

Policy issues for the future intelligent road transport infrastructure

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While the Office of Science and Technology commissioned this review, the views are those of the authors, are independent of Government and do not constitute Government policy.

Abstract

Transport by road will shortly be transformed by a communications revolution, enabling new forms of telematics services. Particularly significant is the emergence of Dedicated Short Range Communication (DSRC), leading to the generation of ad hoc networks between vehicles and between vehicles and the infrastructure. Considerable effort, particularly in the US, has gone into identifying uses for DSRC, with particular emphasis on road safety. Means of communication are reviewed, with particular emphasis given to DSRC and its potential uses. As the UK stands to benefit more as a user rather than as a supplier of intelligent infrastructure components and telematics hardware, nationally funded research and development in this field should focus on applications that best meet UK user needs. In so doing, social trends (like the aging population) and issues of social inclusion need to be addressed. Public-private partnerships may be the best mode of telematics deployment where the benefits are largely public, the infrastructure is presently publicly owned, and the service would not otherwise be commercially viable. A UK-centric vision of the intelligent infrastructure, which the Intelligent Infrastructure Foresight exercise will provide, should guide UK policy toward research, development and deployment in the UK.

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Introduction

Transport has been and will remain a prerequisite for many economic and social activities. However, it also impacts substantially on health, safety and the environment. Evolving technologies are opening up the possibility of more intelligent forms of road transport that offer greater efficiency and an improved quality of life with reduced health, safety and environmental impacts. Underlying this is the *intelligent infrastructure*, consisting of the road network, its sensors, traffic information centres, the vehicles (private, commercial, public transport), and communication networks linking these components. The scope of paper is limited to road transport systems.

The improvement of road transport via the use of information, communication and sensing technology has long been the subject of research and development. Visions of fully automated passenger transport systems developed in the 1950s and 1960s, science fiction at the time, are gradually becoming feasible. Important foundations for the intelligent infrastructure were laid by the European research project PROMETHEUS (PROgramMe for a European Traffic with Highest Efficiency and Unprecedented Safety), which ran from 1986 to 1994. This project, which brought

together European motor manufacturers, their suppliers and electronics companies, developed novel copilot concepts to support driving by automating certain routine activities and assisting in risky situations. Other early research was carried out in the US by the National Automated Highway Consortium from 1991 to 1997 and in Japan by the Advanced Cruise-Assisted Highway System Research from 1996 to 2000 (see ADASE, 1999). In Europe, research on this topic has been supported by many EU projects, EUREKA projects and national projects. Much of this has been driven by the desire to improve road safety, although reductions of emissions and fuel consumption as well as improvements in driving comfort and convenience through information and services have also been stated aims.

Fundamental to the development of the intelligent infrastructure is what is referred to generically as *telematics*, which covers wireless technology, vehicle tracking, on-line navigation and other communications-based services for drivers, vehicle operators and road network managers. At the turn of the millennium, these new technologies were expected to generate substantial new revenue for equipment suppliers and service providers. In 2001 the turnover for telematics services and hardware in 2005 was estimated to be €2bn. By 2003, however, these expectation had been revised downward to €0.8bn for 2005, which today seems to be about right (Kimberley, 2005).

In many respects, it appears easier to build a telematics business case for commercial vehicles because of the ability of these new technologies to reduce costs by monitoring vehicles mechanically and operationally. Customers benefit through both reduced logistical costs (if passed on by the vehicle operators) and better information about the expected arrival times of vehicles. Thames Water, a large water and wastewater services supplier, applied vehicle tracking and fleet management services to its fleet of 1200 vehicles leading to a 10% reduction in fuel consumption (Kimberley, 2005).

In the case of cars, four areas of application for telematics have been identified, namely car-to-dealer communication (for example, to alert dealers to due times for servicing or emerging mechanical and/or electrical problems), navigation services, the tracking of stolen vehicles, and road use charging. Current navigation services are largely autonomous but may include on-line traffic messages broadcast by a service provider. There is, however, increasing interest in subscription-based centralised navigation systems offering better quality guidance (discussed later).

Safety is an important driver behind the development and deployment of telematics equipment services. In line with the objective of halving road traffic deaths by 2010, the EU wants all vehicles sold from 2009 onwards to be equipped with eCall, a system which automatically generates a distress call in the event of an accident. This could form the basis of an in-vehicle telematics platform to which other services could be added. Microsoft has been working on the software for such a platform (see www.microsoft.com/industry/automotive), which combines GPS, wireless telephony and Bluetooth. This will be fitted in all new Fiat, Alfa Romeo and Lancia models from 2006.

As an alternative to cellular communication, Audi, BMW, DaimlerChrysler, Fiat, Renault and Volkswagen have formed the Car-2-Car Communications Consortium to seek consensus on standards for Dedicated Short Range Communication (DSRC) communication. In parallel, DaimlerChrysler, BMW and Siemens VDO with partial funding from the German government are exploring the possibilities of DSRC between vehicles. In the UK, the SLIMSENS project, part of the DTI's Foresight Vehicle programme, is attempting to develop a combined radar and broadband communications unit for installation in vehicles.

The SLIMSENS consortium, led by Chelmsford-based e2v Technologies and including BAE Systems, LEW Techniques of Taunton, Somerset and the University of Birmingham has begun work on an advanced in-vehicle sensor capable of both long and short-range application, with a view to alerting drivers to vehicles or other objects (like pedestrians) in front and behind them. This will be integrated with a microwave communications system that will provide a fast vehicle-to-roadside link enabling internet access as well as the possibility of real-time transmission of the data gathered by the on-board sensors to other traffic in the area. It is envisaged that this unit will enable real-time accident prevention and traffic self-management (for example, taking control of the vehicle when joining or leaving the major road network, or hands-free convoy driving on motorways).

Another driver for telematics deployment is the payment for road use. The pan-European electronic road use charging framework foresees deployment in two stages; electronic tolling for heavy vehicles and coaches by 2005 (now delayed) and for all vehicles by 2010. The objective is seamless travel on Europe's tolled road network. Switzerland was the first country to implement a successful GPS-based nation-wide truck charging scheme, followed by the much larger TollCollect scheme in Germany at the start of this year. The Czech Republic, Hungary, the Netherlands, Poland and Sweden are planning similar systems.

The UK government plans that within 10 to 15 years every vehicle should carry an On-Board Unit (OBU) to allow a satellite system to track progress. This could be used not only for a nation-wide congestion charging scheme but also for the monitoring of compliance with speed limits. However, such intrusive monitoring has serious civil liberty implications and is unlikely to be popular.

Two phases of telematics deployment were foreseen by ADASE (1999). In the first, the vehicle passively receives additional traffic information, for example via the Traffic Message Channel (TMC) of the Radio Data System (RDS). This corresponds roughly to today's situation. In the second, vehicles actively exchange information with each other and the infrastructure. For example, vehicles acting as probes ("floating cars") may collect data on road conditions or travel times which are then shared with other vehicles so that drivers become aware of potential problems before they encounter them. In this way, an "active" map can be maintained which would be superior to static maps as it would contain up-to-date information about the state of the network.

The environmental dimension is covered in greater depth by Bell (2005) while McDonald and Li (2005) provides further details on some of the systems referred to in this paper. There is an emphasis here on the applications opened up by DSRC, with consideration given to the implications for UK policy in this domain.

Positioning

The keys to the successful deployment of telematics are ubiquitous positioning and communication. "Knowing the current position and status (speed and heading) of ... vehicles is essential to maximise the safety and productivity of our highways. This knowledge – and the ability to act on it – is what makes the highway 'intelligent'." (Ruff, 2005). Collision avoidance, lane change warning and other vehicle-based safety functions require highly accurate position and status data. Other functions, like emergency vehicle dispatching, road condition notification and traffic light control require less accurate but nonetheless up-to-date position and status data. In both cases, the vehicle requires the ability not only to locate itself but also to interact efficiently with other vehicles and/or the infrastructure to share this information.

The cost of satellite positioning via the Global Positioning System (GPS) has, since its introduction in 1978, been falling so that receivers are now available for as little as €7 (Ruff, 2005). However, GPS alone does not produce sufficient accuracy for many intelligent highway functions. Standard GPS signals yield an accuracy of 5m to 10m. To increase accuracy, integration with other wireless technologies is required. Differential GPS (DGPS), such as the Wide Area Augmentation System (WAAS) used by aviation in North America, can increase accuracy to 3m or less. This is still not sufficient for many vehicle safety functions like collision avoidance.

The European Galileo system, due to become operational in 2008, is designed to be compatible with GPS, leading to an increase in accuracy. However, tunnels, buildings, bridges or urban canyons lead to outages (periods of unavailability) for all satellite-based positioning systems (a GPS receiver needs a clear view of at least four satellites), so non-satellite sources of positional data are required. Possibilities include television broadcasting, mobile phones, dead reckoning, inertial guidance and map matching (see Ruff, 2005). Most important for vehicle navigation systems are Dead Reckoning (DR) and map matching. The DR position, obtained from speedometer pulses, forward/reverse signals and gyro inputs, is continuously calibrated by the GPS signal. Map matching helps overcome map and position inaccuracies by adjusting the displayed vehicle position to fall on a street. Inertial guidance, using high-precision devices to measure changes in speed and heading, offers higher accuracy than DR and is therefore suitable for functions like lane change assistance. Both DR and inertial guidance require GPS to provide an initial position and then to counteract drift that would otherwise occur.

Communication

Once a vehicle has determined its position, most intelligent highway systems require that this be communicated to other vehicles or the infrastructure. A range of media exist, or are emerging (see Fig. 1). These include satellite, cellular communication, forms of DSRC, and RFID.

Cellular communication, like the Global System for Mobile communication (GSM), its extension the General Packet Radio Service (GPRS) or the Universal Mobile Telecommunications System (UMTS), uses packet oriented data transmission. The Short Message Service (SMS) of GSM, used by the German truck tolling system TollCollect, transmits data as packages containing no more than 160 alphanumeric characters (Hoepfel, 2005). However, the packages may not be received in the same sequence as they are sent. GPRS offers permanent connection with the user paying for data sent or received. Messages are therefore dispatched and received in the correct chronological sequence. UMTS offers faster data transmission speeds.

RFID tags (transponders) carried by vehicles offer a short-range link which is widely used for vehicle location and identification functions, like entry control for garages or ports, priority at traffic signals for buses or emergency vehicles, and automatic toll collection. However, the data transfer rate is slow.

DSRC offers a fast short- to medium range link suitable for vehicle-to-vehicle and vehicle-to-infrastructure systems. It is used in the majority of European Union countries for communication between vehicles and the infrastructure in specific locations (for example, toll plazas), but these systems are currently not interoperable. Standardisation is essential if pan-European interoperability is to be achieved, as required by EU Directive 2004/52/EC. Standardisation will also assist with the provision and promotion of additional telematics services.

In Europe, DSRC takes a number of forms, using either a microwave link or an infrared link (Hoepfel, 2005). In the US, by contrast, DSRC has a very specific meaning, namely a “5.9 GHz link using digital radio techniques to transmit data over short distances between roadside and mobile units, between mobile units themselves and between portable and mobile units” (DIC, 2005). It draws on the IEEE 802.11 “WiFi” standard but is modified to suit high-speed vehicle applications (by, for example, reducing latency). With a range of about 300m (maximum 1000m), DSRC leads to the generation of ad hoc networks as vehicles and roadside equipment come within proximity of each other. Applications lie in the areas of travel and traffic information, public transport management, commercial vehicle operations, advanced vehicle safety systems, electronic payment, and emergency management. It must be noted here that DSRC refers to the generic CALM project definition of DSRC rather than the European standard for DSRC developed for toll collection and road user charging applications around the 5.8GHz microwave standard (Blythe 2005).

A Connected Vehicle Trade Association has recently been established in the US to promote collaboration on vehicle-infrastructure communications and applications thereof (www.connectedvehicle.org). Fig. 2 shows the components of the intelligent infrastructure based on DSRC, and the interfaces between the components. Behind these components and interfaces lie stakeholders, such as equipment manufacturers, service providers and government in various guises (for example, as a traffic authority).

In Europe, there are a number of initiatives, in particular Ertico’s Global Systems for Telematics (www.gstproject.org), the EU’s eCall programme and the Car-2-Car Communication Consortium (www.car-2-car.org). Involving Audi, BMW, DaimlerChrysler, FIAT, Renault and Volkswagen, Car-2-Car is seeking to establish an open European industry standard for vehicle-to-vehicle communication based on wireless LAN components to guarantee Europe-wide interoperability. According to Car-2-Car (email communication), the outstanding issues are frequency allocation for Europe, standardisation, and deployment strategies.

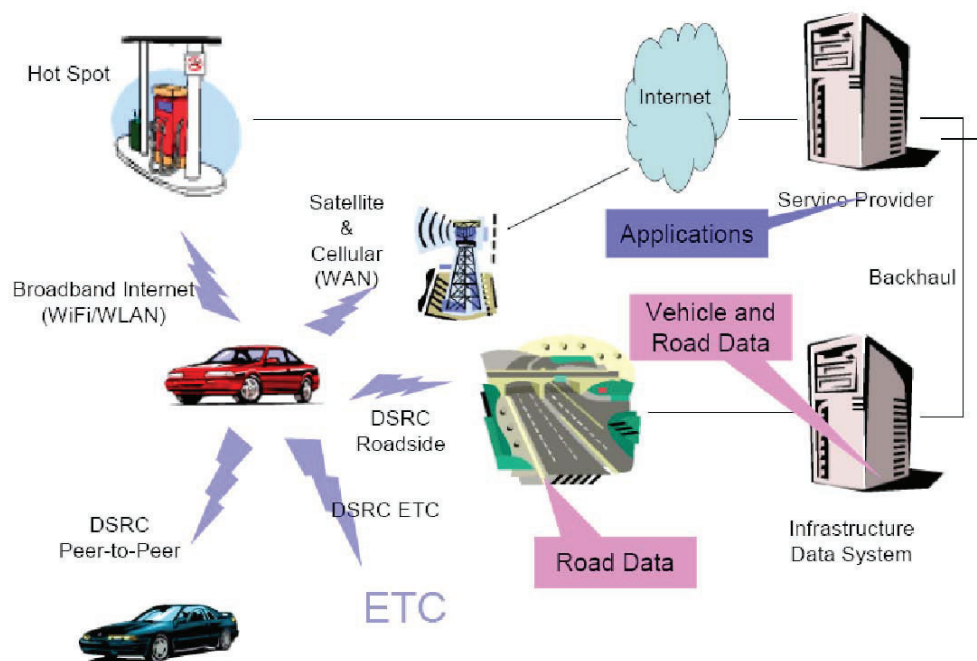


Fig. 1: Components and links of an Intelligent Infrastructure based on DSRC.
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 (Source: Connected Vehicle Trade Association)

There are in the US three major Department of Transport initiatives dealing with the intelligent infrastructure, namely the Vehicle Infrastructure Integration (VII), the Integrated Vehicle Based Safety Systems (IVBSS) and the Cooperative Intersection Collision Avoidance Systems (CICAS) programmes. The VII Consortium was set up in 2003 as a cooperative effort between government and vehicle manufacturers to evaluate the technical, economic, and social/political feasibility of deploying DSRC vehicle-to-vehicle and vehicle-to-infrastructure communication, primarily for improving traffic safety and efficiency. Fig. 3 shows the proposed system architecture for the use of DSRC. Elements in grey are peripheral elements which either use the architecture or provide services (for example, a Traffic Operations Centre sending data to a group of vehicles).

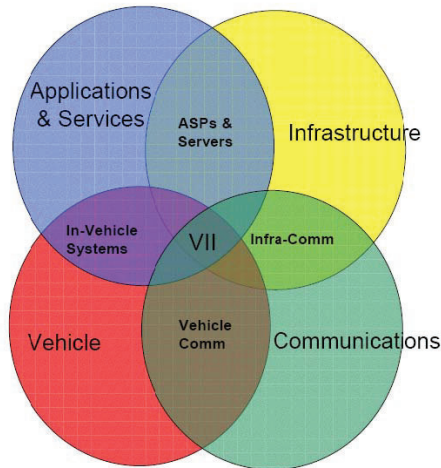


Fig. 2: Intelligent infrastructure components (Source: Connected Vehicle Trade Association)

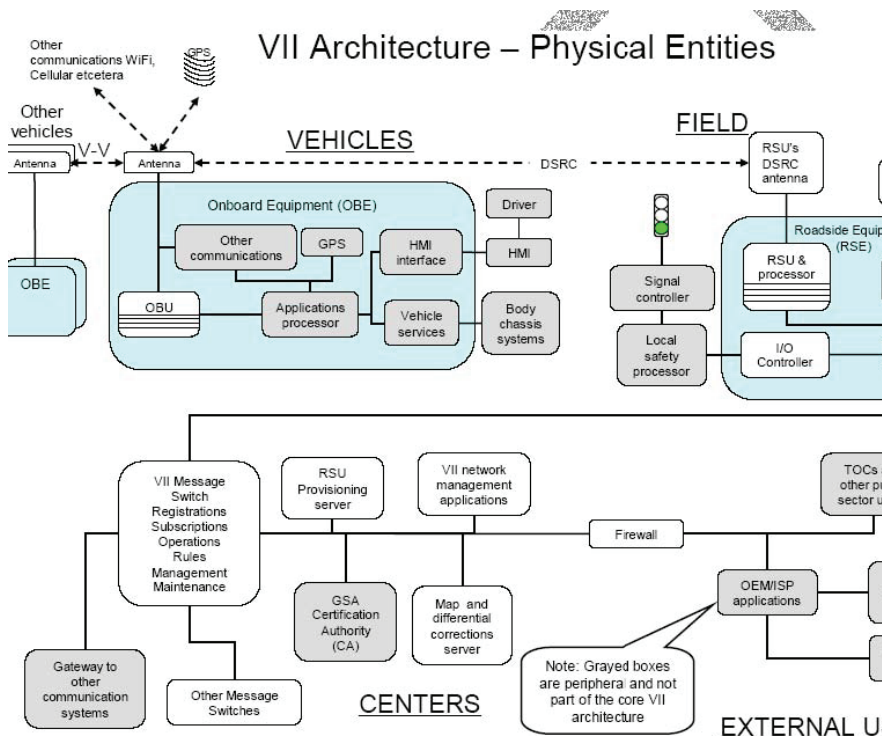


Fig. 3: System architecture for the Intelligent Infrastructure based on DSRC (Source: VII Architecture and Functional Requirements, FHWA, 2005)

In this paper, three application domains for telematics are reviewed, namely:

1. Road safety (eSafety),
2. Traveller information and services, and
3. Traffic management.

Road safety (eSafety) domain

The European Commission has initiated the eSafety Programme to halve road accident fatalities by 2010. A range of active safety measures are enabled by emerging technologies. For example, the European Commission has announced an action plan for the installation of eCall systems in all new vehicles by 2009 (www.escope.info). In the event of a crash, a single location-enhanced European emergency number is called automatically or manually. It is estimated that accurate location information can greatly reduce response times, saving about 2000 lives per year across Europe. Other applications of this technology in the safety domain being looked at in the US are set out in Table 1. Some systems are more difficult to implement than others, so an assessment is made as to whether the system is for the near or medium term. Similar systems are being studied in Europe (see ADASE, 1999).

Table 1: Vehicle safety systems employing DSRC

System	Description
Cooperative forward collision warning (VV)	Follower and leader vehicles warned of a possible front-end collision. Accurate position information is required. Medium term.
Emergency braking notification (VV)	Braking vehicle notifies the vehicle behind electronically, complementing the brake lights. Near term.
Lane or road departure warning (VI)	Driver is warned when leaving a lane or the road. Accurate position information is required. Medium term.
Pre-crash sensing (VVI)	Vehicle detects an imminent crash enabling appropriate action, like pre-tensioning seat belts. Accurate position information is required. Medium term.
Curve speed (or roll over) warning (VI)	Driver forewarned of a curve ahead requiring a speed reduction. Near term.
Right turn assistance (VI)	Conflicts resolved cooperatively to give a driver safe passage. Useful for older drivers. Accurate position information is required. Medium term.
Give way junction assistance (VI)	Driver told when safe to cross. Useful for older drivers. Medium term.
Traffic signal violation warning (VI)	Drivers warned of a potential red light violation. Elimination of the dilemma zone. Near term.
Intersection collision warning (VVI)	Drivers warned of a potential collision so corrective action can be taken in time. Useful for older drivers, pedestrians and electric scooter users. Near term.

Road / rail collision warning (VVI)	Drivers forewarned of level crossing closure. Near term.
Road condition warning (VV)	Warning of treacherous conditions, like ice or oil spillage, disseminated upstream. Vehicle is a weather and road condition probe. Near term.
Approaching emergency vehicle warning (VV)	Warning of approaching emergency vehicle passed from vehicle to vehicle. Complements siren. Medium term.
Emergency vehicle signal pre-emption (VI)	Traffic signal controller forewarned of approaching emergency vehicle. Near term.
Road works warning (VVI)	Drivers forewarned of road works. Near term.
Motorway merge assistance (VVI)	Driver guided safely from a merge lane into the main stream. Useful for older drivers. Medium term.

VV = Vehicle-Vehicle communication; VI = Vehicle-Infrastructure communication;
VVI = Vehicle-Vehicle and Vehicle-Infrastructure communication

Many of the functions listed in Table 1 may be achieved in a degraded way without DSRC. For example, systems for front-end collision warning, parking assistance (near collision warning), lane or road departure warning, blind spot monitoring and merging assistance have been researched using vehicle-mounted sensing (like radar or image processing) only (see Fig. 4).

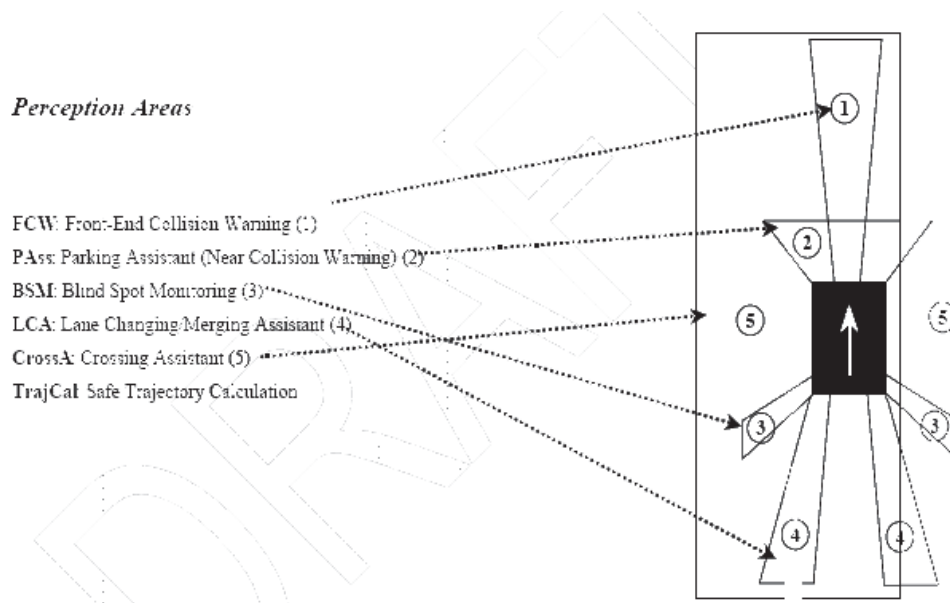


Fig. 4: Collision warning systems (Source: ADASE, 1999)

Freight transport

Across the EU, freight constitutes around 15% of traffic on roads in general and around 25% of traffic on motorways (ADASE, 1999). However, goods vehicles contribute disproportionately to fuel consumption, emissions and wear and tear on the road network, because of their heavier weight. Because of their larger size, they

make a disproportionate contribution to congestion. Moreover, they are three times more likely to be involved in an injury accident and twice as likely to be involved in a fatal accident as a car.

The above statistics emphasise the benefits of greater safety, improved operational efficiency and reduced emissions in the freight sector. Two-way communication between driver and dispatcher has long been a feature of many freight distribution operations. The advent of DSRC, apart from the functions identified earlier, would provide an additional channel of communication for the dispatcher.

Public transport

There are various forms of public transport, such as bus (scheduled or demand responsive), taxi (conventional or shared), rail (heavy rail, metro or tram) and people movers (driverless systems). We focus on road-based forms of public transport, namely bus and taxi. In the case of fixed-route services, accurate positioning requires no more than an accurate odometer. GPS is typically used to calibrate odometer readings. Various public transport-specific telematics applications are listed in Table 2, as well as the time horizon over which they are likely to become available (based on ADASE, 1999).

Table 2: Bus systems

System	Description
Rescheduling and rerouting (VI)	When the locations of all buses are known, corrective action can be taken in the event of incidents. Near term.
Bus priority at traffic signals (VI)	Commonly found.
Timetable improvement (VI)	Bus performance is monitored with a view to producing more accurate schedules. Near term.
Demand responsive operation (VVI)	Passengers make reservations, check on the status of their rides, and obtain billing information. Near term.

Traveller information and services

Emerging technologies are enhancing the ability to “detect, analyse and disseminate traffic and transit conditions” (FHWA, 2005). Vehicles equipped with appropriate sensors can act as probes collecting data on traffic conditions (congestion), weather (ambient temperature, rain fall), and road surface conditions (wet, black ice, spilled oil). This data then can be pooled (sent to a Traffic Information Centre) or shared (disseminated to vehicles in the neighbourhood) using satellite, cellular or DSRC links. Further details on aspects of this topic are to be found in McDonald and Li (2005).

Driver information

In-vehicle navigation systems are spreading inexorably through the vehicle fleet. While the uptake of manufacturer fitted navigation systems is limited because they are optional and expensive, the aftermarket for portable navigation devices is growing rapidly. In part, this is because such systems can be moved from vehicle to vehicle. Current systems are largely autonomous, with a map stored on a DVD, hard

disk or memory card, GPS positioning, and map matching to counteract GPS outages (see earlier). In more complex systems, dead reckoning based on a compass and an odometer is used when contact with the GPS satellites is interrupted. Service providers can supply a limited amount of dynamic data via the Traffic Message Channel (TMC) of the Radio Data System (RDS), a digital data broadcast by FM stations in a non-audible form which is received by RDS enabled devices in the vehicle (such as the car radio).

Some systems take the form of a portable device with a screen for the display of the map, a hard disk or a memory card for the storage of the map, and a GPS receiver for positioning. This can be used to reach destinations on foot or by cycle. The mobile phone could be that portable device.

The autonomous system architecture has a number of weaknesses, namely:

1. The map on the DVD ages, particularly in suburban areas where traffic calming measures are being implemented.
2. The dynamic data is limited to major events such as serious accidents or severe congestion.
3. All travellers making a particular trip at a particular time will receive the same guidance, potentially causing congestion where it did not exist before.

There is increasing interest from vehicle manufacturers (BMW, for example) and providers of traffic information (like TrafficMaster) in more centralised system architectures, where the map is stored centrally in a Traffic Information Centre (TIC) and guidance is downloaded to subscribers. In centralised system architectures, the vehicles can be used as probes ("floating cars") which measure link travel times and delays, referred to collectively as Floating Car Data (FCD). In the Dynamic Assistance and Navigation (Diane) project, vehicles equipped with a Siemens SX1 mobile phone with the PTV Navi Guide mobile navigation system installed and linked to a GPS receiver collect and transmit FCD to a traffic management centre, and in return receive navigation and warnings (www.ptv.de).

The centralised system architecture has a number of advantages:

1. The map can be continually updated.
2. Dynamic data from a wide range of sources including FCD can be added to the map in the TIC (forming an "active" as opposed to a static map), leading to better guidance.
3. Travellers making a particular trip at a particular time can be recommended a range of good routes, avoiding the generation of congestion on any particular route.

Leading auto manufacturers (like BMW) are currently interested in adaptive route guidance, whereby the guidance system learns driver preferences and builds these into the guidance offered. This can be implemented in either an autonomous or a centralised system architecture. In either case, choices made by drivers (for example, to avoid right turns or motorways) are used to infer preferences for link or path attributes. This could be important in the context of increasing numbers of older drivers, as reduced reaction times will make more complex manoeuvres or higher speeds more hazardous. They may then reveal a preference for well-lit routes with less complex manoeuvres and lower speeds.

Other services

Other telematics services that can be supported by emerging technologies include parking allocation assistance, parking access (security or payment), drive-through payment, toll payment, appointment confirmation or changes, downloads of data files (for example, MP3 files or games), and synchronisation with the home or office PC.

Traffic management

Emerging telematics technologies, in particular DSRC, offer interesting possibilities for travel demand management. In addition to long-term switches from more to less congested modes and times of travel, they will enable destination, mode, route and travel time choices to be influenced more immediately by problems as they arise in the road network.

Traffic signal control

Advances in traffic control have been modest recently. On-line traffic control, like SCOOT and SCATS for medium to large urban road networks and MOVA for small networks, have matured over the last two decades into well-established systems. There are now over 40 SCOOT installations in the UK. However, these and similar systems were developed at a time and in an environment in which vehicle traffic was paramount. As priorities shifted in favour of buses, trams, cyclists and pedestrians, fixes were devised. In the case of public transport for example, interventions to give priority to trams or buses were superimposed on the vehicle-oriented SCOOT optimiser, leading to a hybrid system. The recent Urban Traffic Management and Control (UTMC) research and development programme in the UK was designed to modernise SCOOT and align it more with current social and political objectives.

However, there are limits to the extent to which an old system like SCOOT can be adapted to modern requirements, so the day is coming when traffic signal control should be radically rethought. Fuzzy logic offers exciting possibilities for multi-objective traffic control, allowing each junction to operate with its own set of priorities. For example, one junction perhaps located on the edge of a pedestrian precinct, may prioritise pedestrians while another perhaps on a radial route may favour vehicles.

Sensors

Sensors employed in urban traffic control have been basically the inductive loop vehicle detectors. Essentially a metal detector buried beneath the road surface, this technology has also reached maturity. In larger urban areas, inductive loop sensors are increasingly supplemented by video surveillance of key locations and bottlenecks, with the images fed by fibre optic cable back to a control centre. From there, the images are sometimes broadcast either as part of television traffic broadcasts or via the internet. Image processing has found a niche for itself, initially as a "loop emulator", then for automatic incident detection, and most recently for licence plate recognition. In the London congestion charging and the Rome access control systems, vehicle licence plates are read automatically via Optical Character Recognition (OCR) software as part of the enforcement function. When combined with licence plate matching software, OCR may be used to monitor travel times (TrafficMaster does this for the UK national road network, see www.trafficmaster.co.uk).

Other forms of vehicle sensor have found niche applications. Pole-mounted microwave sensors working on the Doppler principle are used for temporary installations at road works. Ultrasonic sensors suspended above the carriageway,

also working on the Doppler principle, are widely used on Japanese expressways. Siemens market an infrared sensor for traffic signal control, while TrafficMaster uses bridge-mounted infrared speed sensors as part of its data collection network.

There is great interest in the use of FCD to improve traffic management. FCD is currently collected by ITIS (www.itisholdings.com) from a fleet of around 40,000 vehicles and sold on to customers, such as BMW, who then feed information about congestion back to subscribing customers via TMC. Typically this leads to the superimposition of congestion warning pictograms on a map displayed to the driver. In some systems, for example the BMW route guidance system, TMC messages can cause the in-vehicle guidance system to seek a new route.

Social and economic trends

Policy toward the evolution of the intelligent infrastructure depends not only on the technological context already reviewed but also on demographic and economic trends.

Aging population

The UK population, in common with that of many other countries, is aging. According to the UK Office of Health Economics, around 25% of the population will be over the age of 65 by 2050 (currently around 16% of the population is over 65). This has implications for:

1. The physical ability to drive, as reaction time diminishes and the senses fade with age.
2. The demand for accessible transport services, like dial-a-ride, special taxis and low floor buses.
3. The need for suitable travel information via a variety of media, including the internet, mobile phones and handheld devices.
4. Alternatives to walking, like electric scooters and wheelchairs.

The ability to drive is widely regarded as an important determinant of the quality of life for older people. The emerging telematics technologies offer a number of solutions:

1. DSRC will enable the development of driver assistance systems to help older drivers negotiate right turns, give way junctions and motorway merges, as reaction time is important for these manoeuvres.
2. Intersection collision warning systems will provide added protection for older pedestrians and electric scooter / wheel chair users, by alerting drivers to their presence when crossing the road.
3. In-vehicle display of roadside information will enable older drivers to focus more on the driving task and absorb roadside information when safe or convenient to do so.

Globalisation

Supply chains are becoming increasingly global. The improving efficiency of the world container industry, stimulated by larger container ships (postpanamax vessels carry in excess of 8,000 twenty foot equivalent units) and faster container handling at ports, is reducing transport costs. Additionally, the cost of information transmission continues to fall. While there may be some scope for shifting freight from road to rail

and water, the flexibility of the truck means that it will remain the dominant mode in most sectors. The implications of globalisation are:

1. Greater international division of labour, resulting from a continued trend to outsourcing and global sourcing, leading in turn to more freight movement.
2. More truck traffic on roads, particularly motorways.
3. More air freight to support global just-in-time deliveries.
4. Greater spatial disassociation between home and work, with greater home working and less peak period commuting.
5. Longer work trips.

Emerging telematics technologies will benefit supply chain efficiency in the following ways:

1. Improved routing and scheduling through better traffic data, in particular FCD.
2. Greater ability to respond efficiently to unexpected eventualities, like road accidents, congestion, etc.
3. Improved safety for goods vehicles through various driver warning systems. This is particularly important for hazardous loads.

Transport and the environment

This field is reviewed in depth by Bell (2005). Environmental standards are becoming increasingly stringent, driven by worldwide concern about global warming and the depletion of natural resources (in particular oil). Transport is a major emitter of greenhouse gases. Increasingly stringent environmental standards have implications for:

1. Forms of vehicle propulsion, in particular the use of hydrogen as an environmentally friendly alternative to oil. Fuel cells are expected to become more affordable with time, leading to their gradual introduction.
2. Use of the pricing mechanism to reflect the cost of environmental externalities (the polluter pays principle).

Telematics will help through:

1. Electronic payment systems. While road tolling systems are now well established, DSRC could improve payment and enforcement.
2. Improved vehicle routing and scheduling, in particular through FCD.

Traffic safety

While road safety has improved over a long period, road accidents remain a major cause of deaths and serious injuries. Further improvements in road safety require:

1. Active safety measures to support manoeuvres like right turns and motorway merges.
2. The protection of vulnerable road users, such as children, older people and cyclists.

Emerging technologies can help through:

1. Vehicle safety systems using sensors, such as radar, and DSRC to support cooperative driving.
2. Driver monitoring systems which detect diminished driving capability due alcohol, drugs or tiredness.
3. Automated highways which chain and guide vehicles electronically with reduced need for driver intervention.

Policy issues

The deployment of intelligent transport solutions to best meet UK needs requires an element of coordination and support. The following principles should underlie policy formulation:

Priorities

There is a consensus that safety takes priority in the application of emerging technologies. This is clearly reflected in the protocol chosen for DSRC by the US Department of Transport, where “safety of life” messages (messages relating to an imminent collision) get top priority, followed by public safety messages (police, fire, ambulance) and then private commercial applications. As indicated in Table 1, DSRC enables a range of active safety systems. UK research and development funding could focus on applications that promise the largest reduction in accident frequency and severity, so it is important to establish what these are first. Additionally, if there is a consensus that the safety of vulnerable road users (children, older people and cyclists) ranks more highly than the safety of other road users, then this could be reflected in the phasing and funding of research and development.

Funding deployment

The infrastructure, in particular traffic signal control systems, is at present largely publicly owned. As most safety systems involve vehicle-infrastructure communication, deployment of these systems will require a partnership between the relevant traffic authorities and the vehicle manufacturers. An appropriate method for funding deployment in the UK may therefore be a public-private partnership, whereby a private sector consortium deploys the technology and is paid by the public sector for services through a service level contract.

In theory, a public private partnership brings the benefits of private sector management, relieves the state of capital costs and shifts the risks inherent in any large project from the state to the private sector. In practice, the extent to which risk is actually transferred to the private sector depends on how willing the government is to allow the consortium to fail. Given the political difficulties of such a failure, governments usually prefer to renegotiate the contract than allow failure (as in the case of congestion charging in London, run by Capita). To keep the cost of private finance within reasonable bounds, the extent of risk accepted by the private sector consortium is usually contractually circumscribed. Even so, there is an argument that private finance is more costly than public finance. Another potential problem with service level agreements is that they can stifle innovation after deployment.

Despite drawbacks relating to ultimate risk transfer and the cost of finance, public-private partnerships will still be the most appropriate mode for telematics deployment where there is substantial public benefit and the system would not otherwise be commercially viable, because of the cost controlling incentives they generate and

their ability to harness the technical and management skills available in the private sector. Care needs to be taken to ensure that contracts encourage innovations which lead to improvements in services. This could be particularly important in situations where the technology is evolving rapidly, as forms of service not currently possible or even envisaged may become feasible after further research and development.

Civil liberties

For telematics solutions to succeed, these systems need to be technically, economically, socially and politically feasible. Social and political feasibility will require the resolution of issues relating to privacy, data ownership, data access and liability. Regarding privacy and data access, boundaries need to be set and security measures implemented to prevent data leaking outside these boundaries. In setting the boundaries, personal privacy and civil liberties need to be considered and security should be sufficient to prevent unauthorised access and tampering.

Social inclusion

Telematics services should be socially inclusive, which means that social groups with special needs who may otherwise be excluded need to be considered. These may be children, older people, shoppers with difficult loads, parents with children, people with disabilities or ethnic minorities. For example, the car gives older people independence, so it is important for their quality of life that such systems take their needs into account. Without a policy to support this, development may focus exclusively on services for those with the highest ability to pay for them.

Polluter pays

Public debate in the UK has recently been initiated by the Minister of Transport on national road use pricing as a remedy for congestion. Pricing offers a mechanism for ensuring that the benefits of road transport, as measured by willingness to pay, outweigh the environmental cost. However, this would require the quantification and then the valuation of environmental degradation due to road use. This in turn requires more extensive monitoring of emissions, including noise. The valuation of emissions is controversial. Yet more controversial is the evaluation of the aesthetic damage perpetrated by traffic, particularly in historic urban centres.

Having resolved these complex pricing issues through the democratic process, telematics offers additional channels of communication with drivers. For price signals to achieve their intended effect, drivers need to be aware of these. Telematics also eases toll collection.

Pervasive information

Emerging journey planners, like TransportDirect (www.transportdirect.info) should be linked to in-vehicle route guidance systems, and both should become more dynamic through the use of FCD which will become more plentiful with time. In the public interest, travellers should be encouraged to use appropriate modes in city centres and home zones.

Interoperability

The effective deployment of telematics requires interoperability, certainly at the national level but also across Europe. This is not only for the comfort and convenience of users but also for the reduction of costs that economies of scale bring. Interoperability is required to maximise the potential of random networks

generated by DSRC (so that BMW cars communicate with other non-BMW cars, for example). However, the formation of protocols and standards requires international cooperation involving all stakeholders, including the UK government. It will be important to ensure that the sorts of applications envisaged for the UK are covered by these standards. To support this, the UK-centric vision of the intelligent infrastructure being developed by the Intelligent Infrastructure Foresight initiative will be key.

Conclusions

An unfolding communications revolution is opening up the potential for new solutions to old road transport problems. Of particular significance is Dedicated Short Range Communication (DSRC), which offers WiFi-like communication between vehicles and between vehicles and the infrastructure. Considerable effort, particularly in the US, has gone into identifying uses for DSRC, with an emphasis on those directed at improving road safety. Precise map data coupled with precise position data will enable a range of safety functions. Richer maps including speed limits, stop signs, and turn restrictions will help drivers avoid common mistakes with occasional tragic consequences. The UK has much to gain from these developments, mainly as a user rather than a supplier. Policy toward research, development and deployment in the UK should be guided by a UK-centric vision of future intelligent infrastructure, which the Intelligent Infrastructure Foresight exercise will provide.

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