Chapter 3
Public Transport in the Era of ITS: ITS Technologies for Public Transport

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Mobility started to grow continuously from mid-nineteenth century thanks mainly to the development of rail transport services, and this trend increased even more rapidly with the growing fleet of cars and buses. The potential of those mechanised transport means made us more mobile. Getting around from place to place is essential to human engagement and endeavour.

As shown in Chap. 1, urban mobility has increased not only in the number of daily trips per person but also in distances travelled. According to the Eurostat Panorama of Transport, the average daily distance travelled during 2006 in land transport means in Europe was 31 km per person. Car trips account for 26 km, which is therefore the largest share of the daily mobility. The increase of problems associated with the urban mobility such as the steady growth in car ownership, increasing congestion and rising energy consumption has led to the system to move away from sustainability targets. The response to those major challenges cannot be limited to traditional measures, and the innovation plays a major role in finding appropriate solutions. New tools and solutions are currently conceived to achieve sustainable mobility in an efficient way.

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Beyond the aspects related to the forms of public transport (vehicle technology, infrastructure, network of lines and level of service), described in Chap. 2, one key driver to improve public transport (PT) performance, and its competitiveness to less sustainable modes of transport, is exploiting the support of information and communication technology (ICT). According to the International Union of public transport UITP, ICT is crucial for the study, design, development, implementation, support or management of computer-based information systems, particularly software applications and computer hardware. ICT deals with the use of electronic computers and computer software to convert, store, protect, process, transmit and retrieve information data.

Taking into account the technical and technological evolution of the new ICT tools, it is possible to provide real-time and accurate information to travellers and to better monitor and manage the public transport system. The application of ICT for transportation systems is usually referred to as intelligent transportation systems (ITSs). Several ITS solutions are currently being deployed to improve PT operations and to offer the PT users a more effective information of the (real-time) status of the scheduled services. Moreover, ITS has an important role for integrated ticketing as well as for enhancing the use of public transport within a multimodal journey.

According to the above potential contributions of ITS to PT systems, this chapter provides an overview of the current ITS solutions in public transport in four main aspects. We focus first on the ITS technologies for improving PT operations. These cover aspects related to individual PT vehicle trajectories, to the line or general service regularity and delays recovery solutions. Then, we explore the current technologies adopted for optimising the traffic infrastructure to the PT services, and in particular to the prioritisation of PT within the supply system. A third aspect covered in this chapter is the introduction of smart ticketing systems, which allow faster and easier transactions, and simultaneously enables the collection of useful information on the transport demand. A fourth aspect is then focusing on the use of ITS for information purposes, i.e., how sensors and data collected from PT services as well as from the smart ticketing are used to dispatch useful information and guidance to the travellers. These aspects are finally linked to the current international deployment of ITS and are consolidated through a survey of the European ITS market.

Since the development of ITS is changing rapidly, the examples presented in this chapter are assumed to present the state of the art at the time of writing. It is not possible to predict how technological solutions and standards will evolve in the future. The main goal is to highlight the various evidences of how ITS has an impact on PT operations and utilisation, and to introduce the main aspects that are later needed to understand how to incorporate ITS in the models described in the next chapters. Hence, the chapter concludes with an overview of the variables used in transit assignment, which will be likely affected by the various ITS solutions.

This chapter concludes the first part of this book, which had the scope of providing the basic knowledge for understanding the functional aspects and characteristics of public transport services, and therefore providing the basic building blocks for formulating and developing transit assignment frameworks and models.

3.1 ITS Solutions for Fleet Management

Public transport fleet management has the objective of improving the efficiency, reliability and the environmental impact of PT systems. ITS brings several advantages to PT fleet management through a number of ICT enablers, which allow, for example:

- Real-time tracking, location, monitoring and visualisation of PT vehicles;
- collect data for analysis of performance and for planning purposes;
- high-quality real-time passenger information services both on-board and off-board (via, e.g., portable devices and information panels);
- dynamic control and advisory systems through on-board communication;
- improved punctuality of bus/tram services through coordinating lines and transfers;
- transit Signal Priority (TSP) at traffic lights; and
- equipment diagnostics and maintenance planning and scheduling.

The best way to monitor and operate bus or train fleets using ITS technologies is through a centralised control centre, which is the current state of practice in some European cities. The system operates based on a two-way communication protocol (Fig. 3.1).

The vehicle provides real-time information to the control centre (via automatic vehicle location—AVL-systems), which in turn produces guidance instructions to each bus, either through the driver display or by information panels along the line. There are different electronic data interchange (EDI) protocols to support this continuous communication between the control centre and each vehicle in

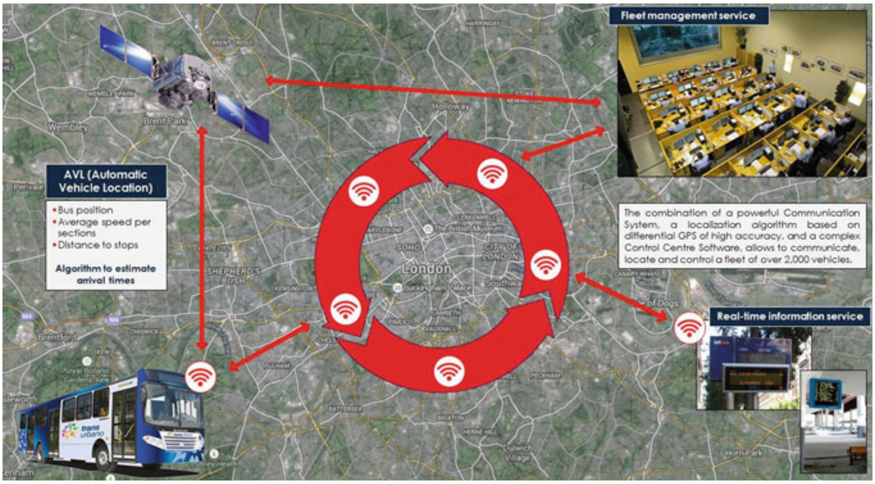

Fig. 3.1 Communication network for public transport fleet management

operation. This communication allows to maintain headways between vehicles and to inform of any incident in the service. The consequence is that drivers are not the only responsible of providing a good and reliable service because they receive the support from the control centre. Even more, any emergency or accident could be solved rapidly or quick actions can be taken to overcome road-obstacles in the vehicle itinerary.

The information collected by these tracking systems could also be used to deliver real-time information to the travellers while at the stops or stations, such as waiting time for the next services and reports on incidents. Some experiences based on the EBSF-FP7 project show that users perceived a clear improvement of service quality when bus stops are equipped with real-time information displays.

Nowadays, large cities already have this type of technology deployed in their PT systems. Smaller cities in size are now investing on fleet management systems, once their positive benefits have been verified. In this regard, an example of fleet management can be found in Craiova (Romania), where a fleet global positioning system (GPS) and a driving efficiency monitoring system were introduced. Other cities, as San Sebastian (Spain), Lodz (Poland) and Forlì-Cesena (Italy), have implemented a fleet monitoring system. The advantages of its implementation result on better service planning, improvement in security and the possibility to monitor consumption in real time, with the installation of additional devices. All these examples are explained in depth within the next sections.

3.1.1 Infomobility Tools for Sustainable Fleet Management (Craiova, Romania)

Craiova is the 6th most populated city in Romania, with approximately 270,000 inhabitants (as of 2011). Currently, the public transport system consists of 3 trolley tram lines and 17 bus lines. It is operated by the Regia Autonomă de Transport Craiova (RAT Craiova), a corporation run by the City Hall. One ticket is around 0.5 €, and the total fleet consists of 342 buses and 49 trams serving the city.

Craiova is also a major railway centre and is connected to all other major Romanian cities, as well as local destinations, through the national Căile Ferate Române network. Craiova is served as well by Craiova Airport, which has recently been modernised.

The EU's quantitative objectives for 2020 include reducing greenhouse gas emissions by 20 % of 1990 levels, reducing energy consumption by 20 % of the projected 2020 levels and increasing the share of renewable sources of energy to 20 % of total energy generation. In order to comply with these objectives, the municipality of Craiova developed and implemented a plan for sustainable development. One of the measures initiated in this area is the introduction of infomobility tools for fleet management (Fig. 3.2). The main objectives of this initiative are to

Fig. 3.2 Ticket counter in bus fleet in Craiova

increase residents' trust in public transport by providing a reliable, predictable, comfortable and safe service, to reduce traffic levels by encouraging people to use public transport instead of private cars and, simultaneously, to reduce the levels of pollution and fuel consumption. One of the measures taken to achieve these objectives is the implementation of a complex management system within the public transport company. This system utilises global positioning system (GPS)-based tracking components in order to increase the efficiency of public transport and to optimise energy consumption.

The basic function of the system is vehicle tracking. Besides locating the vehicles, the GPS transmits to the software application information about speed, direction of travel, etc. The information gathered about the positioning of the vehicles can also be used with the information panels installed in a number of bus stops to make public transport more predictable and attractive, and also for better route management during rush hours.

With the aim of further reducing the energy consumption, the public transport operator RAT rolled out a system that monitored the energy performance of drivers. It was designed to complement a modest capital investment in chopper technology that had been made on the braking systems of nine trams.

The system includes equipment to acquire, store and analyse data with the hope of saving on energy consumption and freeing up funds to improve travellers' comfort. The system allowed a breakdown of energy use on different sections of track via monitoring equipment connected to different power supply stations. This gave a detailed picture of not only drivers' performance, but also each individual's energy profile along different parts of the network.

Together with the new chopper technology installed on the nine trams, the monitoring measure was shown to produce energy savings of up to 40 %. These results clearly show that expanding the measures to cover the rest of the city fleet would be much cheaper than buying new trams.

3.1.2 Monitoring and Planning of Public Transport Systems (San Sebastian, Spain)

San Sebastian is a city situated in the north of Spain, on the Bay of Vizcaya coast and 20 km from the French border. The city is the capital of the region of Gipuzkoa, in the Basque region. The municipality population is about 186,500 inhabitants (as of 2013).

The bus is the primary mode of public transportation system of the city. The service offers 40 lines, plus a special service to the Igara industrial site. In addition to the above, the public transportation system offers four lines of minibuses, a taxi bus service to the districts that conventional buses cannot serve and 10 night lines running all Fridays and Saturdays. The rail service connects different parts of the city with many towns in Gipuzkoa and other important Spanish cities, and including a TGV service towards Paris.

Within the CIVITAS Archimedes project, the Tramway Company of San Sebastian (CTSS-DBUS) has defined and implemented a new expert planning system for the bus fleet and a fleet monitoring system. It is installed on a server and can be used from any computer via online. In this system, it is necessary to calculate the buses' schedules and the drivers' timetables. Before this, it is required to input all the trips of the buses offered to the travellers on every line. These data can be introduced easily in the system using a special input application. Another set of inputs are the labour restrictions and the bus network: lines, line routes, bus stops and points for driver replacement. Once all the inputs are filled in, the system calculates the best solution for the drivers' timetable, optimising the total number of shifts and service hours. Spreading the solution of the different day types for the whole year, the system gives the schedule for every driver about the working shifts for every day.

An important element of quality is the feeling of security of the bus passengers. For this reason, CTSS installed 22 security cameras in the buses. The security camera system on-board of the buses consists of 4 cameras located in different strategic points. The 4 cameras are connected to an advanced on-board computer that administrates and manages and records all the videos. With the security camera system, CTSS-DBUS has improved the security and the physical integrity of the drivers, travellers and material equipment of the public transport.

At the same time, as implementing the security camera system in the CTSS-DBUS fleet, a HSDPA-3G communication system between the buses and the control centre was also implemented. The security camera system has been a solution to reduce vandalism problems (Fig. 3.3). In the first year of operation, CTSS-DBUS detected that vandalism was reduced significantly in the buses with the security camera system, and several accidents were solved.

Fig. 3.3 Security camera system in San Sebastian

3.1.3 CCTV Monitoring System on Public Transport for Security Purposes (Lodz, Poland)

Lodz is the third-largest city in Poland. It is located in the central part of the country, and it has a population of 742,387 (as of 2009). Moving around Lodz with public transport is simple and straightforward, since an extensive, modern bus and tram network is spread throughout the city.

In order to improve the quality of the service in regard to security, Lodz public transport authority decided to install CCTV monitoring systems at both stops as well as on the vehicles. The aim of the project was to improve passengers' safety on city public transport in Lodz by CCTV monitoring system installation. It was a 1 M € project to be co-financed by the Regional Operational Programme (RPO) of the Lodzkie Voivodeship for the years 2007–2013. The project plan was to install 1264 CCTV cameras on 183 vehicles, and 20 other video cameras installed on selected stops and terminals. The system is operated from a dedicated monitoring centre. On some vehicles, there are extra cameras on the outside of the vehicle, either on the front or on the back.

The notification of any incident can be done by phone or by SMS. In the case of a short message, the description has to include identification number of the vehicle and the kind of problem. The observing centre can get the views from all the cameras in the system in real time (Fig. 3.4). The views can also be forwarded to city guards or police. The announcements are encouraging passengers to react as it is the quickest way to achieve a quick reaction from the support and security services. Additionally, there is a GPS unit on every vehicle, which allows to automatically locate the incident and, if needed, send the proper services to the exact location. As all the views from the CCTV cameras are recorded, they can be used as the proof material for the legal procedures.

The CCTV monitoring system has improved security on buses and trams of Lodz. In the first 3 months of functioning, no dangerous incident was recorded.

Fig. 3.4 CCTV monitoring system in Lodz

3.1.4 Consumption Monitoring and Ecodriving Training (Forlì–Cesena, Italy)

Forlì–Cesena is a province of the region of Emilia-Romagna, Italy. Its capital is the city of Forlì. The region has 30 municipalities, and it has an area of 2377 km^2 and a total population of 358,525 inhabitants (as of 2001). In order, cities with more population are Forlì, Cesena, Cesenatico and Savignano sul Rubicone. The Azienda Trasporti Regionale (ATR) public transport network connects Forlì, Cesena and the other main towns by bus. The intertown public transport system in Romagna is over 1600 km long and is divided into 4 routes through the valleys (of which 3 are integrated in the suburban valley routes), 4 routes across the plain, 7 secondary routes in the mountains and 5 routes across the plain.

In this scenario, a modern, environmentally friendly and alternative fleet does not directly mean lower energy consumption and CO_2 emissions. Vehicle procurement, vehicle monitoring and especially proper driving styles are the key elements to achieve real benefits for the environment. Being conscious of the high green impact of combining energy consumption monitoring with improved driving performances is a fundamental rule for the automatic vehicle monitoring (AVM) managers. It also creates the best work environment for employees and their active involvement in greening services.

AVM has implemented a wide awareness campaign on ecodriving issues among its drivers. All drivers received a tailored code of practice with tips and tricks for ecodriving a bus. The FLEAT pilot action was also implemented by an ad hoc test on a specific route. The redesigned Line 6 of the urban public transport service in the Municipality of Cesena is constantly monitored in its energy and environmental performances.

Services are provided with a fleet of 8 buses. Line 6 was monitored from December 2008 to August 2009 for those aspects related to fuel consumption, service interventions, anomalies, driver shifts, etc. Drivers have been informed every week about their actual fuel savings by a wall chart in their meeting and restroom.

After the FLEAT training and awareness campaign, the average aggregated CNG consumption of the line was 3.4 % lower compared to the pretest performances. By using a proper monitoring scheme and enhancing the ecodriving attitude of drivers at Line 6, about 4000 kg of CNG could be saved per year.

3.2 Integrated Management of Traffic and Public Transport Prioritisation

Buses usually use the same road/street infrastructures with cars and duty vehicles, or partly interact at junctions. The coordination of both ITSs for controlling bus services and traffic is very important (Fig. 3.5). It requires a common platform where traffic and public transport control centres are linked and coordinated. The coordination of control centres could produce a number of benefits, such as priority to buses in traffic lights and intersections, green waves for bus lanes and corridors, anticipating information on congestion or incidents in the bus line to allow changing itineraries or rescheduling.

One of the main outcomes of this kind of coordination is to facilitate reliability in bus services, which is the backbone of the quality of public transport and its acceptability. The coordination is also very important for emergencies, accidents and any kind of issue.

3.2.1 Transit Signal Priority

Traffic controls are often considering some form of *TSP*, i.e., additional responsive control policies that aim to improve the efficiency of PT operations at signals.

Fig. 3.5 Dedicated bus lane and different types of signalisation for giving priority

TSP improves PT operations via temporary traffic signal timing adjustments. Active TSP is one of the most efficient and cost-effective measures to improve the efficiency of PT operations. By contrast, lack of appropriate TSP leads to unreliable bus arrival time prediction displayed at bus stops.

Generation and processing of priority is taken care by two logical processes called priority request generator (PRG) and priority request server (PRS). The former determines the necessity for generating a request and communicates the request to the PRS. The PRS selects and sends requests to signal controller for implementation. PRS contains the priority control algorithm that specifies the level of priority that a PT vehicle can receive depending on various criteria. Signal control includes preferential adjustments such as early green, green extension and phase rotation/insertion. The first two are the most commonly used.

TSP consists of three components, a detection system, a signal control system and a communication system that links the two components. The latest (third) generation of TSP is based on automated vehicle location (AVL) as detection systems. This allows developing conditional (differential) active priority, in which the system verifies if the approaching vehicle meets the criteria for granting the priority. These criteria depend on the PT operating policy (typically schedule- or headway-based). In the former, punctuality is used as a criterion, while in the latter, it is regularity. In the future, TSP will include vehicle occupancy criterion—possible thanks to the emerging automated passenger counting (APC) systems. The introduction of AVL allowed to switch from conventional point-based detection (e.g., AVI loops) to zone-based methods. The latest zone-based technique uses infrastructure-less GPS-based virtual detectors, which allows placing and reviewing priority calls at any time, while the vehicle approaches the intersection.

CV technology brings the opportunity to increase efficiency and reduce negative side-impacts of TSP. Therefore, US Department of Transportation listed DSRC-based TSP as one of the high-priority mobility applications

The advances in the communication component of TSP are driven by the fact that currently used communication technologies are restricted to the transmission of small messages. Recent developments based on the IEEE 802.11 standard allow to bypass this limitation and to enable continuous exchange of update messages between vehicles and traffic signals.

These types of ITS solutions encourage the use of public transport, as they reduce travel times, the number of stops at traffic light and consequently the waiting times at stations or stops. In Toulouse (France), the average bus waiting times at traffic lights was reduced by 52 % with this kind of systems. Other cases, as the dedicated bus–tram lane in Warsaw (Poland), and the “greenway scheme” in Edinburgh (Scotland) have also shown that this type of measures yield big results, at a comparatively low cost. These examples are treated below, accompanied by the full integrated management of all public transport services in Madrid. This case is a good practice of how a transport network could be globally coordinated.

The control centre manages all modes of transport and public ones and also interacts with the traffic control systems of the city and the road network in the metropolitan area.

3.2.2 Bus Priority System (Toulouse, France)

Toulouse is the capital city of the department of Haute-Garonne, and of the region Midi-Pyrénées, in the south-west of France. The city has 1,250,251 inhabitants (as of 2011), and its metropolitan area is the fourth largest in the country, with 5381 km^2. The public transport network of Toulouse contains 77 urban bus lines, two underground lines and a tramway line to two neighbouring towns. In addition, a city-wide bicycle rental scheme called VélôToulouse was introduced in 2007, with bicycles available from automated stations for a daily, weekly, monthly or yearly subscription.

Toulouse aims to improve the service quality and to achieve a modal shift towards public transport. The bus priority system can be considered as one of the most effective solutions for improving the quality of the bus network service in the city and therefore for fostering this modal shift.

Within the CIVITAS MOBILIS project, two bus lines were equipped with a priority request system in order to assess the advantages and constraints of the system for both public transport and private car flows (Fig. 3.6). The radio priority system enables a permanent contact between the bus and the traffic junction. It calculates the time when the bus will arrive at the traffic junction and therefore can give green light to the arriving bus.

Surveys in a test phase showed that bus regularity and journey time improved and average bus waiting times at traffic lights was reduced by 52 % which is in average 9 s per traffic light equipped. This ITS solution is particularly adapted to the most congested lanes. Bus priority system permits to smartly deal with conflicts on several lanes on a same traffic junction.

Fig. 3.6 Bus equipped with a priority request system

3.2.3 Revolutionised Public Transport with Dedicated Bus–Tram Lane (Warsaw, Poland)

Warsaw is the capital and largest city of Poland. It is located on the Vistula River, 260 km from the Baltic Sea and 300 km from the Carpathian Mountains. Its population is estimated to be 1.7 million residents (as of 2011) within a greater metropolitan area of 2.67 million. The area of the city covers 516.9 km^2. Public transport in Warsaw includes buses, trams, metro, light rail, urban railway, regional rail and bicycle-sharing systems. Bus service covers the entire city, with approximately 170 routes totalling about 2603 km, and with some 1600 vehicles.

As regards the notice published by ELTIS (European Local Transport Information Service), the "Trasa W-Z" route ("W-Z", eng. east–west) with its total length of 6760 m, and intense public transport traffic (trams and buses) is one of the busiest central thoroughfares of Warsaw, connecting its west and east districts and assuring access to Warsaw underground from the right bank of Vistula. Until the route was reorganised in its middle section (about 3.2 km long), there were two lanes in each direction, accessible for all traffic participants. The tram track was not separated from the road traffic and thus shared a single lane. As a result, trams were stuck in traffic jams during peak hours.

In 2007, it was decided to separate the tram lane from the public one by means of a painted line. Two years later, the tram lane was made accessible also for buses (since 2011, 4 bus lines run the route), creating multimodal interchanges along the route (Fig. 3.7).

Before the new solution was brought in, there were on average 1700 cars per hour running on one direction. Since there was only one public lane left, the number of cars decreased by 40 %, whereas tram passenger numbers have grown by 250 %. Additionally, the transport authority has increased frequency on the four tram lines that operate along the route from 55 up to 60 departures per hour during peak hours.

The separation of the tram track has been met with severe criticism among the users of private cars. However, the city authorities have decided to keep the tram lane active as it has led to great improvement in the service for both the tram and buses that use the route.

Fig. 3.7 Public transport with dedicated bus–tram lane in Warsaw

The application of common bus/tram lane on the "W-Z" route, the first of this type in Warsaw, has shown how to improve the functioning of public transport significantly and how to encourage passengers to use trams and buses instead of their own cars, at low costs and in a short time. Such a solution has the potential to be replicated across other city routes, where tram tracks are embedded in the roadway, leading to loss of time for the passengers.

3.2.4 Bus Priority, the "Greenways Scheme" (Edinburgh, Scotland)

Edinburgh is the capital city of Scotland and its second most populated city. Its population is 487,500 (as of 2013). The city, despite having a metro system, has a *dende* bus network served by 110 bus lines. There are no integration forms with private transport, but Edinburgh has implemented a unitary fare system for different transport modes with an electronic ticketing system.

The problem of traffic congestion in Edinburgh has been acutely felt in the 1980s and 1990s, causing unacceptably high pedestrian accident rates, unpleasant conditions for pedestrians and cyclists, noise and pollution, pressure on parking space, higher business costs and a slower journey into work for many commuters. Increasing dependence on private cars has led to more congestion for public transport in a vicious circle which grinds down the public transport level of service for those without a car.

The "Greenways" scheme, along with other public transport initiatives, was introduced with the aim of restoring the balance of car use and public transport. The "Greenways" primary aim is to improve the reliability and speed of bus services. It aims to cut bus journey times by at least 10 % and thus to encourage more people to abandon the car in favour of the speedier and more reliable bus services. Key elements of the scheme include the establishment of new parking and loading bays, provision of more cycle lanes, more bus shelters and bus stop information or the installation of more pedestrian crossings and raised level crossings. In addition, an electronic detection system has been installed in the road surface at 25 traffic signals.

Before the implementation of these measures, buses were encountering fewer delays while using the extensive bus lanes, which are no longer blocked by illegal and dangerous parking. The eradication of delays should result in shorter journey times and a more reliable service. Improved facilities at bus stops, including new shelters and planned passenger information panels, are assisting both current and potential passengers.

Greenways are an example of a public transport service improvement, in combination with improved conditions for pedestrians and cyclists, at a comparatively low cost.

3.2.5 Speed Advisory Based on Signal Phase and Time (SPaT) Information

Therefore, there is a great potential for reducing the unnecessary stops at traffic lights, hence reducing fuel consumption and tailpipe emissions of PT vehicles by investing on Driver Advisory Systems (DAS).Current advisory systems guide the PT drivers towards more efficient and eco-friendly driving profiles and support the adherence to schedules by monitoring the progress along the route.

A new class of DAS systems is possible thanks to the access to signal phase and time (SPaT) real-time data. In SPaT-based DAS, drivers use signal control information to optimise their trip. Two SPaT-based DAS solutions are using Green Light Optimal Speed Advisory (GLOSA) and Green Light Optimal Dwell Time Advisory (GLODTA). The former facilitates the operations and the access through the signalised intersection by providing a vehicle with speed guidance, while the latter advices additional dwell time at the bus stop preceding the signals (near-side bus stop). For instance, the GLOSA system developed by Audi within Compass4D project receives SPaT data from city's central traffic server using cellular communications technology. Benefits of GLOSA are around 7 % in the average fuel consumption, 10 % in trip time, 90 % in the average stop time, and reductions in CO (80 %), NOx (35 %) and particulate matter emissions (18 %). GLOSA for buses was evaluated in the COSMO project, where it was shown that as soon as bus drivers follow speed recommendations in at least 50 % of signals, the average speed is increased, while fuel consumption and CO_2 emissions are reduced up to 20 %. The Dresden DVB tram north–south corridor is currently the most advanced implementation of a PT GLOSA.

The main objectives of GLOSA can be complemented with additional dwell time advisory (GLODTA), i.e., if a stop at the signals cannot be avoided uniquely by speed advisory, the potential waiting time at the signals is shifted to the near-side bus stop. The main advantages of the GLOSA and GLODTA are that while they improve bus performance with respect to traffic signals, unlike TSP, they are non-intrusive (i.e., do not modify signal timings). At the moment, these systems are being developed and implementations in practice are not available.

3.3 Intermodal Services Coordination and Interchange Facilities

An additional field of coordination is among different public transport modes and operators within the same mode, e.g., different bus operators in the same corridor or within the same city or region. These kinds of ITS developments are rather new, but they are providing rather good results. In many countries and cities, the travellers are no longer specific operator customers, but they are PT system customers.

They use flat-rate travelcards that allow them to use any means of transport within a geographical zone.

In this field, the most advanced level of service coordination happens in the interchanges or intermodal centres which serve as public transport hubs (Fig. 3.8). Therefore, ITS and ICT applications are a key element in the design of interchanges to assure good quality services.

By tracking the basic events taking place, it is possible to create a complete idea and collect up to date information of the activities in the interchange. These basic events (people walking, standing, lying, dropping, etc.) may lead, through the use of some intelligent knowledge-based systems, to the identification of more complex events such as people passing by or using the interchange for non-transport-related activities such as meeting points, how people use the waiting time (stay in the facility or exit it), how people might get lost at the terminal or need some assistance, either critical (medical, security, etc.) or non-critical (just needing some information). In addition, the professional users of the terminal may also take advantage of the technology for receiving complementary information of the status of current and future transport units (trains, buses, etc.) at the terminal (e.g., combining sensoring and advanced decision-making systems), instant information provided to drivers and operators (e.g., by means of the use of the communications embedded in Cooperative Systems, instant information of transport approaching and people flux for vendors, emergency situations for the security services, synchronisation of vehicles and units in time, etc.

Apart from the well-known vehicle-to-vehicle (V2V) and infrastructure-to-vehicle (I2V) communication systems, there are technology allowing new ways of cooperative models: Infrastructure-to-Users (I2U), where particular procedures need to be followed for providing local information of the terminal status and each independent user trip options and/or alternatives in case of incidents. This information can be easily accessible from smart terminals and phones through conventional communication links and data channels for providing advanced information-based ITS mobility services to travellers at the transport interchanges.

In order to facilitate intermodality between different modes of transport, numerous smartphone apps try to compile all public transport services aiming to

Fig. 3.8 Interchange station in which converge several public transport systems

supply valuable information to travellers. Other recent strategies are about to offer facilities to integrate bicycles (publics and privates) with all other modes of transport. Consistent with this type of ITS, the Municipality of Almada (Portugal) made available to the public a transport guide, with information of all modes of transport, as well as details of fare schemes, operating times and routes. In Sofia (Bulgaria), a Website was developed, with real-time information of public transport network, parking and cycling. There are also examples in public bicycles systems, as Call-a-Bike in Germany, in which bicycles can be integrated in a trip chain with public transport.

3.3.1 Integrated Public Transport Guide (Almada, Portugal)

Almada is located to the south of the city of Lisbon, bordering the Tagus River and its estuary, which lies between both cities. The city covers an area of 70.2 km^2, and its municipal population is 164,844 inhabitants (as of 2012). The existing public transport network in Almada consists of buses, trains, boats and a new tram line completely finalised on 2008. This network was slightly fragmented with gaps between certain origins and destinations. The introduction of the new tram in Almada significantly enhanced the public transport network, connecting existing bus, train and boat routes. To encourage and make it easier for people to use the new network, a detailed guide was developed containing the new routes, multi-modal links, timetables and fare information.

The Municipality of Almada and all public transport stakeholders were all jointly involved in the development of the new public transport guide, from its conception, design to final production. This included the main public transport operators, as well as other smaller operators.

The involvement of all public transport stakeholders allowed a coherent overview of all available transport modes, details of various fare schemes, operating times and routes to be included. It also included example routes, for various trip purposes, and contained travel times and different mode options for these trips.

The underlying philosophy for the guide's development was to produce a guide that was sufficiently detailed to provide users with the correct amount and most useful information to allow them to accurately plan their journeys, although, in a manageable form so as not to overburden them with information overload. An online version of the guide was also produced, containing the same practical information as well as an online route calculator (time, cost, etc.) and an interactive overview of pedestrian routes from the individual tram stations to local places of interest.

3.3.2 The Urban Mobility Website: Information About Public Transport on Site (Sofia, Bulgaria)

Sofia is the capital and largest city of Bulgaria. It occupies a strategic position at the centre of the Balkan Peninsula. The city has a population of around 1.25 million people (as of 2012). Public transport in Sofia is well-developed with bus (2380 km) network, metro (31 km of track), tram (308 km) network and trolleybus (193 km network). Despite the extensive offer of public transportation, car ownership has grown by 50 % since 2002.

Public Transport used to be the norm some time ago, but now many people use their cars, even in those cases where it may not be the most appropriate—especially during the rush hour. The urban structure of Sofia was not planned to deal with such a high level of traffic, and therefore, some solution had to be found to make sustainable travel planning easier.

The Sofia Urban Mobility Centre's Website was created exactly for this purpose. Inside one integral and easy-to-use interface, it provides real-time information relating to public transport, parking and cycling. This grouping of services also reflects the organisational responsibilities of the Sofia Urban Mobility Centre itself.

The use of public transport is made easier by an online timetable. Users can either search by route or station, or can use the interactive map, in which they can enter the start and finish points. All these are accompanied by detailed information about service schedules.

These interactive services are accompanied by lots of additional information, and Website users are encouraged to contribute or interact through the online discussion forums, or by telephone. The Website is also optimised for mobile devices, and in this way, all the travel information can be easily access through smart phones.

3.3.3 Call-a-Bike: Public Bicycles in Germany

Call-a-bike is a commercial public bicycle service that is offered by DB Rent, which is a subsidiary company of Deutsche Bahn (DB, German Rail). The service started in October 2001 in Munich. It has expanded to other German cities and is now available in Berlin, Cologne and Frankfurt. 4200 specially designed silver-red bicycles are available for rent in these cities from spring to fall (Fig. 3.9).

The scheme is designed for one-way trips. The bicycles are not bound to a rack but can be left at the nearest crossing in a defined core area, as they have a lock mechanism installed at the bicycles themselves. Therefore, they can be integrated in a trip chain with long distance rail or regional and urban public transport.

To obtain access to the Call-a-Bike service, users have to register once and need to provide their credit card information or give a direct debit authorisation. After

Fig. 3.9 Call-a-Bike public bicycle system in Germany

registration, the public bicycles can be unlocked by using a code that the user receives via cell phone. Call-a-Bike uses an advanced technology for the checkout and returning process of the bicycles. Registered users call by mobile phone a number that is displayed on the bike. They receive a four digit code which is entered on a touch screen to release the lock, integrated in the bike. At the destination, the traveller leaves the bicycle at a crossroad, locked to a fixed object and submits a return receipt code that appears on the display by mobile to DB Rent. The user has to provide also information about the location where he or she leaves the bike. The utilisation fee is charged on the user's credit card or automatically withdrawn from his/her bank account. Call-a-Bike is a so-called smart bike, which enables to track the user of the bike, which reduces the risk of theft.

Currently, the Call-a-Bike service is not financially self-sustaining. However, it is not the goal of DB to make a profit of the service. It is rather aimed at a break-even and at the attraction of rail customers that use the service in a trip chain. Bike sharing is therefore designed as complementary (*last-mile*) service for longer-distance trips where the main mode is train or bus. For the same reason, a similar service was recently established in the Netherlands (the *OV-fiets*).

In 2004, Call-a-Bike had approximately 71,000 clients in Germany (+40 % users compared to 2003), and around 380,000 trips had been made with the bicycles (+19 %). Main users tend to be morning commuters who extend public transportation trips with a bicycle. Bike services tend to peak on sunny days and weekends.

DB Rent is still expecting an increase in the number of Call-a-Bike users. A further expansion of the scheme to other large German cities is possible. The user group of multimodal travellers who are willing to combine different modes in a trip chain is growing.

3.3.4 Multimodal Travel Planners

Multimodal travel planners are front-end–back-end computer systems which provide travellers the best itinerary, according to several parameters characterising and affecting an intermodal passenger transport journey. These systems usually supply timetable, routing and other travel information, as the best mode choice or traffic incidents. Several data are required, as the system needs to know about public transport services, transportation networks and private transportation.

Multimodal travel planners provide better modal integration and more sustainability by enabling travellers to select the most suitable combination of transport modes for the journey and could lead to an increase use of public transport, cycling or walking in urban environment. In case of congestion events, travellers can receive accurate information of alternative routes, allowing better use of existing transport infrastructure.

Currently, the European Union calls for better multimodal travel planning solutions. Simultaneously to the 10th European ITS Congress in Helsinki, the European Commission released the analysis on the state of the art of multimodal travel planners and plans for the way forward. The Commission Staff Working Document towards a roadmap for delivering EU-wide multimodal travel information, planning and ticketing services identifies the major challenges to overcome to create a framework supporting more comprehensive services. It also presents the advantages of multimodal travel information and planning services, before the document suggests an integrated approach in the coming years. The intention is to establish a framework for EU-wide multimodal transport information and respond to the need for further integration of the different modes of transport to make mobility more efficient and user-friendly.

Examples of multimodal travel planners currently being used in Europe are “Resrobot” in Sweden, “SITkol” in Poland, “DELFI” in Germany, “SCOTTY” in Austria, “TransPOR” in Portugal, “INFOTEC” in Belgium, “BilRejseplanen” in Denmark or “Rutebok” in Norway.

3.4 Ticketing

One of the most deterrent factors for the use of public transport is the need of different tickets for different transport means. Integrated ticketing is therefore a key issue for the use of public transport and acceptance of intermodality. It leads to the overall increase of the public transport system usage and better use of intermodality and interchange points. Electronic payment results are extremely important for making the system easy to use and to foster intermodality (Fig. 3.10). ICTs new Near field communication (NFC) protocols provide contactless payment systems for all transport modes incorporated to the platform and even to other services in the city, such as parking and citizens’ services.

Fig. 3.10 Payment process by smart card

These intelligent payment cards are also very convenient for designing different price schemes: special groups (elderly, children, etc.), different times of the day (peak, off-peak) or intermodal services avoiding the penalty of transferring to other mode.

They provide useful information for transport managers and planners, in such flexible way that could be specific for one line, or stop, or type of persons, or for the whole network. Thus, it is possible to avoid survey costs or counting of number of passengers using time-consuming and labour-intensive data collection methods.

At the present time, transport authorities are immersed in a process of renewal of existing ticket validation systems, in which they opt for new contactless payment systems. In this direction, Norwich (UK), Brescia (Italy) and Lisbon (Portugal) have strived to upgrade the e-ticketing system to a new modern one, which has better positive impacts on travellers. Barcelona (Spain), on the other hand, is an exemplary case in the fare integration of several titles and different modes of transport. These advances in fare integration and new ticket validation systems imply improvement of the public transportation system.

3.4.1 On-Street Ticket Vending Machines (Norwich, UK)

Norwich is the regional administrative centre and county town of Norfolk. The built-up area of Norwich had a population of 213,166 (as of 2011). This area extends beyond the city boundary, with extensive suburban areas on the western, northern and eastern sides.

Bus services in the city area operate via the radial road network to and from the city centre. For orbital trips, it is necessary to change services in the city centre, although a few services do provide through-city links. The rail network, even

Fig. 3.11 Ticket vending machine in Norwich

though being considered a mode for long journeys, it can be used for local trips, as there are some stations in Norwich.

Traditionally, the majority of passengers using bus services in Norwich and many other UK cities have purchased their ticket from the driver on boarding. This project is innovative in delivering a comprehensive solution for roadside bus ticket sales suitable for the deregulated environment applicable in the UK outside London. Roadside ticket vending machines (TVMs) have networked communications links to remote monitoring and revenue management systems and enable customers to choose between different operators and tariffs when buying a ticket. Sixteen TVMs are installed at different locations including Norwich Bus Station, Norwich Railway Station and Castle Meadow. Servers for remote monitoring and revenue management systems are located at County Hall (Fig. 3.11).

Initial findings indicate that dwell times at bus stops have decreased due to the contribution of the ticket machines. The machines have generally performed reliably, and the use of them has increased steadily since they were installed.

3.4.2 Development and Upgrade of the E-Ticketing System (Brescia, Italy)

Brescia is a city and municipality in the region of Lombardy, in northern Italy. It is situated near the Alps, with a population of around 194,000 inhabitants (as of 2014). The public transport system in the city includes metro and buses. There are bus routes through all of the main streets. The Brescia Metro is a rapid transit network that opened on 2 March 2013. The network comprises one line, 13.7 km long, with 17 stations between, of which 13 are underground.

Intermodality in the urban area of Brescia was only for suburban travel involving the train station and the main stations of the suburban bus stops, before the development of the measure. Fare integration between the various companies was possible only for students of the suburban area in possession of integrated passes.

The main goal of this project was the introduction of a new contactless card integrating various transport systems in terms of technology and fares. This was intended to encourage the use of collective systems such as local PT, bike sharing, car sharing and the future Metro, and thus enhance Park & Rides.

First of all, research and development activities were carried out in order to design the technical features that would characterise the new e-ticketing system. The second phase began after the new cards were purchased. This involved scheduling the validation test for the software and the analysis of its integration with NFC technology.

The integration of functional services was realised from a technical point of view in a "virtual" way. In order to manage the card and maintain the assets of the existing technology systems, thus limiting investments and development time, the original technologies of each system were implemented and improved.

3.4.3 The Viva Smart Card System (Lisbon, Portugal)

Lisbon is the capital and the largest city of Portugal. The city lies in the western Iberian Peninsula on the Atlantic Ocean and the River Tagus and has a population of 547,631 (as of 2011) within its administrative limits on a land area of 84.8 km^2. Lisbon's public transport network includes metro as its main artery, connecting the city centre with the upper and eastern districts, and reaching the suburbs. Bus, funicular and tram services have been supplied by the Companhia de Carris de Ferro de Lisboa (Carris), for over a century.

At the end of 2001, the *Metropolitano de Lisboa* installed a new ticketing and access control system to the city's metro network. The change was from an open access system to a closed one with control lines and access channels equipped with doors. The doors are commanded by the reading and validation of data stored in tickets. This new access system required a major change in the ticketing system, involving the introduction of magnetic tickets and the contactless card—"Lisboa Viva", which replaces the traditional pass and is intended mainly for regular public transport users in the Lisbon region (Fig. 3.12).

The Lisboa Viva card has an embedded chip and antenna which works by holding the card over a validator, located at entrances of a station. The validator reads and validates the data loaded in the chip and, provided the card is valid, enables access to the networks—presently the Metro and Carris networks. The procedure used for entering the system is the same used to leave the system. The card allows the loading of fares exclusive to each associated operator, multimodal fares and combined fares. The 7 Colinas card is also based on contactless technology, intended to be loaded with multimodal tickets for urban and suburban trips in the Carris and Metro networks.

Since the introduction of the Lisbon Smart Card, the gate access provides greater security and revenue protection, the ticketing is faster, and there is a better knowledge of origin-destination flows within the underground network. In addition,

Fig. 3.12 The Lisbon Smart Card

systematic data collection is possible regarding entrance points of the bus network, so as the Smart Card provides non-frequent users an integrated ticketing system between bus and metro.

3.4.4 The Use of Ticket Validation for Transit Planning Purposes (Barcelona, Spain)

Barcelona is the second largest city in Spain and the largest metropolis on the Mediterranean Sea, located on the coast between the rivers Llobregat and Besòs. The city has a population of 1.6 million (as of 2012) inhabitants within its administrative limits on a land area of 100 km^2. Beyond its urban area, the metropolitan region congregates 5 million inhabitants on a land area of 3240 km^2.

The public transport network includes metropolitan and urban buses, metro, local trains and a tram network (since 2004). There are different operators, which manage these services (Transports Metropolitans de Barcelona, Ferrocarrils de la Generalitat de Catalunya, Renfe and Tramvia Metropolità). Metropolitan Transport Authority (ATM) is an interadministration partnership between administrations with transport service rights, created to coordinate public transport within the Barcelona Metropolitan Region, with the support of the Government of Catalonia and local administrations. Some of its missions consist of coordinating the services offered by public and private operators, taking responsibility of the fare policy, finance the system by the various administrations and execution of infrastructure projects. In this sense, ATM performed in 2001 a fare and ticket integration among the entire metropolitan region. To make it possible, the region was divided into zones on the basis of geographical rings (6 concentric bands), as shown in Fig. 3.13. All transport tickets form part of the system, and the ATM is responsible for pricing. The price is based on the number of zones through which a passenger passes, and it is related with the trip frequency and length. The maximum number of zones to be paid is 6, and transfers are not penalised.

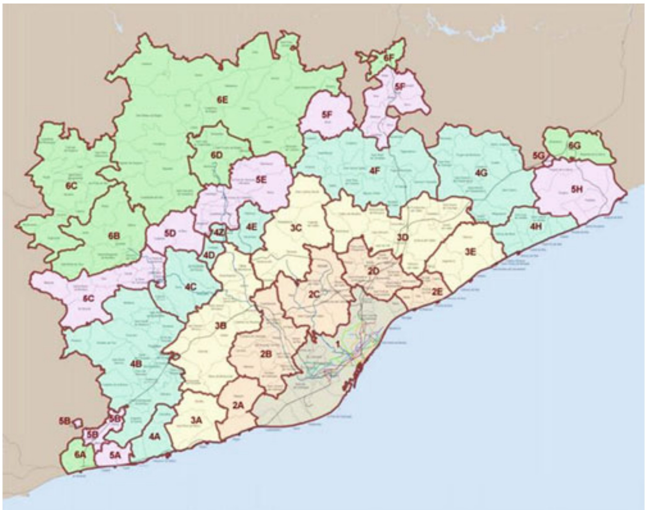

Fig. 3.13 Zoning of the Barcelona faring system

All this information about ticket validations must be treated to further compensate transport operators. Thus, a daily transmission of all validations made in the transport system is carried out in the integrated fare management system. The main problem occurs when a traveller takes a multimodal trip. To solve this issue and to reconstruct the different stages of each trip, a monitoring bit is activated. This is a code that identifies the card, and when this is validated, it leaves a "trail" in the different validating machines and allows to establish the distribution of revenue among the transport operators.

3.4.5 *Using Ticketing Data for Improving Transit Planning and Scheduling Services*

Commuters tend towards more flexible work scheduling, as telecommuting is more and more spread in working environments. Transit agencies should determine whether routes can benefit from weekday exceptions. The impact of exception schedules on ridership was assessed by the automated fare collection data, which revealed a lower ridership on Fridays (by 4.7 %) which allowed a 7.4 % reduction in vehicle hours operated. The processed data gives hourly ridership (boardings) as the annual 85 %-tile and the proportion of the deviation from average weekdays. The assessment of service change is based on service frequency (min and buses/h), operation (pass/bus, utilisation ratio, veh-hours changed) and crewing impacts (assigned operators per day).

Other observations also rely on automated data collection. The case of London Overground network investigates the passenger incidence behaviour with respect to published timetables. Such timetables could be modified in real time, and thus, the passenger incidence could be estimated as a relative frequency of passenger incidences over normalised incidence headway of services.

The impact of holding strategies on level of service and transit performance is analysed based on AVL data, which inform driver and may lead to a next time point where the bus may be held. Measures of effectiveness include average waiting and standing time per passenger, % of bunching, average holding time and delay per bus. Automatic vehicle location (AVL), automatic passenger counting (APC) and automatic fare collection systems are also used to assess transit system performance and reliability, estimate dwell time and estimate passenger waiting times as related to service reliability.

3.5 Real-Time Information Services

Most of the previous applications rely on the exploitation of ICT and ITS services for improving the planning, management and operation of PT services. ITS real-time data can be also used to improve the information offered to the service stakeholders, for instance:

- Information to travellers throughout the total journey, in the trip planning phase and during the trip especially at the interchange points (Fig. 3.14).
- Online integrated information given at the interchange points including incident information.
- Dialogue between information systems of various operators. For the traveller integrated information should appear on the screens in the vehicles, stops and terminals as well as available through mobile equipment (Fig. 3.15).
- Ticket purchasing systems, especially smartphone-based solutions.

Fig. 3.14 Real-time information panel at a bus stop

Fig. 3.15 Real-time smartphone app

- Emergency and daily incident information concerning all players involved, demanding immediate action from the responsible bodies, all operators and guidance and management of the passengers and other customers.

ITS technology allows users to better react to possible incidents or delays in the PT system. Generally, in large cities, bus stops or stations already have screens with real-time information. This type of ITS is spreading to other smaller cities, which contributes to improve the quality of public transportation system. In recent years, this technology tries to position itself even closer to the users through new formats. In this sense, the more requested format is via smartphones, followed by household computers, attending to the fact that this real-time information should be accessible at any time. The current trend shows that transport authorities make all existing data on public transport available to the general public, especially developers, so they can program their own applications (e.g., Moovit, described in Sect. 3.5.4).

Other authorities, however, argue for developing their particular applications (case of London, UK). In the first case, it is necessary to keep in mind that potential developers are equally users of the service, so it has the added value that they can contribute with new ideas and features.

3.5.1 Real-Time Countdown System (London, UK)

London is the capital city of England and the UK. It is the most populated city in the UK with a metropolitan area of over 13 million inhabitants (as of 2013). The city transportation system is famous for its red buses. Approximately 8500 of these iconic red buses carry more than 6 million passengers each weekday on a network serving all parts of Greater London. The service was previously served by a fixed-time bus information system called Countdown. In October 2011, Transport for London (TfL) introduced its new Countdown service, providing real-time bus information for all 19,000 of London's bus stops. It is the largest real-time bus information system in the world. This information is available via the Internet, smartphones and by text message. In addition, 2500 new-generation bus stop displays are being installed replacing old signs. Via the internet on a computer or smartphone, the new system can provide not only live bus arrival times but service disruption information and links to London Underground service updates.

Bus stops can be searched for by route number, street name, postal code or via a map. Users can save their five most used stops. The smartphone mobile Web service is available to all mobile phones with the Internet connection without the need to download an app. To use the text message service, passengers text a bus stop code (displayed on each bus stop or available from the TfL Website) to TfL to receive live information for that stop.

New Countdown signs at bus stops comply with the latest disability guidelines. They use amber LED displays with a black background. Live information is transmitted using TfL's state of the art AVL, radio and on-bus passenger information display and announcement system known as iBus, which is installed on all its buses. This reduces operational costs and allows signs to be sited in places where the current system could not be used and makes Countdown predictions more accurate.

A new communication network to the Countdown signs has resulted in more reliable transfer of bus information, leading to greater accuracy and improved availability of information. Predictions are now 95 % accurate. Operational costs have been reduced, with communication costs now up to only 20 % of the previous level.

3.5.2 Real-Time Passenger Information at Bus Stops (Lille Métropole, France)

Lille is a city in the north of France, the fourth-largest metropolitan area in France after Paris, Lyon and Marseille. Lille is situated in French Flanders, near France's border with Belgium and has a population of 226,827 (as of 2009). The Lille Métropole has a mixed mode public transport system, which is considered one of the most modern in the whole of France. It comprises buses, trams and a driverless metro system, all of which are operated under the Transpole name. The metro system has two lines, with a total length of 45 km and 60 stations. The tram system consists of two interurban tram lines, connecting central Lille to the nearby communities of Roubaix and Tourcoing, and has 45 stops. 68 urban bus routes cover the metropolis, 8 of which reach into Belgium.

The municipality intended to install some screens to improve the real-time information in the public transport system (Hubacher 2012). The first information screens installed in 2003 ran on a battery with a lifetime of 6 months. The screens did not have a sound function, and the font size was quite small, making them inappropriate for use by people with visual and hearing impairments. It was also important to increase the number of screens at bus stops as part of the development of a high-quality bus service. The technology had to be improved, particularly in relation to the battery and the accessibility of the displays.

In 2008, a new call for tender was written with the help of Transpole, the Lille Métropole operator. The industrial company Serelec was the chosen candidate because the technology it had developed matched the goal of implementing more efficient screens. The new screens were installed in 2009 and 2010. The batteries of the new screens are charged at night through public lighting. They have an acoustic support, and the size of the font is bigger and more visible. The new screens are more efficient than the previous ones, and the supervisory control enables the daily operating of the screens to be monitored.

3.5.3 VAO, Traffic Information Austria

The mission of Traffic Information Austria (VAO) is to create information service for all of Austria with consistently high quality that covers all traffic developments (for cyclists, pedestrians, public transport, motor vehicles and Park&Ride).

By highlighting alternatives, the options available to switch to more environmentally friendly means of transport become attractive and greater awareness is ensured. According to the results of the research project ITSworks, the potential for shifting traffic from the car to more environmentally friendly modes ranges up to six percentage points.

VAO can be made available directly, but it can also be used as basis for the project partners' traffic information services. What results is a milestone in data quality and comprehensive information. But the administration, too, is given completely new options in active traffic control and management and in the provision of up-to-the-minute information relating to ongoing traffic developments.

Within VAO II, the project Traffic Information Austria will be further improved: additional data will be collected; detection of traffic data and real-time data will be optimised; and new mobility services (sharing concepts) will be integrated. Usability and performance of end-user services will also be optimised. VAO II cooperates closely with numerous projects such as GIP.at, GIP.gv.at, FCD-model region Salzburg or Testfeld-Telematik.

3.5.4 Two-Way ICT Communications Through Crowdsourcing Data Collection

New generation of personal travel planners is one step beyond real-time information systems. Both of them are usually based on crowdsourcing and open data. However, in contradistinction to the latter, new personal travel planners supply information bidirectionally. In other words, passengers do not only receive real-time information, as they interact with the system providing new data from the passenger side, making it possible to enhance the available information. In this sense, for example, the procedure to calculate the arrival time of a bus to a certain stop is not only based on its GPS coordinates, but also on other users that are travelling in the same route.

These systems are rather new, as they combine existing applications which provides real-time information in one direction (operator–passenger) and social media. They allow to choose the easiest or quickest route as desired by the user and supply information on schedules and last minute incidents. The new social function provides data to other users and operators as well. By this way, users can transmit anonymously their location and vehicle speed when they travel. It is also possible to participle by qualifying drivers, the cleaning of vehicles and the routes according to their experience in their daily commute.

Besides the above, another interesting characterising is that it is allowed to perform campaigns for data collection, obtaining valuable information. This function permits to evaluate as a whole the public transport system or know the opinion of users to specific events (incident management, evaluation of service in peak and off-peak hours.)

One of the most popular applications in this field is Moovit, which supports 41 countries and 400 cities. Another well-known example is OpenTripPlanner, which is also offering its service worldwide.

Moovit uses crowdsourced information to provide real-time transit information for passengers. Since the company began its slow roll-out in January 2012, Moovit's core goal is to enable users to find real-time data about their public transit, finding quicker routes and sussing out the peculiarities of cities' transport routes. The application has the following characteristics:

- Live map: The application gives the user the possibility to view nearby transit stops on a live map, to see lines that stop in the surroundings and check upcoming arrival times.
- Plan a trip: This feature allows to compare different trips from A to B anywhere in a city and select the most efficient and convenient route.
- Navigate the city: Moovit gives step-by-step directions guide to the final destination, including walking segments and transit transfers. This is combined with ride mode, which permits the user to get dynamic estimated time of arrival (ETA) to its destination.

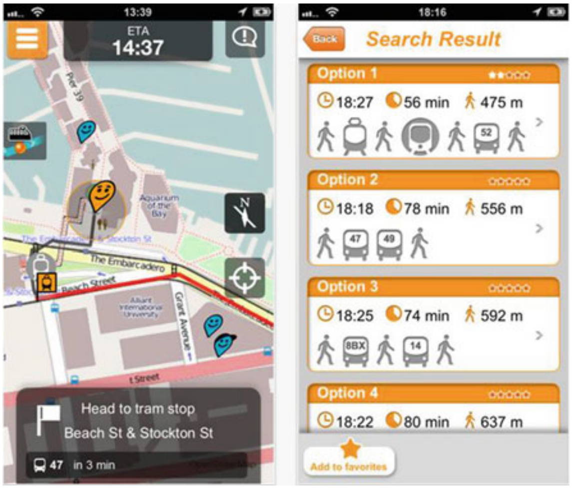

Fig. 3.16 Moovit interface

- Favourites: This characteristic customises usual locations (home, work, etc.) and lines for quick and easy access.
- Service alerts: Users can get personalised alerts and updates on service changes, route alterations or station closures.

Besides these features, users can interact with each other. As shown in Fig. 3.16, it is possible to qualify routes in terms of punctuality, travel time, driver's behaviour and many others. This two ways ICT communication is gaining ground over simple real-time information applications, as it offers more accurate real-time information, based on users' real-time experiences.

3.6 Development and Maturity Level of ITS in Europe

In previous sections, a descriptive review on ITS types and case studies across Europe was carried out. Building on these, the objective of this section is to investigate the degree of policy integration of ITS for public transport in Europe. Indeed, at a focus group held in 2010 by the FP7 CONDUITS project (2009–2011) and featuring representatives from 16 European cities, changing the modal split in favour of public transport was identified as a key priority of nearly all city authorities, with ITS playing an important role (Zavitsas et al. 2010). In fact, ITS were identified as offering potential solutions to many of the cities' problems, with the vast majority of the cities having implemented ITS technologies in terms of providing information to the public and facilitating public transport, alongside road traffic management, or planning to do so in the near future.

The present section, therefore, goes into more detail with regard to analysing the level of maturity of the available ITS applications in Europe and the extent to which these are integrated in public transport policy making and decision making. This is achieved by means of two survey exercises: the first one has been carried out as part of the FP7 CONDUITS project, and its objective is to provide a broad overview of the state of deployment of public transport ITS in Europe using data collected from 33 cities directly with the help of a purpose-developed questionnaire; and the second one has been conducted as part of COST Action TU1004, where a subset of five cities are looked at in more detail.

3.6.1 Broad Overview of the State of Public Transport ITS Deployment in Europe

Within the FP7 CONDUITS project, a questionnaire aiming at collecting detailed data and feedback from cities on a series of best practices in order to create an extended database on public transport ITS policies and technologies implemented has been developed in 2010 (Zavitsas et al. 2010; Bell et al. 2012). The questionnaire covers several areas, such as general statistics of the transport systems, organisational structures, monitoring and forecasting, provision of information and demand management. It has been attempted to identify a group of about 50 key cities who would complete the questionnaire, and cities were chosen from thorough research in the literature and were based on the recommendations of experts, interviewed using the well-known Delphi Method (Linstone and Turrof 1975). The final result offers a diverse group, in which not only European metropolises are included (such as Paris, London, Rome, Istanbul and Athens), but also cities known for their virtuous attitude towards innovative transport systems (such as Trondheim, Karlsruhe and Turin), as well as medium-sized cities (Southampton and Stuttgart) and emerging realities (Kocaeli, Haifa, Funchal). The overall response comprises completed questionnaires from a total of 33 cities, which are shown on the map of Fig. 3.17.

The cities that have participated in the survey range from small towns to large metropolises (Table 3.1): towards the lower end, the sample includes the cities of Funchal and Trondheim, with populations of less than 200,000, while towards the upper end, Istanbul has over 12 million inhabitants. In terms of modal split, the average private transport share is slightly lower than 50 %, while the share of public transport ranges from 10 % in Trondheim to more than 40 % in Prague and Zurich. It can also be noted that the Turkish cities of Istanbul and Kocaeli have a large share of walking, though this is not the case for Ankara. No observable patterns can be identified for cycling, with high shares of cycling occurring in cities of varying sizes.

As can be further seen in Table 3.1, most cities of the sample (24 out of 33) have a concrete and concise 10–20 year strategic plan in place, while another seven state that they “may have one in the next five years”. By reviewing the strategic plans, it can be noticed that some of the main future concerns of cities regard safety,

Fig. 3.17 CONDUITS study participating cities (Bell et al. 2012)

Table 3.1 Key characteristics of the CONDUITS participating cities (Bell et al. 2012)

City	Metropolitan population	Modal split (%)				Strategic plan	ITS architecture
		Private trans.	Public trans.	Walk/cycle	Other		
Ankara	3,890,000	N/A				Yes	No
Athens	3,840,000	54	37	9	0	Yes	Yes
Barcelona	4,930,000	16	33	51	0	Yes	Yes
Berlin	5,970,000	38	27	35	0	Yes	Yes
Bologna	920,000	39	26	28	7	Yes	Yes
Brescia	190,000	N/A				Yes	Yes
Brussels	3,000,000	56	15	26	3	Yes	Yes
Bursa	1,820,000	N/A				Next 5 years	Yes
Edinburgh	470,000	55	20	21	4	No	Yes
Frankfurt	5,500,000	39	23	38	0	Next 5 years	Yes
Funchal	100,000	52	31	17	0	Next 5 years	Yes
Haifa	1,020,000	57	15	18	10	Next 5 years	Yes

(continued)

Table 3.1 (continued)

City	Metropolitan population	Modal split (%)				Strategic plan	ITS architecture
		Private trans.	Public trans.	Walk/cycle	Other		
Istanbul	12,600,000	24	14	49	13	Yes	Next 5 years
Karlsruhe	1,500,000	44	18	38	0	Yes	Next 5 years
Kayseri	900,000	N/A				Yes	No
Kocaeli	890,000	26	33	41	0	Next 5 years	Next 5 years
London	7,570,000	38	38	23	1	Yes	Yes
Milan	3,080,000	52	36	12	0	Yes	Yes
Munich	2,600,000	37	21	42	0	Yes	Yes
Paris	11,600,000	15	29	56	0	Next 5 years	Next 5 years
Prague	1,490,000	33	43	24	0	Yes	N/A
Rome	4,200,000	66	28	6	0	Yes	Yes
Sheffield	1,200,000	54	28	9	9	Yes	Yes
Southampton	230,000	N/A				No	Yes
Stockholm	1,980,000	46	28	26	0	Yes	Yes
Stuttgart	2,700,000	N/A				Next 5 years	Yes
Tel Aviv	3,150,000	51	23	19	7	Yes	Yes
The Hague	1,000,000	56	27	17	0	Yes	Next 5 years
Thessaloniki	800,000	72	22	2	4	Yes	Yes
Trondheim	170,000	58	11	31	0	Yes	Yes
Turin	N/A	56	15	28	1	Yes	Yes
Vienna	3,000,000	34	35	31	0	Yes	N/A
Zurich	1,080,000	36	48	16	0	Yes	Yes

sustainability, efficiency, pollution and reliability. Most cities' strategic plans analyse the objectives, though some focus only on the cities' targets. For example, Brussels has set a concrete target of reducing car traffic by 20 % in terms of vehicle-km, while The Hague has the broader objective of promoting sustainable transport modes. Additionally, several cities stress in their strategic plans the need for more efficient management through the application of ITS.

Many cities already have or are developing public-transport-oriented systems, in order to realise their long-term target that aims at a modal shift from private to public means. Looking at the infrastructure present in the sample (Table 3.2), the bus is clearly the most common public transport means, present in all 33 cities, though with differing network sizes in terms of total length and number of lines,

Table 3.2 Public transport and ITS infrastructure in the CONDUITS participating cities (Bell et al. 2012)

City	Public transport system			Features			
	Bus	Tram	Metro	Priority measures	Integration forms	Unitary fares	Electronic ticketing
Ankara	Yes	Yes	Yes	No	No	No	No
Athens	Yes	Yes	Yes	Yes	No	Yes	In 5 years
Barcelona	Yes	Yes	Yes	Yes	Yes	Yes	No
Berlin	Yes	Yes	Yes	Yes	No	Yes	In 5 years
Bologna	Yes	No	No	Yes	Yes	No	No
Brescia	Yes	No	No	Yes	Yes	Yes	No
Brussels	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bursa	Yes	No	Yes	No	Yes	No	No
Edinburgh	Yes	No	No	Yes	No	Yes	Yes
Frankfurt	Yes	Yes	Yes	Yes	No	No	Yes
Funchal	Yes	No	No	Yes	No	No	No
Haifa	Yes	No	Yes	Yes	No	In 5 years	No
Istanbul	Yes	Yes	Yes	Yes	No	Yes	In 5 years
Karlsruhe	Yes	Yes	Yes	Yes	Yes	Yes	In 5 years
Kayseri	Yes	No	No	Yes	Yes	Yes	Yes
Kocaeli	Yes	Yes	No	Yes	Yes	Yes	In 5 years
London	Yes	Yes	Yes	Yes	Yes	No	Yes
Milan	Yes	Yes	Yes	Yes	Yes	No	Yes
Munich	Yes	Yes	Yes	Yes	No	Yes	No
Paris	Yes	Yes	Yes	Yes	No	No	No
Prague	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Rome	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sheffield	Yes	Yes	No	Yes	No	No	In 5 years
Southampton	Yes	No	No	Yes	No	No	No
Stockholm	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Stuttgart	Yes	Yes	Yes	Yes	No	No	Yes
Tel Aviv	Yes	In 5 years	No	Yes	Yes	No	No
The Hague	Yes	Yes	No	Yes	Yes	Yes	Yes
Thessaloniki	Yes	No	In 5 years	Yes	Yes	No	Yes
Trondheim	Yes	Yes	No	Yes	No	Yes	No
Turin	Yes	Yes	Yes	Yes	No	Yes	No
Vienna	Yes	Yes	Yes	Yes	No	Yes	Yes
Zurich	Yes	Yes	No	Yes	No	Yes	In 5 years

ranging from 150 km in The Hague and 175 km in Zurich to 9300 km in London, and from 18 lines in Brescia to 683 lines in London. It can also be observed that cities of similar size can have considerably different bus network lengths, depending on the presence of other public transport modes in the city; for example, Bologna, Haifa, The Hague and Zurich all have populations of around 1 million, but the lengths of their bus networks are 464, 2140, 150 and 175 km, respectively, possibly due to the fact that in the former two buses are the sole transport means available, while the latter two also have extensive tram networks. Specifically on light rail/tram systems, these are very common (present in 23 of the 33 cities), again with varying network size. This ranges from less than 10 km in Trondheim and Ankara to as much as 530 km in Barcelona. Noteworthy examples are Prague's and Zurich's very dense tram networks (over 100 km of track served by up to 34 lines), which can be attributed to the fact that both these cities have tram-oriented public transport systems, as opposed to most other cities in the sample, which are rather bus-oriented. Finally, out of the 33 cities, 20 have metro networks, which due to the high construction and operational costs are naturally much less extensive than bus and tram networks. Almost all cities of the sample with over 1.5 million inhabitants have metro systems, with the exception of Kayseri, Kocaeli and Tel Aviv. Metro network lengths range from 5 km in Haifa to 402 km in London, while Paris has the network with the most lines (16).

An important element of road-based public transport infrastructure is the provision of priority measures and systems. The most widely used public transport priority measure is the use of bus lanes, present in 30 cities (all except Ankara, Bursa and Karlsruhe), whose aim is to improve the reliability of bus schedules. Systems granting priority at traffic signals to buses and trams over private transport are also in place in most cities of the sample (26). Regarding the underlying detection methods of the priority systems, the most common are loop detection and dedicated signals, used in 16 and 11 cities, respectively.

Besides the infrastructure itself, integration schemes with other modes are an additional important component of a public transport system. These can be classified as "traditional", which include schemes such as car pooling and car sharing, or as "dynamic", which include integrated public transport and feeder services. In the sample used in this study, 16 out of the 33 cities have integration forms with private transport. Finally, unitary fare systems for different transport modes and electronic ticketing are very common methods to simplify and encourage the use of public transport. Unitary fare systems exist in 19 cities. Electronic ticketing, on the other hand, is less widespread, with actual implementations having been deployed in 13 cities (e.g., London's "Oyster" card), but with another 7 planning to introduce it in the next five years.

Twenty-three out of the sample's 33 cities have also provided information as to their current and future uses of ITS in public transport demand management. As such, it is found that 15 cities use ITS for the purposes of improving access to public transport, such as journey planning software and real-time information on expected times of arrival, and 3 more intend to join them in doing so in the near future. On the other hand, few cities (5) make use of ITS for the management of pedestrians and cyclists (e.g., during big events). Looking at the situation of traveller information provision, almost all cities provide information to the public. The types of information provided, though, as well as the methods of dissemination vary. Most cities (30 out of 33) provide information about planned events in public transport. Less common, but definitely of importance, seems to be the supply of alternative routes to public transport users, which is done in 19 cities. 17 cities even go as far as suggesting walking and cycling routes to road users, as an attempt to promote these two sustainable travel modes, while 10 cities also provide travel-related weather forecasts. Finally, considering the methods used to inform the public, most cities have a Website with traveller information in place, with 32 cities out of the sample's 33 doing so. Many cities use television and radio broadcasts to disseminate traveller information (25 out of the 33), as well as information boards which are used in 24 cities. Sixteen cities have a telephone line for traveller information, while 6 cities also use mobile phones, either in the form of SMS text messages, or through smartphone apps.

3.6.2 More Detailed Insight of Public Transport ITS Deployment in Selected European Cities

This aim of this second study is to investigate the state of deployment of public transport ITS in more detail for a smaller number of selected cities. For this purpose, an ad hoc survey has been designed as part of COST Action TU1004 in 2010 to assess the degree of maturity of public transport ITS in five selected European cities in relation to objective indicators, such as population and GDP per capita. The survey looks into the provision of public transport ITS applications in the five cities in more depth and more specifically: the number/percentage of stations/stops equipped with real-time information boards and/or covered by systems disseminating traveller information through mobile phones; and the number/percentage of public transport vehicles equipped with real-time information tools, such as AVL and APC systems.

The five cities selected are Barcelona, Madrid, Stockholm, Thessaloniki and Edinburgh, offering an adequately diverse sample in terms of population, with larger (e.g., Madrid) and smaller (e.g., Edinburgh) cities; wealth, with cities with higher (e.g., Stockholm, €34,500/inhabitant) and lower (Thessaloniki, €19,000/inhabitant) GDP per capita; car ownership, with cities with higher (e.g., Madrid, with 457 vehicles/1000 inhabitants) and lower (e.g., Edinburgh, with 310 vehicles/1000 inhabitants) car ownership rates; public transport usage, with cities with higher (e.g., Madrid, 38 %) and lower (e.g., Edinburgh, 20 %) public transport modal split shares; and soft mode travel, with cities with higher (e.g., Barcelona, 52 %) and lower (e.g., Thessaloniki, 2 %) walking and cycling modal split shares.

Regarding the state of deployment of public transport ITS applications in the five cities, Barcelona has installed real-time passenger information panels at all urban track-based public transport stops (metro and light rail), but only at half of the suburban rail stations and only at a subset of the road-based public transport stops (9 % of the metropolitan bus stops and 4 % of the urban bus stops). Trip planning for all public transport modes is available, but there is no intermodal transport management of public transport ITS applications. In comparison, Madrid has installed real-time passenger information panels in the vast majority of the track-based public transport stops/stations and also offers trip planning. Intermodal transport management of urban buses, metro, light rail and suburban rail is carried out under an integrated system of public transport ITS applications, and e-ticketing is provided in all urban buses, metro and suburban rail, in half of the metropolitan buses and in a quarter of the light rail fleet. Video surveillance is also available in the metro and the suburban rail network. The public transport ITS applications in Barcelona and Madrid are shown in Table 3.3.

Looking at public transport ITS applications in Stockholm, Thessaloniki and Edinburgh (Table 3.4), metropolitan and urban buses in Stockholm are equipped with real-time information devices and AVL. Also, all stations/stops are covered with mobile phone traveller information systems, but only 10 % of urban bus stops are equipped with real-time information panels. APC systems are also in place in small parts of Stockholm's both road-based and track-based public transport networks. On the other hand, Thessaloniki and Edinburgh appear to have a lower deployment level of ITS applications in their entirely road-based public transport

Table 3.3 ITS applications in public transport in Barcelona and Madrid

ITS applications	Units	City	Metro bus	Urban bus	Metro	Light rail	Suburban rail
Number of intersections with traffic light priority	Units	Barcelona	0	0	All	85	All
		Madrid	0	0	All	2	All
Real-time information to travellers	Yes/No	Barcelona	N/A	N/A	N/A	N/A	N/A
		Madrid	No	Yes	Yes	Yes	Yes
Number of public transport stops with real-time information	%	Barcelona	9	4	100	100	50
		Madrid	9	8	100	93	70
Automatic vehicle location (AVL)	% fleet	Barcelona	95	98	N/A	N/A	N/A
		Madrid	0	100	N/A	N/A	N/A
Trip planning	Yes/No	Barcelona	Yes	Yes	Yes	Yes	Yes
		Madrid	Yes	Yes	Yes	Yes	Yes
Intermodal transport management	Yes/No	Barcelona	No	No	No	No	No
		Madrid	No	Yes	Yes	Yes	Yes
E-ticketing	% fleet	Barcelona	0	0	0	0	0
		Madrid	50	100	100	25	100
Video surveillance in the public transportation system	Yes/No	Barcelona	N/A	N/A	N/A	N/A	N/A
		Madrid	No	No	Yes	No	Yes

Table 3.4 ITS applications in public transport in Stockholm, Thessaloniki and Edinburgh

ITS applications	Units	City	Metro bus	Urban bus	Metro	Light rail	Suburban rail
Stations/stops equipped with real-time information devices	%	Stockholm	70	10	100	50	100
		Thessaloniki	N/A	10	–	–	–
		Edinburgh	15		–	–	–
Stations/stops covered with SMS/mobile information systems	%	Stockholm	100	100	100	100	100
		Thessaloniki	55	100	–	–	–
		Edinburgh	100		–	–	–
Vehicles equipped with real-time information devices	%	Stockholm	100	100	0	0	0
		Thessaloniki	N/A	100	–	–	–
		Edinburgh	100		–	–	–
Automatic vehicle location (AVL)	%	Stockholm	100	100	N/A	N/A	N/A
		Thessaloniki	N/A	100	–	–	–
		Edinburgh	100		–	–	–
Automatic passenger counting system (APC)	%	Stockholm	12	12	0	20	10
		Thessaloniki	99	N/A	–	–	–
		Edinburgh	0		–	–	–

networks, consisting solely of metropolitan and urban buses. Specifically, Thessaloniki has achieved complete coverage of all urban bus stops with mobile-phone-based traveller information systems and has also equipped all its vehicles with real-time information panels and AVL systems, but has only equipped 10 % of its bus stops with real-time information boards. Thessaloniki's metropolitan bus system does not have all of these features, but it does provide 55 % coverage of its stops with mobile-phone-based traveller information, as well as near-complete equipment with APC systems. Edinburgh, in comparison, also offers complete coverage with mobile-phone-based traveller information, in-vehicle real-time information and AVL, as well as 15 % of bus stops equipped with information boards, but no APC system.

3.6.3 Discussion and Outlook of Public Transport ITS Maturity and Deployment in Europe

Appraising the results from the two survey studies, certain trends with regard to the state of deployment of ITS in Europe can be extracted. Specifically, from the first exercise, it can be observed that most of the 33 cities surveyed have rather private-transport-oriented networks, which are accompanied by corresponding modal split figures, with only few exceptions of more public-transport-oriented (e.g., Zurich, Prague) and soft-mode-oriented cities (e.g., Barcelona, Paris). Yet, the vast majority of the cities are mainly interested in improving the efficiency of their transport network by achieving a modal shift away from private means, and with infrastructure investments being less attractive, ITS can play an important role.

Indeed, ITS have contributed to the implementation of more advanced public transport management schemes and strategies and have increased the range of techniques available. Examples of these include the granting of priority to public transport vehicles at signalised intersections and the provision of e-ticketing, both of which have become possible through recent advances in the ICT field. ITS have also broadened the field of data collection and information provision, with the latter being disseminated to the public through various means. The information provided mainly concerns delay times and alternative routes, and travellers can be kept up to date through Websites and telephone information lines prior to their travel, or by information panels, radio broadcasts and mobile phones en route.

With respect to the deployment level of public transport ITS, as assessed through the second survey exercise in five selected cities, it appears that this is correlated with the population, but also with the indicative wealth of the city, as expressed by the GDP per capita index. In other words, it seems that cities with a greater population and a higher GDP per capita index (such as Madrid, Barcelona and Stockholm) are likely to have a greater degree of deployment of public transport ITS than smaller and less wealthy ones (Thessaloniki, Edinburgh). This may be explained by the fact that ITS are associated with both initial and maintenance costs, and even though these are substantially lower than corresponding infrastructure investment costs, smaller and less populated cities may still appear reluctant to undertake them at a large scale. It is encouraging to see, however, that the numerous advantages delivered in managing fleets, planning trips or improving accessibility, are gradually acknowledged by the majority of the cities, which has led to a progressive proliferation of public transport ITS in recent years.

The analysis of the results shows several interesting conclusions. Firstly, it is observed that the total surface of a city is directly related to the motorisation rate. In the case of Thessaloniki, with a total surface of 1456 km^2, it is more difficult to provide adequate coverage of public transport to outlying zones, and thus, the use of private vehicles increases, as there are no other transportation alternatives. Similarly, the GDP also affects directly to the motorisation rate. Cities with a high GDP stand out to have high motorisation rates.

Regarding the modal split, it is perceived that cities with larger population (Madrid, Stockholm and Barcelona), and a higher GDP, are also those with a lower percentage of private car use in daily mobility. This is due to the fact that public transport services are more viable, from the financial point of view, in cities with less population. Therefore, in these areas, the percentage of trips by public transport, walking or cycling is higher.

However, it draws attention to the case of the city of Edinburgh. Of the five cities studied, it is the one with the smallest population, and one of the lowest GDP values. Despite of this fact, Edinburgh has the highest percentage of trips made by public transport. This is because the city has a total surface of 264 km^2, being its developed area 120 km^2 (one-third of the developed area of Madrid), which facilitates the implementation of a quality system of public transport.

As for the deployment of ITS services in public transport, they are implanted in a greater proportion in Madrid, Stockholm and Barcelona. This is caused by the fact that they have more population and a higher value of GDP than Thessaloniki or Edinburgh. Generally, ITS services have high costs of implementation and maintenance, and thus, only considerable cities can undertake their installation. However, these services provide numerous advantages when managing fleets, planning a trip or improving accessibility, which have led to a progressive proliferation of ITS services in recent years.

3.7 Including ITS Factors in Transit Assignment

To conclude this chapter, we provide a more direct link to the next book chapters, which will mainly focus on the modelling aspects related to transit assignment. In particular, the ITS solutions applied to real-time information and to ticketing

Table 3.5 Relation between ITS tool and transit assignment variables (input) and impacts (output)

ITS tool	Variables (input)	Impact (output)
Real-time information (at stops) e.g., about arrival times	• VoT for waiting times will change • Reliability is increased • Expected travel time updates	• Less journey times • Reduce uncertainty • Alternative services when delays and alterations occur
Fleet management coordination and control	• Headways (at stops) • Reliability of travel times • Capacity	• Better estimation • Smoother operations • Less delays
(Multimodal) trip planners	• Compliance • Calibration/validation data • Agent-based decisions (micro-level)	• More compliance to advices • Travel time savings • Modal shifts
Traffic control (priority)	• Travel time • Travel time variability/reliability • (Line) capacity	• PT performance • Journey time savings • Modal shifts
E-ticketing	• Monetary expenditures • Total journey times • Boarding capacity • Less delays in bus stops	• Modal shifts • Journey time savings
DSS for operators	• Headways • Line suppression/feed	• PT performance

services should be modelled to influence the travel choices of the PT users, such as departure time and line choice, but also to improve the travelling strategies for more effective intermodal transfers.

Questions we therefore address in this book are, for example, as follows:

- Which ITS tool will affect what input variable or parameter in the assignment models?
- Where do we expect ITS to have an impact?
- How ITS change the traditional formulations of transit assignment?
- Which assignment parameters/factor/variables will be modified or added?
- Which travel behaviour do they affect?

To conclude this overview, a table giving an overview of ITS—variables—impact is given (Table 3.5), where the most relevant decisional variables are related to ITS solutions, and the impact each solution is expected to give to the travellers' choices.

3.8 Reference Notes and Concluding Remarks

Cities are deploying ITS measures for most of their transport services. This is a win–win development: on the one hand, ITS technologies and their applications are cheaper than other technological developments and installations. Nevertheless, they provide a basis for improving quality of public transport services. ITS measures deliver benefits to all actors: operators, city managers and travellers. On the other hand, last generation of ITS services consist of two-way communications systems. That means that facilitating information to users improve the perceived quality of the services, but also those users provide back to the system a very rich information for managing and operating the service. Therefore, once it has been demonstrated its effectiveness and usefulness in the management of transport means, ITS deployment will continue in the coming years.

Fleet monitoring systems are widely used in big–medium size cities, but they are extending to smaller cities. They want to operate their transport networks using also the potential of ITS: real-time information provision, detecting incidents for managing them more effectively, greater safety and quality in the public transport system.

At present, transport authorities focus their attention on ticketing and real-time information. They tend to be more integrated using the same technological platforms: ticket validation systems, based on rechargeable and contactless e-cards, and real-time information system for all modes of transport, either in panels at stops or stations, or via smartphone applications.

The concept of big data is becoming increasingly important in this area, as any developer can access the data to perform transport applications. It is noteworthy that in the new transportation applications information flows bidirectional. These tools simultaneously perform the functions of providing information to the user, while serving as a social platform for users' interaction, and in turn enable transport authorities to collect additional data from the passengers. In addition, non-users can be incorporated to the system by collecting their preferences and expectations and attracting them into the system.

Another point to highlight is that interchanges are key elements for integrating information, as far as they are transfer nodes. They collect real-time revealed preferences and mode choices in only one place where both transport and other services are harmoniously integrated. Public bicycle systems have been recently incorporated to the trip chain, linked to public transport services. Providing bicycle parkings at interchanges and smart information about the public bicycle services is the way forward to link bikes to PT.

However, there is still room for enhancing the system. First, it is necessary a better harmonisation and standardisation. The different communication protocols should be common for all applications in all cities. They would reduce prices and improve users' understanding. Some cities are making agreements with world-wide servers such as Google Transit and other platforms. Those promising integration initiatives are beneficial for users and for operators. They are normally open to researchers and developers of new applications, providing new and enhanced possibilities.

To sum up, it is clear that the implementation of ITS systems in public transport networks produces an enhancement on security, efficiency, reliability and sustainability in the use and operation in all modes of transport. Users are not only granted with better performance of their demands for transport services, but also receive useful information for their choices on services and routes in an increasingly multimodal and complex transport system.

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