Chapter 18 Technology for Network Management

18.1 Introduction

It is now widely acknowledged that it is necessary to make better use of the existing road network and Intelligent Transport Systems (ITS) can help in this respect. Transport telematics (ie the combination of computers and telecommunications technologies) can provide improved methods of network management information systems and services for travellers. The purpose of these intelligent telematics–based systems and services is to manage the network better and to give travellers advice, which is accurate, reliable and timely. The technology now exists to make information available as it actually occurs – known as real–time.

18.2 Operational Objectives

Intelligent Transport Systems can improve traffic operations in the areas of:

- ❑ traffic management and control;
- ❑ public transport management and operations;
- ❑ travel and traffic information systems;
- ❑ automatic toll–collection and congestion–pricing systems;
- ❑ freight operations and fleet control; and
- ❑ integrated urban and inter–urban network management, which combines all these activities and more.

18.3 Scope of Co-ordinated Signal Systems

(Refer also to Chapter 40 on 'Traffic Signal Control' and Chapter 41 on 'Co–Ordinated Signal Systems').

Co–ordinated traffic signal systems, in the form of Urban Traffic Control (UTC), were one of the earliest and most successful applications of telematics for network management. At the network level, they control traffic by adjusting the signal parameters which determine the red and green signal–time allocations to control traffic flows at junctions and pedestrian crossings. The aim is often to produce the minimum total queue–length on the network or the minimum total vehicle–hours for a given amount of travel. Such strategies may be modified to give preference on certain route–corridors (green waves) and/or priority on pre–determined routes for emergency service vehicles or buses.

There are two main types of co–ordinated traffic signal system: fixed time plans, usually developed using the TRANSYT software package, or dynamic plans, usually based on SCOOT (Split Cycle Offset Optimisation Technique) software. Fixed time plans must be updated over time, as traffic patterns change. Dynamic plans do this automatically.

Co–ordinated signal systems can produce large savings in vehicular–delays (typically about 20% – see Chapter 41). They are also able to respond to changing traffic conditions. Priority can be given to selected vehicles (buses, trams, emergency vehicles), although with some delays to other traffic. They are also able to provide 'gating' of vehicles (ie deliberately limiting the volume of traffic passing through a junction) at the periphery of particularly congested areas. However, this requires attention to queue–management to avoid knock–on–effects on other parts of the network..

SCOOT can respond to changing traffic conditions in real time but only relatively slowly. The speed of response can be improved by using 'expert systems', such as CLAIRE (see Chapter 41).

Co–ordinated signal systems are merely demand–responsive and, therefore, cannot control traffic in space, in the sense of actively re–distributing traffic over alternative routes, to cope with changes caused by incidents. Also, the benefits of demand–responsive systems are reduced when dealing with very congested traffic, as the scope to allocate green times to utilise 'spare' capacity is limited. On their own, they are incapable of explaining to drivers what strategies are in operation, and why, or of advising them on alternatives that would contribute to relieving particular congestion conditions. However, these systems do generate an enormous amount of information, collected by the detection loops it uses to obtain information on vehicles and queues. Because of this, other telematics systems are frequently added, as described below, leading ultimately to a fully–integrated Intelligent Transport System (see Section 18.15).

18.4 Selective Detection and Control

Selective Vehicle Detection (SVD) can be employed at a signal–controlled junction, to provide priority at that junction for certain types of vehicle. Usually it will be a component of a UTC system and is generally used for the following purposes:

- ❑ to assist buses and trams in keeping to schedule without undue delay, usually aided by priority lanes; and
- ❑ to give priority to emergency vehicles requiring response on demand – often provided directly from a control centre (eg 'green waves' for fire services).

Vehicles need to be identified and classified as one of the types of vehicle warranting priority and 'located' in relation to the signal (Chandler *et al*, 1985). Identification and classification can be made in several ways, such as:

- ❑ using the vehicle's encoded number or 'signature', which can be recognised by existing detection systems, such as induction loops or video–image detectors (see Section 18.10); or, more usually,
- ❑ using roadside equipment (so–called 'beacons') that may employ infra–red, microwave or ultrasonic technologies to communicate with tags or transponders on the vehicles.

Communication to operate the signal controller will either be directly from vehicles or via the control centre and the UTC computer. Examples of applications of Selective Vehicle Detection for public transport vehicles can be found in London (Meekums *et al*, 1995) and Southampton (CEC, 1994a) (see also Chapter 24). These systems bring benefits for buses but the disbenefits to other traffic may need to be considered. For example, problems can be caused if too many buses demand priority at the same time. One strategy is to detect and respond to those vehicles that are running late and to ignore those that are on schedule.

The positional accuracy required for detection needs to be better than about plus or minus two metres. This tends to favour the use of above–ground detectors or beacons for detection, in preference to buried induction loops. The benefits of SVD for bus operations are that:

- ❑ it provides improved reliability in running public transport vehicles and gives a better service for passengers, who have more confidence in schedules;
- ❑ priority improves the performance of public transport vehicles, in comparison with private transport, and thereby encourages modal shift;
- ❑ improved utilisation of the vehicle fleet leads to reduced bunching and fewer 'lost' seat–kms for operators; and
- ❑ it offers the opportunity to provide on–board information for passengers, such as the name of the next stop and estimated time to reach the terminus.

18.5 Vehicle Location and Polling

The next step up from selective detection is continuous Automatic Vehicle Location (AVL), combined with two–way communication between fleet drivers and their control centre ((see Chapters 24 and 25). The aim of AVL is to locate, at frequent intervals, individual vehicles in a fleet, such as buses, trams, police, ambulance, fire, freight delivery vehicles and AA/RAC patrols, and to pass emergency and status messages between these vehicles and their control centres. This enables better management and deployment of vehicles and resources by fleet operators. A major application of AVL has been with public transport fleets, where it has special use for public transport information systems. Examples are:

- ❑ information (arrival/departure) displays at termini;
- ❑ information displays at bus stops; and
- ❑ enquiry services, including 'public access' terminals (see Chapter 15).

AVL systems use roadside loops, beacons or proprietary navigation systems to locate the vehicles. Vehicles are generally polled in rotation, from the control centre, over a mobile radio or cellular telephone system, for location and status information, including emergency alarms.

Vehicle locations and status can be displayed in the control centre, using a Geographic Information System (GIS), which enables the vehicles' positions, movements and messages to be displayed on a map background. Software is required to monitor performance against schedules, to recognise incidents and to raise alarms requiring an operator's intervention. For public transport information systems, travel–time to the next stop(s) must be estimated and communicated to remote information displays. Examples of the use of AVL in public transport operations can be found in London (see Photograph 18.1 and Balogh *et al*, (1993)) and Southampton (Mansfield *et al*, (1994)) (see also Chapter 24).

Issues which are relevant include the following:

- ❑ some interpolation between the periodic 'fixes' taken by the AVL system is generally necessary, to give the required confidence in location accuracy;
- ❑ problems arise if not all buses are equipped, because unequipped buses will arrive at stops and termini unannounced;
- ❑ as with all information systems, high accuracy

Photograph 18.1: Bus stop information display in London Transport's Countdown System. Courtesy: London Transport Buses.

and reliability of information is needed to sustain credibility with the public;
- ❑ information at stops is not so necessary if buses always run to time or at very frequent intervals;
- ❑ information accuracy of one to two minutes is generally adequate;
- ❑ the system must be programmed with the correct and latest information on scheduling of services; and
- ❑ the cost of continuously–polling vehicles can be considerable unless a privately–owned communications system is used.

The benefits which can be expected from an AVL system are that:
- ❑ it offers the facility for emergency alarms from vehicles, for example, when the driver or a passenger is in trouble;
- ❑ improved reliability of running to schedule gives a better service for passengers;
- ❑ it offers improved information for passengers who are reassured about operations and can make better use of any spare time (see Figure 18.1);
- ❑ there are clear indications that passengers appreciate and value information (HCC, 1996);
- ❑ it offers indications that patronage can be increased (HCC, 1996); and
- ❑ improved utilisation of fleet–resources gives higher returns to operators.

18.6 Variable Message Signs (VMS) (see Chapter 15).

VMS can be used where greater flexibility is required than can be offered by fixed direction or advisory signs. Where their normal state is 'off' or 'blank', they are sometimes referred to as 'secret signs'. Use of VMS is increasing in response to more complex traffic management requirements and the need for more information to be provided to drivers. As with other traffic signs, VMS is governed by the Traffic Signs Regulations and General Directions (TSRGD) (HMG, 1994) [NIa].

The aim of using VMS is to provide drivers with mandatory and/or advisory information, at the roadside, relating to situations ahead or in the immediate vicinity. Applications, some of which might require special authorisation, could include:
- ❑ hazard warning information, for example 'accident', 'congestion', 'delays ahead', 'speed restriction', and 'lane(s) closed';
- ❑diversion route advice;
- ❑ tidal flow lane–allocations;
- ❑ car parking guidance/occupancy (see Chapter 19);
- ❑ lane/road/bridge closed to selected or all vehicles;
- ❑ low bridge/over–height/over–weight vehicle warnings;
- ❑ weather or other environmental warnings of bad road conditions, for example, fog, ice, wind or flood; and
- ❑ estimated travel–times as, for example, on the Boulevarde Peripherique in Paris and the South–Eastern Freeway in Melbourne.

Three general types of technology are employed for VMS: electro–mechanical, reflective flip–disk and light–emitting. It is feasible to combine technologies within the same sign. When used as warning signs, it is usual for them to be fitted with amber–flashing lanterns. The three types are described below.

Electro–Mechanical signs involve rotating planks with two faces or prisms with three faces which are usually used to give versatility to a standard fixed–face traffic sign.

Reflective flip–disk signs are made up of a matrix of disks, one side black, the other fluorescent. The momentary application of an electrical current will magnetically 'flip' a disk between the 'on' and 'off' states. These signs are well suited to showing combinations of letters or symbols as a message.

Light emitting signs normally use fibre–optic or light–emitting diode (LED) technologies. The major advantage of these signs is that a greater range of messages can be displayed than for reflective technology signs. LEDs, being solid–state devices, can also produce very good reliability with minimal maintenance. Representations of standard traffic signs can be made using coloured light sources to generate pictograms, red rings or triangles. Some pictograms, however, can be difficult to show effectively and, as they are not covered by TSRGD, need to be specially authorised. To achieve sufficient brightness, the viewing angles of both LED and fibre–optic signs are comparatively narrow. This can make light–emitting signs difficult to align satisfactorily at some sites but, where aligned correctly, their presence (though not necessarily the detail) can be seen at long range. Drivers must be able to read the signs easily from any approach lane at the required distance.

Examples of VMS and their applications are numerous and it is only possible to give a flavour here. Photograph 18.2 shows an application for parking guidance and information. Photograph 18.3 shows a sign set used on the M25. This is not strictly an urban application but is included to indicate the capabilities of VMS for displaying message–sets involving characters and pictograms. An extensive system (CITRAC/FEDICS) has been introduced in Central Scotland.

In addition to requirements for siting and mounting (see Chapter 15), the sign designer needs to consider a number of factors, including sign–size, character height, legibility, contrast and viewing angle, for a wide range of ambient illumination levels andexpected approach speeds. Messages must be comprehensible to the vast majority of drivers. There is also a need to ensure consistent messages in a series of signs, ie a 'fail–safe' operational strategy is needed. There is usually a requirement for VMS to be able to communicate back to a control centre, to confirm that the correct message is set, although this can also be done using a CCTV surveillance system.

Signs, including the messages, must conform with TSRGD or be specially authorised by the Secretary of State [NIb]. As more experience is gained in the use of VMS, it is likely that Amendment Regulations will include more features and messages within TSRGD, thus reducing the need for special authorisations.

VMS messages can expect to reach a high proportion of drivers. However, their effect is localised as the signs can only affect those who pass by them while the message is displayed. They can be used to slow drivers down and to divert them around problem areas or, for example, to Park–and–Ride (P&R) interchanges. Drivers can also benefit from some, limited, indication of the reason for, and extent of, likely queues and delays. Parking management

Photograph 18.2: Parking guidance VMS in Southampton.

Photograph 18.3: VMS used for warning and speed control on the M25.

systems can improve traffic flow in town centres, by directing drivers to free spaces, and thus reduce the amount of circulating traffic searching for parking spaces They can also reduce the length of car park queues (see Chapter 19).

More generally or, for example in the case of a VMS used for tidal flow systems or to indicate a weather hazard, the benefits are relevant to the particular installation. VMS are fairly costly to instal and are generally used only where particular problems occur and/or where the accident risk is high and the costs can be justified. For instance, messages relating to a low bridge, height or weight restrictions or a road closed due to wind or snow have specific application to accident 'black' spots.

18.7 Ramp-Metering and Access Control

Sometimes also referred to as 'motorway access control', ramp–metering is used to assist the merge of two streams of traffic or to control flow through a bottleneck downstream of the merge. The usual form of operation is to meter traffic from motorway on–ramps, as it seeks to merge with traffic on the main carriageway, with the following aims:

- ❑ to reduce the likelihood of merging vehicles causing flow breakdown in the traffic on the main carriageway;
- ❑ to help to restore free flow after flow breakdown has occurred; and
- ❑ to deter traffic from using that particular on–ramp when flow on the main carriageway is close to capacity (CEC, 1992).

Ramp–metering is occasionally used dynamically to detect incipient gaps in traffic and then to allow vehicles to join the main carriageway by fitting them into the available gaps. The control systems for this need to be quite sophisticated. Vehicle–detection systems, usually pairs of detector–loops, are provided on the on–ramps and also on the main carriageway to monitor the relative flows of traffic in real–time, both up and downstream of the merge. A computer control algorithm is then used to relate the data from the detectors to the speed–flow curve for the main carriageway. The algorithm operates the ramp meter signals and aims to keep the main carriageway operating at flow/capacity (v/c) levels which are less than the critical 'knee' (v/c = 0.95) value, at which flow–breakdown is likely to occur (Owens *et al*, 1990).

Ramp–meter traffic–signals in the UK are of the conventional three–aspect type, following the standard sequence. In other countries, notably the US and the Netherlands, two–aspect signals (red/green) are used to 'gate' the inflow with rapid alternations.

A system has been installed on the M6 in the UK, using conventional signals (Owens *et al*, 1990) (Photograph 18.4). In France, on the Boulevarde Peripherique around Paris, conventional signals are used but, perversely, the system is arranged to give priority to vehicles on the ramp rather than on the main carriageway (CEC, 1992). In the Netherlands, traffic is deterred from using the on–ramp at peak times using VMS and red/green signals are used to 'gate' traffic, releasing as few as one vehicle at a time (CEC, 1992).

Ramp–metering may not be applicable where there is insufficient ramp–length to store queueing vehicles, where sight–lines are poor or where gradients are too steep. In these cases, ramp–queues, caused by the metering signals, may back–up onto surface streets. So, the designer, in conjunction with the relevant authorities, must decide the balance of priorities between the traffic on the main carriageway and on the ramp. To minimise congestion overall, priority is usually given to keeping free–flow on the main carriageway.

Ramp–metering can give priority to a main carriageway, or a ramp, leading to a better balance of flows within a network. It can reduce conflicts, prevent flow–breakdown on the main carriageway and, probably, reduce accident–risks. Above all, ramp–metering can reduce congestion and delays. Results from the M6 sites show benefits of over 20% in vehicle–hours saved, due to delaying or preventing the on–set of congestion on the main carriageway, plus an increase in maximum throughput of about three per cent. On the M6 junctions, where ramp metering is used, the ramps are too far apart for co–ordination of flows but, on urban motorways and ring roads, linking may be warranted and beneficial.

Photograph 18.4: Ramp metering system on the M6.

18.8 Automatic Incident Detection (AID) and Management

The aim of AID is to detect incidents automatically and quickly, in order that the problem can be dealt with and the roads returned to normal operation as soon as possible. Almost all AID systems work by detecting an abnormality in the expected traffic conditions, such as a queue, a stopped vehicle or an empty lane, and comparing it against 'normal' conditions using a computer algorithm and then raising an alarm and/or putting into operation a strategy to deal with the problem.

Methods for detecting queues are essentially the same as those used to detect vehicles (see Chapter 40 Traffic Signal Control; and Chapter 41 Co–ordinated Signal Systems). Methods include:

❑ detector–loops in the carriageway;
❑ above ground detection (AGD), using short–range infra–red, or microwave communication links; and
❑ CCTV, combined with image–processing.

Examples include the MIDAS incident–detection/speed–control system, which is widely deployed on UK motorways (HA, 1994); Traffic*master*, which originally used AGD for motorways and trunk roads, but is extending to include urban applications (Photograph 18.5 and Traffic*master*, 1996); and SCOOT, with extensions, which utilise the SCOOT detector–loops to collect historic data as a basis for detecting incidents (Palmer *et al*, 1995). Image–processing systems (see Section 18.11) also have an application for automatic incident– detection in urban areas.

The management strategies adopted by highway authorities, in response to an incident–alarm, rely mainly on using VMS to warn, slow down or divert drivers (see Section 18.6). A traffic–responsive UTC system, such as SCOOT, can itself respond either, gradually, to help to alleviate the situation or more quickly if, for example, an 'expert system' (see Section 18.3) has been developed in advance. Integrated systems which combine this approach with VMS to warn and divert drivers are also possible (McDonald *et al*, 1995). At the urban/inter–urban interface, variable speed restrictions may be used, as on the M25 (see Photograph 18.3) to calm traffic approaching congested urban areas.

Photograph 18.5: Traffic*master* in–vehicle unit.

Some of the issues which arise are that:

❑ unexpected queues can give rise to increased accident–risk and secondary accidents;
❑ queues can build up extremely quickly, especially in busy periods, to spread out and affect the rest of the road network;
❑ these queues may persist, and extend, long after an incident is cleared and the front of the queue starts to dissipate, because traffic continues to join at the back;
❑ VMS only give information locally and to those drivers who see them;
❑ other driver information systems can give information over a wider area, for example traffic message broadcasting (see Chapter 15); and
❑ CCTV may be a necessary adjunct to AID, for sites with a high incident rate (see Section 18.10).

AID systems alert operators automatically to a problem and to the need to initiate action. The quicker the incident is detected, the quicker it can be cleared and the less are the secondary accident risks and accumulated delays. VMS can be used to warn drivers at known trouble– spots, that they are approaching the back of stationary or slow–moving queues. This leads to reduced accident–risk.

The UTC can be switched rapidly to a new plan to cope with the new traffic situation and thus help to alleviate congestion and delays. Drivers further afield can be informed, for example using traffic broadcasts, and advised to avoid the area and so reduce the build–up of traffic around the incident. Integration of the AID, UTC and VMS systems is possible, using expert systems that will, for example, automatically deduce and implement the best traffic management strategy in response to an alarm.

18.9 Weather Monitoring and Response

The aim is to detect and predict adverse weather and potentially poor road conditions, in order to warn drivers or to initiate treatment of the affected roads (eg to salt or snow plough) or, in extreme cases, to close a road or bridge.

The likelihood of road–icing is generally deduced from measurements of air and road surface temperatures, which are taken using suitable thermometers or thermistors. Measurement of electrical capacitance can be used to test for the presence, and concentration, of salt and to show if further salting is needed.

Wind speed can be measured using an anemometer.

Strong or gusty winds can pose a particular danger for high–sided vehicles, especially when unexpected, such as when crossing a bridge over a valley or estuary which acts as a Venturi funnel.

Fog is usually detected using instruments that measure either the amount of light transmitted or the amount scattered by the air. These measurements can then be related to visibility distance (Jeffery *et al*, 1981). Precipitation (eg rain and snow) is not actually measured, although warnings can be given locally if it causes reduced visibility and poor road conditions. Even relatively shallow floods produce danger of aquaplaning and extreme ones can make roads impassable.

Most weather detection systems are operated in conjunction with Meteorological Office forecasts and aim to provide local refinements, through selecting pre–cursor sites or black spots where, for example, fog or ice is likely to form first. Techniques of thermal infra–red mapping may be used to help identify these precursor sites (Stansfield, 1995). Examples are on the Britannia Bridge (van der Heijden *et al*, 1994) in Wales and, in Devon, where the Icealert system is used (Stansfield, 1995).

One key response of road authorities to advance notice of adverse weather and poor road conditions is to warn drivers of the hazard and to trigger remedial action, such as salting or gritting if ice or snow is forecast. Warnings and advice can be given locally using VMS for fog, ice, wind, snow or flood conditions, together with advisory speed limits or diversion information, if appropriate. Traffic message broadcasting (see Chapter 15) is used to reach drivers further afield and can often be supported by additional TV, radio and even newspaper reports, when sufficient warning can be provided by the Meteorological Office. Adverse weather and poor road conditions are particularly dangerous when they are unexpected; for example, black ice or patchy fog (Jeffery *et al*, 1981). The main benefits from weather monitoring are reduced accidents, delays and congestion and these can be obtained either by reacting quickly to alleviate the problem, for example by salting and gritting roads, or by warning drivers when and where a specific problem exists. However, roadside equipment for weather monitoring tends to be expensive, involving both a number of detectors and VMS. Applications are, therefore, usually confined to black spots, where the costs or risks of accidents can justify implementation.

The Meteorological Office can provide early warnings of bad weather conditions only at a general level. Monitoring–sites can often be identified that will give more local detail and can be used to activate VMS automatically.

18.10 CCTV Surveillance

The aim of CCVT surveillance is to provide network managers with a pictorial view of the operation of key parts of their network. Operators use the pictures as a basis for altering traffic control strategies, for confirmation of incidents reported by the public, and to record conditions or events over a period of time.

Cameras are usually of the solid state Charge Coupled Device (CCD) type and mounted on high masts or buildings. Costs depend on the performance and facilities required, which may include:

- ❑ monochrome or colour picture displays;
- ❑ low–light performance capability;
- ❑ broadcast quality or high definitions;
- ❑ zoom capability; and
- ❑ fixed or with pan–and–tilt manoeuvrability.

The communications link between the camera and the control centre generally uses co–axial or fibre–optic cable or microwave radio transmission.

Control centre monitors are normally set up to rotate through a sequence of cameras, with only a small number dedicated to looking at particular fixed sites. The ratio of control centre monitors to roadside cameras is usually about one–to–five but image–processing techniques, which give an automatic alert for possible incidents, can allow much higher ratios to be used. Photograph 18.6 shows the set–up in the urban traffic control centre for the city of Leicester.

CCTV systems are expensive to deploy, so they are generally only installed where a case can be made in terms of the likelihood of severe congestion, traffic incidents or accidents. Also, cameras must be positioned so that the privacy of people in nearby homes or business premises is not compromised.

Pictures are generally recorded so that visual records of incidents can be obtained and saved. There are usually more cameras than monitors so not all views are available at any one time and preferred views are generally set by the operators from experience.

CCTV is also thought to assist public relations because it provides a highly visible and easily understood feature in a high technology control room. The pictures can also be readily shared between a UTC centre and a police control room and, sometimes, relayed to local TV stations. The systems

Photograph 18.6: TV monitors in Leicester's urban traffic control centre.

thus provide a highly public indication of investment in traffic management tools

CCTV provides the opportunity for an operator to see an incident occur and to get early warning of problems. If the operator does not actually witness the incident, he or she will nevertheless be able quickly to get visual confirmation of the situation and of the consequences of the incident. This avoids the need to dispatch a police patrol and speeds up response–time, because getting a patrol vehicle close to an incident surrounded by congestion can often be difficult and slow.

The operator can also assess the situation and determine the need for emergency services, the nature and extent of action required and, subsequently, can continue to monitor the progress of the incident and any further requirements for action or withdrawal. CCTV, therefore, allows a control centre to make the best use and deployment of all available resources. Recordings also provide visual records of incidents and how they were treated.

18.11 Image-Processing Systems

Image–processing equipment can be used to analyse CCTV camera pictures, to determine a wide range of traffic parameters, including:

- ❑ to detect traffic incidents, differentiating between various types of situation and whether traffic is moving or stationary;
- ❑ to monitor conditions in bus–lanes for infringements by banned vehicles, whether moving or parked;
- ❑ to emulate detector–loops to count vehicles and measure flow, speed, headway, etc., and to classify vehicles;
- ❑ to substitute for loops in traffic control detection systems;
- ❑ to monitor the paths of vehicles and pedestrians through junctions or on crossings; and
- ❑ to identify 'probe' vehicles for transportation planning (O/D) surveys, for journey–time measurements or for the enforcement of traffic and parking legislation, using number– plate recognition techniques.

Image–processing systems work by analysing the picture elements (pixels) of successive frames taken by a CCTV camera and looking for differences in grey–levels due to movements, usually of the 'edges' of vehicles (Hoose, 1991). Examples of systems are given in Photograph 18.7; and in Hoose (1994); Sowell *et al* (1995); and HCC (1996).

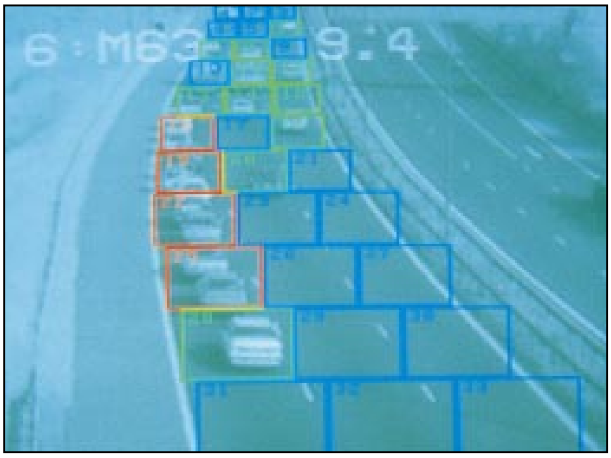
Image–processing systems generally need to be calibrated for each camera–location and view. Fixed cameras are, therefore, preferred or default settings are needed for pan–tilt–zoom cameras, so that they return to a fixed view. Where the system is to be used for Automatic Incident Detection (AID), a threshold must be set for an alarm to be raised. Local conditions can make image–processing difficult, including:

- ❑ dull weather, in fog and at dawn and dusk, when contrasts are low;
- ❑ in strong sunlight, when shadows might easily be confused for moving vehicles; and
- ❑ headlamp glare from wet road surfaces.

Image–processing techniques can also be used for reading vehicle number–plates automatically (Hill *et al*, 1994). Most automatic debiting systems rely on cameras for recording and identifying violators and useful benefits can be obtained from automating the process (see Section 18.13 on 'Automatic Debiting').

Image–processing provides substantial added value to existing CCTV installations, because it has the ability to look at a continuous stretch of road (typically 200m to 300 m), compared with other incident–detection systems using loops, for example, which effectively detect at a single point.

Systems can inspect all of the pictures transmitted to a control centre, not just those displayed on the monitors, and can select automatically the most interesting or relevant views to display. Fast incident–detection, typically less than 30 seconds, is achievable and can be used automatically to warn the operator when an incident occurs, thus relieving him or her of the responsibility of watching the monitors all the time. Consequently, there is a better use and deployment of resources. Also, systems can readily be deployed in temporary situations, such as at a roadworks.



Photograph 18.7: Visual display of the IMPACTS image processing system.

18.12 Route–Guidance and Journey–Planning

The aim is to help drivers to plan and to follow the best routes, using reliable trip information which can be obtained before setting out (pre–trip) or during a journey (in–trip).

Pre–trip planning (see also Section 15.13) is now feasible using proprietary software packages, which enable routes to be planned, using a personal computer in the home or office, before setting out on a journey. Terminals (see Chapter 15), usually in public places, can also be used to plan journeys, although the emphasis here is more usually on travel by public transport modes.

In–trip route–guidance, on the other hand, requires the appropriate equipment to be installed in the users' vehicles. The technology for in–vehicle information systems is described in Section 15.11. VMS direction signs (see Section 18.6) are also sometimes referred to as route–guidance systems where they are used to give route and diversion advice, although the term is more commonly used for in–vehicle systems, where the range of information and the scope for its delivery are vastly greater.

Trip–planning software is commercially available, for example, the 'Milemaster' package from the Automobile Association or 'Autoroute' from Microsoft. The first commercial system to provide dynamic traffic information was Traffic*master* (Traffic*master*, 1996) (see Section 15. 11). It now covers most of the UK motorway network.

Autonomous navigation systems are widely available in Japan. Take–up and development in Europe and the US has been slower, although work supported by the CEC Framework research programmes has produced autonomous navigation systems with RDS–TMC updating, as described in Section 15.11 (see also Photograph 18.8 and CEC, 1996a). Further development of these systems, using two–way GSM cellular telephone links, has produced the SOCRATES dynamic route–guidance (DRG) system (Catling, 1994).

A DRG system, operating in conjunction with a traffic responsive UTC, offers the potential to control traffic, both in time and in space, and so produce a new generation of traffic control systems.

Most other trip–planning and guidance systems, even if dynamic, essentially give all drivers on the same O–D trip the same response to the same question.

Care is needed, therefore, in the way these systems are used. If all traffic is advised to divert, this could result in a worse problem somewhere else. Provided the proportion of vehicles equipped with route–guidance systems is relatively low, both equipped and non–equipped drivers can benefit. This is because the few equipped vehicles will be diverted around an incident and so reduce pressure on the affected route. As the proportion of equipped vehicles rise, so do the control problems.

Systems should be able to handle a range of definitions for the 'best' route including, for example, minimum time, distance or generalised cost, as well as the most scenic, suitable for towing a caravan or suitable for an HGV. Equipment manufacturers need also to exercise care in the way information is presented to drivers. A complicated visual display may cause distractions or take so long to assimilate that it gives rise to increased risks of accidents.

Most autonomous navigation systems require access to a detailed digital road map. These can be expensive to produce and to maintain. Commercial versions are available but they need to be augmented with information about temporary traffic restrictions. Standards are required for systems, such as RDS–TMC, so that they are inter–operable. This will ensure that a vehicle unit produced to receive messages in one region or member–state of the EU will also be able to receive and decode messages in other regions or member–states of the EU and even in foreign languages.

Significant benefits of DRG are estimated to accrue from systems that can help drivers to plan and follow optimum routes (Jeffrey, 1994). From the driver's point of view, these systems are more attractive if they can provide real–time traffic information and

Photograph 18.8: CARIN in–vehicle navigation unit.

they are of most use on unfamiliar journeys. Potential benefits, worth around 10% of journey time, have been estimated for a fully dynamic route–guidance system operating in London. Route–guidance systems, combined with traffic responsive UTC, provide a new generation of traffic control tools that enable traffic to be controlled both in time and in space.

18.13 Automatic Debiting Systems (ADS) and Decremented Pre-Payment

The aim of automatic debiting systems (ADS) is to charge a toll automatically from a vehicle for use of a facility, such as a toll road, tunnel or bridge without requiring the driver to stop. Similar technologies are used for road–use and congestion pricing systems (see Chapter 21), for automatic charging in car parks (see Chapter 19) and can be interfaced to in–vehicle information systems.

A large number of technical possibilities exist, ranging from a 'vignette' (the equivalent of a paper tax disc) in the vehicle that can be inspected visually or using a bar–code type reader from a toll booth, to a transponder with an 'electronic purse' (smartcard) that can be credited through pre–payment with 'electronic cash' units and debited automatically by short–range communication from a roadside unit at each toll point.

The basics of a system require:

- ❑ an effective means of detecting the passage of vehicles and of classifying them;
- ❑ a two–way communication between a device in the vehicle and a roadside unit;
- ❑ a roadside unit that will either interrogate the in–vehicle device for its identity (AVI tags) or instruct a transponder to deduct the toll charge from the smartcard;
- ❑ that all successful transactions using transponders will be anonymous but the identity of the vehicle needs to be recorded (eg by video analysis of the registration plate), whenever the transaction fails, to ensure enforcement after the event; and
- ❑ that the in–vehicle device must be unique to the vehicle, driver or company, depending on whether the system applies different tolls to different classes of vehicles and on how payment is made.

For access control purposes, passage may then be granted or denied using a barrier. For tolling and road–use pricing purposes, all vehicles are allowed to pass unhindered but with violations being recorded and followed up later, or not, depending on the enforcement policy.

Payment can be made:

- ❑ in advance (pre–payment) using the equivalent of a season ticket (vignette) or by stored credit units (smartcard); or
- ❑ at the time, using the equivalent of a debit card with automatic deductions from a subscription account; or
- ❑ in retard (post–payment), where the bill accumulates and the driver (or company) is invoiced later.

Most systems favour pre–payment smartcards linked with a transponder in the vehicle. This is known as ETC (Electronic Toll Collection). If smartcards are used for payment of many different services from many different providers, a sophisticated 'clearing–house' system will be needed to ensure a fair allocation of revenues.

Cards are bought by the driver in advance and can be re–charged with credit units at suitable terminals. Simpler payment systems include:

- ❑ a season ticket, recognised by the system as valid until an expiry date has passed;
- ❑ credits for a fixed number of passages – the credit being incrementally debited by the roadside unit for the cost of each passage; and
- ❑ in the case of a toll road, debits which may be made dependent on the distance travelled.

Communication between the roadside and vehicle units can be achieved using induction loops, radio or infra–red beacons for access control but, increasingly, will use a microwave link. CEPT, the European frequency allocation authority, has defined a microwave band at 5.8 GHz for automatic debiting systems for high–speed tolling (Hills *et al*, 1994).

Examples of ADS are to be found on the Dartford

Crossing, the Mersey Tunnels and increasingly throughout the world (Hills, 1996).

Tag–based systems of ADS with a central account are in use in a number of countries, notably France, Portugal and the US, which have a long history of toll roads. Similar systems are used in the UK but only at major esturial crossings, such as the Dartford Crossing (see Photograph 18.9), the Severn Bridges and the Mersey Tunnels.

Historically, most tolling sites involved extensive toll–plazas, with many lanes and toll–booths, where tolls were taken manually or via a coin–collection machine. Interest in auto–tolling systems is increasing because of the potential for increased vehicle throughput, with less land–take, shorter queues and less pollution (Morton *et al*, 1994).

With most AVI tag systems, the communications range is fairly short (2 m to 5 m) so the vehicles must pass through a controlled gap (ie a single lane).

Likewise, the transaction time needed in most AVI tag–implementations precludes the driver approaching at speeds greater than about 20 miles/h (30 km/h) and this limits throughput.

More advanced developments, such as ADEPT (Photograph 18.10)) and systems developed for the German and UK tolling trials, involve systems that are fully automatic, using transponders with up to 20 m range, and enable drivers to pass unhindered at high running speeds (on motorways in Germany up to, perhaps, 160 km/h) and without lane control.

Adequate reliability is required for public acceptance. Avoiding charging in error is more important than ensuring that everyone is charged. Hence, stringent requirements for reliability and enforcement are needed, which have to rely on a system such as image–video processing for automatic number–plate recognition and reading (see Section 18.10).

Concerns about civil liberties can arise with AVI tag systems because, the identities of vehicles have to be recorded at the roadside and could be traced unless there are data–protection safeguards built into the system. Transponder/smartcard transactions, being anonymous, avoid these problems.

Automatic debiting systems provide a highly convenient method of paying for transport services. They avoid the need for elaborate and expensive toll–plazas and high manpower requirements. Improved speed of transaction and off–line enforcement mean less delay for traffic and greater convenience for drivers.

Photograph 18.9: Toll plaza on QEII bridge at Dartford where the M25 crosses the Thames.

Opportunities for fraud, especially by employees of the toll operator, are virtually eliminated. Automatic systems provide the ability to vary tolls with time of day but the prevailing tariff needs to be displayed prominently (eg using VMS).

The electronic 'purses' on smartcards may also be used, for example, to pay public transport fares and parking charges as well as for in–vehicle information services. In principle, this could herald the onset of a cashless economy.

18.14 Environmental Monitoring

The aim of environmental monitoring is to detect, or to predict, adverse environmental conditions and to warn drivers or, in extreme cases, to initiate a ban on traffic entering sensitive areas.

Photograph 18.10: The ADEPT trial site near Thessaloniki in Greece (1993).

Environmental pollution includes exhaust emissions (see Section 17.5). The rate of build–up and concentration varies considerably with the prevailing weather and atmospheric conditions. With current traffic volumes in some cities noxious gases can, on occasions, approach and even exceed 'acceptable' limits defined by the World Health Organisation (WHO) or the CEC, especially in the summer months (Simms, 1994). Emissions can be monitored and overall conditions estimated from the roadside (Sonnabend, 1994; and Bell *et al*, 1996) but only at a highly aggregated level. The variables affecting the 'micro–climate' in a particular street are too complex to model accurately.

Proprietary sensors are available for measuring and analysing emission chemicals and particulate concentrations in the atmosphere. Regular monitoring is undertaken by the DOE (Hayman, 1994). The results are augmented by additional stations set up by local authorities, designed to monitor background levels.

Leicester, as the 'Instrumented City', is being used to investigate an overall UTC and traffic management strategy, designed to minimise the number of stops/starts, smooth out acceleration profiles and reduce trip–times and distances in order to minimise vehicular emissions (Bell *et al*, 1996). However, the relationship between traffic control and local pollution levels is both complex and variable.

Other management strategies that can be considered when pollution levels become too high are:

- ❑ alternative routeing strategies (using VMS), to divert traffic around the more congested areas of towns; and
- ❑ encouraging drivers to park–and–ride and, thus, to use a less polluting collective mode of transport.

Whatever strategy is employed, it is crucial to make the changes known in advance, using additional signing, radio, TV broadcasts and advertisements in newspapers, to avoid serious congestion occurring at the periphery of the affected area and to minimise the likelihood of a political reaction or even a legal challenge against the strategy.

Demand management, generally, and urban road–use pricing or congestion charging particularly (see Chapter 21) may offer opportunities for reducing the overall impact of exhaust emissions.

Gaseous emissions are the main problem from petrol engines and particulates from diesel engines. For cars, the combination of lead–free petrol and catalytic converters reduces emissions markedly but is not a complete solution, especially for car–journeys that are short and/or involve cold starts. Gases are normally dispersed by winds and dissolved by rain. In fine, still weather, particularly during summer months, they tend to accumulate in street 'canyons'. Local weather conditions will strongly influence the rate at which exhaust emissions accumulate and will, therefore, influence the choice of a control strategy.

Improved traffic control can, in principle, make a useful, though probably only marginal, contribution compared with other methods, such as catalytic converters, reduced emission (lean–burn) engines, alternative fuels, including Compressed Natural Gas (CNG), and electric/hybrid vehicles. However, vehicle emissions can be reduced by avoiding stop/start conditions and smoothing traffic flows. Banning vehicles altogether is a desperate measure and would require public acceptance, which may be achieved in particular locations through public awareness campaigns (see Chapter 10).

The benefits from environmental monitoring and control strategies are mainly in improved air quality in urban areas, with possible reductions in health risks for residents. By–products can also be expected, including reduced noise, vibration, accidents and visual intrusion, all of which contribute to an improved quality of life.

18.15 Integration of Systems and Links to External Systems

The aim of systems–integration is to operate traffic and transportation as one overall system, rather than a collection of separate components, and thereby to achieve a system–optimum. In principle, the synergy that can be obtained from this will result in overall benefits that exceed those from the sum of the parts.

The technical components include many of those already discussed in this chapter and these can be combined in a number of ways, including:

- ❑ UTC, coupled with motorway control systems, to control traffic entering built–up areas and to restrain traffic within towns – perhaps in combination with demand management and road–use pricing systems (see Chapter 21);
- ❑ linking together traffic, AID, weather and environmental monitoring systems to provide short–run forecast information about road and traffic conditions;
- ❑ improved trip planning and information systems that will inform travellers of routes and conditions and enable them to plan journeys by car or public transport before they set out (see Chapter 15);

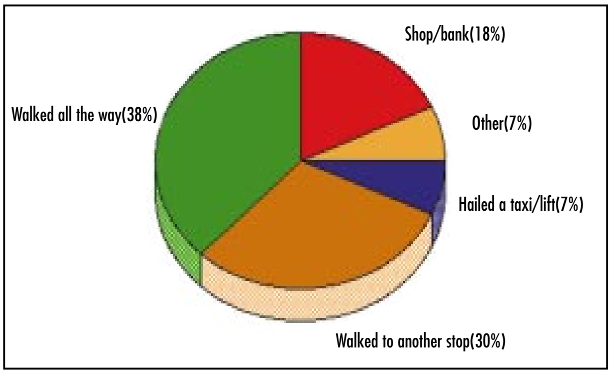


Figure 18.1: Results from ROMANSE survey of use of bus waiting time.

- ❑ improved information and route guidance *en–route*, to tell drivers when part of an urban area is congested and to guide them to alternative routes or to a P&R site so that they can leave their cars in a safe place and transfer conveniently to another mode for the remainder of the journey;
- ❑ improved travel–information systems, to tell travellers what collective transport options exist, and where and how to use them; and
- ❑ integrated (smartcard) ticketing, to enable travellers to use single pre–payment smartcards at toll facilities, parking (P&R) and any combination of public transport modes, using the same card.

Opportunities also exist for using a common infrastructure as the basis for integrating automatic–tolling, road–use pricing, driver information and dynamic route–guidance systems, all using the same communication link and a single smartcard as a means of payment (Hills *et al*, 1994).

The concept of an integrated Intelligent Transport System (ITS) was promoted from 1988, by the EU in the Second and Third Framework (DRIVE) programmes (CEC, 1989). Two major UK projects began in 1992 to develop and implement urban pilot systems (CEC, 1996b). Hampshire County Council's ROMANSE project in Southampton (HCC, 1996) involved:

- ❑ an integrated Travel and Traffic Information Centre (Photograph 18.11);
- ❑ all services and information brought back to the centre for processing; and
- ❑ decisions made and implemented at the centre regarding strategies, messages to disseminate, and so on.

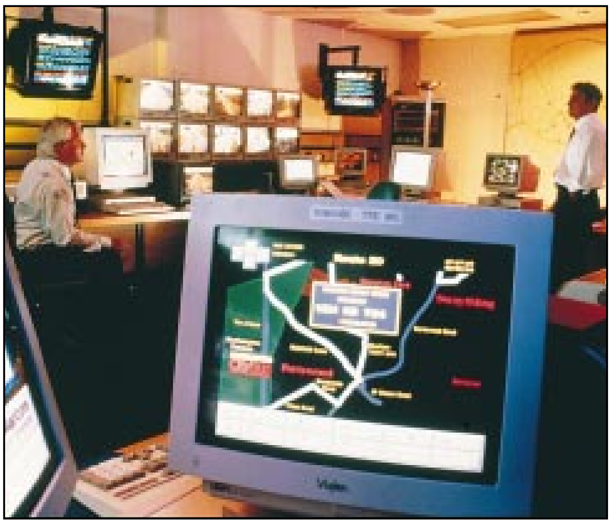
Birmingham City Council's BLUEPRINT project (CEC, 1995) involves a distributed system and various stand–alone sub–systems, such as UTC, motorway control centres, motoring clubs, and emergency services, all connected over a network that enables knowledge and information to be shared.

The ROMANSE and BLUEPRINT pilot projects were completed in 1995. They went some way to realising the concept of an integrated ITS. Both use Geographic Information Systems (GIS) systems to co–ordinate and display the information provided by the sub–systems (see Figure 18.1). Current traffic and travel information can be compared with historic data and/or related to other geographic, ie spatial, information. This can then be combined with accident records, land–use statistics and population distribution giving added value for planning purposes (see Chapter 6 'Transport Policy Components' and Chapter 8 'Estimating Travellers Responses').

Supported by both the EC and the Department of Transport, the projects involved public/private partnerships of local authorities, electronics, telecommunications and traffic systems manufacturing industries, consultants, motoring clubs as information service providers, universities and research institutes. All those involved learned to work together and to deal with some of the many problems related to institutional, legal, and Intellectual Property Rights (IPR) issues.

The ITS concept requires either a distributed system, as in BLUEPRINT, or a centralised system, as in ROMANSE. Either way, the systems only know and disseminate information about conditions in their local area. Longer distance travellers need to know more about conditions on the roads beyond the local area and *en–route* to their final destination. For a national system, therefore, links between local area control centres are needed.

Work on this is also promoted by the EC, in co–operation with the member–states (CEC, 1989 and



Photograph 18.11: The ROMANSE Travel and Traffic Information Centre in Southampton.

1994b). For the various partners in the European projects, such as ROMANSE and BLUEPRINT, and including central and local governments, the EC has supported the development of common standards, aimed at achieving inter–connectivity and inter–operability of systems. These include:

- ❑ systems architecture;
- ❑ message set and protocols;
- ❑ databases; and
- ❑ communications and data–exchange.

This work will enable information–services and control centres to be designed and constructed to common functional specifications and to agreed interface designs.

Through the Fourth Framework Programme (1995–1998), CEC has co–funded demonstration projects including taking forward the work already done in, for example, ROMANSE and BLUEPRINT. The resulting systems will facilitate common levels of service to be achieved in towns and cities across Europe, common information to be presented on, for example VMS, and for inter–operability of driver information (RDS–TMC), trip–planning (TRIPlanner) and route–guidance (SOCRATES) systems.

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