Delivering Information for the Management of Infrastructure and the Movement of Goods and People

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1.0 Introduction

Levels of traffic congestion, environmental pollution and safety are becoming increasingly unacceptable on roads in many regions in the UK and Europe. At the same time, our societies cannot function without adequate provision of transport to serve both the needs and the desires of individuals and essential business purposes. The introduction of new infrastructure is important but it is very clear that the construction of new roads will result in the generation of additional traffic and, of themselves, they will not necessarily lead to sustainable future transport situations. Thus, the general thrust of transport policy in the UK and other European countries is to build essential highway capacity only, and to better manage available capacity for all modes so as to meet increasingly wide ranging policy objectives as effectively as possible. These policy objectives relate to curbing congestion, improving safety, addressing local and global environmental concerns and meeting broader social needs of access and mobility. Developing ways to reduce reliance on private cars is a key issue, whilst maintaining mobility and enhancing accessibility (EC, 2001).

The rapid development of new technologies in areas of location, communications, sensors and control are providing and will continue to provide ways to better achieve current policy objectives and to enable the evolution of new policies which reflect changing social, economic and environmental circumstances. The application of Information Technologies (IT) can revolutionise the way that people and goods move by reducing travel times, operating costs and environmental impacts, and by improving accessibility. Fundamentally, transport is market driven, and individual travellers and those who move goods or parcels make decisions that best meet their own particular requirements, which may include time, cost, security, or reliability factors. Those who provide or operate transport infrastructure or offer transport services make decisions which best meet their financial, social, environmental, safety or economic objectives. All such decisions are based on information and where this is incomplete, incorrect, misunderstood or partially or wholly ignored, the transport outcomes may be far from optimal for the users, or for society as a whole. Also, as transport networks and systems become more congested, accurate, timely, and relevant information and its effective and coherent delivery is becoming increasingly important to enable individuals to make more informed decisions. In addition, the delivery of accurate information will expose shortcomings in the underlying transport systems and services and this should, in turn, drive up their quality through exposure to a more knowledgeable market. Overall, Intelligent Transport System (ITS) technologies are essential to the delivery of the information necessary for a successful and sustainable transport future.

Information needs to be delivered to a wide range of user groups. In this paper, users of information have been considered under the following headings:

i.) *Infrastructure Owners and Managers.* Those who provide infrastructure require information in order to monitor the performance of the infrastructure provided (such as a motorway), to plan new infrastructure and to schedule maintenance. The information needed for this will generally be based on off-line historic data. Depth and subtlety of understanding is increasingly necessary to support sophisticated evaluation processes. These may include origin and destination data, and behavioural understandings may be derived and delivered using new technologies related to people, systems or vehicles. Infrastructure is expensive to provide and credible information is needed to convince public and/or private decision makers of the viability of economic or financial options. Those who manage infrastructure generally require more detailed information to measure performance and to make off-line and on-line decisions for future operations. Information may be stored to monitor trends or be used for "post mortem" analyses to understand the outcomes of situations and what, if any, mitigating measures should be adopted in similar circumstances in the future. Information may be used for on-line management, such as providing bus priority in an urban traffic control system or to initiate speed controls on a motorway, and may involve control algorithms or modelling processes. Information may be general in nature such as traffic flow or passenger counts, or it may involve the specific identification of people, vehicles or goods for charging, security or enforcement purposes. Information may be an essential requirement for financial viability as, for example, third party payments may depend on the numbers of end users. However, in a managed system data will always be sought against specifications, as information collection and delivery will always be a cost which must be measured against benefits. The integration of information between system operators is generally market driven, particularly where the systems relate solely to the provision of traveller information and are not part of a transport service itself. Technology is at the heart of timely delivery of information for management and between service providers.

ii.) *Public Transport Users*. Individuals who, as end users, make travel decisions for themselves, friends, family and colleagues using public transport. They may have a wide range of special requirements, and information sought or given may be general in nature or bespoke and tailored to their specific needs. The information may be limited by, for example, mode, timeliness, accuracy or relevance. It may be available as general information to be searched through, or travel solutions may be presented. Travel and transport decisions to meet specific requirements will be made on a wide range of factors which will include time, cost, convenience and reliability, and will be driven by individual choices and preferences.

iii.) *Car Drivers.* Individuals who choose to drive have been identified as a separate user group because the information collection and delivery processes have been very different from those of other modes. Also, for other than very short trips, the car is the dominant mode of transport. Often groups, such as families, will travel together on a car trip and, whilst all passengers may have an influence on the decisions, for the purpose of this paper we refer to the driver as the end user for car trip.

iv.)*Public Transport Service Providers.* Public transport service providers need information to manage their services efficiently with either on-line or off-line decision processes, and to determine changing services and payment processes. As individuals only use public transport services because of their knowledge of the services on offer, the delivery of such knowledge is a key aspect of service provision.

v.)*Freight/Goods Services Providers*. Decisions on the movement of freight or goods will be made by individuals, albeit in the context of company policies. Cost, timeliness, reliability and security of delivery are key factors. The emphasis will depend on the goods being moved and condition monitoring. The characteristics of the information needed and its delivery for management may vary with the ownership of the service.

A range of *other* groups are interested in the provision and delivery of information. Such groups include vehicle manufacturers, internet service providers, location and communication service industries and those manufacturing information collection or delivery equipment such as roadside detectors or display boards. These groups service the information industry and deliver the technology push which influences the quality and delivery of the information itself.

This paper addresses the context for the delivery of information to various user groups identified above, how such information is collected and delivered at present and how this may change in a vision for the future.

2.0 Users and information delivery

2.1 Context

The ITS applications that are evolving to meet user needs cover a broad range of information and telecommunications technologies to detect people, drivers, vehicles, goods, traffic and environmental conditions, and communicate information to a variety of user groups, operators and stakeholders. User needs are complex, vary between users and are influenced by factors such as levels of system development and deployment and social and economic trends. A simple overview of the relationships between applications and information services is given in Table 1 with additional discussion for user groups in the following sectors.

Table 1. Information needs and sources

User groups	User applications	Types of information	Information sources

Infrastructure owners and managers	Network monitoring Performance monitoring New infrastructure planning Maintenance planning Vehicle tracing Emergency response Enforcement Control Forecasting Safety monitoring Environment monitoring	Network state estimation, e.g. flows, capacity, delays, accidents, congestion, environment, vehicles, passengers, goods. Control strategies	Point detection by sensors to identify vehicle type, pedestrians. Specific identification, e.g. train, buses. Section speed characteristics Probe vehicle data Integration of CCTV Manual information External sources, e.g. weather forecast
Public transport users	Pre-trip decisions Within-trip confirmation and recovery	Static data, e.g. timetables Dynamic data, e.g. display screens, PDAs. Time, cost, location	Public transport service suppliers Public and private traveller information service suppliers, e.g. Transport director

Car drivers	Route optimisation Destination findings Route following Dynamic route guidance	Route and journey time estimations Dynamic rerouting Related information, e.g. parking, garages Road characteristics, e.g. speed limit Multimodal links	Highway/road authority data Traffic information suppliers, e.g. TrafficMaster, ITIS Motoring organisation Media Other people Traveller information suppliers

Public transport service providers	Fleet monitoring Relevant network condition monitoring Setting provision (on-line/off-line) Planning service Incident recovery	Vehicle location Capacity/control conditions Passenger demand	Vehicle sensors Roadside/trackside sensors Operating staff
Freight/goods service providers	Fleet/cargo monitoring Network route planning Service demand Efficient delivery Incident recovery	Vehicle/cargo location Demand characteristics Storage options Network conditions	Vehicle sensors Container sensors Warehouse/delivery data Infrastructure and information service managers Staff

2.2 Infrastructure owners and managers

The provision of new transport infrastructure for any mode or modal interchange is expensive and may be subject to constraints such as those imposed by planning processes. Therefore, increasing the efficiency of management of existing infrastructure is important and requires the delivery of information for effective control and management decisions. In some transport systems, such as rail, elements of the system are largely under the control of the infrastructure manger, whereas for others, such as the road network, the actions of users are largely outside the control of the infrastructure manage.

In recent years, transport management schemes and emergency scenarios have been developed for cities and regions to increase transport efficiency, reduce congestion and improve performance of road transport. However, the real-time implementation of many of these plans is hampered by lack of appropriate information (ROSETTA, 2004a). Real-time and long-term monitoring of the transport system is a fundamental requirement for infrastructure management and mangers should expect coherent and comprehensive information.

2.3 Public transport users

Traffic and traveller information services (TTI) have been one of the fastest and most visible areas of growth in transport telematics in recent years. For travellers, an ITS system should deliver information in a straightforward and clear way which reflects the needs of the individual. In additional to the more traditional ways of obtaining travel information, there is a proliferation of Internet websites offering support for journey planning, including services such as routing, ticketing and traffic or travel news. At present, some information provision is expensive, inaccurate, unreliable, has limited functionality, a lack of integration and is intrusive. Policy makers often see the provision of traveller information as a way to influence transport mode choice in order to encourage the use of public transport and reduce car journeys, but travellers are more likely to have information about satisfaction of time, cost, reliability, convenience, security and comfort (Barker and Connolly, 2005). While cost and travel time can be quantified, this is less true for reliability, convenience, security and comfort, although reliability is increasingly seen to be a key factor (Edwards and Blythe, 2004). User perceptions of service do not always reflect the performance of the service itself. For example, several studies have shown that travellers have perceived a service to improve in terms of reliability after the delivery of on-line traveller information even through the measured reliability fell.

Many studies have been undertaken to understand what traveller information should be delivered. Traveller needs are not uniform and vary with individual and service characteristics as well as by journey purpose and type. For example, the expectation of an international business traveller will be very different to that of a local commuter, and individuals with different lifestyles, income or expenditure will have different priorities and expectations. Issues of social inclusion are of increasing importance, and the needs of an aging population increasingly require additional information which relates to a range of disabilities (Meyer, 2004).

In general, traveller information should (Nottingham, 2002):

- Be accurate and reliable to give travellers full confidence in its use ;
- Cover multimodal options, so that travellers are fully aware of public transport and non-road mode (Lyons, 2001);
- Provide updates on delays, service disruptions, etc., to give 'early warning' to travellers of potential problems and facilitate any necessary change of plan;
- Deliver the information effectively to make messages easier to understand and available via multiple channels.

2.4 Car Drivers

The fundamental characteristics described above in Section 2.3 also apply to car drivers. However, as a driver, information needs to be delivered in a way which does not cause additional risk during the driving process. More accurate routing should result in less route mileage and hence reduce exposure to accident risk. Also, dynamic information systems can warn of problems ahead (FHWA, 2004a).

2.5 Public Transport Service Providers

Public transport service providers need information to monitor the position and status of their vehicles to improve efficiency of management. Such management decisions may be on-line or off-line and will relate to network conditions and characteristics of passenger demand. Longer term decisions to plan services for normal or event situations will also be needed.

2.6 Freight/goods service providers

It is evident that a large information market exists for business applications (the management of the 'mobile' workforce). The range of information needed included

location reference
status of vehicles and cargo
network status
cost, road charging and payment
market and customer needs

Communication technologies, especially the Internet, have enabled data sharing between operators and fleets, operators of different modes and in different regions. Data sharing covers a wide range from real-time monitoring of cargos to seamless e-ticketing and payments. Issues of security and privacy are critical (Giannettoni and Savio, 2004).

3.0 Information Sources

3.1 Types of Information

Information may be considered to relate either to static situations such as fixed timetables which change infrequently, or to dynamic conditions where changes occur in response to prevailing circumstances. For example, dynamic information can enable real-time decisions to be made by system managers, the systems themselves, or by end users to optimise system operations and/or personal decisions. Whilst the boundaries between static and dynamic information may often be blurred, the following gives an indication of the ranges of information which may be available.

Static information includes:

maps and geographical information
navigational instructions
route of public transport and logistics
historical travel times by location, time of day, day of the week and season
planned events, construction and maintenance activities
tolls and payment options;
transport timetables and fares;
intermodal connections;
transport vehicle/system characteristics such as comfort, convenience, accessibility and reliability
vehicle regulations.

Dynamic information includes:

network conditions, including congestion and incident information;
weather information, including road surface condition and visibility;
real-time journey time to a destination;
real-time location of transport vehicles;
alternative routes, modes or timing recommendations ;
whether public transport and freight vehicles are on schedule;
the availability of spaces at warehouses, parks and garages;
the identification of the next stop on a train or bus;

the location or arrival time of the next train or bus.

3.2 The Current Situation

The importance of information for an efficient and well run transport network has been identified for many years (Bonsall and Bell, 1984). Technological advances in sensors, image processing, acoustics and navigation have been applied to collect ever more detailed, accurate and comprehensive traffic and transport data. Advanced computer and communication technologies have been developed in parallel to maximise the use and benefits of the information collected. Governmental and commercial private investments have been made to develop information systems and services which operate for public and private users at individual, company, local, regional and national/trans-national levels. These services have produced significant social and economic impacts in terms of safety, environment and quality of life. The U.S. FHWA Freeway Management and Operations handbook (FHWA, 2003a) states that "alerts via VMS, Internet sites showing real-time traffic conditions are all benefits that do not require a benefit/cost ratio to be understood".

Important progress has been made in the area of collecting and delivering information. The main providers of the information services are at present (ROSETTA, 2004a):

- Infrastructure operators, who collect and deliver information specific to their own operations. The information does not normally address personalised requirements.
- Information services organised at local authorities to provide data covering the area. The information is often a part of tourist information.
- Private service providers, who tailor information specific to their own customers.

Public agencies (e.g. the Highways Agency) or transport operators monitor the network for which they are responsible. Network monitoring is not an end in itself, but usually supports management and control services (FHWA, 2003a), user information in its broadest sense, and provides off-line data for statistical and planning purposes. In some cases, data from public agencies and local authorities are often shared with other operators and service providers. Single service providers collect data for their own interest or for selling the information. There are two main forms:

- Transport service operators: logistics companies, public transport providers, airlines, ports and railway owners. They collect data for business applications, for example workforce management, fleet route planning and public transport scheduling. Some of the data is used to provide information services to meet customers' needs, e.g. real-time passenger information. Otherwise, information is often considered to be company confidential.
- Information providers, e.g. TrafficMaster and ITIS Holdings in the UK. They generate data content and sell the information to customers such as individual travellers, public agencies and fleet managers. The information normally addresses specific market segments or personalised requirements. Heavy investment is required to set up such services.

3.3 Technology

Both public and private data providers claim their respective data collection/monitoring technologies are mature and sufficiently accurate for the specified tasks. In most cases, several technologies are capable of providing these data, with specific implications for accuracy, costs, scalability or multi-functionality (Blythe, 2003). Some techniques are well established in practice, some are more like pilot applications, and many are expected to be improved in cost and quality. Rapid advances in technologies and computing power have left a wide mixture of monitoring devices, communication lines and hardware platforms on the networks and in the monitoring centres.

3.3.1 Sensors

Public agencies and local authorities have invested considerable funds in the implementation of fixed, roadside monitoring equipment, mostly inductive loops. Loops have been used successfully for many years and the increasing cost of loop detectors, both the direct cost of installation and indirect cost of traffic delay during installation and maintenance, has caused a shift toward alternatives. More recently, microwave overhead radar and infrared detectors have become more common, although a wide range of other detectors such as acoustic detectors are available (Turner et al., 1998).

In recent years, video technology has become increasingly popular because of advances in technology which have improved performance and reduced costs. Closed Circuit Television (CCTV) cameras are commonly used for visual incident detection and traffic quality assessment by traffic control staff or using automatic image processing software. Video image detection systems can use imaging processing techniques to collect, analyse vehicle length and classifications, speed, lane occupancy, headways and volume (Yin et al, 2004 and Blythe 2002). These data can be used for congestion monitoring and automatic incident detection (Michalopoulor et al., 1993; Bunn and Barrett, 1997). Software with appropriately located cameras can be used to read number plates on the video images, i.e. Automatic Number Plate Recognition (ANPR). ANPR-based journey time systems have been installed in both urban and motorway networks. Readings of the same registration mark at different monitoring points are then matched to enable travel times between two monitoring points to be calculated (Clark et al, 2002; Wiggins, 1999). ANPR technology is also used for enforcement, e.g. the London Congestion Charging system. For enforcement, the number plates are automatically compared against a database of vehicles for which payment has been made (Blythe, Walker and Knight, 2001). Fines are subsequently issued to those not complying. Similar approaches are used to enforce speed limits, red light running, bus lane use, etc.

Power and communication cables are usually available on the road network, normally introduced for emergency telephones or Urban Traffic Control (UTC) systems. By contrast, private data providers rely on autonomous ‘mobile’ overhead detector units, usually attached to motorway bridges or lighting poles. Communication is by wireless (GSM), which for cost reasons imposes severe restrictions on data bandwidth. Full national coverage of the primary (road) network is usually required for marketing reasons.

3.3.2 Location technology

In the past, most users of radio-navigation services came from with the maritime or aviation community. They understood that the derived position information was to be treated with caution and that it was unwise to rely on a single navigation device due to poor reliability and shortcomings in sensing equipment. The introduction of Global Positioning System (GPS) started a new era for navigation marked by radical changes not only in the level of service, but also the way in which the information is used and, consequently, the type of user (Sen et al., 1997; Faghri, 1999; Barnes, 2000; Moore and Najafi, 2004). GPS receivers incorporate software which greatly simplify the human-machine interaction, automatically providing latitude and longitude, or plotting a position on a map display.

Space-based positioning and navigation systems can provide meteorological, passive, three-dimensional position, velocity, and time data worldwide. The only GNSS (Global Navigation Satellite System) service to be widely available is the American GPS. The Russian Global Navigation Satellite System (GLONASS) shares the same principles, but has never been fully functional. As many transport applications are safety critical, mission critical or both, stand alone GPS is not able to give authentication and integrity information. European Geostationary Navigation Overplay Service (EGNOS) satellites which started service in 2005, can give integrity information of GPS (ESA, 2004). Over next few years Europe will be commissioning its own GNSS system, GALILEO, which will operate along with GPS 2 (available from 2007) and GPS 3 (expected in 2015) as well as GLONASS (EAS, 2005).

The number of users is set to expand dramatically from a few hundred thousand to billions with rapid growth occurring in use for all modes of transport. The numerous applications in the transport field include business activities associated with inland waterways, road travel, railways and emergency services, as well as the more traditional aviation and maritime areas. Millions of private individuals have purchased GPS devices to use the location information for route guidance when driving, and for leisure activities such as sailing, walking or cycling.

The incorporation of GPS receivers into mobile phones enables information to be received and delivered. Vehicles equipped with GPS and wireless communication systems have been increasingly used as probe vehicles to collect real-time traffic information, especially journey times (ANL, 1997; Kroes et al, 1999; Clarl and McKimm, 2003). The use of probe vehicles is considered to be an extremely cost-effective means of monitoring real-time journey times when compared with the alternative of installing fixed detectors, particularly when the probe vehicles are undertaking their normal journeys. A probe vehicle can be considered to be a mobile sensor in the traffic stream which reports location and speed information to a central information operator.

Various location-dependent applications have very different operational characteristics. While simple static position information is sufficient for some, others need information on direction, dynamic velocity or vehicle/infrastructure status from one or many users within an operational system. In terms of location accuracy, while a few services require very high precision (to within centimetres), for the majority of services medium levels of location accuracy are sufficient, but high levels of reliability and availability over a very wide area are needed.

3.3.3 Smartcard and AVI

Until recently most approaches to Electronic Toll Collection (ETC) have been based on the concept of short-range communication between an in-vehicle smartcard and roadside equipment using Dedicated Short-range Communication (DSRC). The in-vehicle smartcard can be a passive or active tag. The passive tags used today can be read from a distance of about two metres and store just enough data for an identifier and a small amount of other information. This data can be stored, displayed and sent to another location (Nelson, 2003, and Blythe, 2004). Active tags have a greater reading range (about 15 metres), but are larger and cost more. While passive tags can last indefinitely, active ones last only as long as their batteries.

In-vehicle smartcards enable the vehicle to be uniquely identified (Automatic Vehicle Identification, or AVI). One of the main uses of AVI is for toll collection. The 5.8 GHz microwave beacon has been standardised for use in ETC systems in the European

Union (ASFiNAG, 2004). DSRC beacons at 5.8 GHz are being deployed in European countries.

Toll collection has been extended from motorways to car parking and city centre access, e.g. Singapore Congestion Charging. Since the time when a vehicle passes a roadside reader can be known, individual vehicles can be tracked to provide journey times between two roadside readers. Some ETC agencies use AVI technology for journey time data collection in addition to toll processing (Turner et al., 1998; Chien and Kuchipudi, 2002).

An early use of AVI was for selective vehicle priority at traffic signals (Catling, 1987). Systems have been developed in Europe which enable operators to track fleet location and give priority, when it is needed, to selected vehicles – usually buses, or emergency vehicles.

In logistics, electronic tags attached to the goods are valuable for tracking items. The advantage is that the tags can operate in any kind of environment and do not need to be visible to the reader. Passive tags can be used to map identify and map containers onto the vehicle in order to speed up loading and unloading operations. Active tags could be used to monitor and record data with a loading/unloading zone, following goods by means of sensors on trucks, small electric vehicles or in parking bays. They may also be used to monitor condition, particularly important for temperature controlled systems (Hills and Blythe, 2002).

3.3.4 Communication

Important progress has been made with the communication technologies required to transfer /exchange data and deliver information to end users. The decreasing cost of mobile phone communication (GSM) has played an important role in information collection and delivery. GSM technology is used to upload collected data from fixed sensors, often in association with solar panels to provide power.

GSM itself can be used to provide location reference (VTT, 2003; Barlett and Morris, 2002). The technologies were introduced for locating an emergency call (FCC, 2005). The use of cellular phone data to provide traffic information has been studied because of the low cost and large sample size (Yim and Cayford, 2002; Ygnace et al, 2000). There are several approaches to using mobile telephones as detectors, differing in the source of the data within the cellular network and hence varying in accuracy, cost-effectiveness and coverage. Researchers have used mathematical filters to remove “noise” effects such as mobile phones used by cyclists, pedestrians, train passengers etc, resulting in more accurate and comprehensive interpretations. More theoretical developments and large-scale trials are currently underway within the EC 6^{th} and 7^{th} EC FP. However, mobile telephone location-based probe vehicles face two inherent challenges:

- To overcome the relatively low accuracy of the cellular-phone location
- To distinguish between relevant cellular phones (carried in moving vehicles) from other moving cellular phones (pedestrians, motorcycles, trains, etc.)

Most operators of public transport or road services now deliver information to the public on their own services or network. Although this is made available through various channels, web-based services are dominant. The Internet is also the key medium to carry out e-ticketing and payment as well as information exchange.

A range of DBA (digital Audio Broadcasting)-based applications, from simple traffic information to dynamic navigation tasks, have been investigated in various European projects (ROSETTA, 2004a). Traffic information can be received by a navigation system (a personal device or on-board unit) for dynamic route guidance.

3.4 Future Information Services

Inductive loop detectors will remain the main source of road traffic information for some time into the future. They are a proven technology which can provide accurate information on a range traffic measures (Turner, 2004). However, installations requires lane or road closure and in some situation, radar or ultrasonic detectors are more appropriate and will continue to be used although their performance varies more with environmental factors. Increasingly, the low cost of video technology with improving video image detector systems, which can have the added value of visual interpretation of a situation by control room staff, will become more common. Other sensor systems, particularly those measuring air quality by sampling at roadside locations, are being used increasingly to provide information to address local air quality issues. Other sources of data such as information from police, motoring organisations, motorists themselves or others such as event organisers will remain valuable. In particular, police reports and their forecasts of when accidents will be cleared will remain critical to effective on-line control decisions when an incident occurs on the road network.

The main growing source of road traffic information is that derived from vehicles, whether externally using ANPR or from the movement profile of individual vehicles, i.e. as probe vehicles. It is very likely that there will be a rapid increase in the number of vehicles which are fitted with location and communication devices. This will be driven by a mixture of navigation, emergency call, road user charging, insurance, intelligent speed adaptation, and other related applications, and sufficient probe vehicles will provide comprehensive understandings of network conditions. Schemes of road user charging according to distance travelled have been proposed for years. Systems have been developed and used for heavy goods vehicles in Switzerland and Germany. These are dependent on autonomous vehicle location (normally obtained via GNSS), in-vehicle trip logging, and communication with a service centre which calculates the fee and does the billing. One technological shortcoming of such a charging scheme is the lack of precision and robustness of satellite positioning in some circumstances, e.g. some urban areas. Galileo will shortly offer significant increase in performance and integrity over GPS. This will increase confidence in the charging mechanism. Such charging schemes with proper software and privacy protection policies will enable full coverage of the road network with probe vehicles and cost-effective monitoring of all vehicles on the road. Via the vehicle management systems, data may also include information on factors such as rain, road surface, skidding resistance, adherence to speed limits, and engine performance.

As probe vehicle information is generated by the individual vehicles, there are issues of access, costs of collection and transmission, and reliability which need to be addressed to ensure a future database for network management and control. This will include issues of security and privacy which may encourage network managers to continue to search for cheaper, more accurate non-vehicle based information. An area which is receiving more interest and research is that of data fusion, where new software can be used to provide better understandings from a range of data sources than could be obtained from the data sources separately. Other areas of recent research relate to grid systems of sensors which can be intergraded to form a comprehensive picture of movement within the grid. This may or may not include nanotechnologies. Many of the on-line control functions such as UTC or ramp metering rely on algorithms based on point measurement. These will need to be radically altered to benefit from the increasing richness of information available.

Road traffic accidents remain a problem and it is likely that new vehicle technologies of driver support and control will change accident patterns. This will also provide new data to enable casualties and remedial measures to be better identified. Vehicle-based collision warning and collision avoidance systems may not be adequate in the foreseeable future.

For freight operations the development of radio frequency identification (RFID) systems for goods and vehicles and the associated management processes are likely to become more universal and provide significant benefits in efficiency.

4.0 Delivering information and its impact

4.1 Infrastructure management

4.1.1 Current situation

4.1.1.1 Highways

Major public investment has been made to provide detection on interurban roads. Data from roadside sensors are transferred to control centres for highway management and control including the provision of traveller information. Although fixed roadside sensors are expensive, investments have been justified by identifying public benefits from reductions in accidents, time savings, environmental improvement and traveller satisfaction (FHWA, 2003a). A strategic advantage in these developments has been availability of communication and power cables along the highway network introduced mainly for the roadside emergency telephone system. The integration of data stemming from a variety of different sources, technologies and content owners is currently a challenge to providing comprehensive information.

Rapid detection and response to an incident is a key task for highway management. MIDAS (Motorway Incident Detection and Automatic Signalling) was developed and implemented in mid 1990 on the M25, one of the most busiest motorways in the world. MIDAS uses a “High occupancy algorithm” (HIOCC) to process signals from loops spaced at 500m intervals on approximately 700 km of the motorway to detect incidents and abnormal congestion. Results from the MIDAS project showed that after detecting the presence of stationary traffic on a motorway, setting signals with a 50 mph advisory speed limit can result in a raw reduction of 28% in number of accidents (McDonald, et al., 2000) and a net reduction of 18% in personal injury accidents.

The National Traffic Control (NTCC) project, funded by the Highways Agency (HA) and Department for Transport (DfT) started in 2001. The 10-year project aims to provide a range of traffic management services on the motorways and major strategic highways across England. These services focus on strategic traffic movement and route advice. The NTCC gather:

- Network data (flow and journey time)
- Roadwork and other planned event information
- Unplanned event (incident) information
- Real-time monitoring of network performance
- Weather information.

The NTCC data is obtained through:

Inductive loops
ANPR cameras
CCTV cameras
Police and agency patrols
Motoring organisations
Telephone calls from motorists.

The information is used in the NTCC for:

Incident detection and management, e.g. road closure and traffic diversion
Performance indication and evaluation
Roadworks and other planned event management
Dissemination of traveller information via VMS, public access Internet site, public access telephone service, etc.

The HA has developed a journey time database for the motorway and all-purpose trunk road network in England (Frith, Pearce and Sutch, 2004). The database contains information on the journey time for each 15-minute interval throughout the year for road links between two junctions and is an example of fusing data from:

inductive loops of the HA's MIDAS
journey time data from the NTCC measured by loops and ANPR cameras
TafficMaster journey time
ITIS journey time and speed data collected by floating vehicles fitted with GPS satellite tracking devices.

The data fusion can not only increase network coverage, but can also improve quality. It allows system operators to identify the problem location, infer factors influencing traffic, e.g. weather, seasonal effects, school term/holidays and special events such as football matches. The HA can address the causes of congestion using construction and management approaches, which include giving motorists information so that they can retime their journeys or choose an alternative route, mode or destination.

4.1.1.2 Urban roads

All major cities have Urban Traffic Control (UTC) Centres, such as ROMANSE in Southampton and Hampshire. Such traffic control centres typically aim to:

Influence travel behaviour
Increase the use of public transport
Maximise the efficiency of the transport system
Improve environmental conditions
Provide planners and decision makers with improved transport information

The ROMANSE pilot project, starting in 1992, was partially funded by the EC (ROMANSE, 2000). A fully integrated, location-referenced traffic and travel database has been created for the strategic information system within ROMANSE. The strategic information supports the display facilities in the ROMANSE central computer for command and control. Inductive loop-based SCOOT urban traffic control system has been installed on corridors for monitoring of network conditions and traffic signal control. The system provides information on flow, delay and congestion. A specific algorithm uses SCOOT data to detect incidents and provide relevant details. The information will be automatically transferred to the ROMANSE central processor and a separate message is displayed via VMS.

CCTV is one important data source in urban areas. CCTV images are monitored by staff and/or automatically processed to identify abnormal traffic behaviour such as stationary or slow moving vehicles. Such occurrences are flagged for the operators to respond as necessary. More recently ANPR systems are being used to estimate journey times on key corridors (Gillam, 2005).

Encouraging the use of public transport is normally achieved by providing real-time passenger information and by giving priority to public transport. Bus location is measured either by GPS or by roadside beacons (Shrestha, 2003). Buses may be given general priority as they approach signals or they may be specifically identified and only given priority if behind schedule. Additional functionalities which are becoming available in UTC systems include environmental monitoring from roadside sensors, parking monitoring from detectors in car parks and from tickets sold from on-street parking systems.

4.1.1.3 Railways

Revitalising the railways is one of the priorities defined in the European Commission White Paper on Transport (EU, 2001). Rail transport in Europe has experienced a worrying decline for years, especially in the area of freight. The railway market is in the early stages of a major revolution that is being driven by competition between different operators and with the other means of transport. Railway operators will have to offer even more services at lower costs to gain competitiveness.

Within the current European harmonised framework, the major performance requirements of a railway system are expressed by the RAM(S) requirements - Reliability, Availability, Maintainability and Safety (if safety-related application). Railway users would expect that for the large majority of mass / commercial and information applications, the requirements would be met by products that are common to other transport systems (aviation, road, maritime), which could create more efficient market and service support (Wiss et al, 2000). The key to the integration of railway operations is modern telematics with satellite-aided location, wireless communication and integrated database applications. Many national train fleets already use satellite navigation for fleet management. These systems, along with associated communications infrastructure, allow tracking and monitoring of rolling stock, enabling operators to efficiently track the position of their resources. The introduction of satellite navigation within the European Train Control Systems (ETCS) will mainly contribute to increasing performance on high-density lines and lowering the costs on low density and regional lines. The use of satellite navigation for location of rail vehicles and trains will reduce cost, allowing cheaper train signalling and traffic management systems whilst increasing line capacity and efficiency (Urech et al., 2003; Mertens and Franckart, 2003).

Information about train arrival and departure times, especially when there are delays, is important to maintain a good service. On-board passenger information is also essential (ERRI 2001). Knowing the position of the train can also provide additional services to the train passengers, such as connection and tourist information. Equipping engines and carriages with GNSS receivers will allow operators to track their vehicles efficiently and provide their clients with up-to-date information.

Substantial international research has been initiated to address the use of GNSS technology in order to locate and control the next generation of trains and demonstrate their potential to enhance the performance and safety of the European railways. Several EC-funded projects, e.g. LOCOPROL (Low Cost Satellite Based Train Location System for Signalling and Train Protection for Low Density Railway Lines) and GADEROS (a Galileo Demonstrator for Railway Operation System), have developed and demonstrated applications of GNSS in low-density railway operations. Existing command and control systems, adapted for medium traffic density lines or the future European Railway Traffic Management System (ERTMS) dedicated to high speed and/or high-density traffic railway lines, remain too expensive for use on lines with low and very low traffic densities. As a consequence, many Low Density Traffic Lines (LDTL) across the world remain equipped with over-aged human-based safety equipment with high maintenance costs (Marais and Berbineau 2004; Gutierrez, 2004). GNSS-based train position systems provide automatic location information to a control system with a digital map for signalling operation and railway worker protection. Benefits from such systems are:

- increased line capacity
- reduced trackside equipment
- limits on-board sensors
- increases train autonomy
- cost-effective and safe solution.

Location and geographic information plays an important role in network control, train location, and recommends speed and traction force to the driver in order to reduce energy consumption (research has shown 15% energy saving possible). It also protects against speeding and helps train punctuality. Integrated rail control systems, e.g. Bombardier *INTERFLO* 50, have been designed to enhance the knowledge of rolling stock positioning within a network or geographical area (Bombardier, 2004).

4.1.2 Infrastructure management: the future

From the viewpoint of infrastructure management, an idealised vision is one where:

i.)There is comprehensive knowledge of network conditions and vehicle and/or passenger movement.
ii.)An accurate prediction of future conditions is available.
iii.)There are opportunities to intervene with control, enforcement and information to meet clearly identified objectives.
iv.)There is an integrated information base relating to all infrastructure and services available to enable comprehensive decision making.

In this vision, the infrastructure or system manager would be able to make and execute efficient decisions. However, as systems approach capacity and the times and locations where congestion occurs become more frequent, the risk of instabilities becomes greater, and the flexibility to respond decreases. For this vision, it is critical that demand is managed, and this must be done to meet clear objectives which will relate to financial, economic, safety, environmental and social issues. A range of physical, fiscal and informational/behavioural based approaches are available to manage demand, including road user charging. Whatever the package of approaches used, the delivery of information will involve:

- Greater fusion of traffic data from various sources (local measurement points, floating vehicle data, video observations, etc.) to describe network conditions and to detect incidents

Short term and medium term traffic prediction based on historical and current data as well as on models, considering the interactions between route choices caused by current information, the control strategies and its acceptance by drivers

Estimation of dynamic origin-destination traffic streams

Low cost measurement and communication of floating car data; this is a great expectation from the full functioning of the GALILEO system

Enhanced video image processing, especially under adverse visibility conditions

Measurement of road conditions (wetness, visibility)

The co-operation of data owners

The establishment of public-private partnerships (PPP) by adequate contracts clarifying the competences of involved actors and the financing.

A key element of a future vision is the relationship between infrastructure and vehicle technologies which are market driven (STARDUST, 2005). Such technologies include those for lateral and longitudinal support and control (e.g. Adaptive Cruise Control and Lane Departure Warning) and those for driver comfort, convenience and safety (e.g. navigation assistance, Intelligent Speed Warning/Adaptation). Intelligent infrastructure technologies are related significantly to urban and interurban traffic management but may also include applications such as intelligent speed adaptation (ISA). In a fully cooperative vehicle/highway system (CVHS), vehicle-based technologies will work actively with highway technologies to develop safe and efficient movement. A knowledge of vehicle location relative to infrastructure and/or other vehicles and means of communication are crucial elements for cooperative systems.

CVHS offers the long term prospect of vehicles driving autonomously, thereby removing the risks and inefficiencies resulting from driver performance limitations and driver-to-driver variability. Cooperative systems can operate at a series of levels, but the ultimate vision is that the vehicle, in cooperation with highway systems, will take the driver safely to the destination. Such a vision could only be achieved in the distant future, but there are a series of more achievable short term scenarios which will contribute to safety and efficiency in particular types of location or operating conditions. Cooperation can exist at three main levels:

a) The vehicle receives information from the highways. In this situation the vehicle must locate itself and the highway information will enable the vehicle to ‘anticipate’ future conditions. Such conditions may be static information such as road curvature, and dynamic traffic information such as congestion, or speed limit information.

b) The highway receives information from the vehicle. The information may be used to supplement detector information on flows, queues and journey times to enable the highway operators to better manage the network through information and control technologies. Control may operate at a local level where knowledge of individual vehicle reactions may trigger immediate and short-term system response to reduce accident risk or enhance capacity.

c) Fully cooperative systems where vehicle and highway information is exchanged for general benefit. For example, this approach would enable the headways of vehicles approaching an interchange to be manipulated to match metered entry flows to achieve and maintain optimum capacity.

The vision for the foreseeable future does not include fully cooperative systems with full vehicle automation. It is difficult to see how many of the practical problems associated with fully cooperative systems could be overcome, other than in urban 'niche' markets with speeds restricted to little more than 10-15 km/hr. However, levels (a) and (b) above are likely to be reached in the not too distant future, perhaps associated with applications such as TTI. However, all parties must develop a common architecture and framework of applications if vehicle and highway technologies are not to develop in directions which subsequently prove to be incompatible.

GNSS has been applied in railway control and management, and more potential applications in rail have been proposed (ESA, 2003). Applications based on location and communication technologies will replace or improve some existing classing technologies, and provide some services beyond the current operation solutions. These applications can be grouped under the following three headings:

Signalling and train control:

- Infrastructure operation applications
- Train-borne application
- Protection application
- Train Control Centre application
- Additional application
  Passenger information
  Management information system

4.2 Movement of goods

The efficient transport of goods and freight is fundamental for the success of industry and commerce, and is a major factor in the smooth working of the economy. However, the high percentage of freight carried by road contributes to traffic congestion and also has serious implications for safety and the environment due to accidents, vehicle emissions and noise. Over the last two decades, considerable efforts have been made to promote the use of non-road transport and encourage intermodal solutions, although it is recognised that the majority of goods and freight will continue to be moved by road (DfT, 2004).

4.2.1 Current situations

4.2.1.1 Road freight

The overwhelming majority of freight in Europe is carried by road – the European average is around 75% (Beecroft et. al., 2003). Despite the growing frequency of serious traffic congestion, the relative convenience (door-to-door service) and cost advantages of road haulage have made it difficult for other modes to substantially increase their share. An exception in the overall picture for non-road transport is the large growth in maritime container traffic in recent years due to economic globalisation.

While road haulage is now far more efficient than in the past, in terms of logistics as well as reductions in energy consumption and toxic emissions, it is nevertheless still characterised by:

A multitude of uncoordinated transport operations, due to the many small-scale fleet operations

A high percentage of unused load capacity, in particular a high percentage of empty return trips

A large amount of time 'wasted' in various types of delay.

The main causes of delay to road freight are shown in Figure 1:

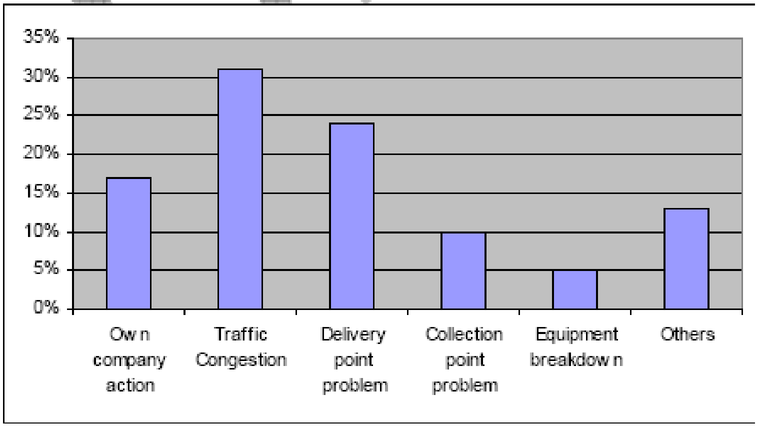

Figure 1. Main causes of delay to road freight (McKinnon, 2003)

It can be seen that traffic congestion is the main cause of delay. Information on road traffic conditions will enable operators to optimise the planning of freight deliveries. Fleet management platforms, which use GPS for monitoring vehicle location, can offer a range of services which can help more efficient sequencing of loading/unloading operations, send driver instructions, and collect statistics relating to the trip, etc.

Information technology, which includes the application of hardware, software and network technology to enhance information flow and facilitate decisions, is a key to improving overall efficiency and effectiveness. This is particularly important as the logistical environment is becoming increasingly complex as a result of globalisation and market segmentation strategies. The following table shows examples of recent innovations in information technology in logistics (Kang and Kwon, 1997).

Table 3. Logistics Information Technology

ITS Systems	***Functions***	***Use of Results***
Automatic Vehicle Identification (AVI)	Transmit vehicle information identification, size and weight, vehicle type or class	Traffic counting and vehicle classification; Comply with regulatory requirement; Automatic toll collection
Automatic Vehicle Location (AVL) and on-board navigation system	Provide driver information, highway and traffic conditions	Identify most direct or least time route (avoid incidents, congestion and delays); avoid road hazards particularly during bad weather
On-board computer	Monitor vehicle and driver behavior, vehicle speed , engine rpm, engine idle time, engine oil temperature and pressure	Decide when maintenance and service needed; Diagnose major breakdown; evaluate driver's performance

Two-way communication system	Exchange messages between operators and driver, trip and shipment information, e.g. location, speed.	Manage logistics when in transit; arrange repairs for breakdown; respond to emergency
Bar-coding	Provide product and packing information, e.g. identification, type, size, weight, origin and destination	Sales and inventory, track shipment and check status

Electronic data interchange	Transmit business data and provide electronic business documents: purchase order, bill, invoice, packing slip, electronic funds transfer	Electronic ordering and billing; verify pick-up and delivery

4.2.1.2 Non road freight and intermodality

After a period of growth in the 1990s, intermodal transport demand now seems to have reached a plateau. Since 2000, it has levelled out at about 5% of total tonnage in the EU (ROSETTA, 2004b). The critical question is whether this represents a maximum viable ceiling or whether the difficulties currently experienced in encouraging shippers to use intermodal solutions can be overcome.

As well as higher direct costs, rail and waterborne transport also suffer from a lower quality of service (real and/or perceived) than road haulage in relation to reliability, punctuality and security. Information technologies are as yet not widely used for intermodal transport. However, some progress has been made to support intermodal transport through information services:

- Improving efficiency (time-saving) in transfer operations, e.g. by permitting data exchange between freight terminals and vehicles on the move before their arrival
- Improving the quality of services offered, e.g. tolls, to facilitate the tracking of containers across modes, anti-theft systems for the rail/waterborne legs, and their continuity across borders
- Providing a more accurate expected time of arrival with knowledge of speed and location of transport, as well as the network condition
- Making it easier for small transport operators to gain access to intermodal services via tracking of goods and data exchange.

Rail transport is technically and economically viable for a specific market segment: the large scale movement of non time-sensitive goods over a long distance, generally at international level. The use of ITS to manage rail wagon assets with established procedures between national operators and infrastructure managers allows for virtual and physical wagon access. F-MAN (Fleet Manager) project within the EC 5th FP programme set out to improve the competitiveness and sustainability of rail freight transport by providing innovative ITS tools to enable a better control of the international wagon fleet and enhance the performance of the whole rail system (Kuhla and Cosulich 2004). There are three main modules:

- The Tracking System Module that was composed of On-Board Terminals (OBT) and a ground-based information management system. The OBT was composed of a GNSS receiver combined with a suitable communication system as well as a number of sensor readings, e.g. temperature, shocks, door open, etc.
- The Data Processing Module which concentrated and distributed all information coming from the OBTs to the ground system and from the latter to different workstations located in the user premises. It was an articulated communication system based on Internet technologies
- The Asset Management Module was developed as a Decision Support System, thus it suggested to the fleet manager the most appropriate management actions for rail car planning activities taking into account financial and commercial incentives.

A Ground Station located in Belgium and the Web Application Server hosted in Germany were used to verify the outputs on European corridors.

4.2.2 Expectations and targets

A number of fleet management platforms which use tracking and communication technologies are available on the market, and offer significant improvements in efficiency, reliability and security. The take-up of such systems for smaller companies in particular is rather disappointing. In the ITIS floating vehicle data (FVD) system, a large proportion of probe vehicles are lorries with GPS tracking devices (Simmons et al., 2002). Location and speed of these lorries is transferred into journey time in the ITIS database. This is a win-win situation since the journey time database can be used by operators to optimise logistics planning and operation. Road charging for Heavy Goods Vehicles (HGV) which is in operation in Switzerland and Germany can be considered as a way to initiate the installation of on-board units (Balmer, 2002; AG, 2005). However, GPS/GSM-based road charging mode is not universally promoted in European countries, for example, Austria is using a DSRC/smartcard-based charging system (ASFiNAG, 2004).

Although goods deliveries generally represent only a small part of urban traffic, the impact on congestion and the generation of emissions is often high due to the type of vehicles and their stopping behaviour. Pressure is mounting to find better ways of managing urban logistics. Considerable potential exists for the development of information services to support the efficient management of delivery operations, and helping local authorities to manage the movement of goods in urban areas more effectively. AVL and AVI equipment will enable city mobility authorities to monitor and control the access of vehicles to various parts of the urban area and to collect valuable statistics on delivery patterns.

4.2.3 The future movement of goods

It is likely that road user charging for trucks will trigger a range of equipment and related services via an on-board unit based on location and communication technologies. The on-board unit could transfer real-time data from the vehicle and receive data from outside the vehicle. The real-time data from the vehicle will be integrated into the real-time monitoring system of network, and the real-time traffic information, e.g. congestion and incident warning, weather, etc, will enable better route guidance. The on-board unit will also provide the route and speed profile for monitoring performance and for tracking and tracing, and possibly for speed enforcement by police to improve road safety. The on-board unit can report and track the vehicle after being stolen (anti-theft). The on-board unit can further be connected with the vehicle immobilisation system to enhance security. Remote vehicle immobilisation systems, which disconnect ignition or reduce engine power of a vehicle after confirming the vehicle being stolen have been developed and installed in some vehicles (Hammond and Rooke, 2003). Remote vehicle immobilisation systems enable police to immobilise a vehicle after it has been stolen/hijacked, or suspected of being used for dangerous purposes.

Applications which may go forward for CVHS HGV fleets are tow-bar and lane-keeping systems (Promote-Chauffeur, 2003). Information exchange between the logistics industry and infrastructure manager will be standard practice.

All the above applications will enhance the attractiveness of road freight transport. In the future, a shift towards non-road modes could be encouraged by congestion increases, road user charging and enforcement regulation, e.g. speed limits and making driving hours less attractive, thus helping to favour intermodal transport. Seamless information chains delivered by ITS systems have the potential to increase security, reliability and convenience of non-road transport. ITS-based information will be key to drive the market and to enable decision makers to move towards applications of information services, to promote the necessary research and development for future deployment. Important steps towards are:

- Standardisation of tracking and tracing devices of containers and individual items, which enables the tracking information to be integrated into logistics and transport management platforms

Standardisation of automated data collection to provide valuable information for planning delivery and traffic management strategies in a way that is inexpensive and easy to organise. The data can also be used to seek alternative delivery for certain types of goods

Development of platforms which can provide information support for logistics operators and highway/city authorities to use for the management and control of delivery traffic, e.g. through real-time information on the availability of loading bays, automated allocation of time-slots.

4.3 Movement of People

For most people and for most trips, the car will be the natural first choice because decisions will be made on a cost basis, and drivers are unlikely to have the same level of knowledge of the public transport alternatives. Thus the provision of information can enable travellers to make more informed decisions and lead to changes in modal choice. However, of itself information cannot change the disutility associated with a particular mode, but it can be crucial in changing the perception of a mode such as rail (Crockett, 2004). In the past, travellers had to approach providers individually to obtain information, service and tickets, although more recently tickets, route or schedule information are available and accessible via cable and wireless web-based services.

4.3.1 Current situations

4.3.1.1 Public transport operations

There has been a growing understanding of the importance of identifying the needs of travellers more clearly and the provision of public transport services which better meet both existing and evolving needs (Blythe et. al., 2000). This has led to some significant improvement in conventional services as well as initiatives to encourage and develop multimodal opportunities and new services such as shared door-to-door operations. To be effective, multimodal and door-to-door service services require operators to have more information for management and control.

Operators use location referencing for dynamic scheduling. The dynamic bus scheduling application has two parts: off-line scheduling of vehicles and crews, and on-line re-scheduling in response to real-time information, and provision of real-time passenger information (Scemama et al., 2000). Technical validation of the integrated fleet management system was performed successfully. User acceptance of the off-line application to schedule vehicles and crews was high and the time to create a bus and crew schedule was reduced by one third. The on-line dynamic scheduling application may not achieve full success due to insufficient incident information. Further integration of real-time information into bus operation system is required.

In the EC-funded project AUSIAS (Advanced transport telematics in Urban Site with integration And Standardisation), an automated fleet maintenance tool was developed to monitor bus engine parameters in real time (Bachiller et al., 1997). Sensors constantly check the activities of the engine and send an alarm with information of the current state to the control centre if an abnormality is observed. Additional information such as problem history is integrated in the control centre and is sent to drivers. Similar remote monitoring and maintenance systems have also been developed for railways (EUROMAIN, 2005). The need for fixed schedules for maintenance will be removed as the actual state of vehicles will be provided through real-time information, reducing maintenance down-time and costs.

E-ticketing and payment in public transport has been available for years for public transport providers. For passengers, e-ticketing improves the journey experience as passengers can change operators and modes with the same ticket. E-ticketing allows more flexible and complex tariffs, and has more direct advantages through increasing speed of boarding (Wergles, 2004, Koenen, 2004). For operators, e-ticketing offers a new data source for better understanding customers' activities and habits through the detailed analysis of the travel patterns enabled by the system.

4.3.1.2 Traffic and traveller information service

Since the mid 1990s, traffic and traveller information services (TTI) have disseminated information by cable and wireless web sites to travellers, and traditional methods, e.g. VMS, telephone services and radio, remain popular. Many TTI systems are already in operation, and an increasing number of services are being developed and offered. For example, static fixed timetable information of public transport services is available on the Internet, and dynamic timetables are displayed at stops and can be accessed via short-message service (SMS) using mobile phones.

Passenger information is generally available from:

- Displays at stops/stations/interchanges (static and dynamic information)
- On-board display
- Internet (cable and wireless)
- Telephone service, including SMS.

Motorist information is generally available by:

- VMS
- Internet
- Radio broadcast
- On-board navigation system (dynamic route guidance)
- Telephone enquiry services
- Motoring organisations.

Since many trips involve the use of several modes or services and multi-mode travelling is encouraged by the government in order to reduce car usage, many new traveller information providers support decisions for the whole journey with the integration of information across different transport modes (car, bus, train, ferry and underground/metro), operators and regions. Information on Park & Ride, or car park availability at a railway station, is expected to encourage non-car journeys.

The benefits of traffic information have been assessed by evaluation of information service projects, simulation and questionnaire surveys, and results are well documented, e.g. The U.S. Federal Highways Administration (FHWA) ITS benefits and costs database (www.benefticost.its.dot.gove). The impact of information relies on market penetration, i.e. the percentage of the potential audience reached by the dissemination efforts. However, it is expected that some technologies, such as in-vehicle dynamic route guidance, will require only limited market penetration in order to achieve overall operational benefits as well as benefiting individual drivers. All drivers who pass a VMS will receive the same information and benefits will relate strongly to the message content and the location of the sign and any incidents reported relative to the destinations of the drivers (Chatterjee and McDonald, 2004).

An impact assessment of VMS in the Kingston area of London investigated the effects of using VMS messages to encourage drivers to re-route when the network in Kingston became sufficiently congested (Bretherton et al. 2000). It was found that such VMS messages resulted in a 12% reduction in traffic flow along the affected route, and the net effect on traffic flow in the Kingston centre was a reduction of 4%. Simulation results showed that individual travellers who use web sites for pre-trip information (including weather and route planning) would receive annual benefits of a 5.4% reduction in delay, a 0.5% reduction in accident risk, and a 1.8% reduction in fuel consumption (FHWA, 2003b).

The current state-of-the-art of service providers is illustrated by the examples given below. It is a market which is maturing rapidly.

National Traffic Control Centre (NTCC)

As introduced above the NTCC provides a range of traffic management services on the motorways and major strategic highways and trunk roads across England. An important function of the NTCC is traffic and traveller information provision. The traveller information is disseminated via VMS, public access Internet site, telephone information service and via other service providers. The NTCC also promotes and administers the Travel Information Highway (TIH), which provides a mechanism for data change between multiple sources of information and multiple users of such information.

Transport Direct

Launched by the UK government in 2001, Transport Direct aims at providing a “complete picture” of the transport system to travellers in the UK (www.transportdirect.info). The prime channel to deliver information to the travelling public is via the Internet. Transport Direct is the only website that offers information for door-to-door travel for both public transport and car journeys around Britain. It can:

- Compare train/coach journeys with car journeys to make sure you travel in the most efficient way
- Find the quickest car route that takes into account predicted traffic levels at different times of the day so that you can make informed decisions about when to travel
- Find fares for train and coach journeys
- Buy train and coach tickets from its affiliated retail sites without having to re-enter your details
- Check ‘Live Travel’ information on the live departure boards for all 2500 national rail stations.

The service is currently available on any browser-enabled device, but by 2006 Transport Direct services should be available on SMS and WAP-enabled mobile phones, PDAs, interactive digital and cable TV. Its services are also likely to be embedded in other websites and available through some touch-screen kiosks. Transport Direct works together with both public and private travel operators and local/national government. The non-profit service is funded by the UK Department for Transport, the Welsh Assembly and the Scottish Executive. There are a large number of data providers for Transport Direct, from local authorities, e.g. Transport for London, bus, train and taxi companies, the Highways Agency to private sectors, e.g. TrafficMaster and ITIS.

TrafficMaster

TrafficMaster has pioneered the collection and dissemination of digital real-time traffic information in the UK and established the first traffic monitoring network on the M25 in 1990. Since then the TrafficMaster network now covers over 8,000 miles of motorway and trunk roads in England, Scotland and Wales. TrafficMaster's real-time traffic information is derived from continuous data supplied by a network of 7,500 sensor sites that consist of: fixed infra-red sensors mounted on motorway overbridges for speed monitoring and ANPR cameras installed at the roadside on trunk roads for journey time calculation. The real-time information is supplied to in-vehicle units (voice or screen-based units), telephone information services or the Internet site. TrafficMaster's digital traffic information is also used to supplement GPS-based navigation systems, overlaying useful information about the traffic ahead and thereby augmenting the value of the navigation for the driver.

ITIS

ITIS Plc has implemented the largest Floating Vehicle Data (FVD) system in the world to provide journey time statistics and real-time traffic information (Cowan and Gates, 2002). The FVD system has been collecting and storing traffic data since February 2000 with initially only a limited number of probe vehicles on the network. By 2002, the system had in excess of 30,000 probe vehicles of various characteristics contributing to the gathering of data on live and historical traffic conditions (Simmons et al., 2002). The number of probe vehicles now is about 100,000. Probe vehicles equipped with GPS and GSM technology regularly send data on their current position and speed. The Floating Vehicles include commercial trucks, coaches and passenger cars. The information is collected and centrally analysed, then transmitted to subscribers of the services in the form of up-to-date traffic information. FVD captures data for motorways and arterials. These data are aggregated into “road timetable” and “congestion schedule” by road and day/time category. The FVD system identifies recurring congestion and uses these patterns to predict future conditions, thus enhancing route planning and navigation. The information of dynamic traffic content can be integrated with navigation systems.

4.3.2 Expectations and targets

The information systems for vehicles, roads and travellers should be robust and open which means they can be updated or individualised as new features are developed. Three main issues are:

Ways of improving of data quality
Ways of opening up the TTI market
Ways of establishing a common high-level approach in Europe.

Identification is needed to provide targeted information to optimise pre-trip planning and dynamic journey modification. Considerations include real-time, multi-modal arrival and departure information, travel time, route and cost comparison for all modes, events, weather and safety warnings and specific user constraints (accessibility, security). Journey times will be more reliable with comprehensive pre-trip information updated during the journey. Vehicle-to-vehicle and vehicle-to-infrastructure linkages will ensure optimum integration with other traffic and with traffic management systems.

Personal navigation systems will offer opportunities for more specific and personalised information to be delivered. Furthermore, such information will be integrated with other commercial traveller services, e.g. e-booking and e-ticketing (Blythe, 2004). Thus travellers will have access to a whole range of specialised services to facilitate both the planning and the execution of journeys. In case of emergency, location information will help in quick and efficient rescue. This will not only increase travel comfort and efficiency, but also improve personal safety.

New concepts need to be developed for the integration of multi-modal connection to enable seamless links, utilise real-time multimode information systems, and offer other value-added services to the passengers (meeting place, multimedia, restaurants, shops). Network integration is needed between the physical and the information worlds to optimise mobility demand and planning through mobile and stationary communication points. Development of real-time traffic information systems, in combination with a European digital road map database, including traffic restrictions, road condition data and parking availability, should allow reliable travel time prediction and better route selection.
Multi-modal journeys should be supported from origin to destination, with a customised HMI (Human–Machine Interface) and a range of additional services for the user (Kunze et al, 2004). Accurate real-time information to support such personal travel is essential. To deliver an attractive service, positioning of various stakeholders and low-cost, reliable, and timely communications between them are the key functional parts.

4.3.3 The future: movement of people

Three issues should be addressed when considered TTI service for the movement of people:

Potential of open platforms and market
Opportunities offered by new technologies
Social change and user requirement in the future society.

Important progress has been made with the communication technologies required for advanced TTI services. The integration with GSM and GNSS makes it possible to provide interactive, personalised information. The GALILEO initiative is of particular significance for TTI services. GALILEO will provide more accurate, integrated location services which will provide a foundation for the expansion of the market for hand-held and on-board navigation devices. Digital Audio Broadcasting (DAB) channels and broadband communications are particularly suited to TTI applications with a view to standardisation. As Google 3D map has been available free of charge, route guidance and planning are moving from 2D to 3D. With 3D Maps, travellers can be more aware of road curvature and topographical change, which would enhance safety.

While basic transport information is likely to be provided free of charge by transport and infrastructure operators, a growing number of added-value services will be offered on a commercial basis by private service providers. Travellers will choose the appropriate level of service according to their needs and willingness to pay. Paid services will offer customers significant benefits in terms of time and cost saving, level of comfort and convenience by providing personalised, detailed traffic and transport information.

As the use of TTI services becomes more widespread in the future, it will generate significant social effects. However, the provision of more accurate, relevant and timely route guidance to drivers may encourage greater car usage. This may be constrained naturally by congestion, but it is inconceivable that management by congestion will continue and that demand will not be controlled. Also, there may be particular issues concerning parts of the network which may be environmentally sensitive and which would be targeted by dynamic route guidance systems. Although dynamic route guidance is only one of the technologies being incorporated into vehicles, there may be issues of driver distraction which impact on applications and support systems which encourage driving, particularly for the elderly. The elderly will be likely to benefit directly from TTI systems which guide them to their destinations simply and clearly using multimodal systems.

5.0 Conclusion and recommendations

The demand for the delivery of accurate, timely and relevant information will increase. This demand will be driven by the needs of all user groups, for the ranges of current and future objectives to be met more effectively and for new objectives to be set. The public, and perhaps private, objectives will incorporate greater emphasis on sustainability. However, whatever the directions towards which society moves in the future, the delivery of traffic and transport information will be critical. It may just be used differently to meet alternative user priorities. However, there is likely to be change in the funding arrangements and data collection processes depending on the extent to which future transport provision will be user driven or society driven.

Advances in the field of information services have been substantial. Systems have been produced, prototypes demonstrated, and a variety of services delivered. However, an open overall framework has not been achieved. Most of the prototypes have been implemented directly by transport operators to support and market their respective operations. This has limited the penetration rate of interoperable multimodal personal and goods transport services.

Research and development of technologies and a policy for information collection and dissemination is not currently part of the forthcoming GALILEO programme. Based on GALILEO, many location and navigation systems are expected to perform better and be less expensive than those based on GPS, resulting in increased market penetration. Research on the market, public acceptance and corresponding government policies towards Galileo-based systems should be further focussed. The emerging position and mobile communication technologies will also provide valuable information sources. How to use the new data sources and integrate them with existing transport controls system and information services should be addressed. Application of these technologies may significantly change individual life styles and the society. Understanding of such changes and the potential risks associated with of behavioural changes and privacy protection is needed and should be considered in the systems. Development of future information may focus on sustainability issues. Information systems which have potential benefits to safety (e.g. Mayday system) and to the environment should have priority to be encouraged. Transport services specific to the elderly and disabled must be provided in order to maintain mobility over a longer lifespan.

Most transport operators (public transport, road, concessionaires, etc) deliver information on their services through various media, and Internet-based services are dominant. Transport and travel information services are moving to a “business” market. Travel and traffic information is increasingly more integrated into business applications, such as fleet and freight management and workforce management. This offers marketing opportunities for operators in the information market to sell their components (aggregated contents, specific services, applications, application interfaces) to the specific clients. The market is maturing and is moving from a “technology push” to being led by the requirements of users and companies. More complex requirements are emerging and the requirement of “integrated services” is important. That the supply side of the market is restructuring (companies are disappearing or changing roles, new ventures are being created) could also be used to support this trend.

In terms of technology, the changes are toward more “interoperable applications”. The number of in-vehicle navigation systems will continue increasing, and more personal navigation devices will continue to appear, able to interact with the user conducting a journey and provide updated support. Low cost wireless connection will be a fundamental component of such devices. In order to serve as a basis for reliable and integrated travel information services, “telematic platforms” will have an important role to play in future. This would be in the interest both of the final users and of the transport operators. The users will have easier access to multi-modal and multi-network information. The operators will be able to share data through the platform, increase the visibility of the services, and co-operate better with each other.

The level and extent of the development of systems and related services varies substantially across Europe and this is constraining the application of telematics to trip requirements. Existing data exchange systems will move forward to support the location reference services. Standard frameworks and information unification are therefore needed to enable travellers having the same level of service while travelling across borders. This is particularly important since information is more valuable in an unfamiliar environment.

Traffic information systems are evolving from just road information to multimodal information. Data collected via in-vehicle navigation systems, i.e. probe vehicles, will increase its importance in traffic information provision. Data fusion and information integration will be a challenge to existing traffic control systems. The fused data is expected to enhance the flexibility and efficiency of transport management and operations. Algorithms for incident management and control strategies using the new data sources should be developed to maximise the use of such new information. Probe vehicle technology is likely to provide a substantial contribution to network state estimation, in which most vehicles are fitted with location and communication devices installed for a wide range of applications. Such applications are likely to include road user charging.

There is a lack of regulation on competition which could delay the adoption of personal travel services. This would leave the user with a limited transport choice and the tendency to opt for the easy option, the private car. Recent experience indicates that a boost for information services could come from opening the market to a variety of operators. An information service market could be developed in the following stages: Firstly, transport operators should collect, structure and deliver their own information, as part of their normal operation. In a second stage, as discussed in the previous section, public administrations should foster the creation of “telematic platforms” capable of giving unique access to users for all transport data relative to specific territory. A third stage would be the development of Value Added Service Providers (VASPs) which can access specific needs of particular market segments.

Reference

Abott J. 2004, Real-time passenger information gains ground, *Eurotransport*, Vol. 2 (3), pp.45-47.

Act Planning and Land Authority, Canberra, Australis (ACTPLA), 2004, “Real time information in Canberra”, *Government Report*, available on www.actpla.act.gov.au .

Argonne National Laboratory (ANL), 1997, “The ADVANCE Project, Formal Evaluation of the Targeted Development,” *Project Report*.

ASFiNAG, 2004, Tolling Regulation for the Motorway and Expressway of Austria, *Government Document*, available on www.asfinag.at.

German Federal Office for Goods Transport (BAG), Smooth start for German Truck Toll, *Government Document*, available on www.destatis.de .

Bachiller C., Sebastian V. Ferri R., Little J. Bonet E., 1997, ATT in Urban Sites with Integration and Standardisation – final report, *Project Report*.

Barker L. and Connolly D., 2005, "Scottish Household Survey Topic Report 2005: Mode Choice," *Government Report*, available on www.scotland.gov.uk .

Barnes J., 2000, Guiding Principal: Getting A Fix on GPS, *Traffic Technology International*, Oct/Nov, pp 56-58.

Balmer U., 2002, One year on: has the new heavy vehicle fee affected transport demand in Switzerland? Published by *European Conference of Ministers of Transport*.

Bartlett D. and Morris P., 2002, CVB: A Technique to Improve OTDOA Positioning in 3G Networks. *Technical White Paper*, Cambridge Positioning Systems Limited.

Beecroft M., Lyons G. and Chatterjee K., 2003, Freight and Logistics, Lodor Publising.

Blythe P., Rackliff T., Holland R. and Mageen J., 2000, The potential for ITS in improving and integrating services at urban transport interchanges for public transport, In *Proceedings of the 10th International Conference on Road Transport Information and Control*, pp. 192-199, London.

Blythe, P.T., 2003 Delivering Intelligent Location Based Public Transport Information to Mobile
Phones and PDA's. *Proc. IQ's Third Annual Conference on Real Time Passenger Information Services for Transport*, London, September**.**

Blythe, P.T., 2002 Video-Based Vehicle and Pedestrian Tracking and Motion Modelling. *Proc. IEE*
International Conference on Road Traffic Monitoring and Control, London, March

Blythe, P.T., Walker, K. and Knight, P.K., 2001 The Technical and Operational Feasibility of
Automatic Number-Plate Recognition as the Primary Means for Road-User Charging. *Journal of the Royal Institute of Navigation*, Vol. 54, No.3, pp345 -355

Blythe, P.T., 2004 Delivering a framework for interoperable smartcards in the UK Public Transport
Industry. Special edition of the ICE Journal, The Municipal Engineer. Issue 157, pp 47-54,

Bombardier, 2004, GNSS-based Telematics Applications, *European Satellite Navigation Cooperative Day*, Warsaw, Poland.

Bonsall P. and Bell M., 1987, Information Technology Applications in Transport, *VNU Science Press*.

Bretherton D., Wood K., Baker K. and Radia B., 2000, Congestion and Incident Management Using the SCOOT UTC system, In *Proceeding of the 10th Road Transport Information and Control Conference*, London.

Bunn J. and Barrett D. J., 1997, Automatic Number Plate Reading: What Are The Difficulties? In *Proceedings of 4th world Congress on Intelligent Transport Systems,* Berlin.

Cairns S., Sloman L., Anable J., Kirkbride A and Goodwin P., 2004, "Smart Choice - Changing the Way We Travel", *Government Report*, available on www.dft.gov.uk .

Caltling I., 1987, Automatic Vehicle Identification, "*Information technology application in transport*," pp. 41-64. VNU Science Press.

Chatterjee K. and McDonald M., 2004, Effectiveness of using Variable Message Signs to disseminate dynamic traffic information: evidence from field trails in European cities, *Transport Reviews*, Vol. 24 (5), pp. 559-585.

Chien S. I. J. and Kuchipudi C. M., 2002, Dynamic Travel Time Prediction with

Real-time and Historical Data. In *Proceedings of the Transportation Research Board 81st Annual Meeting,* Washington D. C., 13-17 January.

Clark S. D., Grant-Muller S. and Chen H., 2002, Cleaning of Matched License Plate Data. *Transportation Research Record*, Vol. 1804, pp. 1-7.

Clark S. D. and McKimm J., 2003, Using GPS to Collect Journey Time Information. *Traffic Engineering and Control*, Vol. 44 (4), pp. 124-131.

Gillam J., 2005, Using ANPR to measure network performance, *Traffic Engineering and Control*, Vol. 46 (10), pp 316-318.

Cowan K. W. and Gates G, 2002, Floating Vehicle Data System – A Smart Move. In *Proceedings of 9th World Congress on Intelligent Transport Systems*, Chicago.

Crockett J., 2004, Understanding and Measuring Perceptions of Convenience in Rail Travel, *PhD thesis*, University of Southampton.

Department of Transport (DfT), 2004, "The Future of Transport," *Government White Paper.*

Department of Transport (DfT), 2005, "Intelligent Transport Systems (ITS): The Policy Framework for the Roads Sector," *Government Report*.

Edwards, S and Blythe, P.T. (2004) Demand for and Willingness to Pay for Geo-Referenced Info-

Mobility Services. *Proc. 11th World Congress on Intelligent Transport Systems and Services*, Nagoya, Japan, October.

EUROMAIN, 2005, European Railway Open Maintenance System, available at www.euromain.org .

European Commission (EC), 2001, European transport police for 2010: time to decide, *Government White Paper*.

European Space Agency (ESA), 2003, Galileo Becomes a Reality for Europe, available at www.esa.int .

European Space Agency (ESA), 2004, EGNOS brochure, available at www.esa.int .

European Space Agency (ESA), 2005, The future -Galileo, available at www.esa.int .

Faghri A, Hamad K., Hehman D. and Henck H., 1999, Application of GPS to Travel Time and Delay Measurements--1997 Phase, *Department of Civil and Environmental Engineering, University of Delaware*, Delaware, USA.

Federal Communication Commission, 2005, Enhanced 911, *Government Document*, available at www.fcc.gov .

Federal Highway Administration (FHWA), 2003a, Freeway Management and Operations Handbook, *Report number FHWA-OP-04-003*.

Federal Highway Administration (FHWA), 2003b, Intelligent Transportation Systems Cost and Benefits 2003 Update, *Report Number: FHWA-OP-03-075*.

Frith B., Pearce D. and Sutch T., 2004, The Highways Agency Journey Time Database, *in Proceedings of the 12th Conference on Road Transport Information and Control*, London.

Garcia-Ortiz A., Amin S. M. and Wootton J. R., 1995, Intelligent Transportation Systems – Enabling Technologies", *Mathematical and Computer Modelling*, Vol. 22 (4-7), pp 11-18.

Giannettoni M. and Savio S., 2004, Fleet management in railway freight transport: the EU project F-Man, In *Proceedings of Ninth International Conference on Computer Aided Design, Manufacture and Operation in the Railway and other Advanced Transit Systems (COMPRAIL)*, Dresden, Germany, May.

Gutierrez R., 2004, Test Report on Trials*, GADEROS Project Report*, available on http://www.gaderos.com/ .

Hammond J. and Rooke A., 2003, Enhancing safety by remote vehicle stopping, In *Proceedings of the 10th world congress in ITS*, Madrid, Spain.

Hills, P.J. and Blythe, P.T., 2002 The Future for Road User Charging in the UK.

Ingenia, Journal of the Royal Academy of Engineering, No. 14, December
Infopolic project, 1999, “At-Stop Displays”, *Project Document*, available on www.ul.ie/~infopolis/project.html .
Kang K. and Kwon O., 1997, Integrated Logistics Information System in Korea, *Logistics Information Management,* Vo. 10 (1), pp. 43-51.
Koenen K. 2004, Electronic ticketing in public transport – the activities of the knotiki working group, *Eurotransport,* Vol. 2 (3), pp. 13-18.
Kroes E., Hagemeier F. and Linssen J., 1999, A New Probe Vehicle-based Floating Car Data System: Concept, Implementation and Pilot Study. *Traffic Engineering and Control*, Vol. 40(4), pp 200-204.
Kuhla E. and Cosulich G., 2004, F-MAM: Asset Management European Freight Wagons, In *Proceedings of Conference on ERRI Satellite-based Application for Railways*, Paris.
Kunze R., Mate J. L., List H. and McDonald M., 2004, Strategic Research Agenda, *European Road Transport Research Advisory Council.*
Lyons G. D., 2001, Towards Integrated Traveller Information, *Transport Reviews*, Vol. 21 (2), pp. 217-235.
Marais J and Berbineau M, 2004, Analysis of Satellite Availability for Satellite-based Train Control Command Application to the LOCOPROL project, In *Proceedings of Conference on ERRI Satellite-based Application for Railways*, Paris.
McDonald M., Allsop R. and Bonsall P., 2000, Final Report of Peer Review of Highways Agency Toolkit Projects.
McDonald M., Henry A., Vaa T. and Piao J. and Tveit O., 2004, Acceptance of ADAS/AVG systems from questionnaires in three European cities, *Traffic Engineering and Control*, Vol. 45 (7), pp.251-255.
McKinnon A., 2003, Influencing Company Logistics Management, *Organisation for Economic Cooperation and Development*, pp. 60-74.
Mertens P. and Franckart F-P, 2003, A low cost train location and signalling system for “low density” lines, In *proceedings of world congress on railway research 2003*, Edinburgh.
Meyer W., 2004, “Access to Public Transporrt”, *Eurotransport*, Vol. 2 (1), pp.8-11.
Michalopoulos P. G., Jacobson R. D., Anderson C. A. and DeBruycker T. B., 1993, Automatic Incident Detection through Video Image Processing. *Traffic Engineering and Control*, Vol. 34 (2), pp. 66-75.
Moore P. M. and Najafi F. T., 2004, The effect of the integration of handheld computers, GPS devices and a GIS on the efficiency of congestion inspection duties, In *Proceedings of Transportation Research Board 83rd Annual Meeting*, Washington, D.C., 11-15 January.
Nelson L. J., 2003, An AVId reader*, Traffic Technology International, April/May*, pp. 72-75.
Nottingham City Council (2002), Public Transport Information Strategy, *Government Document*, available at www.nottinghamcity.gov.uk .
Promote-Chauffeur, 2003, Report on socio-economic evaluation, *Project Report*.
Rail Research UK (RRUK), 2004, Rail User Needs and Delivery Mechanism, *Report Number: RRUK/C2/02*.
ROMANSE, 2000, Road Management System for Europe – Executive Summary, *Government Document*.
ROSETTA Final Report, 2004a, Real OpportunitieS for Exploitation of Transport Telematics Applications, *Project Document*.
ROSETTA Final Report, 2004b, Freight transport service, *Project Document*.
Scemama G., Balbo F., Caruso M., Rodriguez J. and Tendjaoui M., 2000, Real time aid to decision system for bus operators, In *Proceedings of the 10^{th} International Conference on Road Transport Information and Control*, pp. 200-204,

London.
Shrestha B. P., 2003, Simulating advanced bus priority strategies at traffic signals, *PhD thesis*, Dept. of Civil and Environmental Engineering, University of Southampton.
Simmons N., Gates G. and Burr J., 2002, Commercial Applications Arising from A Floating Vehicle Data System in Europe. In *Proceedings of 9th World Congress on Intelligent Transport Systems,* Chicago, 14-17 October.
STARDUST, 2004, Towards sustainable town development: a research on development of urban sustainable transport systems: final report, *Project report*, available at www.trg.soton.ac.uk .
TABASCO, 1998, Telematics Applications in Bavaria, Scotland and others – Final Evaluation Report, *Project Report*.
Turner S. M., Eisele W. L. Benz R. J. and Holdener D. J., 1998, Travel Time Data Collection Handbook. Technical Report*, Texas Transportation Institute*, Report Number: FHWA-SA-97-064.
Turner S. P. E., 2004, Defining and measuring traffic data quality: white paper on recommonded approaches, In *Proceedings of Transportation Research Board 83rd Annual Meeting*, Washington, D.C., 11-15 January
Uekawa A., Asai Y., Shimotani M., Kusama T., Hashimoto K. and Ideno H., 2001, "Victoria Car Navigation Software Development Framework," In *Proceedings of the 8th World Congress on Intelligent Transport Systems*, Sydney, Australia.
Wiggins A. E., 1999, Helsinki Journey Time Monitoring System, In *Proceedings of IEE Seminar CCTV and Road Surveillance*, London, pp. 7/1-7/9.
Zhang X., Takeda K., Hansen J. H. L. and Maeno T., 2004, "Audio-visual speaker localization for car navigation systems," In *Proceedings of International Conference on Spoken Language Processing*, South Korea.
Urech A., Prieto M G, de Mignel S., 2003, Latest development of the GADEROS Pilot Project, In *Proceedings of GNSS 2003 – European Navigation Conference*, Graz, Austria.
Vonk T. and van den Broeke A., 2003, A new mobility service concept: an individual, real-time, integral and multi-modal travel assistant, In *Proceedings of the 10th world congress on Intelligent Transport Systems*, Madrid, Spain.
VTT Information Technology, 2003, Mobile Location Technology, Available: http://location.vtt.fi
Wergles K., 2004, Electronic ticketing system versus tariff associations, *Eurotransport* Vol. 2 (3), pp. 13-18.
Wevers K., 2000, "The Dynamics of Digital Map Databases", In *Proceedings of the 7th world Congress on Intelligent Transportation Systems*, Turin, Italy.
Wiss J-M, Barbu G., Frosig P. et. al., 2000, Requirements of Rail Application, *GNSS Rail User Forum Report*.
Ygnace. J.L., Drane C. and Yim Y. B., 2000, Cellular Phone Positioning and Travel Times Estimates. In *Proceedings of the 7th world congress on Intelligent Transport Systems*, Turin, Italy, 6-9 November.
Yim Y. B. and Cayford R., 2002, Positional Accuracy of Global Positioning System and Cellular Phone Tracking for Probe Vehicles, In *Proceedings of Transportation Research Board 81st Annual Meeting*, Jan., Washington, D.C., 13-17 January.
Yin Z., Yan F., Lin H.X. Ran B., 2004, Using image sensors to measure real-time traffic flow parameters, In *Proceedings of Transportation Research Board 83rd Annual Meeting*, Washington, D.C., 11-15 January.
Zhang X., Takeda K., Hansen J. H. L. and Maeno T., 2004, Audio-visual speaker localization for car navigation systems, In *Proceedings of International Conference on Spoken Language Processing*, South Korea.

Zito R., D’este G. and Taylor M. A. P., 1995, “Global Positioning Systems in the Time Domain: How Useful a Tool for Intelligent Vehicle-Highway System?”, *Transportation Research Part C*, Vol. 3 (4), pp. 193-209.