors are located on the motorway upstream and downstream of the on-ramp in order to provide guidance on setting the ramp metering rate.

12.2.7 Services

A conduit system should be designed for the connection of power and telecommunications.

12.3 Typical layout

Figure 12.3 illustrates a typical RMS installation on a ramp. Not all components are always installed (that is, a bypass lane for High Occupant Vehicles (HOV) may not be required or possible in every location).
The geometric design of the entrance ramp will need to have sufficient acceleration and storage lengths for the expected traffic volumes. Ramp metering should be planned for every entrance ramp, though it may only be implemented in future.

Space is required on the verge for field cabinets. Columns for ramp metering signs should be protected by a barrier. Safe access for maintenance personnel is required, preferably from a service road. Refer to Section 16.
12.4 Implementation considerations

The roadway designer must face a number of considerations in the implementation of ramp metering. Some protection for future RMS installations (that is, in greenfield scenarios) can be accomplished by reviewing the following considerations:

- property acquisition to protect for the ultimate requirement of the bypass lanes and maintenance access and enforcement areas
- ramp nose locations and ramp radii which provide sufficient acceleration distance from a future stop bar and ultimately a safe transition to the mainline traffic flow
- sufficient queue length storage upstream of the stop bar to keep arterial roads clear and uncongested
- conduit system for both power and communications, especially at the stop bar location (that is, under-pavement duct crossing), are installed more economically while the roadway is under construction as opposed to once the roadway is existing, and
- loops may be installed while the road surface is being built or upgraded if RMS is imminent.

Ability to install future ramp meter bypass lanes should be considered on all metered ramps to enhance Transit Lane or HOV strategies. If a bypass lane is installed and metered, an additional presence loop and a passage loop may be required.

If RMS is being considered on existing ramps, consideration may be given to the acceptability of the acceleration length from stop bar to mainline, the ramp storage length (that is, to minimise spill-over onto surface streets), and the availability of property for equipment and maintenance access.

13 Weigh-in-Motion systems

13.1 Introduction

Weigh-In-Motion (WIM) systems improve the processing efficiency of commercial vehicles at inspection stations. A WIM system uses sensors installed on a roadway to measure the weight of moving vehicles as they pass over. These sensors may either be permanently installed in the roadway or used temporarily to inspect the weight of vehicles.

For example, a permanent WIM system installed in the approach to a truck inspection station (which caters to a heavy demand of commercial vehicles) can be used to measure the weight of the approaching trucks prior to their arrival at the truck inspection station scales. The WIM system may provide the truck inspection station personnel with the data to selectively focus on trucks which are potentially at risk for being overweight. This reduces congestion and truck queue lengths entering the truck inspection station. Long queue lengths (which extend onto the motorway gore area) reduce the safety of motorists by increasing the potential for vehicle collisions.

13.2 Physical components

WIM systems usually consist of:

- mat or piezoelectric strip type sensors (can be used both in permanent and temporary installations)
- lower speed lane (the technology for WIM systems is relatively mature; however, it is required that they be installed in locations where the trucks are travelling at lower speeds)
• special WIM zone pavement construction to maximise accuracy and pavement life
• Changeable Message Sign (CMS) for diverting the trucks
• a conduit system for power and communications
• controller cabinet
• maintenance access
• CCTV for monitoring, and
• heavy vehicle inspection station (optional).

13.3 Typical layout

A typical layout for a WIM system at a truck inspection station is illustrated in Figure 13.3.

Figure 13.3 - Weigh-In-Motion layout in a truck inspection station application

Sensor locations should be determined, and implications for pavement design assessed.

Space is required for the placement of field cabinets and WIM equipment. Safe access for maintenance should be supplied, preferably via a service road. Refer to Section 16. Further information about the inspection station can be found in Technical Note TN115 Signing and linemarking for heavy vehicle interception sites.

13.4 Implementation considerations

13.4.1 Installation

In greenfield installations, WIM sensors may be strategically located to optimise the truck inspection station. Provisions may be installed to accommodate the use of other ITS elements like CMS, CCTV or Automatic Number Plate Recognition (ANPR) systems used in conjunction with the WIM system.
CMS may be used to provide the truck driver with visual direction of where to proceed; for example, a potentially overweight truck is directed to the inspection station scales for a more accurate measurement. If the truck is underweight, it may proceed back onto the road network without stopping for inspection. Overweight trucks may also be directed to proceed back onto the road network without stopping for inspection if the inspection bay becomes full; therefore, consideration should be given to ensure adequate space is provided at inspection areas.

Designers shall verify the requirements of the WIM site with the department’s Heavy Vehicle Management branch.

### 13.4.2 Positioning

WIM systems should be installed in locations where trucks have the opportunity to safely slow down prior to passing over the sensors. Trucks braking whilst on the sensor may damage the sensor or produce inaccurate data. Excessive braking of heavy vehicles also have the potential to damage the road pavement. Special consideration for carriageway alignment shall be made in order to minimise truck dynamics, special pavement requirements and lane markings.

The system should be installed in a location where it does not directly cause congestion on adjacent roadways.

### 14 Automatic number plate recognition systems

ANPR systems use optical character recognition in order to capture number plate information. ANPR provides an accurate method through which journey time monitoring and overall network performance may be verified. ANPR may be used for enforcement in WIM applications and other policing duties.

ANPR systems may use inductive detector loops, laser or other sensors as part of the trigger mechanism for image capture.

#### 14.1 Physical components

The equipment required to implement an ANPR outstation may consist of equipment housed in a single unit that provides infrared illumination, video capture, character recognition and data transmission.

Other components include:

- conduits for power and communications
- maintenance access
- lightning protection
- detector loops / sensors as necessary
- field cabinets, and
- poles and gantries.
14.2 Mounting

The ANPR unit may be mounted on existing structures or road furniture such as overpasses, overhead gantries or poles. Figure 14.1 illustrates mounting arrangement for a roadside ANPR system.

The ANPR system for each traffic lane shall be installed in order to capture the vehicle front number plates.

Vertical clearance of the ANPR system should be a minimum of 6.1 m for overhead mounting.

Due to the operating nature, special attention shall be given to structures, mounting supports or poles to ensure that vibration effects are minimal.

14.3 Implementation considerations

14.3.1 Accuracy

Accuracy is a major issue with ANPR systems.

Vehicle number plates may not be located at the same position – their condition may vary significantly; for example, old, new, reflective, non-reflective and features may vary within a state and from state to state. Correct positioning of the ANPR system is crucial if high recognition rates are to be made possible. Over-the-road mounting promotes accuracy for most systems.

Headlamps and/or speed of travel may affect recognition. Use of detectors / sensors allows image capture to be done at roughly the same point and the camera system can be set to aim the position that gives best results.

14.3.2 Number of automatic number plate recognition sites

The number of ANPR installations required will depend on the application and the acceptable recognition accuracy. More than one ANPR system serving one lane may be necessary in cases where very high recognition accuracy is required. A single ANPR installation may be able to service one or more traffic lanes, depending on the technology.

Generally, the higher the mounting, the lower the recognition rates and the more ANPR installations are required for a given number of lanes.

Travel time and/or origin and destination applications will need at least two ANPR installations.
14.3.3 Maintenance

A design consideration that must be made includes provision of access to the ANPR installation. Maintenance should be made possible without the need for road closure.

14.3.4 Automatic number plate recognition services

Each ANPR system must be provided with mains power and telecommunication facilities to allow it to be connected to the ITS network. Bandwidth requirements will depend on the information the ANPR system is required to supply. If there is no requirement for a video image of the vehicle, bandwidth requirements will be low.

14.3.5 Legal issues

Number plate and owner information is protected under privacy laws and this stands in the way of rollout of possible ANPR applications. Privacy issues need to be resolved before any ANPR application is made. Anonymity may still be retained depending on configuration of the ANPR software system.

15 Tunnel systems

15.1 Introduction

The warrants of ITS applications within a tunnel must be evaluated against the tunnel length and operations. Further information is given in Austroads Guide to Road Tunnels.

There are initiatives aimed at standardising minimum tunnel safety and operational requirements. The European 2004/54/EC directive on minimum safety requirements for tunnels in the Trans-European Road Network lists the mandatory requirements for a tunnel exceeding 500 m in length. The department’s ITS and Electrical unit should be contacted concerning the applicability or otherwise of this directive. Considerations should include:

- Provision of normal and emergency lighting.
- Provision of emergency power supplies – redundant pad mounted power supply transformers fed from separate parts of the power grid shall be considered as part of the design to achieve high reliability and essential power supply shall be provided in the form of a sufficiently sized UPS with batteries located in a fully ventilated room within the tunnel electrical switch room to prevent build-up of explosive or hazardous gases.
- Automatic incident detection and/or fire detection – for incidents including but not limited to stopped vehicles, pedestrian detection, wrong way detection.
- Fire resistance of equipment and cabling (that is, LSZH jacketed cabling).
- Emergency stations at least every 250 m, equipped with help phone / point and at least two fire extinguishers.
- Road signs for all safety facilities provided.
- Provision of an air quality monitoring and ventilation system.
- Provision of a tunnel egress passageway differential pressurisation system which is based on the use of variable speed drives to control air pressure – fixed speed axial fan and mechanical damper based solutions shall not be used as these require significant maintenance due to the large quantity of mechanical louvers and associated mechanical drive mechanisms.
• Provision of deluge system where required by the respective project fire engineering design brief.
• Emergency public AM / FM radio messages for tunnel users.
• Where there is a tunnel control centre, ACMA-compliant radio re-broadcast for private, trunked and emergency services mobile radio repeaters is mandatory for tunnels exceeding 1 km in length and carrying at least 2000 vehicles per lane per day.
• ACMA-approved Public Mobile Phone Re-broadcast for general public mobile communications.
• Public address system (including any associated egress passageways), emergency assembly / rendezvous points or and any other areas required by Transport and Main Roads.
• All systems shall run autonomously in local mode via locally based redundant PLCs but be fully integrated with any existing Transport and Main Roads head end systems of the monitoring entity as described in the ITS functional design. The integration shall allow Transport and Main Roads head end systems to:
  − receive monitoring and alarms from all tunnel PLC-connected devices and local tunnel systems (including the F&LS, lighting systems)
  − perform remote override local control functions, and
  − allow the trending, logging and reporting of all alarms and events received.

15.2 Physical components

A tunnel may be equipped with the following ITS elements:
• Vehicle detection devices to monitor the speed, direction and flow of traffic approaching and through the tunnel (inductive loop, video, microwave, radar based detectors).
• All cables within a tunnel shall be of the type LSZH.
• Closed circuit television CCTV (typically fixed cameras), mounted on walls or on the roof to provide video imagery both inside and outside the tunnel – this may allow traffic management operators to visually assess incidents inside the tunnel and to more efficiently deploy the appropriate emergency services and, if tunnel length can justify, the tunnel may be equipped with video-based automatic incident detection (AID).
• Help phones with appropriate access and user protection.
• VMS upstream and at the tunnel portal to display tunnel status messages based on the traffic data; for example ‘Traffic in tunnel stopped’; ‘Tunnel Closed’; ‘Right lane closed inside tunnel’.
• VSL / LCS to display the regulatory speed where adaptive speed control is in place.
• Portal warning lights may be used in conjunction with VMS to advise motorists the state of passage of the tunnel.
• Lane control signs to open or close individual lanes of traffic.
• Over-height sensors installed before the tunnel portal to detect trucks that exceed a height above which safe passage through the tunnel is compromised.
• Changeable message signs upstream of the tunnel for over-height protection or emergency gate access – a CMS may redirect the truck to an alternative route.

• Physical barriers (such as gates) for closing the tunnel, controlled remotely and/or locally – when controlled remotely, they can be opened in advance of responding vehicles arriving on the scene to increase response times during incidents and generally, the barriers are monitored for safe conditions using CCTV while opening and closing.

• Field cabinets to house the communications equipment, CCTV control, detectors, VMS control equipment and the like.

• Applicable sensors to monitor tunnel systems (communications, illumination, air quality, visibility, ventilation, and so on), and

• Tunnel control room, fire control room (preferably outside the tunnel envelope) that has:
  − easy access at all times, especially in emergencies
  − vehicle access, and
  − good ventilation and/or air conditioning.

The control and monitoring of such systems / equipment is typically interfaced with ITS / Traffic Management Systems.

15.3 Typical layout

A typical tunnel layout for an ITS installation in a motorway application is shown in Figure 15.3.
Figure 15.3 - Typical tunnel layout
15.4 Implementation considerations

15.4.1 Vehicle detector stations

Vehicle detection may be installed at significantly shorter intervals than 500 m to ensure quick and accurate detection of the traffic flow through the structure (refer to Section 3). If off-pavement sensors are used, they should be resilient to low light levels and the effect of reflection on the tunnel walls.

15.4.2 Help phones

Help phones should typically be located at or a short distance outside the tunnel portal and intermittently along the tunnel (both directions), depending on the length of the tunnel.

The frequency and placement of help phones within the tunnel should allow motorists to access them within a reasonable time. Typically help phone spacing is every 120 m. If possible, these phones should be placed near fire hose reels or hydrant cabinets.

Both the help phone and the motorist using it should be protected from any moving vehicles. Local widening should be provided as necessary. The phones and their respective access should be clearly marked. Phones with both audio and visual stimuli may be necessary in the louder tunnel environment. Provisions to assist the blind such as by way of tactile paving leading to the location of the phone shall be made.

15.4.3 Variable Message Signs

VMS may be located within the tunnel, at (or in advance of) the tunnel portal. Enough distance should exist between an upstream VMS and the tunnel to allow motorists to respond to any appropriate messages. If visibility is limited within the tunnel (due to the horizontal alignment or changes in elevation), a VMS should be located within the tunnel, capable of warning motorists of congestion or incidents ahead. VMS illumination intensities will need to be adjusted to suit the darker tunnel environments. For more information on VMS deployment, refer to Section 8.

15.4.4 Closed Circuit Television cameras and automatic incident detection

CCTV cameras are useful for monitoring incidents such as congestion in and around the tunnel, and for verifying the accuracy of images or messages displayed on VSLs or VMS. Pan / Tilt / Zoom features are especially useful on the outside of the tunnel. Even if the Pan / Tilt features are not needed within the tunnel, the Zoom feature may be useful. AID requires that cameras be placed close enough to allow adequate coverage of the kinematic envelope and other areas of interest.

Camera location (either on the tunnel wall or suspended from the roof) should be low enough to avoid the initial smoke layering in the event of a fire but must remain outside the kinematic envelop of the tunnel.

Mounting must take into account the position of fixtures such as overhead cable trays, tunnel lighting luminaries and support structures.

Camera positions must be such that focus on strategic or safety critical items is maintained or is obtainable on demand. Such items or areas include passenger entry and exit points, egress tunnels entry / exit points, control, communications, ITS equipment rooms’ entrances, help phone and fire control points.

Refer to MRTS225 Imaging for CCTV technical and integration requirements for Transport and Main Roads infrastructure.
15.4.5 Traffic signals

Traffic signals may be located at the portal entrances, and within the tunnel. Mounting arrangements within tunnels should ensure visibility of the signals and allow motorists to stop as required. Stopping sight distances should be in accordance with AS/NZS 1158.5:2007 Lighting for roads and public spaces – Tunnels and underpasses and should take gradients into account. Placement of traffic signal posts and respective pits must comply with the requirements of the MUTCD. Dual use poles may have other ITS devices such as CCTV cameras or off-pavement detectors mounted on them. Electrical and communication cabling must remain segregated.

15.4.6 Public address systems and Highway Advisory Radio

Public address (PA) systems and Highway Advisory Radio (HAR) can be used to warn travellers of tunnel conditions well in advance of the tunnel. Radio re-broadcast with emergency message break-in capability shall be provided in tunnels. Re-broadcast of traffic data radio signal shall also be provided.

15.4.7 Global Positioning Systems

Static Global Positioning Systems (GPS) beacons shall be provided throughout in tunnels longer than 500 m to provide uninterrupted GPS signal.

15.4.8 Mobile phone re-broadcast system

Mobile phone reception shall be sustained inside tunnels. Provision for mounting additional antennae must be made in the design. Antennae should not interfere with the kinematic envelope of the tunnel. Liaison with mobile telephone service providers is required. Independent third party mobile telecommunications service providers typically alternate responsibility for the provision of mobile re-broadcast within tunnels for the major carriers. The following items should be taken into consideration for a tunnel mobile phone re-broadcast system:

a) allocation of sufficient space in tunnel switch-rooms or provide dedicated GSM / CDMA repeater rooms of approximately 15 – 20m² per tunnel for installation of repeater cabinet equipment provided free of charge by up to four independent ACMA-approved public mobile phone carriers

b) design for metered power supplies and submains to each repeater room

c) design for conduits and pits for lead-in optic fibre cabling from the point of entry agreed with the carriers’ agent on the nearest available property boundary with the public road network

d) design shall include lighting, general purpose power socket outlets and air conditioning of the repeater room accommodation spaces, and

e) design to include tunnel wall penetrations, conduits and allocated spaces within the tunnel services cable ladders for installation of antenna feeder cables, splitters and couplers.

15.4.9 Radio re-broadcast system

Mobile phone reception shall be sustained inside tunnels. There must be provision for mounting additional antennae. The following requirement apply to radio re-broadcast in tunnels:

a) The frequency donors covered shall include but not be limited to Queensland Fire and Rescue Service (QFRS), Queensland Police Service (QPS), Queensland Ambulance Service (QAS), Department of Community Safety (DCS), State Emergency Service (SES), Queensland
b) All frequencies shall be confirmed with the relevant contributing donor party and notified to Transport and Main Roads.

c) If the existing ambient terrestrial RF leakage into tunnels means tunnel egresses are not sufficient for operational use, the following needs to be undertaken by the respective project:

i. obtain permission from radio stakeholders to rebroadcast their respective RF channels using preferred repeater sites determined by propagation testing

ii. obtain in the respective name(s) of the radio stakeholders, all applicable Australian Communications and Media Authority (ACMA) licences or licence amendments necessary for the erection of RF repeaters and the rebroadcasting of their radio channels

iii. pay to ACMA all applicable licences, site establishment fees and RF spectrum charges applicable to the first year of operation of each repeater site, and comply with all applicable ACMA license conditions

iv. install all radio repeater equipment and antennae required to provide the necessary UHF radio coverage, and

v. modify, through engaging relevant mobile radio stakeholders approved RF communications' service providers, the stakeholders' base station equipment or erect its own RF repeaters as applicable, to establish the required mobile radio coverage.

15.4.10 Over-height detection and warning

Over-height detection sensors determine whether a vehicle height exceeds that allowable for safe passage through the tunnel. They should be used in conjunction with VMS and/or CMS to provide the driver with a visual warning. The over-height vehicles should be detected and warned far enough from the tunnel to allow the drivers to take evasive action.

15.4.11 Foreign vehicle detection

ANPR is employed as a tool for identification of the contravening vehicles. A database of vehicles that are allowed thorough the tunnel is maintained and vehicles passing through the tunnel that do not appear on the list of allowable vehicles classified as foreign. An image of the contravening vehicle is also captured.

Provision may have to be made for detector loops / conduits to service the ANPR system, depending on the detection logic.

15.4.12 Tunnel ITS control equipment

If possible, ITS control equipment should be located outside the tunnel. If this is not possible, embedded rooms may be provided inside the tunnel to house the equipment. Sufficient room needs to be allowed for ITS equipment from communication rooms to conduits or cable trays as the case may be. ITS communications rooms need to be separate from the associated tunnel fire or tunnel ventilation equipment rooms.

Coordination between civil, structural, electrical, mechanical or architectural disciplines is required from design through to installation. Allowance needs to be made for structural penetrations, ducts or conduits leading to the rooms that house ITS equipment.
Consideration should also be given to the space requirements of any overhead signs such as VSL / LCS in tunnels. Local height increases in the tunnel ceiling may be required to accommodate ITS devices. Placement of VSL / LCS and other signage should be considered in the design to avoid issues relating to sight distances.

For tunnels, all plant and monitoring equipment shall be fully compatible and integrated with any existing facilities management system (FMS) Supervisory Control and Data Acquisition System (SCADA) using high availability PLCs.

15.4.13 Ducts, conduits and barriers

The provision of ductwork or a system of conduits through the tunnel must be addressed. Typically, the tunnel illumination is installed on the roof. Ducts or conduits should be installed within the tunnel walls, concrete barriers or under the shoulder of the roadway. Designers need to supply exact routes and coordinates for entry or exit points for such conduits to facilitate installation.

ITS ducts or concrete barriers should be equipped with pull access points or barrier voids to assist in the installation of cables.

Besides pulling points, barrier voids may provide termination points for detector loops, spaces in which to place junction boxes or transfer points of cables from conduits to cable ladders and vice versa.

16 Intelligent Transport Systems field equipment

16.1 Real estate

Real estate refers to the property adjacent to the travelled edge of roadway within the operating agency’s right-of-way. Generally, each subsystem has a requirement for aboveground equipment (for example, controller cabinet, poles, and so on) to be placed off the roadway. The roadside equipment should be easily accessible during construction and afterwards to allow for easy maintenance access.

This typically entails flat level ground local to the equipment as well as an all-weather access path to the equipment for routine or emergency maintenance. If the real estate requirements have not been addressed, or if property allowances have not been made early in the planning process, alternate sites can be challenging and costly to develop after the initial road design is advanced. Field cabinets and other equipment that require frequent access should ideally not be located in the medians.

16.2 Intelligent Transport Systems field network

ITS field equipment may be:

- mounted in standalone cabinets placed on the ground
- pavement mounted
- pole mounted
- mounted on structural columns, and
- mounted on barriers on purpose built voids or compartments.

Final location of ITS field equipment including cabinets must be established as part of the ITS designs.

A system of conduits, ducts, cable trays and cable trenches must be designed in order to connect these devices to the ITS telecommunications network. Figure 16.2(a) shows typical civil provisions for a traffic signal post.
Conduits for ITS communications and power cabling conveyance should be provided along the motorway. Backbone ITS cabling typically runs all the way along the roadway up to the ITS communications or switch rooms. Conveyance of backbone (backhaul) communication and power cabling must be done by at least 2 x 100 mm diameter communications and 1 x 100 mm diameter power conduit coloured white and orange respectively. Where backhaul conveyance is provided on both sides of the road, at least one communication and one power conduit shall be placed along either side of the motorway.

Such conveyance may be underground in ducts or conduits, aboveground within conduits in barriers or in cable trays. Provision must be made for points of access of the ITS network to the public telecommunications network where such access is required outside the communications rooms.

Connection to ITS backbone telecommunications network shall be provided to service the entry or exit ramps. At least one 100 mm diameter communications and one 100 mm diameter power conduits shall be used for this purpose.

Connection to ramps or devices located at either side of the motorway necessitates cross road conduits. Transition from one side to the other shall be done through use of circular pits. No pits are permitted in the trafficked roadway, including parking bays.

Road crossing communications and electrical power conduits are usually laid side by side in a single 750 – 800 mm wide trench under the pavement with at least 500 mm cover below the finished asphalt wearing surface. An alternative is to provide two separate 450 mm trenches; one carrying communications conduits and the other power conduits.

For existing roads, conduits may be bored with a minimum 500 mm cover below the finished pavement surface.

Power and communications cabling need to be segregated in line with provisions of AS/NZS 3000 Electrical installations (known as the Australian / New Zealand Wiring Rules) and AS/ACIF S009 – Installation requirements for customer cabling (Wiring rules). Separation between communication (extra low voltage) and power cabling (low voltage) must be at least 300 mm.

High voltage (HV) shall not be installed through barriers. Separation from HV must comply with the Electrical Safety Regulation 2013 (Qld) and the Wiring rules.
The example in Figure 16.2(b) is typical for conveyance through barriers.

*Figure 16.2(b) - Cross section through part of roadway*

Cable pulling points must be provided in the backbone conduit system, in barriers or underground trenches or ducts in accordance with MRS91 *Conduits and Pits*. Spacing of pulling points must be such that the maximum force that can be withstood by the cables to be pulled through cannot be exceeded.

The location of underground cabling (that is, power or communications) is subject to property considerations and the existence of other utility services. Conduits and pits should be located away from areas that would be impacted by future roadway widening.

Wherever practicable, communications conduits should not be installed in the median.

Extra care should be taken when installing communications conduit system meant for routing fibre optic cables. Joints and bends in the conduit network should allow for the minimum bending radius of fibre optic cable. Bending radius for 100 mm diameter conduits should not be less than 600 mm. Bending angle calculated as the total of the tangent deviations of the conduit bends between pull points should be less than 90°. Circular pits shall be provided unless impracticable. No pit size less than Number 4 shall be deployed for communications cabling. Number 3 or 4 pits may be used for vehicle detector loop termination. Sufficient drainage shall be allowed for in the area surrounding each pit and each pit shall have a 25 mm drain hole to prevent flooding of the ITS network through the conduit system.

Conduit design for the ITS network must take into account provision for road lighting.

Some ITS devices may be required to be installed as part of early works. When installed under this condition, such installation may be required to be relocated as required by the sequencing of road construction works. Communications systems for early works may need to be upgraded or integrated into the final design. Alternatively, wireless communications may be used during early works or construction activities.
16.3 Cabinets

Additional requirements regarding clearance areas around equipment added.

Field cabinets are a critical aspect of ITS infrastructure provision. Field cabinets include:

- communications cabinets and network nodes that house ITS equipment along the roadway
- traffic controller cabinets, house traffic controller equipment and other related ITS equipment, and
- junction boxes that provide intermediate termination points for equipment.

These may be mounted roadside on the ground, on poles, support structures or on road barriers where voids for the purpose have been provided.

Figure 16.3(a) shows a typical ITS field cabinet installation. Generally roadside cabinets would require at least one power and one communications cable conduit. Actual number will depend on the equipment to be housed in the cabinet, conduit sizes, layout of the ITS network and pit arrangements. The following guidelines need to be observed:

- conduits need to be suitably sized and provide at least 100% extra capacity over and above that required by the project to allow for network expansion in future
- minimum bending radius of cables / conduits needs to be maintained as per the Australian and New Zealand Wiring Rules for effective operation – this also requires larger pits, preferably circular pits
- concrete pads for traffic cabinets must be such that effects of erosion are minimised and to prevent entry of rodents; area around conduits and ends of unused conduits need to be sealed off; rodent and vermin infestations have been identified as significant issues that have to be addressed in field networks, and
- conduit risers should fit in the geometry of the hole cast in the concrete pads. An example is illustrated in Figure 16.3(b).

Figure 16.3(a) - Intelligent Transport System field cabinet, showing separate communication and electrical pits
Mounting must take into account maintenance personnel space requirements.

Some installations will require special consideration, particularly when one of the following is involved:

- restricted width corridors (for example, tunnels and bridges)
- verges that incorporate steep batters, and
- retained soil structures or other types of retaining walls.

The clearance area requirements for maintenance, repair and rescue are provided in MRTS201 General Equipment Requirements. The cabinet must be set back from a steel / wire barrier to allow for deflection and vehicle rollover across the barrier. Designers should consult with the department’s Traffic Data and Engineering unit to confirm the minimum spacings required for the road environment and the type of barrier used. Communications cabinets should provide an additional access door to the back of the cabinet.

Location of pits should not restrict access to cabinets. The pits shall be located besides the field cabinet so as to reduce the chances of maintenance personnel inadvertently falling into open pits during maintenance. Cabinets and doors shall be arranged to maximise visibility of roadway to maintenance personnel.

Typically, the field equipment should be integrated with other roadside features (for example, conduits, landscaping, signs, structures and so on).

16.4 Poles

16.4.1 Sign poles

For the placement of sign poles, refer to Section 5. Details of the signing requirements and clearances must also conform to MUTCD requirements.

16.4.2 Tilt poles

Tilt poles are often used in ITS applications to allow maintenance on pole-mounted equipment without the need for a bucket truck. If a tilt pole is used, adequate space must be provided around the pole to tilt it safely without intruding into traffic flow. The tilt pole shall be arranged such that maintenance staff face oncoming traffic while tilting the pole.
16.5 Safety and protection of equipment

16.5.1 Use of barriers

The placement of equipment should adhere to Transport and Main Roads roadside safety policies and guidelines. The equipment may pose a roadside hazard if not adequately offset from the travelled edge of pavement or protected by barrier. The use of barriers in ITS installations will serve to protect motorists from the danger of a collision with roadside furniture, and also protect the equipment itself. Barriers also increase the safety of the site for maintenance personnel.

For information regarding the design of barriers, see RPDM (2nd edition) Volume 3, Part 6 – Roadside Design, Safety and Barriers.

16.5.2 Protection from vandalism

As ITS equipment is typically both expensive and susceptible to damage, the threat of vandalism has become a restriction in some areas. Equipment such as solar panels should only be used in these areas if it can be obscured from general view, is suitably protected and/or mounted out of reach of unauthorised users. ITS equipment installed on the roadside near a steep upward slope should maintain at least 3.5 m clearance from the ground in order to deter vandalism.

16.6 Maintenance access

Safe and reliable access to equipment is critical. It is needed to ensure that the equipment can be serviced as required. If there is no provision for maintenance access, the alternative is costly lane closures. Road closures require lead time for setup, are disruptive to traffic and may be restrictive in terms of the time at which one may access the equipment (that is, no am or pm peak hour maintenance).

Figures 16.6 and 16.6.1 illustrate typical maintenance provisioning for roadside signs.

Figure 16.6 - Maintenance access at the back of sign

16.6.1 Maintenance vehicles

In general, it is preferable that this access be provided from a service road. If not, stopping bays should be provided for maintenance vehicles. Emergency stopping bays should usually be placed every 1 km along a motorway. If ITS equipment is placed near an emergency stopping bay, it may serve as a safe place for maintenance vehicles to stop.
16.6.2 Maintenance personnel

On arriving at the ITS site, maintenance personnel should be able to access equipment safely. If the equipment is placed on the verge, barriers should be placed to protect them from traffic. Wherever practicable, protection should be provided for both the maintenance personnel and maintenance vehicles.

16.7 Restricted corridor

Restricted corridors exist in situations such as tunnels, bridges, or elevated motorway. If a restricted corridor exists, it will impact on ITS installations, from the sensor to any associated cabinet-mounted processor, to the broader communications network backbone. Examples of such situations typically are:

- local widening in tunnels to allow for emergency stopping bays
- bridges or tunnels generally preclude any or subsequent cutting or excavation to place (post original construction) covered reticulation – typically, installation of surface mounted duct systems post construction could impose traffic disruptions / hazards and would be aesthetically displeasing
- cabinets with double doors instead of single doors may need to be considered in order to reduce maintenance space requirements in tunnels
- there may be restrictions on cutting sensors into the carriageway or adjacent to the carriageway; restrictions may also exist in attaching sensors or element support structures to portions of the structure that have not been designed to support point loading
- placing or maintaining roadside enclosures on multi-level interchanges or elevated motorways may not be possible without having to implement expensive and disruptive lane closures, unless specifically developed
- in situations of steep fill or cut, it may be difficult to place and/or access equipment – earth retaining systems to provide a lay-by for maintenance and servicing may be expensive;
however, they may be more cost effective over the long term when compared to lane closures, and/or

- some roadways are super-elevated from the surrounding ground on reinforced soil structures. Placing equipment, power and communications on these roads (or on roads adjacent to such structures) after the road is in operation will be difficult, as it may require transitioning through the side or excavating into areas where tie backs may be located.

16.8 Pavement design

Pavement design should take into account placement of loops used in vehicle detection and ramp metering subsystems and in the location of under pavement conduit crossing. Where the roadway is constructed directly on fractured or unfractured rock material, it can be very costly and disruptive to traffic to excavate or break the rock to facilitate the placement of in-ground pavement sensors or under-pavement conduit crossings. They may have negative impacts on the long-term performance for portions of the corridor under consideration, unless appropriate construction sequencing is planned for.

16.9 Planning issues

The transportation planning process provides the avenue by which planners, system operators, managers, local and regional governments and community leaders make decisions with respect to the long-term goals for various transportation facilities. It is imperative that ITS become integral to this process. This requires both the recognition that electronics, technology and communication are part of the transportation system, and the routine consideration of ITS in all aspects of planning.

17 Emerging Intelligent Transport Systems areas and implications

The key drivers to change in ITS remain the need to improve safety, transport system efficiency and to reduce the impact of transportation on the environment. Change will continue in vehicle to vehicle, in-vehicle and vehicle to infrastructure technologies.

The challenge will be seamless integration of the various ITS technologies and applications so as to optimise efficiencies and maximise benefit to travellers.

There is convergence of previously disparate systems with systems such as vehicle presence detection, automatic number plate recognition, speed measurement and classification being obtainable from a single system.

Increased wireless connectivity, low or self-powered devices and non-invasive technologies are expected. Issues regarding network security and running costs will have to be addressed. Gantry or pole mounted field cabinets may be a more common feature. The inductive detector loop will still be the norm in the foreseeable future although alternative solutions are being investigated. The need for power provision and a communication backbone to the Traffic Management Centres will remain. Reliance on optic fibre networks for the backhaul communications will increase. Safe and reliable access for maintenance activities must be provided.