DELIVERABLE 3.1
THE POTENTIAL ROLE OF ICT IN FAVOURING A SEAMLESS CO-MODAL TRANSPORT SYSTEM
POTENTIAL ROLE OF ICT

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EXECUTIVE SUMMARY

The objectives of this Deliverable “Opportunities through ICT” are the following:

1) To identify the ICT solutions with potential to favour seamless co-modal journeys, to be fully analysed in WP5 (ICT solutions for co-modality);

2) To stress their role in favouring data collection and management, providing indications on how they can improve data collection in the passenger transport sector (data collection methods), to be fully analysed in the WP4 (Travel surveys);

3) To provide indications how ICT-based solutions can meet future passengers needs in the light of the likely future trends affecting transport demand, e.g. ageing, economic and energy scenarios, etc, to be addressed in the D3.2 “Key trends and emerging traveller needs” (June 2012).

Concerning the relationships between ICT solutions and seamless co-modal trips, the identified ICT solutions and technologies have shown significant potential in favouring co-modal seamless solutions. In particular, ICT technologies are deemed to represent the key instruments to convey the relevant information to the passengers for making a seamless trip possible: from the information on timetables, delays and interconnections to the availability of smart ticketing.

More transport safety (through cooperative applications), a better environment (through transport management tools) and accessibility (in particular the development of Demand Responsive Transport (DRT) services) will also benefit from the extensive implementation of ICT applications.

The ICT solutions identified can be classified in the six following broad categories:

1) Transportation management systems, helping to plan and running efficiently the transport system;

2) Traveller information systems, in which the key characteristic is to assist the traveller with several parts of information (travel time, routes, traffic conditions, etc);

3) Smart ticketing and tolling applications, addressing new ways to get tickets and to pay for using transport services;

4) Vehicle-to-infrastructure (V2I) applications, which are a form of wireless cooperative interaction between vehicles and infrastructure, based on systems that can improve safety and traffic management (UNECE, 2012);

5) Vehicle-to-vehicle (V2V) applications, allowing direct interaction between cars with the potential to increase safety and efficient infrastructure use;

6) DRT services, which provide a mechanism whereby passengers can be picked up and dropped off at their chosen locations, at a price usually closer to those of fixed route bus services than to taxis.

Table 0-1 shows that important enabling applications are represented by smart ticketing options combining tariff information of several transport modes (smart cards) and traveller information systems, informing transport users on timetables and travel time (multi-modal traveller information systems). In particular, it must be stressed that in this latter category, the real-time co-modal traveller information systems are deemed to be the most promising ICT applications, to the extent that they can take into account of the dynamic context-related event, e.g. delays, traffic interruptions, etc, updating the travel planner and favouring seamless journeys. The qualitative assessment uses three categories: low capability (√), medium capability (√√) and high capability (√√√).
Concerning the opportunity towards a better data collection process for passenger mobility surveys, this deliverable stresses that ICT applications are continuously evolving to meet transport data needs, using a broad range of information and telecommunications technologies to detect people, drivers, vehicles, goods, traffic and environmental conditions, and to communicate information to a variety of user groups. Transport data needs are complex, vary between sectors and are influenced by factors such as levels of transport system development, the degree of intermodality involved in the trips, etc. The overview of the relationships between ICT categories by relevant applications and data needed for passenger transport surveys is given in Table 0-2. It should be noted that the table only contains four ICT categories, because it is thought that the other two will not be able to contribute relevant data.

### Table 0-2 ICT categories and information provided

<table>
<thead>
<tr>
<th>ICT categories</th>
<th>Relevant applications/solutions</th>
<th>Types of information provided</th>
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</table>
| Transportation management systems | • Urban Traffic Control systems  
• Performance monitoring  
• Traffic planning  
• Priority management  
• Public Transport Management  
• Transport Demand Management  
• Enforcement  
• Traffic Control  
• Traffic Forecasting | • Network state estimation  
• Traffic flows  
• Capacity  
• Delays  
• Congestion  
• Traffic composition, e.g. public transport share, private motorisation |
| Traveller Information Systems    | • Travel planners  
• Pre-trip decisions tools  
• Within-trip confirmation and recovery (Real time-Travel time tools)  
• Route optimisation  
• Destination findings  
• Route following  
• Dynamic route guidance | • O/D flows  
• Number of trips by link and zone.  
• Time, cost, trip location  
• Distance travelled, routes  
• Route and journey time estimations |
| Smart Ticketing and Tolling     | • Electronic Toll Collection  
• Access Management  
• Public Transport smart-cards | • Cost information, charges, tickets, fees  
• O/D flows  
• Road characteristics, e.g. speed limits |
| Vehicle-to Infrastructure (V2I) | • Floating probe vehicles  
• Routing applications  
• Micro routing applications | • Vehicle location  
• Travel time  
• O/D routes  
• Traffic flows |
Concerning the opportunities of the ICT solutions to meet the future challenges deriving from the socio-economic factors, e.g. population ageing, migration flows, urbanisation patterns, three sub-sets of drivers, relevant for ICT solutions, have been identified:

1) Demographic factors (population ageing). The level and composition of the population in terms of person types, with considerable variation in trip making and trip distances between persons by age, sex, economic position, income, etc is clearly one of the factors that influences transport demand. Particular attention is paid to the way trip rates change for each person category, and especially in relation to age and income dependent behaviour. From the 2012 Ageing Report (EC, 2011): “The age structure of the EU population will dramatically change in coming decades due to the dynamics of fertility, life expectancy and migration. The overall size of the population is projected to be slightly larger in 50 years time, but much older than it is now”.

2) Motorisation rates. Over the past 20 years, in the European cities car ownership rates have been growing and it is likely that in the near future the car ownership rates continue to grow, even if at slower rates. It should be considered in fact that income effect and behavioural patterns and lifestyles will continue to exert their influence in increasing the rate of private motorisation rates. This trend must be interpreted in association with the population ageing. In fact, in the future older people will comprise a larger share of the driving population than in the past. Older people will wish to retain their driving licence as long as possible and therefore licence holding among older people will be more similar to licence holding among younger and middle aged people now.

3) Urbanisation trends. Concerning the urbanisation driver, urban growth is nowadays accompanied by urban sprawl – a relative shift in the location of activities (housing, industries, retail and other services) towards the peripheries of the urban agglomeration. This was and currently is an established trend that affects the growth of modern cities, which can be assessed by taking into account global trends in the housing, retail and business sectors, in order to understand why this phenomenon has steadily marked the development of urban areas over the last decades. Growing car ownership and the concentration of work and shopping in out-of-town locations have resulted – and may continue to result - in continuing increases in journey length for all purposes, but particularly for commuting.

The following table shows the relationships between the drivers of changes in transport demand, the identified broad ICT categories and the impacts on transport demand and passengers needs.

<table>
<thead>
<tr>
<th>Change in passenger transport demand</th>
<th>Role of ICT solutions</th>
<th>Impacts</th>
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</thead>
<tbody>
<tr>
<td><strong>Drivers</strong></td>
<td><strong>ICT Solutions</strong></td>
<td><strong>Impacts</strong></td>
</tr>
<tr>
<td>Population ageing</td>
<td>Advanced Driver Assistance Systems (ADAS)</td>
<td>• Improve communication and safety and comfort</td>
</tr>
<tr>
<td></td>
<td>Adaptive Cruise Control (ACC)</td>
<td>• Assist the driver during drive and operations</td>
</tr>
<tr>
<td></td>
<td>Demand Responsive Transport Services</td>
<td>• Favouring mobility for disabled, and older people</td>
</tr>
<tr>
<td>Growing motorisation rates</td>
<td>Real-time Co-modal Traveller Information Systems</td>
<td>• Integrate public transport planning information (e.g. real time information on bus schedules)</td>
</tr>
<tr>
<td></td>
<td>Public Transport Management</td>
<td>• Modal shift in favour of public transport</td>
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<td></td>
<td>Incident Management and ITC Safety Services</td>
<td>• Saving in congestion and travel time</td>
</tr>
<tr>
<td></td>
<td>Intelligent Speed Adaptation (ISA)</td>
<td>• Reduce accident rates by improved accident management and in-vehicle tools</td>
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<tr>
<td>Urbanisation trends</td>
<td>Travel planners</td>
<td>• Saving time and trips, by providing additional feeds into the navigation systems and make the information mix even richer by combining weather conditions en</td>
</tr>
<tr>
<td>Change in passenger transport demand</td>
<td>Role of ICT solutions</td>
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<tr>
<td><strong>Drivers</strong></td>
<td><strong>Impacts</strong></td>
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<tr>
<td>• Need to more frequent multi-modal transport trips (e.g. commuting)</td>
<td>Applications</td>
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<tr>
<td><strong>ICT Solutions</strong></td>
<td><strong>Impacts</strong></td>
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<tr>
<td>Applications</td>
<td>route, feedback from commuters already on the road, measurements from road sensors, etc.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Assist passenger providing information on transport services, timetables and interconnections</td>
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1 INTRODUCTION

The Deliverable 3.1 “The potential role of ICT in favouring a seamless co-modal transport system” is part of the COMPASS Work Package 3 “Key trends”. In such a context, this Deliverable pursues three different but interrelated objectives:

1) To identify the ICT solutions with potential in favouring seamless co-modal journeys,

2) To stress their role in favouring data collection and data management, providing indications on how they can improve data collection in the passenger transport sector (data collection methods for passenger travel surveys),

3) To provide suggestions on how ICT based solutions can meet future passengers needs in the light of the likely future socio-economic trends affecting transport demand, e.g. population ageing, economic integration (globalisation), energy scenarios, etc,

Furthermore, there is a direct relationship between these objectives and three other COMPASS Work Packages:

1) Relationships with the WP5 (ICT Solutions for Co-modality), to the extent that the Deliverable 3.1 provides the list of ICT solutions and technologies with higher potential in favouring seamless co-modal journeys;

2) Relationships with the WP4 (Travel Surveys); through the indication of the key variables (indicators), that the identified ICT solutions can allow to collect, in the prospective of improving data collection methods for travel surveys;

3) Relationships with WP3 (Key Drivers); reviewing how the ICT solutions can address the challenges arising from the likely future socio-economic trends.

The point 1 of the above list, the identification of the promising ICT solutions, has benefited of the background analysis carried out in the COMPASS Milestone MS1, which has provided a first overview of the ICT based-solutions drawn on the outcomes and the insights of several FP7 current and past European projects and literature review, e.g. STADIUM (2010), ROADIDEA (2009), ETISplus (2011).

The point 2 takes stock of the insights from the COMPASS Milestone MS2, which has provided a preliminary analysis on information needed for understanding present and likely future traveller behaviour, to be fully developed in the COMPASS D4.2 “The role of ICT in travel data collection” (to be issued in January 2013).

The point 3 points out indications on how ICT solutions can accommodate current and future passenger needs, in the light of the ongoing research on the relationships of key socio-economic trends on passenger transport demand and passenger needs, that will be carried out in D3.2 “Key trends and emerging traveller needs”, to be issued in June 2012.

On top of that, the analysis is carried out by taking into account the key aspects of the analytical framework of the COMPASS project:

- The freight transport sector is not considered.
- The time horizon for the analysis of the ICT based applications is the medium term (2020), which implies highlighting the ITS applications characterised by mature technologies able to be applied and to produce significant results in the near future.

The structure of the Deliverable 3.1 follows the development of the three main objectives above mentioned.

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Chapter 2 deals with the identification of the ICT solutions and underlying technologies, with a classification in the six following broad categories:

1) Transportation management systems, helping to plan and running efficiently the transport system;
2) Traveller information systems, in which the key characteristic is to assist the traveller with several basic information (travel time, routes, traffic conditions, etc);
3) Smart ticketing and tolling applications, addressing new ways to get tickets and to pay for using transport services;
4) Vehicle-to-infrastructure (V2I) applications, which can be generally defined as wireless cooperative interaction between vehicles and infrastructure, based on systems that can improve safety and traffic management (UNECE, 2012);
5) Vehicle-to-vehicle (V2V) applications, allowing direct interaction between cars with the potential to increase safety and efficient infrastructure use;
6) Demand responsive transport services (DRT), which provide a mechanism whereby passengers can be picked up and dropped off at their chosen locations, at a price usually closer to those of fixed route bus services rather than taxis.

It is important to stress that when dealing with the individual ICT applications, a certain overlap among the categories should be taken into account, e.g. the ERTMS application in the rail sector has been classified under the transportation management system, even though it also includes examples of applications under the Vehicle-to-Infrastructure and Vehicle-to-Vehicles categories. This happens due to the extreme pervasiveness of ICT applications, which makes the one-to-one allocation to just one of the above six COMPASS ICT categories unlikely.

In order to address the complexity of the ICT applications a section of the chapter has been devoted to the description of the relevant basic ICT technologies and infrastructure, whose combination and further cross-integration form the six broad categories of ICT applications and solutions, which will be used as reference for the further steps of the project.

Chapter 3 provides an overview of how the ICT solutions can improve data collection for passenger transport modelling, e.g. mobility patterns, behaviour, and travel surveys. In such a context, an important input has been provided by the COMPASS Milestone MS2, which has identified a long list of the most important indicators needed for improving passenger travel surveys. The capability of the ICT applications to improve the data collection and availability has been carried out by looking at a short list of the likely relevant indicators identified in the COMPASS Milestone MS2.

Chapter 4 reviews the most important challenges for mobility and passenger transport arising from the analysis of the likely socio-economic trends in the medium-long term horizon (2020-2050), carried out in the COMPASS WP3. Although the work is still on-going, enough research has been carried out to identify the trends and their implications on passenger transport mobility. In such a framework, the identified ICT applications will be compared with the emerging trends to stress which applications can be useful to meet the future passenger needs.

Conclusions will be drawn in the final chapter, aiming at the inclusion of the specific insights in the overall objectives of the COMPASS project.
2 ICT SOLUTIONS AND SEAMLESS TRANSPORT MOBILITY

2.1 ICT TECHNOLOGIES

2.1.1 Cloud Technologies

Source
- European Communities, Information Society & Media Directorate-General “The future of cloud computing”, 2012
- INFSO-ICT-257992 SmartSantander project D1.1 “First Cycle Architecture Specification”, 2011
- Inspiring the Internet of Things” A Comic book on the future of Internet”, 2011

Transport modes involved

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Description
The term “Clouds” do generally not refer to a specific technology or framework, but rather to a set of combined technologies, respectively a paradigm / concept characterised by a networking of infrastructure which integrates all kind of resources, usage domains, data and information. To be more specific, a cloud is a platform or infrastructure that enables execution of code (services, applications etc.), in a managed and elastic fashion.

The concept of “internet of things” (IoT), made possible by the application of clouds technologies and infrastructure, addresses the capability to manage many detectors and services (RFID, GPS), dealing with rapidly varying data volumes and rates. Clouds provide an elastic facility to manage this variability. Of course a Cloud environment can also provide the services for analysis of the data streams often associated with synchronous simulation to aid the provision of information to the end-user in an optimal form.

The field of transportation, where the high volumes and rates of data need rapid processing to information for understanding, can be a potential area of application.

The following examples are taken from the EU project Smartsantander, whose main goal is the creation of a European experimental test facility for the research and experimentation of architectures, key enabling technologies, services and applications for the IoT in the context of the smart city:

- Management of scarce parking, delivering real-time information about the parking spaces available in the limited parking zones. This information may be shown in panels located inside the parking zones or via SMS sent to mobile devices. Two different users are distinguished: Neighbours of the parking zones have a special without paying anything, but a fix quantity per month/year. Other users must pay for a ticket whose value changes based the parking zone (maximum 2 hours). When this time is exceeded, user must obtain a new ticket in order to keep their vehicles parked in the same parking space.
- Parking Management for People with Disabilities: This use case provides people with disservice for checking the available parking spaces for people with disabilities as we as pre-reserving them. The city council can study the statistics they are provided with, in order to plan the number and location of parking spaces for people with disabilities for the future.
- Load/unload areas management: The goal of this use case is to keep control of the load and unload areas. This task involves preventing unauthorised vehicles park in areas reserved for the load and unload of goods (RFID tags or similar are used for the identification of authorised vehicles), controlling that the time that one authorised vehicle spend in these areas doesn’t exceed an established number of minutes, as well as identifying the need to provide the city with
Other than ICT applications inside smart cities, Clouds technologies and IoT framework can provide services to extra urban and multimodal passenger transport users:

- **Commuters**: the users leaving for work in the morning can use the intelligent commuter applications on their mobile phones to find the best route to work. The application receives live traffic and public transport updates and computes the best route. Using live traffic and public transport data, the intelligent commuter applications can guide the users to the light rail saving valuable time. Clouds applications and IoT will provide additional feeds into the navigation systems and make the information mix even richer by combining weather conditions en route, feedback from commuters already on the road, measurements from road sensors, etc. Such rich information mix will make planning of a trip even more efficient and the trip itself more pleasant.

- **Payment**: Users can pay automatically via mobile phone when, for example, a bus crosses different charging zones. This can be made possible through Near Field Communications (NFC) technologies, which is an important technology of the Internet of Things. NFC is closely linked to the mobile phone and is a specialised technology in the radio frequency identification (RFID) technology family. It enables many mobile phone applications such as for instance secure payment transactions. The Internet of Things and location-based services empower a whole new view of the world. RFID tags provide an identification of an object in their most primitive form. But if this is combined with location information, it is a powerful means of tracking objects, people and animals.

- **Transport management**: Interactive Street Sensing can gather data about the city – the city’s pulse. Sensors on every lamppost in the city measure data about noise, traffic, environment, crowds, temperature –. Data is transmitted and processed and information is presented as, for example, a map illustrating real-time and historic data of pollution can be viewed. Dynamic info graphics, showing interesting detail about the city as a living organism, e.g. how it is used by people, flow of traffic and impact on the environment. All that can improve dramatically the info available to urban planning, transport modellers and urban traffic controls centres.
2.1.2 Global Positioning System (GPS)

Source

- STADIUM, Smart Transport Applications Designed for large events with Impacts on Urban Mobility, Del.2.1 “State-of-the-Art Report”, 2010
- S. Ezell ITIF "Intelligent Transportation Systems - Explaining International IT Application Leadership", 2010

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Description

The Global Positioning System (GPS) devices are widespread in navigation systems, taxi fleets, freight transport fleets and as security device in passenger cars. The GPS receivers in vehicles’ on-board units (OBUs, a common term for telematics devices) receive signals from several different satellites to calculate the device’s (and thus the vehicle’s) position. This requires line of sight to satellites, which can inhibit use of GPS in downtown settings due to “urban canyon” effects. Location can usually be determined to within ten meters. GPS is the core technology behind many in-vehicle navigation and route guidance systems. Several countries, notably Holland and Germany, are using or will use OBUs equipped with satellite-based GPS devices to record miles travelled by automobiles and/or trucks in order to implement user fees based on vehicle miles travelled to finance their transportation systems.

GPS is vital in the identification of vehicle location/proximity which feeds into Traffic Management systems and provides real-time service schedules for travellers which can be disseminated via Mobile Phones, VMS, and Websites etc. GPS signals can be used to monitor a variety of event aspects:

- Volume Monitoring;
- Availability Monitoring; and
- Activity Monitoring.

Volume monitoring for congestion and flow monitoring recording and analysing could be applied to both traffic and travellers. This area consists of:

- Flow Monitoring;
- Monitor Traffic Flow (Vehicles/PT);
- Congestion;
- Availability monitoring covers;
- Vacant Unreserved Seating;
- Monitor Venue Coordination;
- Empty Parking Spaces;
- Monitor Movement Co-ordination;
- Taxis at a Taxi Rank;
- Monitor Movement Co-ordination.
2.1.3 Dedicated-Short Range Communications (DSRC/RFID)

Source
- STADIUM, Smart Transport Applications Designed for large events with Impacts on Urban Mobility, Del.2.1 “State-of-the-Art Report”, 2010
- S. Ezell ITIF “Intelligent Transportation Systems - Explaining International IT Application Leadership”, 2010

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Description

DSRC is a short- to medium-range wireless communication channel, operating in the 5.8 or 5.9GHz wireless spectrum, specifically designed for automotive uses. Critically, DSRC enables two-way wireless communications between the vehicle (through embedded tags or sensors) and roadside equipment (RSE). DSRC is a key enabling technology for many intelligent transportation systems, including vehicle-to-infrastructure integration, vehicle-to-vehicle communication, adaptive traffic signal timing, electronic toll collection, congestion charging, electronic road pricing, information provision, etc. DSRC is a subset of radio frequency identification (RFID) technology. The technology for ITS applications works on the 5.9GHz band (United States) or the 5.8GHz band (in Japan and Europe).

At present, DSRC systems in Europe, Japan, and the United States are generally not compatible (although there are indications that Europe may be trying to migrate to 5.9GHz). In 2004, the U.S. Federal Communications Commission (FCC), atypically for a U.S. regulator, prescribed a common standard for the DSRC band both to promote interoperability and to discourage the limitation of competition through proprietary technologies.

Radio-frequency identification (RFID), the sub-set to DSRC, is used as an object (typically referred to as and RFID tag) applied to or incorporated into a product, animal, or person for the purpose of identification and tracking using radio waves. Some tags can be read from several meters away and beyond the line of sight of the reader.

Most RFID tags contain at least two parts. One is an integrated circuit for storing and processing information, modulating and demodulating a radio-frequency (RF) signal, and other specialised functions. The second is an antenna for receiving and transmitting the signal.

There are generally three types of RFID tags: active RFID tags, which contain a battery and can transmit signals autonomously, passive RFID tags, which have no battery and require an external source to provoke signal transmission, and battery assisted passive (BAP) which require an external source to wake up but have significant higher forward link capability providing great read range. RFID has many applications, for example, it is used in enterprise supply chain management to improve the efficiency of inventory tracking and management. The technology can also be implanted within a ticket.

In particular, it must be stressed that 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.
2.1.4 Wireless Technologies

**Source**

- STADIUM, Smart Transport Applications Designed for large events with Impacts on Urban Mobility, Del.2.1 “State-of-the-Art Report”, 2010
- S. Ezell ITIF “Intelligent Transportation Systems - Explaining International IT Application Leadership”, 2010

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**Description**

Similar to technology commonly used for wireless Internet access, wireless networks allow rapid communications between vehicles and the roadside, but have a range of only a few hundred meters. However, this range can be extended by each successive vehicle or roadside node passing information onto the next vehicle or node. South Korea is increasingly using WiBro, based on WiMAX technology, as the wireless communications infrastructure to transmit traffic and public transit information throughout its transportation network.

Wireless networking is used to meet many needs. Perhaps the most common use is to connect laptop users who travel from location to location. Another common use is for mobile networks that connect via satellite. A wireless transmission method is a logical choice to network a LAN segment that must frequently change locations. The following situations justify the use of wireless technology:

- To span a distance beyond the capabilities of typical cabling,
- To provide a backup communications link in case of normal network failure,
- To link portable or temporary workstations,
- To overcome situations where normal cabling is difficult or financially impractical, or
- To remotely connect mobile users or networks.

Wireless communication can be via:

- Radio frequency communication,
- Microwave communication, for example long-range line-of-sight via highly directional antennas, or short-range communication, or
- Infrared (IR) short-range communication, for example from remote controls or via Infrared Data Association (IrDA).

Nowadays, 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. 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.
2.1.5 Mobile Phone

Source

- STADIUM, Smart Transport Applications Designed for large events with Impacts on Urban Mobility, Del.2.1 “State-of-the-Art Report”, 2010
- S. Ezell ITIF “Intelligent Transportation Systems - Explaining International IT Application Leadership”, 2010
- ETISplus “Del 2.1 Review of ITS and their usability for European data modelling purposes”, 2011

Transport modes involved

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<th>Road</th>
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Description

ITS applications can transmit information over standard third or fourth generation (3G or 4G) mobile telephone networks. Advantages of mobile networks include wide availability in towns and along major roads. However, additional network capacity may be required if vehicles are fitted with this technology, and network operators might need to cover these costs. Mobile telephony may not be suitable for some safety-critical ITS applications since it may be too slow. The speeds of standard Ethernet and other common wire-based LAN technologies.

Mobile phones can be used as anonymous traffic probe, in fact the mobile phone position, and therefore the vehicle’s position, is continuously transmitted to the network usually by means of triangulation or other techniques (e.g. handover). In this way, the average speed of the driving vehicle and the travel time along the route are derived. This technique is particular efficient in urban areas where the lower distance between antennas makes easier monitoring data. It should be noted that mobile phone has to be turned on to be operative but not necessarily in use.

Mobile devices represent a cheap device compared to the others system (i.e. stationary traffic detectors and GPS-based system) as any hardware/device is needed for transmitting data that are collecting continuously. On the other side, sophisticated algorithms are necessary to transform high quality data. The last generation of mobile phone UMTS technology (3G) provides more accurate data than the previous version for which the location precision is low (generally 300 m) conversely this weakness is balanced by the large number of devices in use.

Whenever a mobile phone is in motion at a certain speed and in a certain direction, reliable and useful traffic information becomes available. For example, the TomTom provider can access this anonymous data from millions of Vodafone customers, giving an accurate view of the traffic situation throughout the road network.

However, some drawbacks related to cellular based system are however to be faced:

- Complex processing data: Extraction methodologies require the reconstruction of the road and cellular network within a digital mapping system and the handling of a large volume of information that should be filtered in some way.
- Accuracy and sampling issues: determination of sample size, sample timing and statistical significance (i.e. level of standard deviation) to get reliable and accurate information. Accordingly further R&D efforts are still needed
- Privacy concerns: protection ensuring that all the data collected is anonymous.
- Data ownership: this is a critical issue that has to be tackled in the short-term given the impressive deployment of the market.
### 2.1.6 Radiowave or Infrared Beacons

**Source**
- STADIUM, Smart Transport Applications Designed for large events with Impacts on Urban Mobility, Del.2.1 “State-of-the-Art Report”, 2010
- S. Ezell ITIF “Intelligent Transportation Systems - Explaining International IT Application Leadership”, 2010
- CONDUITS “Coordination Of Network Descriptors for Urban Intelligent Transportation Systems Deliverable 2.3 “Define R&D needs for ITS implementations in cities”, 2011

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**Description**

Microwave or infrared beacons transmit short bursts of data at high speeds over short distances, typically from roadside furniture and signs; they can be location beacons, which transmit their own location and identifying number; information beacons, which also relay current traffic information that they receive via cable; and communications beacons, which can collect data from the vehicle as well.

For example, the Japan’s Vehicle Information Communications System (VICS) uses radio wave beacons on expressways and infrared beacons on trunk and arterial roadways to communicate real-time traffic information. (Arterial roadways are moderate capacity roadways just below highways in level of service; a key distinction is that arterial roadways tend to use traffic signals. Arterial roadways carry large volumes of traffic between areas in urban centers.) VICS uses 5.8GHz DSRC wireless technology. The VICS can be considered as one of the most prominent ITS application in Japan. It represents the nationwide deployment of widespread adoption of Telematics car navigation systems. The Vehicle Information and Communication System Center (VICS Center), a government established non-profitable organisation (provides a digital data communication system with road traffic information to drivers via telematics units, car navigation manufactured by the private sector. The following figure shows how the VICS operates:
2.1.7 Roadside Camera Recognition (CCTV, ANPR)

Source
- STADIUM, Smart Transport Applications Designed for large events with Impacts on Urban Mobility, Del.2.1 “State-of-the-Art Report”, 2010
- S. Ezell ITIF “Intelligent Transportation Systems - Explaining International IT Application Leadership”, 2010

Transport modes involved

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Description

A traffic enforcement camera is a system, including a camera and a vehicle-monitoring device, used to detect and identify vehicles disobeying a speed limit or some other road legal requirement. Examples include:

- Speed cameras - for identifying vehicles travelling over the legal speed limit; many such devices use radar to measure a vehicle's instantaneous speed; Sts of multiple cameras with number-plate recognition software which can check the average speed of a vehicle between two points;
- Red light cameras - to detect vehicles which cross a stop-line or designated stopping place after a red traffic light shows;
- Bus lane cameras - for identifying vehicles travelling in lanes reserved for buses; In some jurisdictions, bus lanes can also be used by taxis and/or vehicles engaged in car pooling;
- Toll-booth cameras - for identifying vehicles proceeding through a toll booth without paying the toll;
- Level crossing cameras - for identifying vehicles crossing railways at grade illegally;
- Congestion charge cameras - for recording vehicles inside the chargeable area;
- Double solid line cameras - for identifying vehicles crossing these lines;
- High-occupancy vehicle lane cameras - for identifying vehicles violating the occupancy requirements;
- Turn cameras - at intersections where specific turns are prohibited on red; This type of camera is mostly used in cities or heavy populated areas;
- Parking Cameras - which issue citations to vehicles which are illegally parked or which were not moved from a street at posted times.

Camera- or tag-based schemes can be used for zone-based congestion charging systems (as in London), or for charging on specific roads. Such systems use cameras placed on roadways where drivers enter and exit congestion zones. The cameras use Automatic License Plate Recognition (ALPR), based on Optical Character Recognition (OCR) technology, to identify vehicle license plates; this information is passed digitally to back-office servers, which assess and post charges to drivers for their use of roadways within the congestion zone.

Closed-circuit television (CCTV) is the use of video cameras to transmit a signal to a specific place, on a limited set of monitors. It differs from broadcast television in that the signal is not openly transmitted, though it may employ point to point wireless links. CCTV is often used for surveillance in areas that may need monitoring such as banks, casinos, airports, military installations, and convenience stores.

CCTV systems may operate continuously or only as required to monitor a particular event. A more advanced form of CCTV, utilising Digital Video Recorders (DVRs), provides recording for possibly

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many years, with a variety of quality and performance options and extra features (such as motion-detection and email alerts).

Surveillance of the public using CCTV is particularly common and its increasing use has triggered a debate about security versus privacy.

**Automatic number plate recognition (ANPR)** is a mass surveillance method that uses optical character recognition on images to read the licence plates on vehicles. As of 2006, systems can scan number plates at around one per second on cars travelling up to 100 mph (160 km/h). They can use existing closed-circuit television or road-rule enforcement cameras, or ones specifically designed for the task. They are used by various police forces and as a method of electronic toll collection on pay-per-use roads and monitoring traffic activity, such as red light adherence in an intersection.

ANPR can be used to store the images captured by the cameras as well as the text from the licence plate, with some configurable to store a photograph of the driver. Systems commonly use infrared lighting to allow the camera to take the picture at any time of the day. A powerful flash is included in at least one version of the intersection-monitoring cameras, serving both to illuminate the picture and to make the offender aware of his or her mistake. ANPR technology tends to be region-specific, owing to plate variation from place to place.

Concerns about these systems have centred on privacy fears of government tracking citizens' movements and media reports of misidentification and high error rates. However, as they have developed, the systems have become much more accurate and reliable.
2.2 ICT SOLUTIONS

2.2.1 Transportation Management Systems

2.2.1.1 Urban Traffic Control (UTC)

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Description

Urban Traffic Control (UTC) systems deliver continuous monitoring of traffic conditions and can implement a fully adaptive control strategy. The Traffic Signal plans (cycle length, offset and stages duration) can be dynamically optimised to minimise the overall travel time for private traffic and give priority to public transport. Places where multiple travel/transport modes intersect (such as Level Crossings) can be managed in the same way.

Most cities operate a UTC System that can deliver the above functionality.

Urban traffic control (UTC) systems are a specialist form of traffic management which integrate and co-ordinate traffic signal control over a wide area in order to control traffic flows on the road network. Integration and co-ordination between adjacent traffic signals involves designing a plan based on the occurrence and duration of individual signal aspects and the time offsets between them and introducing a system to link the signals together electronically. A traffic responsive signal control system is a means of adjusting the traffic signal settings (cycles, green splits and offsets), which optimise a given objective function, such as minimising travel time or stops, in real-time based upon estimates of traffic conditions. There are many different UTC systems in operation around the world, but they provide the basis for an extended control system, generally termed Urban Traffic Management and Control (UTMC).

UTC systems can be used to obtain better traffic performance from a road network by reducing delays to vehicles and the number of times they have to stop. UTC systems also can be used to balance capacity in a network, to attract or deter traffic from particular routes or areas, to give priority to specific categories of vehicles such as public transport or to arrange for queuing to take place in suitable parts of the network.

Demand impacts usually reduce travel time, but reduced travel times and good network performance may increase road capacity. This may cause a shift in demand towards car use. UTC systems may not make a positive contribution to all policy objectives.

There are many different UTC systems in operation around the world, but they can be distinguished into two basic types based on different control strategies. These are fixed time systems and traffic responsive systems. Examples are SCOOT (widespread in UK cities), SCATS (applied in several Polish cities), 5T in the city of Turin, etc.
2.2.1.2 European Railway Traffic Management System (ERTMS)

Source
- FREIGHTVISION, Freight Transport Foresight 2050, Del.3.1 “Relevance of infrastructure and ITS, vehicle and engine and logistics technologies on long distance freight transport in Europe”, 2009
- Intelligent Transport System “Thematic Transport Research Summary”, 2009

Transport modes involved

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Description

The European Railway Traffic Management System (ERTMS) is a major industrial project developed by six UNIFE members – Alstom Transport, Ansaldo STS, Bombardier Transportation, Invensys Rail Group, Siemens Mobility and Thales – in close cooperation with the European Union, railway stakeholders and the GSM-R industry.

ERTMS has two basic components:
- ETCS, the European Train Control System, is an automatic train protection system (ATP) to replace the existing national ATP-systems;
- GSM-R, a radio system for providing voice and data communication between the track and the train, based on standard GSM using frequencies specifically reserved for rail application with certain specific and advanced functions.

ERTMS aims at replacing the different national train control and command systems in Europe. The deployment of ERTMS will enable the creation of a seamless European railway system and increase European railway’s competitiveness.

From the technological point of view, GSM-R applications will be primarily used. A derivation of the global GSM mobile telephony technology, GSM-R has been developed in Europe for railway operations to support the European Train Control System (ETCS). This technology is proven for rail operations in metropolitan and rural networks in Europe, but its use in Australia will require the construction of a standalone network, probably in concert with one or more of the GSM carriers. There are potential spectrum issues for GSM-R in Australia, as the optimum 900 MHz spectrum is owned by the various mobile telephony carriers. There is cross compatibility between GSM and GSM-R for most handsets, however the special rail functionality such as group calling and priority calling is not available on non-GSM-R equipment.

As an example, the GSM-R (Global System for Mobile Communications – Railway) system offers the standardised function to launch an emergency call to the driver. When receiving the call in country A the driver may have to brake immediately and bring the train to a standstill; in country B, in the same situation, the driver may only have to ‘run on sight’ or reduce the train’s speed… This example shows how important operational harmonisation is, especially in this case of a potential emergency situation which requires semi-reflex actions from the driver. Thanks to their harmonised onboard systems, ERTMS trains are able to cross borders; however, we also have to consider that these trains operate in different national environments. The difficulty is therefore in identifying the range of operational situations to be harmonised; a functional approach to rail operation will detect these limits.

The potential for transferability to other modes are significant. Improving interoperability, optimising international rail transport and the general principle of increasing the interoperability of systems can also be applied in other transport modes (co-modality).
2.2.1.3 River Information Services (RIS)

Source
- ETISplus “Del 2.1 Review of ITS and their usability for European data modelling purposes”, 2011
- Intelligent Transport System “Thematic Transport Research Summary”, 2009
- G.A. Giannopoulos “The application of information and communication technologies in transport”, Elsevier, 2004

Transport modes involved

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Description

In the framework of the RIS directive 2005/44/EC of the European Community, several European countries are implementing and testing the electronic reporting infrastructure and processes.

The River Information Services (RIS) concept aims at the implementation of information services in order to support the planning and management of traffic and transport operations on inland waterways network as well as to ensure compatibility and interoperability with other modes of transport.

The RIS Directive aims at a Europe-wide framework for the implementation of the RIS concept in order to ensure compatibility and interoperability between current and new RIS systems at European level and to achieve effective interaction between different information services on waterways.

The Directive applies to all waterways of class IV or higher across the European Union. The River Information Services comprises services such as:

- Traffic information services: these consist of tactical traffic information (display of the vessel characteristics and movements on a limited part of the waterway) and strategic traffic information (display of vessels and their characteristics over a larger geographical area, including forecasts and analyses of future traffic situations);
- Information for transport management: this information includes estimated times of arrival (ETAs) provided by boat masters and fleet managers based on fairway information making it possible to plan resources for port and terminal processes. The information on cargo and fleet management basically comprises two types of information: information on the vessels and the fleet and detailed information on the cargo transported;
- Statistics and customs services: the RIS will improve and facilitate the collection of inland waterway statistical data in the Member States.

The development of the RIS applications is accompanied by the ICT technologies for the management of maritime transport, i.e. the Automated Identification Systems (AIS). These are used for the automatic identification of a vessel and its coordinates. They invariably consist of a radio transponder allowing broadcasting vessel data in a fixed format and to a restricted extent also free text messages. The development of such applications will also allow better management at Port level: a) optimisation of support services such as pilot, b) tug and mooring services; c) improved organisation of public services such as health, immigration and customs services; d) optimisation of port and terminal services such as berth, loading and discharge services; e) organisation of shipping company and agent services.
2.2.1.4 Traffic Management Systems for Air Transport (SESAR)

Source

- Intelligent Transport System “Thematic Transport Research Summary”, 2009
- G.A. Giannopoulos “The application of information and communication technologies in transport”, Elsevier, 2004

Transport modes involved

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Description

The SESAR system is the EU’s programme to shape the future Air Traffic Control in international corridors. The European Council identified the project in 2005 as one of the “projects of common interest” for infrastructure to be implemented. SESAR is the technological element of the Single European Sky, adopted in March 2004, which lays down a clear organisation and establishes cross-border blocks of airspace. With these blocks, routes and airspace structures are no longer defined in accordance with borders but in accordance with the operational reality of traffic.

The implementation of SESAR has required several stages. Given the differences between the various air traffic control systems in Europe and the diverse nature of the fleet currently in service, a transitional period was necessary. The implementation of SESAR therefore is being carried out in three phases:

- A definition phase (2005-2007), in which the air traffic modernisation plan (or “ATM Master Plan”) was carried out, dealing with the different technological stages, priorities and timetables;
- A development phase (2008-2013) will make it possible to develop the basic technologies which will underpin the new generation of systems;
- A deployment phase (2014-2020), which will see the large-scale installation of the new systems and the widespread implementation of the related functions. In the view of the Commission, the new system will triple capacity in comparison to the current situation, with safety increased tenfold and unitary operating costs far lower than current levels.

The areas of activity influenced by the SESAR programme are manifold, most of which with relevant implications for transport data availability and improvement of co-modality and inter modality:

- System-Wide Information Management: Information management will be improved in order to establish the framework for defining seamless information interchange between all providers and users of shared air transport movement (ATM) information.
- Access by all air and ground ATM actors to the same up-to-date information will improve their situation awareness and the quality of their decisions.
- Network Management operations and systems validation: the following areas will be involved: Real-time update of airspace status and integration of operational air traffic flight plans (OAT FPLs), network crisis management, performance regulation, from calculated take-off time (CTOT) to target time of arrival (TTA), interoperability between aircraft operators and network manager, initial user-driven prioritisation process (UDPP) and short-term ATFCM measures (STAMs).

European projects, e.g. the EMMA (European Airport Movement Management by A-SMGCS) project, the REACT-CR project (Reduction of Emissions using CDAs in TMA) have tested the potential of the ICT applications in reducing CO₂ emissions.
2.2.1.5 Strategic Transport Management for Corridors and Networks

Source
- QUANTIS – Quality Assessment and Assurance methodology for Traffic data and Information Services, Definition of Key European ITS Services and Data Types, 2009

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Description
Strategic traffic management for corridors and networks covers both handling of a predefined scope of traffic situations and real-time traffic control with a set of pre-defined measures. The objective of strategic traffic management is to improve traffic safety and ensure fluent traffic flow through corridors and networks.

The Strategic traffic management is usually provided by the road operator or local public authorities. These organisations may have outsourced actual traffic management operations or functions such as traffic monitoring to private contractors. Data sources utilised in traffic management of corridors and networks are usually in the hands of various different organisations. The tools used for traffic management are various traffic control and traveller information applications.

Data sources are the following:
- Traffic monitoring systems (inductive loops, video cameras, automatic number plate reading);
- Road weather information systems (road weather stations);
- Reports from public authorities (traffic police, rescue services, public safety answering points);
- Road maintenance contractors (status of road maintenance and winter maintenance operations);
- Messages from road users (direct calls from road users to TMC or via radio stations);
- Meteorological service company or meteorological institute (meteorological information; now casts and forecasts).

Information provided by the application:
- Traffic situation on the corridor or network (travel time);
- Traffic control measures (setting of variable speed limits, lane closures);
- Incident information (type, place, effects to traffic, estimated time to clearance, estimated delay caused to road users);
- Warnings (adverse weather or road conditions, congestion, incidents affecting safety of road users).

Among the key requirements
- Timeliness: traffic control is a real-time application, and it has to adapt to the traffic situation in a reasonable time;
- Completeness: traffic control measures have to always be in line with the status of corridor or road network (for example, setting speed limits on the basis of a single data source or only one type of events cannot be recommended).
2.2.1.6  Public Transport Management

Source

- STADIUM, Smart Transport Applications Designed for large events with Impacts on Urban Mobility, Del.2.1 “State-of-the-Art Report”, 2010
- ROADIDEA “D4.3 Utilisation of advanced information in public sector”, 2009
- KonSULT, the Knowledgebase on Sustainable Urban Land use and Transport.

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Description

Public Transport Management improves the regularity of bus/tram/train services. It compares the actual position of PT vehicles with their planned schedule and can give priority at intersections to those behind schedule (and special priority vehicles).

Data gathered during this process can form the basis for some of the traveller information services and trip planning operations.

The operation and development of public transport services are the main concern of city authorities and local public transport operators. National governments and authorities provide guidelines and overall strategy as well as also often finance the strategic development of public transport. Deciding on whether the strategic focus lies in railway networks or in road transport and how this is financed (perhaps from congestion tolling or subsidising from heavy goods vehicle charges as in Switzerland) is governmental issue.

Among the examples of applications is the Bus Fleet Management. The basic definition of a bus fleet management system is that it is a system which facilitates the efficient management and scheduling of bus routes to ensure that buses run as per the schedule. Management of the bus fleet involves the timely arrival and dispatch of buses throughout its journey and the ability to predict and react to changing circumstances which may disrupt this, e.g. vehicle breakdowns or heavy congestion. This in turn improves the operational performance of the bus which helps: 1) improve the perception of the bus in the eyes of the travelling public and; 2) reduce the financial costs of operating services. The former can be realised by improving journey reliability and minimising the wait and in-vehicle time when travelling by bus. The latter will result from being able to better to utilise bus fleets and by reducing maintenance and operating costs (less idling and better driving styles).

The key requirement of a bus fleet management system is the ability to locate a vehicles location throughout its journey, the ability to transmit this information back to a base office and then the ability to process this data usefully to ensure you make effective use of your fleet. Increasingly the information on vehicle location is being fed to various other systems to provide better Urban Transport Control (UTC), bus vehicle priority (including intelligent bus priority) and real time information both pre-journey (at the bus stop, on the web, via SMS) and during the journey (in-vehicle).

In sum, the present situation concerning public transport service development can be condensed in the following:

- ITS have been well adopted in public transport services. There are intelligent solutions (fleet management, location services, green light priority, smart ticketing etc.) in use to make the services more efficient and save money in operators’ point of view.
- One stop shopping created by smart ticketing, multimodal terminals and journey planners (trip chaining) make the public transport easier to use and attracts more customers.
### 2.2.1.7 Demand Management Systems

**Source**

- STADIUM, Smart Transport Applications Designed for large events with Impacts on Urban Mobility, Del.2.1 “State-of-the-Art Report”, 2010

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**Description**

Demand management has a very human focus in that controlling demand is a strategic issue supported by the appropriate information to publish the messages intended to change behaviours. However, it is wrong to say that Information systems are demand management systems.

Another system view of Demand Management is the control of traffic flow. In pure terms this is only controlling the demand for transport infrastructure space (such as road space) – it is not really controlling the demand for travel. The demand is still there but it is diverted or halted. This can cause its own problems. This aspect of ‘demand management’ is often implemented through dedicated lanes and through public transport improvement coupled with public awareness. Here again the lane management systems are really traffic management systems, not Demand Management Systems. The ultimate Demand Management system is a Decision Management System that can trigger the other ITS systems to take action in response to a disruption, or flag up an issue for operator action.

Characteristic of the Decision Management System, i.e. a Situation Management Systems that must be able to support all stages of situation resolution, are the following:

- Situation detection and recording;
- Classification and initial support;
- Investigation and diagnosis;
- Resolution and recovery;
- Situation closure.

Situation detection can be automated using equipment monitoring systems that can detect when an equipment failure has or is likely to lead to a transport situation. Detection can also be automated using Visual Scene Analysis systems that can identify activities or behaviours that are likely to lead to a transport situation. The situation detection can be partly automated by the definition of business rules applied to the activities that are recorded either automatically or manually. However, there is likely to be a high degree of human intervention. Automated classification and diagnosis can be achieved through Enterprise Decision Management (EDM) technology, but the effectiveness of this is governed by the business rules encapsulated within the system.

Classification & analysis (Investigation and diagnosis) can be speeded up by the use of Complex Event Processing technology, but as with EDM this is dependent upon the event analysis that feeds the business rules. Resolution and recovery is twofold:

- Resolve the Episode;
- Resolve the Situation.

The Episode is the cause and the Situation is the effect. Neither of these resolutions can be totally automated. However, in both sets of resolution information to staff and information to travellers is paramount. This can be automated. The resolution to the situation usually precedes the solution to the episode and once the episode is resolved the resolution to the situation usually needs to be rolled back to allow situation closure.
### 2.2.1.8 Probe Vehicles or Devices

**Source**
- STADIUM, Smart Transport Applications Designed for large events with Impacts on Urban Mobility, Del.2.1 “State-of-the-Art Report”, 2010
- S. Ezell ITIF “Intelligent Transportation Systems - Explaining International IT Application Leadership”, 2010
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**Description**
Several countries deploy so-called “probe vehicles” (often taxis or government-owned vehicles equipped with DSRC or other wireless technology) that report their speed and location to a central traffic operations management centre, where probe data is aggregated to generate an area-wide picture of traffic flow and to identify congested locations. Extensive research has also been performed into using mobile phones that drivers often carry as a mechanism to generate real-time traffic information, using the GPS-derived location of the phone as it moves along with the vehicle. As a related example, in Beijing, more than 10,000 taxis and commercial vehicles have been outfitted with GPS chips that send travel speed information to a satellite, which then sends the information down to the Beijing Transportation Information Center, which then translates the data into average travel speeds on every road in the city.

Cellular telephones have been used to collect travel time data basing on cellular telephone reporting technique, like for example in the pilot study carried out by Boston, Massachusetts Smart Route System and Houston, Texas AVI traffic monitoring system. It requires that volunteer drivers call a central facility when they pass checkpoints along the freeway. An operator at the central control facility records each driver’s identification, location, and time by monitoring the time between successive telephone calls. A qualitative assessment of current traffic conditions (e.g., stop-and-go, bumper-to-bumper, free flow) can be provided; moreover, this technique is useful for collecting travel time data during delays or accidents. Nevertheless, probe vehicle drivers often miss checkpoints or fail to report locations at the proper times. The cellular telephone reporting method is recommended for short-term studies with low accuracy requirements.

An example of real world application concerning FCD is the so called telematics fleet, implemented in Italy by OCTO Telematics (www.octotelematics.com), a private company that is among the European leaders for development and deployment of Telematics for Insurance application, with approximately 1,000,000 On Board Units (OBU) installed on private vehicles at 2010.

Other than performing the “conventional” telematic functions as antitheft satellite tracking and fleet management, the OCTO Telematics is providing services to 32 insurance companies in Europe, through the installation of on board units able to collect statistics on driver behaviour, mileage, accident detection and reconstruction, traffic detection and estimation, road user charging data and remote automotive diagnostics. The application of on-board units also plays an important role in supporting road safety and reducing the number of accidents in compliance with European e-Call regulation.

The OBU consists of a GPS receiver, a GPRS transmitter, a 3-axis accelerometer sensor, a battery pack, a mass memory, processor and RAM. The OBU has a dimension of 13.5 x 8.5 x 3 cm. The OBU stores GPS measurements (position, heading, speed, quality) and periodically transmits (on request or automatically) the recent accumulated measurements to the central data system. Transmission occurs every 100 km travelled or every 12 minutes when the equipped car is running along predefined motorways or crossing city centres.
One the most promising applications arising from the OBU is the Large Scale Floating Car System: the Central Data System tracks the received data along the travelled routes by matching the related trajectories data to the road/street network in order to estimate link travel speeds.

Currently, through WEB pages data are presented in 6 speed categories ([http://traffico.octotelematics.it/index.html](http://traffico.octotelematics.it/index.html)), updated every 3 minutes, 24 hours a day, 7 days a week, showing the circulating number of vehicle with OBU installations and the corresponding estimates of average speed.
2.2.2 Traveller Information Systems

2.2.2.1 Travel Planners

Source

- Directorate-General Mobility and Transport “Towards a European Multi-Modal Journey Planner”, 2011
- QUANTIS – Quality Assessment and Assurance methodology for Traffic data and Information Services, Definition of Key European ITS Services and Data Types, 2009

Transport modes involved

<table>
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Description

Travel planners allow the user to integrate information from different modes. They could be regional, national or international as for their geographical coverage. The information of key relevance to such travellers for multi-modal and inter-modal planning of their journey include the following (not all the below information can be present in every individual travel planner):

- Reliable timetable information;
- Door-to-door routing including mode transfer ideally with maps for reaching destination at the last mile and support for orientation at interchanges;
- Information on how and where to buy a ticket for local and regional public transport at the interchange point or the operations of key P+R points;
- Information on where to buy long-distance tickets on line and where to pick up tickets at interchanges/stations (if purchase on departure is being used);
- Effective door-to-door travel time, cost and emissions comparison of long-distance door-to-door options at least between the public transport options but ideally also against the car option.

The following examples concern co-modal traveller information services, which offer route planning service involving several transport modes:

- **Routerank** - a travel search engine which addresses the entire travel route by integrating rail, road and air connections:
  - Available in English, French, German, and Spanish;
  - Available for trips throughout Europe, domestic and international;
  - Information given bases on real schedules;
  - CO₂ emissions shown per travel alternative;
  - Real price information is included as well (on international rail trips only estimated prices apply);
  - Search results include links to websites for booking the trip;
  - URL is http://www.routerank.com/

- **Flyrail** – A website for booking combined air / rail trips to & from Sweden.
  - Available in English, Swedish;
  - Available for trips to / from destinations in Sweden. On international trips the origin or destination outside Sweden can only reached by air transport;
  - Intermodal trips are limited to the transfer airports Stockholm or Copenhagen and to flights...
with the Airlines SAS;

- Information given bases on real schedules;
- Real price information is included as well (on international rail trips only estimated prices apply);
- Search results in most cases can by booked directly via the website;
- For the intermodal trip a ‘get you there’ guarantee is given by the Airline and the rail company SJ;
- URL is http://www.flyrail.se/.

Vialsace.eu

- Vialsace.eu offers information on fare tables, but not the real cost for a door-to-door trip for the Alsace region;
- The journey planner covering:
  - Bus & tramways on the different urban and departmental public transports networks on the regional territory;
  - Regional train (TER);
  - They do not cover the car mode.

Rejseplanen

- Rejseplanen and the Danish Road Directorate (DRD) have developed a co-modal journey planner which covers public transport, cars and Park & Ride, for the whole country of Denmark.
- The suggested routes are compared on travel time, costs and environmental impact. Car routes use realistic travel times, also in rush hours. These were gathered by DRD through a probe car project using GPS;
- The planner is now fully operational and deals with between 5.5 and 6 million journey planning queries each month (to compare to the Danish population of 5.3 million people).
2.2.2.2 Real-time Co-Modal Traveller Information Services

Source
- STADIUM, Smart Transport Applications Designed for large events with Impacts on Urban Mobility, Del.2.1 “State-of-the-Art Report”, 2010
- Directorate-General Mobility and Transport’ Towards a European Multi-Modal Journey Planner”, 2011
- QUANTIS – Quality Assessment and Assurance methodology for Traffic data and Information Services, Definition of Key European ITS Services and Data Types, 2009

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Description
Real-time co-modal traveller information services, or Advanced Traveller Information Systems (ATIS), provide drivers with real-time travel and traffic information, such as transit routes and schedules; navigation directions; and information about delays due to congestion, accidents, weather conditions, or road repair work. The most effective traveller information systems are able to inform drivers in real-time of their precise location, inform them of current traffic or road conditions on their surrounding roadways, and empower them with optimal route selection and navigation instructions, ideally making this information available on multiple platforms, both in-vehicle and out.

Passenger Information Systems can:
- Enhance integration by improving passenger information at interchanges;
- Additionally enhance integration through achievement of other Governmental policies, especially e-government requirements.

In combination with other measures such as bus priority, road geometry alterations and new vehicles, real time information systems can:
- Enhance economy/efficiency and environment through encouraging modal shift in favour of public transport;
- Reduce social exclusion by enhancing the Public Transport service offering with associated accessibility benefits.

Passenger Information Systems also better inform people of when services are due, thus reducing their perceived waiting time (and possibly their actual wait time through provision of pre-trip information). Users like Passenger Information Systems and in some instances suggest that their presence make them feel safer. In addition, passenger information systems can offer a higher level of traveller care, due to people being better informed as to the nature of any delays that may affect their arrival time (especially true for in-vehicle information).

It should be noted that often passenger information systems are implemented with a fleet management system and Public Transport Priority. Very often, therefore, passenger information and fleet management systems are implemented in partnership with and with funding from local bus companies. This means bus operator scheme objectives must also be considered. These may include patronage improvements, efficiency improvements etc.

Co-modal traveller information services provide information about different transport modes. They cause a modal shift to more environmental-friendly transport modes and lead to a more efficient network operation as well as a better utilisation of the transport infrastructure. The end users can make a better informed choice on different transport modes and on intermodal combinations of different transport modes. Two examples for co-modal traveller information services are multi-modal...
traveller information Internet portals and multi-modal travel planning.

Co-modal traveller information services require information about several transport modes. Information about road traffic may be produced by road operators or private companies. Schedules of public transport are usually obtained either directly from the transport operator or authorities working with public transport. Co-modal traveller information services may be provided by public authorities, with public-private partnerships or private companies. The service provider may produce itself all the components of the service, integrate other service providers’ content to its own service or provide links to other web pages.

Data sources are:

- Loop detectors (speed and traffic volumes);
- Automatic number plate reading cameras (travel times);
- Floating car data systems;
- Traffic control systems (traffic lights, ramp meters);
- Mobile network (road traffic data);
- Management of road works (data on road works);
- Public transport authority;
- Public transport operator.

Co-modal traveller information portals offer usually at least:

- Current road traffic situation (speed and travel times on major links of road network);
- Pre-trip public transport information (schedules, route network).

The following example concerns co-modal traveller information services, which offer route planning service involving several transport modes:

**IDOS Czech Republic**

- IDOS is the national inter-modal public transport route planning timetable information system of the Czech Republic which integrates international, national, regional and urban public transport connections including buses, rail and air. The government objective is to enable high quality public transport timetables to be freely available in a journey planning form.

- The information is available on the Internet: [www.idos.cz](http://www.idos.cz) and also from third party suppliers, mainly mobile phone and phone services. IDOS.cz offers the following functionalities for travel (not necessarily even with a trip leg in the Czech Republic):
  - Information about the connection (journey time, distance, number of bus or train, ticket price, timetop schedule, transfer time, long-distance train wagon order, etc.);
  - Full European rail timetable integration;
  - Extensive international coach integration;
  - Real time information on Czech trains;
  - Graphical presentation of selected start/destination on the map background;
  - Contextual links into the reservation systems for purchasing / booking tickets where available;
  - Pre-reservation of services in the selected long-distance trains.
2.2.2.3 Real-Time Travel Time and Vehicle Positioning Information Services

Source

- STADIUM, Smart Transport Applications Designed for large events with Impacts on Urban Mobility, Del.2.1 “State-of-the-Art Report”, 2010
- QUANTIS – Quality Assessment and Assurance methodology for Traffic data and Information Services, Definition of Key European ITS Services and Data Types, 2009
- S, Ezell ITIF “Intelligent Transportation Systems - Explaining International IT Application Leadership”, 2010

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Description

2.2.2.3.1 Road transport (cars)

Travel time is an indicator of the fluency of traffic and overall traffic situation on a corridor or a road network. Travel time information can be produced and disseminated to road users in different ways. For example, travel times on the different segments of a road network can be shown as colour codes on a map on the web page of road operator or a local newspaper or on the screen of car navigator. Travel time information is also used by radio stations as content for traffic reports.

It is possible to demonstrate tangible evidence of traffic-reduction measures is having a positive effect through the use of a Journey Time Measurement System (JTMS) using Automatic Number Plate Recognition (ANPR).

Traditional Urban Traffic Control systems have always been able to provide an indication of congestion and journey times, but the use of Automatic Number Plate Recognition (ANPR) technology provides a better, more accurate mechanism for monitoring journey times to provide a meaningful measure of overall network performance.

The integration of journey time information into a UTC system can provide incident detection capabilities to the operator in the control room. By comparing the current ‘live’ journey time with a historical profile, the system can automatically alert operators to abnormal conditions, allowing prompt action to be taken. JTMS is proving to be a multi-faceted solution, enabling traffic managers to report back on long-term performance and justify spending to councillors and the public.

Information on travel times on a road network or a corridor can be collected by several means by different organisations. Fixed traffic monitoring equipment is usually operated by the road operator or a private service provider. Travel time information can also be generated from floating car data. Floating car data is usually collected by private service providers, but there are differences in business models and technical implementations. Travel time information services are usually produced by private companies which may also deliver the travel time information to road users with their own web sites. Public authorities or media companies having travel time information services on their web sites usually purchase these services from service providers rather than implementing the needed data collection and data processing functions themselves. Some radio stations also use these web sites as information sources for their traffic reports.

Requirements to the service:

- Automatic number plate readers
- Inductive loop detectors;
- Mobile networks.
Information content: travel times on a given time on the links of road network

Based on GPS technologies, several applications provide information on real time geographical positioning of vehicles, addressing air, rail and waterborne transport and other services, e.g. connecting flights in airports, as described in the following examples:

### 2.2.2.3.2 Road transport (public transport)

The ICT service include applications such as automatic vehicle location (AVL), which enable transit vehicles, whether bus or rail, to report their current location, making it possible for traffic operations managers to construct a real-time view of the status of all assets in the public transportation system. APTS help to make public transport a more attractive option for commuters by giving them enhanced visibility into the arrival and departure status (and overall timeliness) of buses and trains. This category also includes electronic fare payment systems for public transportation systems, such as Suica in Japan or T-Money in South Korea, which enable transit users to pay fares contactless from their smart cards or mobile phones using near field communications technology. Advanced public transportation systems, particularly providing “next bus” or “next train information, are increasingly common worldwide, from Washington, DC, to Paris, Tokyo, Seoul, and elsewhere.

Information provided in real-time has to be reliable, otherwise it will hinder or confuse users rather than aid their decision making. The technology has been developed over many years and can now be considered relatively stable.

For services with dedicated rights of way (e.g. metro services), the technology calculates the predicted arrival times for the next vehicles based on the location of the vehicles within a signal “block”, the speed of the vehicles and the distance to the next station. Web surveys of major metro operators of the COMET (COMET is the Community of Metros, a consortium dedicated to sharing best practice and a knowledge exchange cum benchmarking forum for the world’s largest metro operators) and NOVA (NOVA is the sister organisation to COMET) consortia of operators suggest that Real Time Passenger Information is already provided at most metro stations/interchange points and at metro stops (at least for the operators within the consortia). For road running public transport modes such as buses, a major difficulty is that they are constrained by other vehicles and pedestrians on the road. At the same time there have been advances in Automatic Vehicle Location (AVL) technology to enable tracking of bus locations (using sensors).

Early variants (e.g. those operating in London) operate using beacon technology. An on-board unit receives signals from roadside beacons as the bus passes the beacon, and since each beacon has a unique identifier the location information is forwarded by radio link directly to a central system. The central system compares the scheduled arrival time with the current positioning and computes the “countdown” to arrival at the stop.

However, this tag and radio technology is considered dated and has been improved by on board Global Positioning Systems (GPS) based on satellite technology. By calculating data based on GPS satellites, a vehicle’s location (longitude and latitude) can be calculated to within 3 to 6 metres (Sun et al 2007). This can then be similarly transmitted to the electronic matrix displays available at stops/interchange points. Whatever the technology deployed, all the traveller sees is the information available on the electronic displays. In addition, real time data can be sent to mobile phones and personal digital assistants (when users utilise a short messaging service (SMS or “text message”) to request the information), as well as displayed in the vehicle or via the Internet.

### 2.2.2.3.3 Air transport

- **Real Time Information on connecting flights through an airplane’s IFE.**
  - Numerous airlines provide information on connecting flights within an aircraft approaching an airport: Either on request of specific passengers, announcements by the staff of an aircraft or display information on the monitors of the (personal) IFE (in flight entertainment) systems, available in long-haul aircraft. Examples known for IFE solutions are Lufthansa (see picture), Emirates when approaching their hub Dubai, Singapore Airlines, Austrian Airlines, Qatar Airways, Air France, Air New Zealand, Japan Airlines, Air Canada.
• Available at least in English, the language of the home country of the specific carrier, and the languages in the countries of the routes connected by the flight

• Available in aircraft with IFE, while in others aircrafts connecting flights and their gates are announced by the staff

➢ Real time geographic information for many flights not only within Europe

• Flightradar24 shows live airplane traffic from different parts around the world. The technique to receive flight information from aircraft is called ADS-B. That means the Flightradar24 can only show information about aircraft equipped with an ADS-B transponder. Today about 60% (about 30% in USA and about 70% in Europe) of the passenger aircraft and only a small amount of military and private aircraft have an ADS-B transponder.

• Flightradar24 has a network of about 500 ADS-B receivers around the world that receives plane and flight information from aircraft with ADS-B transponders and sends this information to a server, and then displays this information on a map on Flightradar24. Only aircraft with an ADS-B transponder, within the coverage area of the 500 receivers are visible.

• Flightradar24 covers about 90% of Europe. There is also some coverage in USA, Canada, Australia, Brazil, Middle East, Japan and other parts around the world.
• Additional flight information (airline, number of flight, from, to, actual aircraft including registration number, altitude, Speed) is also available.

• Flightradar24.com has released apps for iOS (iPhone / iPad / iPod Touch) and for Android. The apps are available from App Store (iOS) and from Android Market.

• URL is http://www.flightradar24.com

➤ Flight Status, Timetable, Check In and Booking of Lufthansa flights via mobile phone

• This app preferably used via mobile phones enables the traveller to check the real time status of flights, get timetable information, to check in and also to book flight of the carrier Lufthansa and other airlines offering code share with Lufthansa.

• URL is http://mobile.lufthansa.com/

➤ Flightontime – punctuality statistics at UK Airports

• Available in English

• Since 2003 we have been providing detailed analysis of airline delays at 10 major UK airports, and have grown to become the UK’s trusted source for airline and airport punctuality statistics.

• Data is derived from statistics published monthly by the UK Civil Aviation Authority.

• Information can be displayed by airport or by airline for the current year or former years (up to 2004).

• Also for key routes statistics are available.

• URL is http://www.flightontime.info

2.2.2.3.4 Rail transport

➤ (Real time) geographic information for all trains within Switzerland

• The website displays a map of Switzerland where most trains are displayed with their geographical position.

• For the time being the display work with the scheduled times, delays and cancellation of
trains is not taken into account

- A future upgrade of the system will incorporate real time information (e.g. delays)
- URL is [http://www.swisstrains.ch](http://www.swisstrains.ch)

- Zugfinder – Real time information (map & display) and punctuality statistics on long-distance trains in Germany
  - Available in German only
  - On base of real time information this website shows geographical position and punctuality of all long-distance trains in Germany.
  - Furthermore overall punctuality of trains of these trains is shown, including top delays and statistics covering the last month. Also information on reasons of delays is given.
  - URL is [http://www.zugfinder.de/](http://www.zugfinder.de/)

- Viaggia Treno – Real time information (map & display) on long-distance trains of trenitalia in Italy
  - Available in Italian, English and German
  - On base of real time information this website shows geographical position and punctuality of all long-distance trains of trenitalia in Italy.
  - URL is [http://www.viaggiatreno.it/](http://www.viaggiatreno.it/)

### 2.2.2.3.5 Waterborne transport

- Real time positions of ferries and corresponding feeder trains
  - Available in German
  - The Wyker Dampfschiff-Reederei connects the islands Föhr and Amrum with the mainland harbour at Dagebüll. At Dagebüll a short line train service is offered with public trains linking the harbour to the main line Westerland – Hamburg, including through coaches to big cities in Germany (Frankfurt, Berlin, Cologne, Dusseldorf)
  - The company provides a web service where basing on real time info the position of the ferries and the corresponding trains can be seen. The service includes the ships of the Adler Reederei.
  - CO2 emissions shown per travel alternative
  - Real price information is included as well (on international rail trips only estimated prices apply)
  - Search results include links to websites for booking the trip

- MarineTraffic.com - Real time positions of ships and ferries maritime and inland navigation
  - Available in more than 30 languages
  - The website shows the position of all types of ships and vessels – for passenger transport as well as for cargo
  - Additional information about the ship (technical and administrative data) is given as well
  - Also information Routing, origin and destination, last harbours served, etc. is available
  - URL of the company is [www.marinetraffic.com](http://www.marinetraffic.com)
2.2.2.4 Weather Information Services

Source
- STADIUM, Smart Transport Applications Designed for large events with Impacts on Urban Mobility, Del.2.1 “State-of-the-Art Report”, 2010
- QUANTIS – Quality Assessment and Assurance methodology for Traffic data and Information Services, Definition of Key European ITS Services and Data Types, 2009

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Description

Weather information has a great significance in the context of traffic. The safety of road users can be improved by informing and warning them on adverse weather and road conditions such as slippery road surface caused by snow or ice or reduced visibility because of snow, fog or heavy rain. Information delivered to road users may consist of road weather forecasts, nowcasts and warnings.

Organisation of service provision

Weather information services are provided to road users and road maintenance contractors by meteorological institutes, meteorological service companies and information service providers specialised in traffic information. Most raw data used to produce weather-related information and warning services to road users and road maintenance operators is usually collected by meteorological institutes and road operators.

Concerning the rail transport, it is generally acknowledged that climatic conditions are changing. Natural causes are threatening the safe operation of railways (flood, strong winds, excess of water in the soils, unusual heights of snow, extremely low temperatures, as well as potentially volcano ashes, earthquakes, tsunamis, etc). Generally railways are prepared to environmental conditions experienced in the past century. Recent development imply the integration in situ of data detected from on board sophisticated innovative measuring systems, with Earth Observation techniques (based on weather forecast, System Analysis Recording and optical data), in order to be capable to foresee and monitor landslide events along rail networks. Particular importance shall be attached to the use of advanced SAR interferometry techniques capable to detect small ground surface deformations that in several cases precede the critical failure phase leading to landslide movements.

Data sources
- Weather monitoring stations;
- Radar networks;
- Weather satellites;
- Road weather stations.

Information content
- Road/rail weather nowcasts;
- Road/rail weather forecasts;
- Warning services to road and rail users (reduced friction, poor visibility due to snow, fog or rain, wind);
- Alerts to road/rail maintenance personnel.
2.2.2.5 Parking Management Systems (PGI)

Source
- STADIUM, Smart Transport Applications Designed for large events with Impacts on Urban Mobility, Del.2.1 “State-of-the-Art Report”, 2010
- S, Ezell ITIF “Intelligent Transportation Systems - Explaining International IT Application Leadership”, 2010
- http://www.smartplanet.com/blog/transportation/dynamic-pricing-fluctuating-parking-meter-prices/877"

Transport modes involved

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Description

Problems generated by the lack of parking spaces in predominantly, highly populated areas are manifesting themselves as increased traffic congestion and longer travel times. These in turn lead to a lower quality of life and a lower level of accessibility for citizens. Searching for parking spaces may be responsible for as much as 30% of the traffic on main urban roads and time spent searching for a parking place can often reach up to 40% of the total travel time.

Earlier systems, such as that in St Helier, involve limited function signs with very simple space counters and availability display units. However the technology used for the systems evolved dramatically. Nowadays, electronic message signs are able to display a full range of messages and symbols.

Parking guidance and information (PGI) systems, or car park guidance systems, present drivers with dynamic information on parking within controlled areas. The systems combine traffic monitoring, communication, processing and variable message sign technologies to provide the service. PGI systems are a product of the worldwide initiative for the development of intelligent transportation system in urban areas. PGI systems can assist in the development of safe, efficient and environmentally friendly transportation network.

PGI systems are designed to aid the in the search for vacant parking spaces by directing drivers to car parks where occupancy levels are low. The objective is to reduce search time, which in turn reduces congestion on the surrounding roads for other traffic with related benefits to air pollution with the ultimate aim of enhancement of the urban area. On an operational level, recent PGI systems consist of the following elements and equipment:

- Driver information equipment which may be of various types, with the most usual being the variable message signs (VMS) panel located at roadside;
- Occupancy loops or automatic vehicle identification (AVI) equipment that can count the number of vehicles entering and exiting the car parks, and closed circuit television (CCTV) equipment ;
- Television cameras monitoring traffic status in the streets;
- Electronic payment devices using electronic, inductive, magnetic or smart card technology;
- Electronic parking meters used to control how long vehicles park in the streets, charging fees and checking availability;
- A control centre with an occupancy rate equaliser (equilibrium) that controls the display of information on the VMS;
- A telecommunication network and computers to exchange data (information) between the above systems. Parking Control monitors the use of parking areas, calculates occupancy forecasts and can provide an advance booking service. Current and forecast occupancy data can be included in information dissemination.
The city of Los Angeles (USA) provides an example of innovative parking management system: the dynamic parking meter price (smart meters).

This technology manages parking according to supply. During peak periods, meters will be priced high enough to ensure some parking is always available. During off-peak times, meter prices will go down, so that most spots are used. The idea is that if you really have to drive, you shouldn’t have to cruise around or risk a ticket. Along with an easier time finding parking during peaks, and lower prices when and where there is lower demand, other carrots for motorists include easing time limits during periods of low demand, enabling payment by cell phone, and delivering text messages to drivers when their meters are running out.

The pilot program hopes to turn the city’s current parking meter system on its head. Currently, meter rates are set according to geographic limits - meaning that a meter on one corner can charge $4 for parking, while a meter on a nearby street charges only $3.
2.2.3 Smart Ticketing and Tolling

2.2.3.1 Electronic Toll Collection (ETC)

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Description

ETC is a combination of techniques and technologies that allows vehicles to pass through a toll facility without requiring any action by the driver (i.e., stopping at toll plazas to pay cash). In fact, today’s conventional toll plaza is not necessary in a fully dedicated ETC facility. ITS have a central role to play in funding countries’ transportation systems. The most common application is electronic toll collection (ETC), also commonly known internationally as “road user charging,” through which drivers can pay tolls automatically via a DSRC-enabled on-board device or tag placed on the windshield (such as E-Z Pass in the United States). The most sophisticated countries, including Australia and Japan, have implemented a single national ETC standard, obviating the need, as in the United States, to carry multiple toll collection tags on cross-country trips because various highway operators’ ETC systems lack interoperability.

An increasing number of cities throughout the world have implemented congestion pricing schemes, charging for entry into urban centres, usually at certain peak hours, as a means to not only reduce congestion but also to generate needed resources to fund investments in public transportation and to reduce the environmental impact of vehicles. Singapore, Stockholm, London, Oslo, and Jakarta are just some of the cities that have put congestion pricing systems in place to reduce traffic congestion, smog, and greenhouse gases. By charging more at congested times, traffic flows can be evened out or reduced. As half the world’s population now lives in urban areas, some economists believe that urban congestion and emissions will be virtually impossible to reduce without some form of congestion pricing. For example, in Europe, urban areas account for 40 percent of passenger transport but 53 percent of all transport-related emissions. There are three main approaches to charging, each comprising a cluster of the technology building blocks:

- DSRC;
- CN/GNSS/DSRC and augments;
- ANPR.

DSRC and GPS have evolved in parallel from very different origins, and both were conceived as tangible technologies in the mid-1970s. Both have passed through several generations, both are now available in mass-market products, and both are well supported by an internationally competitive industry. GPS and DSRC perform completely different functions (positioning and communications, respectively), but this has not stopped frequent, direct comparison and misleading claims of the relative split of cost between the vehicle and infrastructure by industry segments that have historical roots (and significant R&D investments) in either GPS-based or DSRC-based developments. ANPR was initially used in closed user group access control schemes from about 1985. It then provided support to manual enforcement processes for toll plazas from about 1990. It has generally been accepted as an essential enforcement tool for tolling and road user charging applications.
### Source

- STADIUM, Smart Transport Applications Designed for Large Events with Impacts on Urban Mobility, Del.2.1 “State-of-the-Art Report”, 2010

### Transport modes involved

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<th>Road</th>
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### Description

Access restriction schemes can broadly be classified into four types:

- **Point based** (e.g. restriction to cross a bridge or to enter a small section of city)
- **Cordon based**: a restriction is applied for crossing a cordon, and may vary with time of day, direction of travel, vehicle type and location on the cordon. There could be a number of cordons with different rules/prices.
- **Area licence based pricing**: a restriction is applied for driving within an area during a period of time. The rules may vary with time and vehicle type.
- **Distance or time based**: it is essentially a pricing restriction based upon the distance or time a vehicle travels along a congested route or in a specified area, and may vary with time, vehicle type and location.

Point based charges are reasonably commonplace, but they are generally limited to specific small locations and not spread across the network.

Cordons are simply combinations of point-based schemes located to form a continuous or semi-continuous boundary around an area.

Toll rings are the straightforward application of the highway tolling scheme, somehow similar to the cordon but generally applied to regulate the access to the entire city. This solution is implemented in Singapore and in many Norwegian cities. Flexibility is featured as in the cordon schemes.

Area licensing or entry permit schemes are applied to restrict the access to areas mainly in the inner core of cities. Their main attraction is that they are simple to understand and straightforward to implement; rules may vary with time and vehicle type.

In terms of ICT solutions, access to vehicles and venues is often via some sort of ticket or pass. There are now many advanced technologies to facilitate the use of a single ‘smart’ ticket to provide access to multiple venues and multiple vehicle journeys. Where such technology is used the ticket gate and/or card reader can collect valuable statistics concerning actually routing and actual attendance. Enforcement is accomplished by a combination of a camera which takes a picture of the car and a radio frequency keyed computer which searches for a driver’s window/bumper mounted transponder to verify and collect payment. The system sends a notice and fine to cars that pass through without having an active account or paying a toll. Factors hindering full-speed electronic collection include significant non-participation, entailing lines in manual lanes and disorderly traffic patterns as the electronic- and manual- collection cars “sort themselves out” into their respective lanes; problems with pursuing toll evaders; need, in at least some current (barrier) systems, to confine vehicles in lanes, while interacting with the collection devices, and the dangers of high-speed collisions with the confinement structures; vehicle hazards to toll employees present in some electronic-collection areas; the fact that in some areas at some times, long lines form even to pass through the electronic collection lanes; and costs and other issues raised when retrofitting existing toll collection facilities.
### 2.2.3.3 Automated Fare Collection Systems (AFC) - Ticketing Systems

#### Source

- STADIUM, Smart Transport Applications Designed for large events with Impacts on Urban Mobility, Del.2.1 “State-of-the-Art Report”, 2010
- KonSULT, the Knowledgebase on Sustainable Urban Land use and Transport.

#### Transport modes involved

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</table>

#### Description

Ticketing systems need to be able to deliver end to end functionality including:

- Ticket sales/issue;
- Control of Access to vehicles and venues (See Access Management);
- Refunds & Cancellations;
- Top-ups of Smartcard Tickets; and
- Analysis of ticket holder activity.

AFC systems originated with tokens or paper tickets dispensed by staff or from self-service vending machines. These have generally been replaced with magnetic stripe cards.

Since their introduction in 1997 with the Octopus card in Hong Kong (the first to use contactless smart cards), contactless smart cards have become the standard fare media in AFC systems, though many systems support multiple media types.

International electronic ticketing standard for microprocessor contactless smartcards, have been designing by groups of several European transit operators, e.g. Belgium, Germany, France, Italy and Portugal. The applications ensure multi-sources of compatible products, and make possible the interoperability between several transport operators in the same area.

The application is based on two main technologies:

- The microprocessor smartcard, widely used in many monetary transactions;
- The contactless interface ensuring both remote powering and communication between the reader and the card.

The application, whatever its form (card, watch, mobile phone or other NFC object...) has a microprocessor which contains all the information related to its owner rights for the application, and which implements the medium authentication scheme for security. This could make the difference with other e-ticketing system, where the card is only a memory chip with no processing capabilities.

The following examples concern automated, paperless, ticketing systems in road and rail transport:

- The Oyster card
  - The Oyster card was first issued to the public in July 2003 by Transport for London and is used on public transport services in Greater London in the UK. This card also takes on the London Travelcard highlighted in the previous case study and integrates it amongst its various pricing structures. The card is valid on the London Underground and Overground, buses, trams, the Docklands Light Railway and some National Rail services. It was first issued with a limited range of features and there is continued phased implementation of further functions. It is a form of electronic ticketing being a stored value card which can hold single tickets, period tickets and travel permits which have to be added to the card before
travel. It is also a contactless smart card with a claimed proximity range of about 8 cm (3 inches) that passengers have to pass over electronic readers when entering and leaving the transport system in order to validate it or deduct funds. The cards may be ‘recharged’ in person from various sales points, by recurring payment authority or by online purchase. The card decreases the number of cash transactions at ticket offices and the number of single paper tickets sold on the London transport network. Usage is encouraged by offering substantially cheaper fares on Oyster than payment with cash.

- The card uses MIFARE technology and is operated by TranSys for Transport for London. The technology used for the Oyster card is known as radio-frequency identification (RFID), which is the same technology used in other electronic pass cards. The Oyster card acts as an aerial while the reader acts as a receiver. However, this technology means that the cards transmit information whenever they come into range of a reader and it has been suggested that a good reader could read personal details from quite a distance. Aluminium shielding has been suggested to prevent any personal data from being read.

- Rail tickets and real time train information via mobile phone
  - The core online services of Deutsche Bahn AG (journey planner, ticketing, real time arrival departure information, real time information on punctuality of a distinct train, find the next railway station) are also available via mobile phone. Especially ticketless booking of rail trips can be done in a breeze, after registering once.
  - Booking rail trips on the spot, without using ticket offices, travel agencies or a computer, makes travelling by rail more easy and flexible and there improves co-modality of rail transport
  - URL is http://mobile.bahn.de/bin/mobil/detect.exe/eox?
2.2.4 Vehicle-to-Infrastructure (V2I) Applications

2.2.4.1 Cooperative Urban Applications

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Description

Cooperative Urban Applications provide drivers with optimised speed and route recommendation based on more accurate detection of vehicles, hence of the traffic status on the road network, in order to reduce both delay and vehicle emissions. Traffic management applications provide drivers with route recommendations based on the current traffic situation and traffic management strategy, while traffic managers can define and evaluate strategies based on full knowledge of the status of the road network and the traffic on it. In a public transport application cars equipped with an intelligent device could communicate with the infrastructure and other vehicles, to share a public transport lane when there is spare capacity.

The following table describes the applications defined the range of urban applications and their potential compared to similar "traditional" applications:

<table>
<thead>
<tr>
<th>Name of Application</th>
<th>Description</th>
<th>Goal and innovative potential compared to &quot;traditional&quot; solution</th>
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<tbody>
<tr>
<td>Traffic Control Assessment</td>
<td>Traffic Control Assessment is aimed that give short term and long term performance indicator on the state of the traffic control function at intersection and network level. The information is presented to the traffic operator for design, configuration and maintenance.</td>
<td>Traffic Control Assessment will benefit from the measurement from vehicle to increase performance of traffic control assessment.</td>
</tr>
<tr>
<td>Routing Application</td>
<td>The application provides suggestions of routes that take into consideration the strategy of the network, current traffic information and the willingness of following the route.</td>
<td>The goal is to reduce the congestion and travel times within the urban network by dynamic routing.</td>
</tr>
<tr>
<td>Adaptive Micro routing application</td>
<td>Re-routing of traffic on a neighbourhood level based on delays and travel times derived from controller intersections and floating car data.</td>
<td>Balancing the load on the network in terms of efficiency, safety and environment.</td>
</tr>
<tr>
<td>Strategy Application</td>
<td>It concerns a strategy management system based on assessed and pre-defined strategies.</td>
<td>It results in the selection of the most suitable cooperative network management solution</td>
</tr>
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</table>
2.2.4.2 Cooperative Interurban Applications

Source

Transport modes involved

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Description

Cooperative Inter-urban Applications aim on the delivery of alerts and warnings directly from roadside equipment to in-vehicle displays and thus the drivers. The information sets include the road conditions in the vehicle’s direct vicinity, speed regulations, weather and traffic conditions and also include warnings of accidents or wrong-way drivers. The CINT applications are subdivided into two groups, namely Co-operative Traveller Assistance (CTA) including pre-trip planning and on-trip information delivery and Enhanced Driver Awareness (EDA) supporting features to make a driver better aware of the road environment around his vehicle.

The following table briefly presents the applications demonstrated by CINT within CVIS.

<table>
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<tr>
<th>Name of Application</th>
<th>Description</th>
<th>Goal and innovative potential compared to “traditional” solution</th>
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<tr>
<td>Co-operative Traveller Assistance</td>
<td>The Co-operative Traveller Assistance (CTA) Application is focused on providing assistance to drivers. The assistance to be provided comprises: a) Pre-trip and On-trip Planning; b) On-trip seamless service with tracking and rerouting if needed; c) Vehicle Data feeding to Traffic Control Centres. Assistance is provided to Drivers directly from the Service Centre to units in the Vehicle, and information from Drivers feeds Traffic Control Centres.</td>
<td>Better predicted travel times based on (planned) routes from cars and assistance for drivers in rerouting to evade accidents and travel delays improving the efficiency of the overall system since the full fletch of available information sources is used.</td>
</tr>
<tr>
<td>Enhanced Driver Awareness (EDA)</td>
<td>The Enhanced Driver Awareness (EDA) Application focus on providing awareness to Travellers when they are driving Vehicles as part of the journeys and to drivers of other vehicles. The facilities provided comprise: a) Advice on driving conditions for the part of the road network that is immediately ahead of the Vehicle’s current position; b) Detection, management and provision of advice about “Ghost Drivers”.</td>
<td>Increased efficiency of real time, actual drivers information resulting in significantly improved safety. The cooperative aspect involves vehicles and fixed infrastructure thus providing a much better overview on the traffic related conditions than one system could on its own.</td>
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2.2.4.3 **Intelligent Speed Adaptation (ISA)**

**Source**

**Transport modes involved**

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**Description**

Another application enabled by vehicle-to-infrastructure integration is intelligent speed adaptation (ISA), which aims to assist drivers in keeping within the speed limit by correlating information about the vehicle’s position (for example, through GPS) with a digital speed limit map, thus enabling the vehicle to recognise if it is exceeding the posted speed limit. The system could either warn the driver to slow down or be designed to automatically slow the vehicle through automatic intervention. France is currently testing deployment of an ISA system that would automatically slow fast-moving vehicles in extreme weather conditions, such as blizzards or icing. The province of Victoria, Australia, is testing a system in which trains could remotely and autonomously brake vehicles attempting to cross their path at railway intersections.

Intelligent Speed Adaptation (ISA) is a system which uses information and communications technology to provide speed limit information on a vehicle’s dashboard. The typical means to do this is with a digital road map of the kind used in satellite navigation systems, but with the important difference that it also contains speed limit data for very road. When the map is combined with current position information from a GPS (Global Positioning System) receiver, then the ISA system can display the speed limit and warn the driver if the vehicle is being driven above the speed limit. This is advisory ISA. The same information about speed limit can be linked to the vehicle’s engine management system to provide voluntary (overrides) or even mandatory (non-overridable) ISA.

The Effects of Active Accelerator in Cars have been studied in a large scale trial with Intelligent Speed Adaptation (ISA) in urban areas. During a period of 6-10 months, 225 cars were equipped with the system consisting of an active accelerator, a digital map with all the speed limits within the city limit, a GPS system and data logging facilities.

The active gas pedal provides drivers with counter-force whenever they try to exceed the pre-set speed limit. An extensive evaluation was carried out in order to study driver behaviour, acceptance and effects on safety, travel time and the environment. In order to be able to observe any attitude changes in the city, surveys with 750 citizens were carried out before the start of the project and after the project.

In order to study driver reactions and behaviour, in-car observations were carried out. In order to see any changes in the attitude and acceptance of the test drivers, they were interviewed when recruited, during the test drives and after the trial. A number of drivers were asked to fill in a diary every day on their driving. Driving data was logged in the test cars and speed profiles, gas pedal activity, travel time and exhaust emissions were analysed. In order to measure possible system effects, a number of studies were carried out in the field: traffic counting, speed measurements, observations of interactions between road-users, observation of frequency in driving against red. Similar studies have been carried out in a control city in order to be able to see if possible changes due to the ISA-equipped cars.
### 2.2.4.4 Yellow Signal Warning System (YSWS)

**Source**

**Transport modes involved**

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**Description**

This system is aimed at reducing accidents by helping drivers avoid hazardous situations at crossroads controlled by traffic lights. The purpose of the system is to inform the driver when their vehicle is approaching a crossroad with a speed in excess of the official limit. The system therefore contributes to the avoidance of traffic violations at crossroads and helps to mitigate the effects of unavoidable collisions.

The following impacts are likely to be observed:

- The driver with the system can reduce his speed earlier and he does not have to make a fast stop. This will reduce the risk of rear-end crashes.
- The driver with the system can anticipate that the traffic light will soon turn into red and the deceleration of the vehicle in front doesn’t come as surprise, the driver will have more time for evasive actions.
- The system reduces the number of situations where the driver recognises a red light at a very late stage or doesn’t recognise the light at all and will violate red light accidentally.
- The consequences are mitigated due to lower speeds in collision situations at the intersections due to earlier warnings.
- The driving task is changed because the driver may at times glance at the device which provides the warnings. The task becomes a divided attention task. The driving task becomes more complex when there is important visual information both inside and outside the car.

After the driver has learnt to trust the system, this will affect his strategy for approaching signalised intersections. For example drivers might learn to approach the intersections at higher speeds, or more often to disregard to observe the actual traffic signals than before relying on the system to warn them in good time of a red signal ahead. This is harmful for safety and especially in situations when the intersection is not equipped with the system. These effects are affected by the way in which the messages are provided to the driver; especially the message concerning ‘drive ahead’.

Concerning the modification of route choice, it is also expected that drivers are more likely to choose the routes with equipped signals, because the routes with equipped signals will have more fluent traffic due to less abrupt stops at signals and hence, becoming more attractive to drivers.
### 2.2.4.5 Probe Vehicles or Devices

#### Source

- STADIUM, Smart Transport Applications Designed for large events with Impacts on Urban Mobility, Del.2.1 “State-of-the-Art Report”
- S. Ezell ITIF “Intelligent Transportation Systems - Explaining International IT Application Leadership”, 2010
- ETISplus “Del 2.1 Review of ITS and their usability for European data modelling purposes”

#### Transport modes involved

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#### Description

Several countries deploy so-called "probe vehicles" (often taxis or government-owned vehicles equipped with DSRC or other wireless technology) that report their speed and location to a central traffic operations management centre, where probe data is aggregated to generate an area-wide picture of traffic flow and to identify congested locations. Extensive research has also been performed into using mobile phones that drivers often carry as a mechanism to generate real-time traffic information, using the GPS-derived location of the phone as it moves along with the vehicle. As a related example, in Beijing, more than 10,000 taxis and commercial vehicles have been outfitted with GPS chips that send travel speed information to a satellite, which then sends the information down to the Beijing Transportation Information Centre which then translates the data into average travel speeds on every road in the city.

Cellular telephones have been used to collect travel time data basing on cellular telephone reporting technique, like for example in the pilot study carried out by Boston, Massachusetts Smart Route System and Houston, Texas AVI traffic monitoring system. It requires that volunteer drivers call a central facility when they pass checkpoints along the freeway. An operator at the central control facility records each driver's identification, location, and time by monitoring the time between successive telephone calls. A qualitative assessment of current traffic conditions (e.g., stop-and-go, bumper-to-bumper, free flow) can be provided; moreover, this technique is useful for collecting travel time data during delays or accidents. Nevertheless, probe vehicle drivers often miss checkpoints or fail to report locations at the proper times. The cellular telephone reporting method is recommended for short-term studies with low accuracy requirements.

An example of real world application concerning FCD is the so called telematics fleet, implemented in Italy by OCTO Telematics (www.octotelematics.com), a private company that is among the European leaders for development and deployment of Telematics for Insurance application, with approximately 1,000,000 On Board Units (OBU) installed on private vehicles at 2010.

Other than performing the "conventional" telematics functions as antitheft satellite tracking and fleet management, the OCTO Telematics is providing services to 32 insurance companies in Europe, through the installation of on board units able to collect statistics on driver behaviour, mileage, accident detection and reconstruction, traffic detection and estimation, road user charging data and remote automotive diagnostics. The application of board unites also plays an important role supporting road safety and reducing the number of accidents in compliance with European e-Call regulation.

The OBU consists of a GPS receiver, a GPRS transmitter, a 3-axis accelerometer sensor, a battery pack, a mass memory, processor and RAM. The OBU has a dimension of 13.5 x 8.5 x 3 cm. The OBU stores GPS measurements (position, heading, speed, quality) and periodically transmits (on request or automatically) the recent accumulated measurements to the central data system. Transmission occurs every 100 Km travelled or every 12 minutes when the equipped car is running along predefined motorways or crossing city centres.
One the most promising applications arising from the OBU is the Large Scale Floating Car System: the Central Data System tracks the received data along the travelled routes by matching the related trajectories data to the road/street network in order to estimate link travel speeds.

Currently, through WEB pages data are presented in 6 speed categories (http://traffico.octotelematics.it/index.html), updated every 3 minutes, 24 hours a day, 7 days a week, showing the circulating number of vehicle with OBU installations and the corresponding estimates of average speed.
2.2.5 Vehicle-to-Vehicle (V2V) Applications

2.2.5.1 Advanced Driver Assistance Systems (ADAS)

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Description
Advanced Driver Assistance Systems represent a wide range of systems designed to help the driver, making the driving process safer and more efficient.

When designed with a safe Human-Machine Interface (HMI) they should improve car safety and road safety in general. Examples of such systems include: adaptive cruise control; adaptive light control; automatic parking; blind spot detection; collision avoidance system (pre-crash system); driver drowsiness detection; intelligent speed adaptation or intelligent speed advice; in-vehicle navigation systems (typically GPS and TMC for providing up-to-date traffic information); lane change assistance; lane departure warning systems; night vision; pedestrian protection systems; traffic sign recognition etc.

The first application from the above list is a system used for the automatic control of speed. Using a distance gauge, either radar or laser, the vehicle is able to perceive the presence of another vehicle immediately ahead of it in the same lane.

Other examples of driving support functions available on the market or at an advanced stage of development are:
- Night vision: infra-red cameras enable the driver to have better perception in conditions of low visibility, such as at night and in fog.
- Blind spot detection: rear-view mirrors are affected by the blind angle a side area the driver cannot see unless they turn their head. A camera and an electronic image processing unit could serve as a vital warning system to alert drivers to a vehicle overtaking them.
- Parking manoeuvre support: parking sensors are already widespread on many vehicles. Furthermore, some vehicles have recently been equipped with a function that detects the space between two vehicles and - if sufficient – aids manoeuvring by guiding the steering wheel.

In ADAS, both warnings and controls play an important role in safety enhancement. Effective warnings have the potential to compensate for driver limitations, helping to prevent road accidents.

When dealing with humans, warnings and control measures need to be carefully assessed in terms of frequency and priority. High-priority warning signals are communicated via human interface systems to promote awareness and timely, appropriate driver action in situations that present potential or immediate danger.

There are typically three levels of warning priority
1. Low-level: driver should take action within the timeframe of 10 seconds to 2 minutes; may escalate to a higher level if not acted upon.
2. Mid-level: requires action within the timeframe of 2 to 10 seconds; may escalate to high-level warning if not acted upon.
3. High-level: warning requires the driver to take immediate action within 2 seconds to avoid a potential crash.
2.2.5.2 Adaptive Cruise Control (ACC)

Source

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Description

Adaptive Cruise Control (ACC) is an automotive feature that allows a vehicle's cruise control system to adapt the vehicle's speed to the traffic environment. A radar system attached to the front of the vehicle is used to detect whether slower moving vehicles are in the ACC vehicle’s path. If a slower moving vehicle is detected, the ACC system will slow the vehicle down and control the clearance, or time gap, between the ACC vehicle and the forward vehicle. If the system detects that the forward vehicle is no longer in the ACC vehicle's path, the ACC system will accelerate the vehicle back to its set cruise control speed. This operation allows the ACC vehicle to autonomously slow down and speed up with traffic without intervention from the driver. The method by which the ACC vehicle's speed is controlled is via engine throttle control and limited brake operation.

The ACC system consists of a series of interconnecting components and systems. The method of communication between the different modules is via a serial communication network known as the Controller Area Network (CAN).

ACC Module – The primary function of the ACC module is to process the radar information and determine if a forward vehicle is present. When the ACC system is in 'time gap control', it sends information to the Engine Control and Brake Control modules to control the clearance between the ACC Vehicle and the Target Vehicle.

Engine Control Module – The primary function of the Engine Control Module is to receive information from the ACC module and Instrument Cluster and control the vehicle's speed based on this information. The Engine Control Module controls vehicle speed by controlling the engine's throttle.

Brake Control Module – The primary function of the Brake Control Module is to determine vehicle speed via each wheel and to decelerate the vehicle by applying the brakes when requested by the ACC Module. The braking system is hydraulic with electronic enhancement, such as an ABS brake system, and is not full authority brake by wire.

Instrument Cluster – The primary function of the Instrument Cluster is to process the Cruise Switches and send their information to the ACC and Engine Control Modules. The Instrument Cluster also displays text messages and telltales for the driver so that the driver has information regarding the state of the ACC system.

CAN – The Controller Area Network (CAN) is an automotive standard network that utilises a 2 wire bus to transmit and receive data. Each node on the network has the capability to transmit 0 to 8 bytes of data in a message frame. A message frame consists of a message header, followed by 0 to 8 data bytes, and then a checksum. The message header is a unique identifier that determines the message priority. Any node on the network can transmit data if the bus is free. If multiple nodes attempt to transmit at the same time, an arbitration scheme is used to determine which node will control the bus. The message with the highest priority, as defined in its header, will win the arbitration and its message will be transmitted. The losing message will retry to send its message as soon as it detects a bus free state.
2.2.5.3 Incident Management and ITC Safety Services

Source
- STADIUM, Smart Transport Applications Designed for large events with Impacts on Urban Mobility, Del.2.1 “State-of-the-Art Report”, 2010
- S. Ezell ITIF “Intelligent Transportation Systems - Explaining International IT Application Leadership”, 2010

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<td>X</td>
<td></td>
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<td></td>
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</tr>
</tbody>
</table>

Description

To improve traffic flows and mitigate the negative impacts of incidents, effective incident management is required. Incident management consists of incident detection, actions taken by rescue services, incident clearance, and information to road users and needed traffic control measures.

The first information on an incident usually arrives with an emergency call to the local public safety answering point (PSAP) which then sends needed rescue services and traffic police to the site. Traffic management centre then receives information on the incident from traffic police, rescue services or PSAP. After receiving information, traffic management centre can make needed traffic control measures. Traffic management centre can also perform the functions of traffic information centre and inform road users about the location and type of incident and its probable effects on traffic. Traffic Management centres responsible for traffic control are usually operated by road operators or public authorities such as police, while traffic information centres are also operated by traffic information service providers.

Intersection collision avoidance systems can help save lives by preventing intersection related crashes. A combination of autonomous-vehicle, autonomous-infrastructure and cooperative communication systems can potentially address the full set of intersection crash problems. Intersection collision avoidance systems use both vehicle-based and infrastructure-based technologies to help drivers approaching an intersection understand the state of activities within that intersection:

- Vehicle-based technologies and systems - sensors, processors, and driver interfaces within each vehicle;
- Infrastructure-based technologies and systems - roadside sensors and processors to detect vehicles and identify hazards and signal systems, messaging signs, and/or other interfaces to communicate various warnings to drivers;
- Communications systems - dedicated short-range communications (DSRC) to communicate warnings and data between the infrastructure and equipped vehicles.

Advanced Driver Assistant Systems (ADAS) are systems to help the driver in its driving process. An ADAS is a vehicle control system that uses environment sensors (e.g. radar, laser, vision) to improve driving comfort and traffic safety by assisting the driver in recognising and reacting to potentially dangerous traffic situations.

The in-vehicle e-Call is an emergency call generated either manually by the vehicle occupants or automatically via activation of in-vehicle sensors after an accident. When activated, the in-vehicle e-Call device will establish an emergency call carrying both voice and data directly to the nearest emergency point (normally the nearest E1-1-2 Public-safety answering point, PSAP). The voice call enables the vehicle occupant to communicate with the trained e-Call operator. At the same time, a minimum set of data will be sent to the e-Call operator receiving the voice call.
2.2.6 Demand Responsive Transport Services (DRTs)

2.2.6.1 Public Transport Services in Low Demand Areas

Source


<table>
<thead>
<tr>
<th>Transport modes involved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road</td>
</tr>
<tr>
<td>X</td>
</tr>
</tbody>
</table>

Description

Traditionally, areas of low demand and density, e.g. rural areas, have been served by conventional public transport, where they have been served at all. Usually this has been the conventional bus service, running at low frequency – maybe as little as one return journey each day or even each week, which is only suitable to meet the most basic of demands to go shopping in the nearest town. Such services are of no value for travel to work, for training, for education, for medical, social or recreational journeys. Consequently, people either have to be provided with special services (for travel to a hospital, a special vehicle, at very high cost to the public sector), or they simply do not make the journey at all and become excluded from mainstream society. If authorities and operators want to contain the pre-eminence of the car, they need to consider the whole chain of mobility and reposition public transport to fill in the gaps left by conventional services. The request is for door-to-door seamless travel by providing the market with one public transport offer that integrates different products from conventional public transport to demand responsive solutions, regardless of the type of providers. It is to be stressed that the implementation of Demand Responsive Transport (DRT) is highly facilitated by the development of new information and communication technologies, which enable a greater flexibility of operation.

The DRT (Advanced Demand Responsive Transit Service) is an advanced, user-oriented form of public transport characterised by flexible routing and scheduling of small/medium vehicles operating in shared-ride mode between pick-up and drop-off locations according to passengers needs.

The key component of DRTs is a computer-aided system assisting the control centre staff in the whole process of meeting user’s requests, providing dynamic routing and scheduling of vehicles, together with the reporting and accounting operations.

This system is enhanced by the use of:

1. An automated vehicle location device,
2. An on-board small PC to exchange data between the vehicle and the control centre,
3. An automated payment system based on Smart-Cards,
4. An automated geo-coding system to locate all vehicles on a billboard.

The on-board small PC can also be connected to other on-board sensors to collect and process vehicle maintenance data, as well as other various devices.

- Improve journey times and connections, to tackle congestion and the lack of integration and connections which impact on our high level objectives for economic growth, social inclusion, integration and safety.
- Reduce emissions, to tackle the issues of climate change, air quality and health improvement which impact on our high level objective for protecting the environment and improving health.
- Improve quality, accessibility and affordability, to give people a choice of public transport where
availability means better quality transport services and value for money or an alternative to the car.

DRT operations can be defined in the following terms:

- Fixed routes
- Semi-fixed routes
- Flexible routes
- Area-wide services

Most DRT services are run on a small scale and do not require sophisticated IT based booking and scheduling infrastructure. However, once a certain level of operation is reached such tools are essential to achieve and maintain efficient and effective management of resources and costs. This includes the use of automatic vehicle location communication in real time with DRT vehicles to maximise the flexibility and effectiveness of the service and use of assets.

Counties like Lincolnshire and Shropshire (Scotland, UK) have adopted DRT as a key feature of their transport provision integrating flexible services with fixed route and feeding into towns and cities from rural areas.
2.2.6.2 Car Sharing

Source


<table>
<thead>
<tr>
<th>Transport modes involved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road</td>
</tr>
<tr>
<td>X</td>
</tr>
</tbody>
</table>

Description

The initial implementations of car sharing were based on a very simple process, whereby a telephone booking system was supported by a log-book to manually record the data related to the use of the vehicle (kilometres and time). In addition to a box located at the parking area with the set of well recognisable keys for each car in the parking lot, a variant of this scheme devised the box to be mounted directly into the car. Every user of the system would have held, in the first case, a key to open the box situated in the parking area whilst, in the second case, 2 keys were required, one to get into the assigned vehicle and the second to open the box containing the key for the engine.

One can easily understand how cumbersome this process was in being the operator registering the booking, collecting data on the usage of the vehicle, doing the bookkeeping, and managing the fleet manually with little or no technological support. The same applies to the user’s booking, collection and return of the vehicle. This solution can only be viable for managing small fleets and is nowadays only used by small organisations.

The growth of the market share and the spreading of the service over the territory have recently led some organisations enjoying greater success to modernise the service, which is possible thanks to the considerable development of technologies like informatics and telecommunications.

The support provided by the new telematics technologies to the management of the fleet and the service can pertain to a number of operations, bringing huge advantages to include the user’s accessibility to the service, the registration at the control centre of the data on vehicles, the management of the bookings and the administrative management of the service.

The most recent experiences of car sharing, as a result mainly of internal efforts of the participating organisations, have led to an heterogeneous spreading of informatics based systems and automated procedures with little or no change to be reproduced elsewhere. Many technological systems have been introduced only recently and some of those are still at the stage of being developed only upon request rather than standardised.

At present, the architecture of the most modern systems for the support of the management of car sharing includes the operations centre, the car on-board system, and, in some cases, also the fixed architecture situated at the parking lot. The main fundamental component of the operations centre is the informatics system, which is fulfilling the task of providing the call centre operators with a set of semi-automatic procedures for the management of the bookings and, at the same time, offering the administrative department all the statistical information required to monitor the service, the accounts of the company and the clients.

The components of the system which can offer these functions are: the on-board sensors of the vehicle, the on-board PC, a smart card reader/writer, one or more electronic devices to prevent theft and non-authorised use of the vehicle, a system for mobile telecommunications and vehicle location, and a small printer to provide Demand Responsive Transport Services: Towards the Flexible Mobility Agency receipt of the trip. The collection of data relating to the state of the vehicles and the engine is achieved through on-board sensors.
2.2.6.3 Collective Taxi

Source


Transport modes involved

<table>
<thead>
<tr>
<th>Road</th>
<th>Rail</th>
<th>Waterborne</th>
<th>Air</th>
<th>Cross-modal</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Description

As part of the family of DRT (Demand Responsive Transport) systems, the collective taxi offers a service similar to that of the taxi but at a much lower price. Savings are obtained through users sharing their trips with others. Obviously the service will not be unaffected. However, in many cases, thanks to the lower costs, the service will be welcomed by users and will be profitable for the manager.

The collective taxi can be defined as a good quality DRT service that presents the same features of the conventional taxi, which are limited in conventional public transport, but using comfortable vehicles with limited capacity (shuttle buses with 8-10 seats, in certain cases the same vehicles used by conventional taxis), and that takes the user to his doorstep and is organised for clients who are without particular expectations but at the same time sensitive to the economic factor.

In the service managing departures the automated procedure for the planning of a day will start when the booking deadline has elapsed. The managing computer will divide the set of passengers wishing to depart into a number of homogeneous groups (typically from 4 to 6), belonging to the same sector and that can be grouped by close departure time (departure lists). In order to fill in the departure lists the managing software will use optimisation algorithms which take into account factors such as the passenger waiting time, the number of passengers on board and the length of the route to accompany them to the city. A route departure time is associated with each list, which has to be strictly observed, in order to meet the agreements made with the users. The departure lists are indeed the core of the whole system and are left to the responsibility of the individual drivers. Each driver is given one or more departure lists per day. If more than one, there must be a sufficient gap between the end of a list and the start of the next.

The route taken by vehicles in their trip to the destination is also optimised by the computer. A driver who has been given two departure lists, one following the other, could be forced, in the case of a delay, to go back without passengers in order to be in the city at the times agreed on the second list.

For example, in order to organise a service of collective taxis for an airport the following requirements are required:

- Computers for the bookings: these are to be used at the reservation desks and for the bookings via telephone;
- A free-phone number;
- A computer for central management which will be connected to the computers devoted to the bookings through a client-server link;
- Software for the management and optimisation algorithms;
- A computerised geographic system;
- A computerised graph for the road network;
- Reservation desks at the airport;
- Signs and related stopping areas to allow passengers to get on and off the vehicles at the airport;
- A fleet of 40-50 vehicles which will be used at the same time;
- An on-board radio and possibly modem and printer;
- Two operators who have to be present at any moment at the reservation desk.
3 ICT SOLUTIONS AND DATA COLLECTION

The analysis of the opportunities of the ICT solutions in improving data collection is carried out on the basis of the COMPASS WP4 (Task 4.1), providing an overview of data and indicators normally gained from travel and traffic surveys.

The following table shows the list of the most relevant indicators drawn from the COMPASS WP4 (Task 4.1). The list of indicators represents the basis against which the potential of ICT solutions identified in chapter 2 to collect and provide them is evaluated.

<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>INDICATOR</th>
<th>Unit</th>
<th>Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mode</td>
<td>Modal split</td>
<td>%</td>
<td>All</td>
</tr>
<tr>
<td>Mode</td>
<td>Modes used in a single trip</td>
<td>modes</td>
<td>All</td>
</tr>
<tr>
<td>Trip</td>
<td>Number of trips per person</td>
<td>trips</td>
<td>All</td>
</tr>
<tr>
<td>Trip</td>
<td>Number of trips starting in a zone</td>
<td>trips</td>
<td>All</td>
</tr>
<tr>
<td>Trip</td>
<td>Number of trips ending in a zone</td>
<td>trips</td>
<td>All</td>
</tr>
<tr>
<td>Trip</td>
<td>Number of trips zone-to-zone (OD matrix)</td>
<td>trips</td>
<td>All</td>
</tr>
<tr>
<td>Trip</td>
<td>Number of trips (by mode, aggregated)</td>
<td>trips</td>
<td>All</td>
</tr>
<tr>
<td>Trip</td>
<td>Trip purpose</td>
<td></td>
<td>All</td>
</tr>
<tr>
<td>Trip</td>
<td>Trip length (door-to-door)</td>
<td>km</td>
<td>All</td>
</tr>
<tr>
<td>Trip</td>
<td>Ratio of trips requiring long-term parking</td>
<td>%</td>
<td>Road</td>
</tr>
<tr>
<td>Trip</td>
<td>Percentage of intermodal trips</td>
<td>%</td>
<td>All</td>
</tr>
<tr>
<td>Travel Time</td>
<td>Travel time</td>
<td>h, min</td>
<td>All</td>
</tr>
<tr>
<td>Travel Time</td>
<td>Average time needed to find a parking place at the destination</td>
<td>min</td>
<td>Road</td>
</tr>
<tr>
<td>Travel Cost</td>
<td>Household transport expenditure</td>
<td>€/pers/a</td>
<td>All</td>
</tr>
<tr>
<td>Travel Cost</td>
<td>Passenger trip costs (user cost)</td>
<td>€/km, €/trip, €</td>
<td>All</td>
</tr>
<tr>
<td>Travel Cost</td>
<td>Value of time</td>
<td>€/h</td>
<td>All</td>
</tr>
<tr>
<td>Travel Cost</td>
<td>Generalised cost</td>
<td>€</td>
<td>All</td>
</tr>
<tr>
<td>Accessibility</td>
<td>Walking time to the parking place</td>
<td>min</td>
<td>Road</td>
</tr>
<tr>
<td>Accessibility</td>
<td>Walking time to the closest PT stop</td>
<td>min</td>
<td>Road</td>
</tr>
<tr>
<td>Accessibility</td>
<td>Accessibility (number/ratio of people accessible to a place/PT stop/zone/node within certain time)</td>
<td>pers., %</td>
<td>PT, Air, Coach, Rail</td>
</tr>
<tr>
<td>Accessibility</td>
<td>Number of people with car access</td>
<td>pers.</td>
<td>Road</td>
</tr>
<tr>
<td>Accessibility</td>
<td>Percentage of employed and residents owning a driving license for cars and motorcycles</td>
<td>%</td>
<td>Road</td>
</tr>
<tr>
<td>Accessibility</td>
<td>Percentage / number of people with driving license</td>
<td>%, pers.</td>
<td></td>
</tr>
<tr>
<td>Traffic</td>
<td>Traffic flow</td>
<td>veh</td>
<td>Road</td>
</tr>
<tr>
<td>Traffic</td>
<td>Flow/capacity ratio</td>
<td>%</td>
<td>Road</td>
</tr>
<tr>
<td>Traffic</td>
<td>Vehicle-km travelled in a zone/link</td>
<td>veh-km</td>
<td>Road</td>
</tr>
<tr>
<td>Traffic</td>
<td>Vehicle-time travelled in a zone/link</td>
<td>veh-h</td>
<td>Road</td>
</tr>
<tr>
<td>Traffic</td>
<td>Airport-to-airport traffic</td>
<td>pax/a</td>
<td>Air</td>
</tr>
<tr>
<td>Traffic</td>
<td>Station-to-Station train / coach traffic</td>
<td>pax/a</td>
<td>Rail / Coach</td>
</tr>
<tr>
<td>Traffic</td>
<td>Number of passengers</td>
<td>pers.</td>
<td>PT, Air, Coach, Rail</td>
</tr>
<tr>
<td>Traffic</td>
<td>Passenger volume (travelled passenger-km)</td>
<td>pax-km</td>
<td>All</td>
</tr>
<tr>
<td>Traffic</td>
<td>Terminal throughput (number of aircraft/train/coach/vessel movements)</td>
<td>departures, arrivals</td>
<td>Air, Rail, Coach, Ferry</td>
</tr>
</tbody>
</table>
The indicators have been classified in six categories, addressing six different types of data:

1. **MODE**
2. **TRIP**
3. **TRAVEL TIME**
4. **TRAVEL COST**
5. **ACCESSIBILITY**
6. **TRAFFIC**

The first five categories generally come from National Travel Surveys statistics, while the last one (Traffic) is made available through transport models or traffic surveys.

Mode category addresses modal split indicators which serve as to depict the situation of the frequency with which the different transport modes are used for mobility purposes.

Trip category indicators relate to a complex basket of data, generally addressing the number of trips by origin/destination zone, purpose and by link. They also include the degree of inter modality and the average speed on the links and O/D.

Travel time indicators provide the assessment of the travel time components, in hours (or minutes) incurred by the passenger, including the time spent in parking.

Travel cost category indicators relate to data concerning the costs of the journey to the passengers. It is acknowledged that travel choices and mobility patterns are influenced by the generalised prices of the transport types. The generalised prices include both the out-of-pocket costs (tickets, charges, etc), the travel time and the time lost in traffic jams or waiting for public transport.

Accessibility indicators concern data and information on the accessibility to private motorised transport means and public transport. Private motorisation ownership rates (in percentage) is also included.

Traffic indicators concern passenger volume indicators informing on the volume of passenger transport activity expressed in vehicle kilometres and passenger kilometres travelled on a given link and O/D. The flow-capacity ratio is also included.

The availability, quality and level of specification of the above indicators and data is important for allowing the analysis of passenger mobility and outline mobility patterns. The following figure shows the relationships between the ICT solutions classified by main categories and the categories of indicators needed for the analysis of travel surveys.
DATA NEEDED FROM TRAVEL SURVEYS

- **Travel costs**
  - Cost/km
  - Value of Time
  - Passenger Trip
  - Costs (User Cost)
  - Generalised Cost

- **Travel Time**
  - Travel time
  - Car congestion time
  - Car free-flow time
  - Generalised Time
  - ..
  - ..

- **Trip**
  - Number of trips per person
  - Trip Length (Door-to-door)
  - Number of Trips Starting/Ending in a zone
  - Number of Trips Zone-to-Zone (OD Matrix).
  - ..
  - ..

- **Accessibility**
  - Number of people with car access
  - Distance to closest PT stop
  - Walking time to the parking place
  - ..
  -..

- **Traffic**
  - Flow/capacity ratio
  - Traffic Flow
  - Days per year where capacity limits are exceeded (>90% of hourly design capacity) on a TEN link or node

- **Mode**
  - Modal Split
  - Modes used in a single trip (Modes)
  - Share of Public Transport

Figure 3-1 Relationships between ICT solutions and data needed from travel surveys
Figure 3-1 indicates the most promising ICT categories addressing data collection for the set up of passenger mobility surveys. That does not prevent, however, that some ICT application belonging to the ICT categories with no significant relationships with passenger mobility surveys data, e.g. Demand Responsive Transport Services and Vehicle-to-Vehicle (V2V) applications, could, in some case, provide useful data.

For instance, in the case of the most advanced ICT applications concerning flexible transport services in low demand areas (Demand Responsive Transport Services) the overall organisation of the service (i.e., order management, travel planning, vehicle assignment, trip time estimate, scheduling and service planning) involves data collection by the Travel Dispatch Centre for several indicators of potential interest for travel surveys, e.g. travel time on specific routes, O/D trips, etc. The same could be said for the most advanced solutions concerning car sharing. However, it should be stressed that in the overall context of travel data surveys, data from DRTs may play a minor role (niche data), compared to the other ICT categories. For example, data from car sharing or collective taxi or public transport services in low demand areas are in general limited compared to the flows captured by other ICT applications, e.g. traveller information systems or transportation management systems.

Vehicle-to-vehicle applications, e.g. speed adaptation due to weather conditions, obstacles or congestion, local danger / hazard warning, post crash warnings, etc generally provide information addressing road safety or vehicle speed, with a minor relevance in the case of data from passenger travel surveys.

Conversely, the role of the other ICT categories in providing data for passenger travel surveys is more relevant. Namely:

- Transportation Management Systems. As described in chapter 2, the ICT category Transportation Management Systems involves a broad range of ICT applications:
  - Urban Traffic Control, delivering continuous monitoring of traffic conditions, can be implemented in a context of a fully adaptive control strategy. The Traffic Signal plans, for example, can be dynamically optimised to minimise the overall travel time for private traffic and give priority to public transport.
  - Priority Management, where dedicated event lanes and priority routing paths have been provided, ensuring an effective dynamic allocation and control of traffic flows.
  - Public Transport Management, improving the regularity of bus/tram/train services. The underlying technologies can compare the actual position of PT vehicles with their planned schedule and can give priority at intersections to those behind schedule (and special priority vehicles). Data gathered during this process can form the basis for some of the traveller information services and trip planning operations.
  - Demand Management Systems, aiming at the control of traffic flows. In pure terms this is only controlling the demand for transport infrastructure space (such as road, rail, air space) – it is not really controlling the demand for travel. The demand is still there but it is diverted or halted through messages. This aspect of ‘demand management’ is often implemented through dedicated lanes and through public transport improvement coupled with public awareness.

The type of information used and dealt with by Transportation Management Systems make them liable to provide information on a) traffic situation on the corridor or network (travel time); b) traffic monitoring systems (traffic flows); c) use of public and private transport at urban level (modal share) d) mapping of the network of public transport (accessibility).

- Traveller Information Systems. The technological core of the traveller Information Systems (travel planners, real time traffic information systems, etc) is represented by ICT technologies using Global Positioning Satellite (GPS) and Visual Scene Analysis (VSA) technologies. The former ones are a powerful means of collecting much valuable information on travel time, traffic flows, O/D relationships and accessibility. In fact, GPS is vital in the identification of vehicle location/proximity which can feed into Transportation and Public Transport Management and provides real-time service schedules for travellers which can be disseminated via Mobile Phones.

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3 For a full description of the ICT, technologies, see STADIUM (2011) and QUANTIS (2009)
VMS, Websites etc. VSA technologies can be used to monitor a variety of event aspects: Volume Monitoring, Activity Monitoring and Flow Monitoring. These activities address volume monitoring for congestion and traffic flow monitoring recording and analysis.

The type of information managed by traveller information systems concern the following areas: location of the event on the network, type of event effects on traffic, possible warnings and expected duration of the event. The implications in terms of data collection relevant for passenger travel surveys are manifold: congestion level (travel time), number of trips on specific O/D (Trip), location and proximity of O/D to stations, ports and airports, (Accessibility), vehicle-km and pass-km on given link, traffic flows and O/D relationships (Traffic),

- Smart Ticketing and Tolling. Instruments and technologies to ensure automatic ticketing and tolling may provide information useful to travel surveys, even if to a minor extent compared to the information provided by traveller information systems or transportation management systems. In terms of ICT technologies, access to vehicles and venues is often carried out via some sort of ticket or pass. There are now many advanced technologies to facilitate the use of a single ‘smart’ ticket to provide access to multiple venues and multiple vehicle journeys. Where such technology is used the ticket gate and/or card reader can collect valuable statistics concerning actually routing and actual attendance.

In particular, the microprocessor smartcard, widely used in many monetary transactions contains relevant information of the cost of the trip (Travel costs), specifying under which conditions tickets have been issued, e.g. routes, type of road, time of the day, etc).

- Vehicle-to-Infrastructure (V2I) applications. Vehicle to Infrastructure communication can be defined as wireless cooperative interaction, between vehicles and infrastructure, based on systems that can improve safety and performance on roads (UNECE, 2012). V2I applications are currently in use; for example ETC (Electronic Toll collection) applications, which is a cooperative service that provides better comfort, better use of capacity, as well as enhanced safety (avoiding queues on toll plazas). ETC systems are the only cooperative systems with bi-directional communication that have so far reached an significant level of penetration in several regional markets, with several million “On-Board Units”(OBU) in circulation. This aspect could be very promising in terms of data collection.

Floating vehicle applications can indeed offer a wide range of information through the installation of on board units able to collect statistics on driver behaviour, mileage, accident detection and reconstruction, traffic detection and estimation, road user charging data and remote automotive diagnostics.

Using mobile phones as tools for transmitting information from the vehicle can be considered another application of V2I. ERTICO and German Aerospace Centre (DLR) identified and validated the limits of using mobile phone data to monitor traffic by performing a field test during the World Cup in Berlin. When either an activated mobile phone moves from one cell to another, or a mobile phone in standby mode moves to different area, a handover is performed. If the route can be derived from the data, then a velocity can be calculated by using the time between two events. As a result, data from a huge number of mobile phones can shed light on the traffic situation.

The implications in terms of data collection address the following indicators: a) assessment of the average speed and congestion level (Travel time), b) information on O/D zones number of trips (Trip), c) vehicle-km travelled on a given link, traffic flows (Traffic).

All in all, Table 3-2 summarises the opportunities from the ICT solutions in terms of data collection for passenger travel surveys.
Table 3-2 ICT applications and data for travel surveys

<table>
<thead>
<tr>
<th>ICT categories</th>
<th>Relevant applications/solutions</th>
<th>Types of information provided</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transportation management systems</td>
<td>• Urban Traffic Control systems&lt;br&gt;• Performance monitoring&lt;br&gt;• Traffic planning&lt;br&gt;• Priority management&lt;br&gt;• Public Transport Management&lt;br&gt;• Transport Demand Management&lt;br&gt;• Enforcement&lt;br&gt;• Traffic Control&lt;br&gt;• Traffic Forecasting</td>
<td>• Network state estimation&lt;br&gt;• Traffic flows&lt;br&gt;• Capacity&lt;br&gt;• Delays&lt;br&gt;• Congestion&lt;br&gt;• Traffic composition, e.g. public transport share, private motorisation</td>
</tr>
<tr>
<td>Traveller Information Systems</td>
<td>• Travel planners&lt;br&gt;• Pre-trip decisions tools&lt;br&gt;• Within-trip confirmation and recovery (Real time-Travel time tools)&lt;br&gt;• Route optimisation&lt;br&gt;• Destination findings&lt;br&gt;• Route following&lt;br&gt;• Dynamic route guidance</td>
<td>• O/D flows&lt;br&gt;• Number of trips by link and zone.&lt;br&gt;• Time, cost, trip location&lt;br&gt;• Distance travelled, routes&lt;br&gt;• Route and journey time estimations</td>
</tr>
<tr>
<td>Smart Ticketing and Tolling</td>
<td>• Electronic Toll Collection&lt;br&gt;• Access Management&lt;br&gt;• Public Transport smart-cards</td>
<td>• Cost information, charges, tickets, fees&lt;br&gt;• O/D flows&lt;br&gt;• Road characteristics, e.g. speed limits</td>
</tr>
<tr>
<td>Vehicle-to Infrastructure (V2I)</td>
<td>• Floating probe vehicles&lt;br&gt;• Routing applications&lt;br&gt;• Micro routing applications</td>
<td>• Vehicle location&lt;br&gt;• Travel time&lt;br&gt;• O/D routes&lt;br&gt;• Traffic flows</td>
</tr>
</tbody>
</table>

ICT applications are continuously evolving to meet transport data needs, using 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. Transport data needs are complex, vary between sectors and are influenced by factors such as levels of transport system development, the degree of intermodality involved in the trips, etc. A simple overview of the relationships between ICT categories by relevant applications and data needed for passenger transport surveys is given in the following table. It should be noted that the table only contains four ICT categories, because it is thought that the other two will not be able to contribute relevant data.
4 FUTURE SOCIO-ECONOMIC CHALLENGES, TRAVELLER NEEDS AND ICT SOLUTIONS

4.1 FUTURE DRIVERS OF CHANGES

Technological change is one of the most important drivers affecting the transport system, both on the supply and demand side. As such, it is part of the COMPASS Deliverable 3.2 “Key trends and emerging travellers needs”, which will analyse how the technological as well as other relevant socio-economic factors, e.g. population ageing, migration flows, urbanisation patterns, etc, can affect the future passenger transport demand.

In the context of this Deliverable, the preliminary conclusions from the Deliverable 3.2 (to be issued in June 2012) are taken into account, in order to stress a sub-set of relevant drivers of changes that are going to affect future passenger transport demand/needs and for which the ICT solutions identified in the chapters above can provide opportunities to address the related challenges.

The following sub-sets of drivers can be identified:

- **Demographic factors (population ageing).** The level and composition of the population in terms of person types, with considerable variation in trip making and trip distances between persons by age, sex, economic position, income, etc is clearly one of the factors that influences transport demand. Particular attention is paid to the way trip rates change for each person category, and especially in relation to age and income dependent behaviour. Now, despite some uncertainty concerning for example the future immigration flows, it is acknowledged that in the medium-long term future (2030-2050) the European population structure is going to change. From the 2012 Ageing Report (EC, 2011): "The age structure of the EU population will dramatically change in coming decades due to the dynamics of fertility, life expectancy and migration. The overall size of the population is projected to be slightly larger in 50 years time, but much older than it is now. The EU population is projected to increase (from 501 million in 2010) up to 2040 by almost 5%, when it will peak (at 526 million). Thereafter, a steady decline occurs and the population shrinks by nearly 2%. Nonetheless, according to the projections, the population in 2060 will be slightly higher than in 2010, at 517 million."

- **Motorisation rates.** Over the past 20 years, in the European cities car ownership rates have been growing as shown in the following figure (from the EUROSTAT Urban Audit database: European cities with more than 100,000 inhabitants).

![Figure 4-1 Car ownership rates in European cities (1989-2009)](image)

It is likely to happen that in the near future the car ownership rate continues to grow, even if at slower rates. It should be considered in fact that income effect and behavioural patterns and lifestyles will continue to exert their influence in increasing the rate of private motorisation rates. This trend must be interpreted in association with the population ageing. In fact, in the future
older people will comprise a larger share of the driving population than in the past. Older people will wish to retain their driving licence as long as possible and therefore licence holding among older people will be similar to licence holding among younger and middle aged people now.

- **Urbanisation trends.** Concerning the urbanisation driver, urban growth is nowadays accompanied by urban sprawl – a relative shift in the location of activities (housing, industries, retail and other services) towards the peripheries of the urban agglomeration. This was and currently is an established trend that affects the growth of modern cities, which can be assessed by taking into account global trends in the housing, retail and business sectors, in order to understand why this phenomenon has steadily marked the development of urban areas over the last decades. It has also important consequences in terms of associated trends of increasing land consumption and car dependent mobility. Finally, there is an important relationship between the urbanisation driver and daily commuting patterns. Indeed, one of the consequences of urban sprawl is an increasing dependence on the automobile for intra- and inter-metropolitan travel. Urban sprawl entails building extensive transportation systems because houses are increasingly far away from workplaces and commercial centres. This new constructed infrastructure, in return, spurs further urban sprawl – investments made in new motorways or road connections attract new development along the improved transport lines. Growing car ownership and the concentration of work and shopping in out-of-town locations have resulted – and may continue to result - in continuing increases in journey length for all purposes, but particularly for commuting. Trends in trip lengths in some EU15 countries (e.g. the United Kingdom, Denmark and Belgium) showed a growth in travel during recent decades, with people living further away from work, leisure activities, shopping centres and schools (EEA, Indicator Fact sheet – TERM 2001 14 EU). Increased average trip length and suburb to suburb trips increase fuel consumption and related emissions of air pollutants and greenhouse gases.

### 4.2 IMPACTS ON FUTURE PASSENGER DEMAND/NEEDS

Population ageing, the growing private motorisation rates and the continuation of the current urbanisation trends in the future have several implications:

#### 4.2.1.1 Population ageing

- Growing mobility of older people. The ageing of society will affect the transport system through its impacts on the structure and patterns of leisure activities. Nowadays older cohorts are more interested in travelling in their leisure time. In view of the current ageing trends, this will result in the future in an increase of demand for collective forms of transport by road and air. However, older people may show more variable habits in terms of mobility than in earlier times, possibly due to better health of the elderly in the more distant future. In addition, even if collective public transport such as rail are not currently preferred by older people, this could change with significant improvements in terms of quality (comfort, accessibility, information) and adapted tariffs. More persons aged over 60 will still active in the labour market. Thereby ageing will affect mobility also through its impact on the labour market. Assuming that labour market demand grows in the future it can be expected that this will generate a higher transport demand for daily passenger transport of the growing segment of older workers.

- Improving safety and vehicle design. The ageing of society provides compelling reasons for improving vehicle design to meet the problems experienced by older people. Because ageing is associated with frailty and increased vulnerability to injury in the event of a crash, older transport users are likely to be the prime beneficiaries of continuing improvements to protect vehicle occupants.

#### 4.2.1.2 Motorisation rates

- Growing mobility by private transport means. The use of car and private motorised transport means may increase as an effect of the growing motorisation rates.

- Growing safety standards. The increase of motorisation rates may also raise the issue of major safety standards, in particular for road transport.

- Addressing congestion. The growing rates in private motorisation rates may also lead to higher congestion level, mainly in urban areas and long distance corridors.
4.2.1.3 Urbanisation patterns

- Higher transport demand. Urban sprawl may increase transport demand for short/medium distance through uni-modal trips (mainly by road).

- Growing share of multimodal trips. Urban sprawl may also increase the demand for multimodal transport (short/medium distance), linking car and public services through efficient interchanges. In such a context, truly integrated transport systems must be set up, allowing flexibility and seamless connectivity. When people travel, they should be able to connect much more smoothly and quickly between different modes of transport than is usual today.

4.3 THE ROLE OF ICT SOLUTIONS

The following table shows the relationships between the drivers of changes in transport demand, the identified broad ICT categories and the impacts on transport demand and passengers needs.

<table>
<thead>
<tr>
<th>Change in passenger transport demand</th>
<th>Role of ICT solutions</th>
<th>Impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Drivers</strong></td>
<td><strong>Impacts</strong></td>
<td><strong>ICT Solutions</strong></td>
</tr>
<tr>
<td>Population ageing</td>
<td>Growing mobility of older people: the need of improving safety and vehicle design</td>
<td>Advanced Driver Assistance Systems (ADAS)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Adaptive Cruise Control (ACC)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Demand Responsive Transport Services</td>
</tr>
<tr>
<td>Growing motorisation rates</td>
<td>Growing mobility through private motorised transport means</td>
<td>Real-time Co-modal Traveller Information Systems</td>
</tr>
<tr>
<td></td>
<td>Growing congestion</td>
<td>Public Transport Management</td>
</tr>
<tr>
<td></td>
<td>Safety problems</td>
<td>Incident Management and ITC Safety Services</td>
</tr>
<tr>
<td>Urbanisation trends</td>
<td>Urban sprawl and higher transport demand (road)</td>
<td>Intelligent Speed Adaptation (ISA)</td>
</tr>
<tr>
<td></td>
<td>Need to more frequent multi-modal transport trips (e.g. commuting)</td>
<td>Travel planners</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Real-time Co-modal Traveller Information Systems</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Vehicle-to-Infrastructure Applications</td>
</tr>
</tbody>
</table>

Table 4-1 Drivers of changes in passenger transport demand and ICT solutions
5 CONCLUSIONS

In conclusion, the identified ICT solutions and technologies have shown significant potentiality in favouring co-modal seamless solutions. In particular, ICT technologies are deemed to represent the key instruments to convey the relevant information to the passengers for making possible a seamless trip: from the information on timetables, delays and interconnections to the availability of smart ticketing.

The following table shows that important enabling applications are represented by smart ticketing options combining tariff information of several transport modes (smart cards) and traveller information systems, informing transport users on timetables and travel time (multi-modal traveller information systems). In particular, it must be stressed that in this latter category, the real-time co-modal traveller information systems are deemed to be the most promising ICT applications, to the extent that they can take into account of the dynamic context-related event, e.g. delays, traffic interruptions, etc, updating the travel planner and favouring seamless journeys. The analysis is carried out according to the following qualitative assessment: low capability (√), medium capability (√√) and high capability (√√√).

Table 5-1 Uses of the different ICT categories and seamless trips

<table>
<thead>
<tr>
<th>COMPASS ICT categories</th>
<th>Seamless multi-modal integration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Transportation Management Systems</td>
<td>√√</td>
</tr>
<tr>
<td>2. Traveller Information Systems</td>
<td>√√√</td>
</tr>
<tr>
<td>3. Smart Ticketing Applications</td>
<td>√√√</td>
</tr>
<tr>
<td>4. Vehicle-to-Infrastructure Applications</td>
<td>√√</td>
</tr>
<tr>
<td>5. Vehicle-to-Vehicle Applications</td>
<td>√</td>
</tr>
<tr>
<td>6. Demand Responsive Transport Services</td>
<td>√√</td>
</tr>
</tbody>
</table>

The opportunity for a better data collection process, serving transport modelling data requirements and in particular the realisation of transport mobility surveys has also been stressed.

More specifically, it has been pointed out that Transportation Management Systems, Traveller Information Systems, Smart Ticketing and Tolling and Vehicle-to-Infrastructure applications represent the most promising ICT applications for improving passenger data collection.

By addressing these issues, one of the most important themes of the COMPASS project, i.e. the capability of ICT solutions to reduce CO₂ emissions, can be adequately introduced, and, at the same time, it would be possible to test how ICT can cope with future challenges, i.e. shaping the future transport demand towards a sustainable path.

However, in order to provide a complete assessment of the opportunities from ICT applications there are other important issues that need to be raised:

1) Do the solutions increase trip-making (i.e. generate new trips)?
2) Do the solutions reduce travel (i.e. shorter or fewer trips)?
3) Do the solutions promote modal shift (towards or away from ‘sustainable’ modes)?

The following table provides an indicative assessment of the above questions (the same qualitative evaluation criteria of the table 5-1 has been used: low capability (√), medium capability (√√) and high capability (√√√).
Table 5-2 ICT solutions overall assessment

<table>
<thead>
<tr>
<th>COMPASS ICT categories</th>
<th>Generate new trips</th>
<th>Increase travel distance</th>
<th>Promote modal shift</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Transportation Management Systems</td>
<td>√√</td>
<td>√√√</td>
<td>√</td>
</tr>
<tr>
<td>2. Traveller Information Systems</td>
<td>√√</td>
<td>√√√</td>
<td>√√√</td>
</tr>
<tr>
<td>3. Smart Ticketing Applications</td>
<td>√</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>4. Vehicle-to-Infrastructure Applications</td>
<td>√</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>5. Vehicle-to-Vehicle Applications</td>
<td>√</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>6. Demand Responsive Transport Services</td>
<td>√√</td>
<td>√√</td>
<td>√√√</td>
</tr>
</tbody>
</table>

At this stage of the COMPASS project, it must be said that the answers to the three above questions are not yet final.

Concerning the capability of ICT solutions to curb unnecessary passenger transport, it is not clear whether ICT acts as a brake or as an accelerator in what currently seems a relentless growth in the demand for passenger travel. Timely information on traffic conditions and interconnections (Transportation Management Systems), could reduce congestion (and emissions), but at the same time it might encourage other longer distance travel, like leisure travel by air or ship (most polluting transport means).

The direct effects on transport may be some replacement of existing travel, but in the longer term new patterns of longer distance travel may appear as the ICT becomes embedded in lifestyles (Traveller Information Systems). ICT may allow people to live in remote parts of the European Union and to develop locally based travel patterns with occasional longer distance journeys to the city. The improvement of accessibility made possible by ICT, e.g. in rural areas, may be overcome, increasing the total transport demand by public transport modes or collective car services.

In the city (short distance trips), the need to own a car may be reduced as the quality of public transport and information services is enhanced by ICT. Car sharing and innovative forms of leasing favoured by ICT applications may result in less city car ownership (Demand Responsive Transport Services).

Concerning long distance trips, the ICT impacts may be different. The application of Internet-based online booking and debiting systems can be combined with the use of travel information systems and smart ticketing, with embedded intelligence to ensure that high-quality options are presented to allow customised mobility. The increasing opportunities of last-minutes deals done through the Internet have become increasingly important as the flexibility of the Internet has been used to sell excess capacity, particularly for flights, hotels and holidays. The direct effects have been higher occupancy rates on airlines, railways and hotels, as space is sold at costs slightly above the margin. At one level, this may just be using up excess capacity and so there is little additional travel, but in the longer term it may result in additional capacity being added as new markets are developed. In this case, the growth in long-distance travel is likely to be substantial.
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