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Original

Application of Geomatic techniques in Infomobility and Intelligent Transport Systems (ITS) / Boccardo, Piero; Fabrizio, Arneodo; Danilo, Botta. - In: EUROPEAN JOURNAL OF REMOTE SENSING. - ISSN 2279-7254. - ELETTRONICO. - 47:(2014), pp. 95-115. [10.5721/EuJRS20144707]

Availability:

This version is available at: 11583/2599157 since:

Publisher:

AIT

Published

DOI:10.5721/EuJRS20144707

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Application of Geomatic techniques in Infomobility and Intelligent Transport Systems (ITS)

Piero Boccardo^{1*}, Fabrizio Arneodo² and Danilo Botta²

¹DIST, Politecnico di Torino, Viale Matteoli 39, 10125, Torino, Italy

²5T srl, via Bertola 34, Torino, Italy

*Corresponding Author, email address: piero.boccardo@polito.it

Abstract

During last years, we assisted to an increment of mobility demand, implying the need of adequate infrastructure and efficient public transport. The deployment of informative services and Intelligent Transport Systems (ITS) assumed a fundamental importance to address mobility demand, strictly correlated to the territory characteristics.

At the same time, mature Geomatic technologies, especially related to GPS differential positioning (both in real time and in post processing), mobile mapping systems (MMS), remotely sensed imageries (aerial, satellite and UAV platforms), archiving and management systems (Spatial Data Infrastructure - SDI) will play a crucial role.

These applications to infomobility and ITS are described in this paper.

Keywords: Fleet management, floating car data, infomobility, integrated ticketing, remote sensing, geomatic.

Introduction

The costs reduction of after market GPS devices, remotely sensed imageries (acquired by different platforms) and wide usage of GIS platforms encompassing digital maps (also in web and/or connected environment) led to a progressive increase in the diffusion of vehicles localisation devices, either for individual or for public transport. In the last years, these devices have become increasingly smart and now are capable of exchanging localisation data with dedicated control centres. The huge data amount exchanged can be used in different ways: in this paper we will focus on infomobility applications that can be enabled by localisation data usage [Sylos Labini et al., 2012; Boccardo, 2013; Bhattacharya et al., 2013; Tarolli et al., 2013; Gil et al., 2014].

We will describe the state of art of Intelligent Transport (IT) Location Based Services (LBS), then we will review some already deployed operative services and finally we will present some potential future applications in the framework of several research projects.

Usage of vehicle localization data - State of the art

Next paragraphs, shortly describe data categories collected from vehicles and IT-LBS, that could be enabled by the analysis and processing of such data.

Individual transport: localization and Floating Car Data (FCD) for traffic measurements

Individual transport can be characterised by systematic (e.g. home-work journeys) or non-systematic (e.g. tourists) journeys: the former are predictable through the usage of mature methodologies, mainly based on statistical elaboration of surveys results, while the latter are not predictable at all. It is then necessary the usage of ITS for Traffic Management to identify the current and forecast traffic status, in order to quickly detect traffic jams or impedances in the monitored road network, due to static events, like road works, or due to dynamic unpredictable events, like incidents.

In order to enable ITS, Geomatic techniques can be used: the actual location of individual vehicles correlated with information about their journey (speed, direction, etc.) can be used to forecast road capacity, adding those impedances to road graphs and in particular to link and node entities. Each single vehicle equipped with the required localization devices is then able to generate Floating Car Data (FCD) and can operate as a dynamic sensor moving along the monitored road network: no on-board digital map is required, since vehicle store only their current GPS position (NMEA sentences) into a specific buffer and then, periodically, send it to Fleet Manager Server according to proprietary communication protocols. Fleet Manager Server is the front-end able to get and send back re-processed data and added value information to the On Board Unit (OBU) mounted on vehicles.

FCD generated by vehicles are then processed to retrieve measures on the monitored area without sensors. These measures (operationally differentiable by a GPS permanent stations on a sub-metric base) can then be integrated with data coming from the fixed sensors (e.g. Infrared, loops, radar, etc.) to perform *Data Fusion* and *Data Completion*.

As far as the State of the Art in Italy is concerned, there are only a bunch of Fleet Managers with a significant number of equipped vehicles (from 120,000 to 900,000), already collecting Floating Car Data as a part of their core business (theft cars insurance market and fleet management). The huge amount of gathered data becomes an opportunity to develop new business: in particular Fleet Managers are interested in selling “traffic” data to Vehicle Service Centres, while, at the same time, the last ones are interested in providing real time traffic status at national level, gathering data coming from different sources and aggregating them.

Fleet Managers can provide different types of FCD according to the kind and dimension of the monitored fleet. In particular, Fleet Managers can generate:

- Raw Data (RD): these data basically contain information about speed, position, timestamp and are usually provided according to NMEA 0183 (National Marine Electronics Association) [http://www.nmea.org/content/nmea_standards/nmea_0183_v_410.asp] position through GPS receiver without any map-matching elaboration;
- Raw Data Public Transport (RDPT): these data are similar to the RD type and are generated by Automatic Vehicle Monitoring (AVM) systems mounted on public transport buses and are usually generated on a polling basis (e.g. each 20 sec);

- Map-matched Raw Data (MRD): these data still consist in speed, position and time, but the position is processed by a map-matching algorithm and associated to an element of the geographic reference system used by Fleet Manager to represent the real network roads;
- Travel Time (TT): the available information is already aggregated, the travel time for each single element of the geographic reference system is communicated.

Public Transport localization for fleet management

Vehicle localization is also widely used in collective transport. In particular, surface Public Transport (PT) has become a critical point for mobility especially in large urban areas, where many commuters are moving in and out to and from the cities. The need to respect timetable schedule, giving, in the meantime, precise geo-information to passengers, has become a fundamental requirement.

In order to guarantee a suitable and sustainable PT service, it is important to set-up a Fleet Management system, that typically is performed through the usage of Automatic Vehicle Location (AVL) systems, that determine and transmit geographic localization of a vehicle. These data, from one or more vehicles, may also be collected by a vehicle tracking system and used to monitor vehicle travels. Most commonly, the localization is determined using GPS and the transmission mechanism is based on 2.5G, 3G (or higher) mobile communication from vehicle to a radio receiver. GSM and GPRS are the most common services applied because of low data rate needed for AVL and low cost.

For more complex PT monitoring applications, an Automatic Vehicle Monitoring (AVM) system is adopted: it typically adds information about the status of the vehicle service (advance or delay) to location data. This way, AVM can also enable Location Based infomobility services, in particular, starting from dynamic tracking of buses and travel time modelling, AVM Systems can also provide accurate and reliable Estimated Arrival Times and Travel Times on digital displays at bus stops, as well as via SMS and on website.

By providing information about public transport operation to passengers during a trip it is possible to make public transport more attractive while increasing its usage. Then, fleet management systems can also help in providing dynamic routing, scheduling, and fleet allocation and improving the reliability of operations facilitated by two-way communication between control centre and drivers.

To summarize, the main benefits relevant to the usage of geodata coming from AVM system are:

- *PT service optimization*: it guarantees the passage of vehicles according to the schedule and optimal sizing of the vehicles number to be used, with real time update of Transport Network (i.e. in case of road networks);
- *Location Based infomobility services*: for passengers (next stop announcement, forecast arrival time, BUS priority at intersections, etc.);
- *Environment impacts*: CO₂ emission and fuel consumptions reduction having a correct behaviour of public transport fleet according to defined schedule;
- *Security*: it is possible to identify the vehicle position in case of emergency.

Location-based Electronic ticketing and Mobile Payments

Commuters travelling along routes from home to work, are often used to switch different

transportation modes and/or PT companies delivering such services: this implies the need of interoperability among different fare systems that can be addressed with the design and implementation of an integrated ticketing system for public transport introducing a lot of advantages for the public administration and for the passengers too.

Interoperation among different transport operators on the same territory is widely guaranteed and other public services payment (i.e. parking payments, etc.) is sometimes also supported.

The system is characterized by a three levels architecture:

- On-board level;
- Communication level;
- Centre level.

The “on-board level” consists in a set of specific electronic equipments installed on buses, for electronic tickets validations, storage of all the mobility information and fare calculation.

The “communication level” guarantees the safe and secure exchange of data between vehicles and centre, typically using 2G, 2.5G and 3G (or higher) technology.

The “centre level” (Company Control Centre - CCA) is where all ticketing and validations data are stored for fare verification.

Figure 1 depicts a simple high level architecture for a generic integrated ticketing system.

The core of this technology is a Common Mobility Card (Smart Card), typically a pure contactless smart card (substituting legacy paper-based travel documents), with its Card Data Model, that defines smart card content and rules to access it.

The above system deployment implies a massive data exchange, requiring an extremely high security level.

The main benefits of geodata usage in electronic ticketing system are:

- improved support to Public Transport Planning phase having a huge amount of passengers journey data;
- easier creation of Origin/Destination Matrices;
- more flexible tariffs plans management;
- possible improvements related to routing applications, giving real time information to the users and planning better connections by the PTs based on usage and scheduled times.

Geodata can also be used in parking payment and city logistics, in particular to book parking slot for goods distribution.

In both applications, through precise localization of vehicles, providers can give citizens the chance to automatically look up the correct tariff zone and start a parking transaction. Typically, ad-hoc smartphone applications are designed to pay parking by phone, confirming current location for actual fare calculation. There are multiple functionalities to start and stop parking sessions as well as to give the driver the possibility to set a duration time or to extend a parking transaction. The applications also provide a history of last parking actions. Historical data allow to know where the driver likes to park and could eventually drive him to its preferred parking stalls.

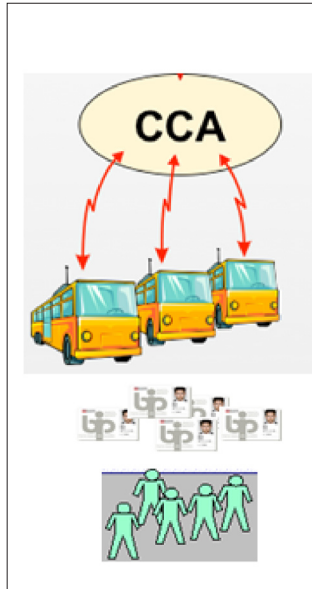


Figure 1 - Integrated Electronic Ticketing system hierarchy.

Case history of location-based services

All the potential application presented above have already been applied all over the world: in the next paragraphs a short description of their main implementations, divided by category application, will be presented.

Traffic Supervisor systems in “Smart Cities”

Usage of ITS and geodata techniques is a key factor inside the more general initiative called “Smart Cities”. In particular Smart Cities can be ranked (Tab. 1) along six main axes or dimensions:

1. Smart economy;
2. Smart People;
3. Smart Governance;
4. Smart mobility;
5. Smart Environment;
6. Smart Living.

A city can be defined “Smart” when investments in human and social capital and traditional (Transport) and modern (ICT) communication infrastructure feed a Sustainable Economic Development and a high quality of life, with a wise management of natural resources.

The usage of geodata in smart mobility (Transport and ICT) can help in getting Local Accessibility, (Inter) National Accessibility, availability of ICT infrastructure, sustainable innovative and safe Transport systems.

Table 1 - List of first thirty Innovation Cities worldwide [http://www.innovation-cities.com/].

Rank	City	State	Country	Region	Sub Region	Classification	Index Score
1	Boston	Massachusetts	United States	AMERICAS	USA	1 NEXUS	57
1	New York	New York	United States	AMERICAS	USA	1 NEXUS	57
3	Vienna		Austria	EUROPE	EUROPE	1 NEXUS	57
4	San Francisco Bay Area	California	United States	AMERICAS	USA	1 NEXUS	56
5	Paris		France	EUROPE	EUROPE	1 NEXUS	56
6	Munich		Germany	EUROPE	EUROPE	1 NEXUS	56
7	London		United Kingdom	EUROPE	EUROPE	1 NEXUS	56
8	Copenhagen		Denmark	EUROPE	EUROPE	1 NEXUS	55
9	Amsterdam		Netherlands	EUROPE	EUROPE	1 NEXUS	55
10	Seattle	Washington	United States	AMERICAS	USA	1 NEXUS	54
11	Toronto		Canada	AMERICAS	CANADA	1 NEXUS	54
12	Los Angeles	California	United States	AMERICAS	USA	1 NEXUS	54
13	Berlin		Germany	EUROPE	EUROPE	1 NEXUS	54
14	Hong Kong	Hong Kong	Hong Kong	ASIA	CHINA	1 NEXUS	54
15	Frankfurt		Germany	EUROPE	EUROPE	1 NEXUS	54
16	Stockholm		Sweden	EUROPE	EUROPE	1 NEXUS	53
17	Lyon		France	EUROPE	EUROPE	1 NEXUS	53
18	Melbourne	VIC	Australia	ASIA	ANZ	1 NEXUS	52
19	Hamburg		Germany	EUROPE	EUROPE	1 NEXUS	52
20	Sydney	NSW	Australia	ASIA	ANZ	1 NEXUS	52
21	Seoul		Korea, South	ASIA	ASIA	1 NEXUS	52
22	Washington DC	District of Columbia	United States	AMERICAS	USA	1 NEXUS	52
23	Philadelphia	Pennsylvania	United States	AMERICAS	USA	1 NEXUS	52
24	Manchester		United Kingdom	EUROPE	EUROPE	1 NEXUS	52
25	Tokyo	Tokyo	Japan	ASIA	JAPAN	1 NEXUS	52
26	Chicago	Illinois	United States	AMERICAS	USA	1 NEXUS	52
27	Stuttgart		Germany	EUROPE	EUROPE	1 NEXUS	52
28	Tel Aviv		Israel	EUROPE	MID-EAST	1 NEXUS	52
29	Shanghai	Shanghai	China	ASIA	CHINA	1 NEXUS	51
30	Singapore		Singapore	ASIA	ASIA	1 NEXUS	51

Usage of on-line available real-time traffic data: Europe and U.S.A.

There are different sources [Guillaume, 2008] providing real-time traffic data on-line; it should be noted that these data are assumed to be daily, hourly or even per minute (typically used in the U.S.). Most of the examples proposed hereafter are available freely on-line and mostly without requiring any access registration.

Traffic data are most often obtained from permanent count stations installed on major roads (generally on motorways). Therefore typical parameters are traffic flow and average speed. Further data such as occupancy rate and travel times (e.g. calculated from FCD) can also be collected. Although raw data are implicitly collected by transport centres for many years, always more countries are making them available on-line by means of new displaying tools (e.g. Google maps and/or satellite/aerial images) [Aguilar et al., 2008].

Spain

Since summer 2007, the DGT (Dirección General de Tráfico) of the “Ministerio del Interior de España” has been providing a large amount of real-time traffic data integrated in Google Maps: this allows users to download real-time traffic flow and average speed from more than 4000 traffic sensors located over the Spanish road network. For instance, it is possible to collect hourly traffic flow and average speed in the surroundings of Madrid from sensors located on motorways links (e.g. A6, M40, M11) (Fig. 2). These sensors provide 4 raw traffic parameters namely every hour: traffic intensity, average speed, occupancy rate and percentage of light duty vehicles. Historical data are also available for different time periods. However, this tool is still at an early development stage and only a limited part of Spanish roads is covered: notwithstanding this, it is probably one of the best traffic information tools that are currently freely accessible on-line in Europe.

Another project called “Cascade on Wheels” proposed an original way of visualizing traffic dataset for the city of Madrid: daily average of vehicles number for each day of year 2006 is visualized through Walls Map piece (3D vertical columns emerging from streets map) and Traffic Mixer piece (visualization combined with a sound toy).

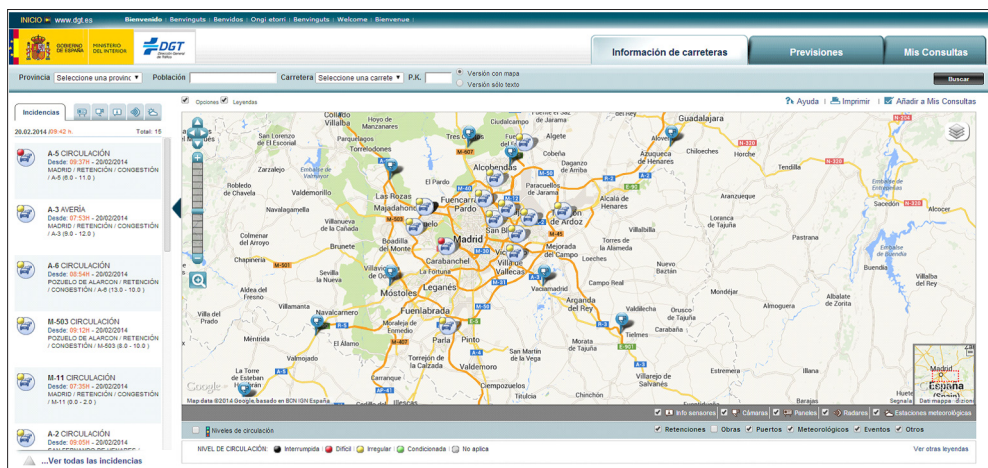


Figure 2 - Spain DGT Traffic Information system [http://infocar.dgt.es/etraffic/].

Finland

The Finnish Road Administration provides real-time information measured from around 330 automatic counting stations placed along the Finnish road network (Fig. 3). Traffic data concern traffic flows and average speed on major roads in Finland over 7 regions: Helsinki area, Tampere, Southern Finland, Jyväskylä, Turku, Oulu and South-Eastern Finland. Up to seven days historical values can also be provided displaying both traffic flow (in veh/h) and average speed (in km/h).



Figure 3 - Travel and Traffic information in Finland [<http://www2.liikennevirasto.fi/alk/english/>].

France - Strasbourg area

This case is very similar to the Spanish one, except that it covers only one specific zone. An interactive map of the area of Strasbourg provides the user with real-time measurements of traffic flow, average speed and occupation rate on motorways around Strasbourg (Fig. 4). The latest version of the automatic system used (called Gutenberg) was set up in the beginning of 2006. Traffic data are collected every minute from 42 traffic recording stations by means of loop sensors placed every kilometre on the road. In addition, 50 video cameras have been installed on the road network in order to improve/complete these measurements. These data are released on the interactive map provided by the “Direction Départementale du Bas-Rhin” through their website.

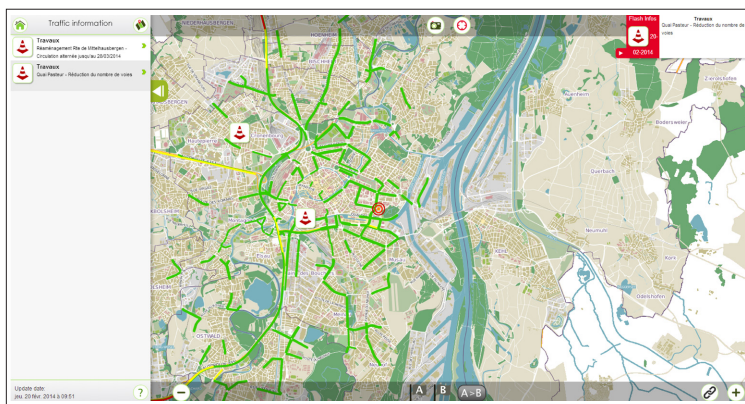


Figure 4 - Strasbourg interactive traffic map [http://www.carto.strasbourg.eu/traffic_info/].

France - Paris area

Real-time traffic information in Paris area is provided by Sytadin (Fig. 5). An interactive map shows current speed and travel time on the major roads around Paris. Data is calculated from inductive loops through the SIRIUS network. It is worth mentioning that the accuracy of travel time was compared with the Floating Car Data method: it resulted that the difference between both methods was less than 1 min for travel time up to 25 min and less than 5 min for travel time between 25 min and 45 min. This website makes also an interesting analysis of the speed and congestion situation based on different charts. Travel times in the area of Paris are also provided by V-Traffic (Mediamobile) via Google Maps.



Figure 5 - Paris Île-de-France region real time traffic state [<http://www.sytadin.fr/>].

The UK

In the UK, it is possible to get a wide number of real-time traffic data (Fig. 6). Some data refer to the average speed (in mph) and traffic flow (veh/min) measured at five selected areas: Birmingham, Kent, Leeds, M25/London and Manchester. This service (called “Real Time Traffic Service”) is provided on a trial basis by the Highways Agency.

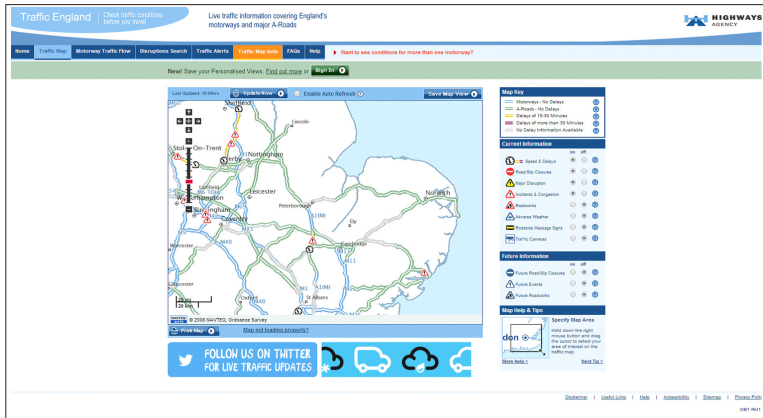


Figure 6 - “Traffic England” page [http://www.trafficengland.com/].

Portugal

A large amount of traffic data are available on the website of “Estradas de Portugal” (Fig. 7) which are released by the SICIT (Sistema Integrado de Controlo e Informacao de Trafego). It consists of a set of equipments and applications that collect and spread real-time traffic data with the aim to reinforce road security and provide a more efficient road network management.

For this purpose, a specific application (called ALQUEVA) was created to guarantee immediate and generalized access to all traffic information. Data are collected by more than 300 automatic count recorders installed on major Portuguese roads.

Available traffic data are related to different categories (e.g. traffic flow classified by vehicle category, average speed, vehicle weight, etc.) and can be downloaded with different time resolutions (annual, monthly, daily, hourly, 15 min, 5 min and 1 min) during the period 2002-2007. The results are also available in several format including the Excel one.

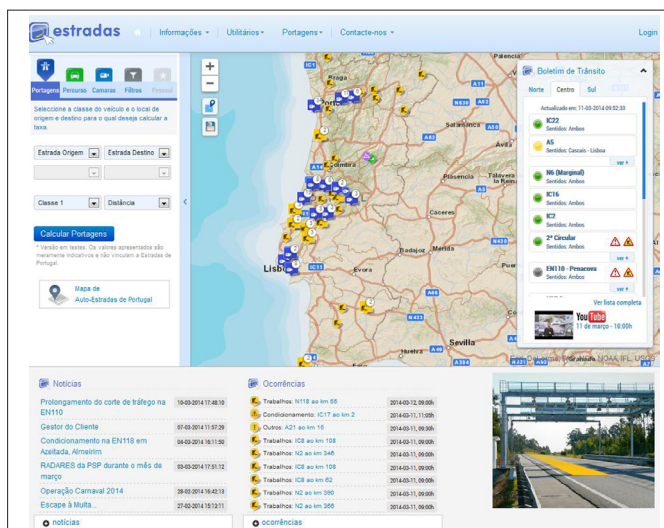


Figure 7 - “Estradas de Portugal” page [http://www.estradas.pt/index].

Germany

The Traffic Information System presents the current traffic situation and traffic forecasts (30 min and 60 min) on the motorway network in North Rhein Westphalia (2250 km length). Traffic simulation model is fed by real-time traffic data (vehicle speed and traffic flow) collected from 2500 automatic traffic data detection units updated every minute. This project was initiated by the Ministry of Transport, Energy and Spatial Planning of Nordrhein-Westfalen. It is one of the most relevant and reliable source of road traffic forecasts in Europe.

Also, the Bavarian Ministry of the Interior (Fig. 8) distributes real-time traffic data covering the region main cities, real-time speed measurements are provided as well as traffic forecasts. GPS-based FCD information from taxi fleets are used to collect traffic data.

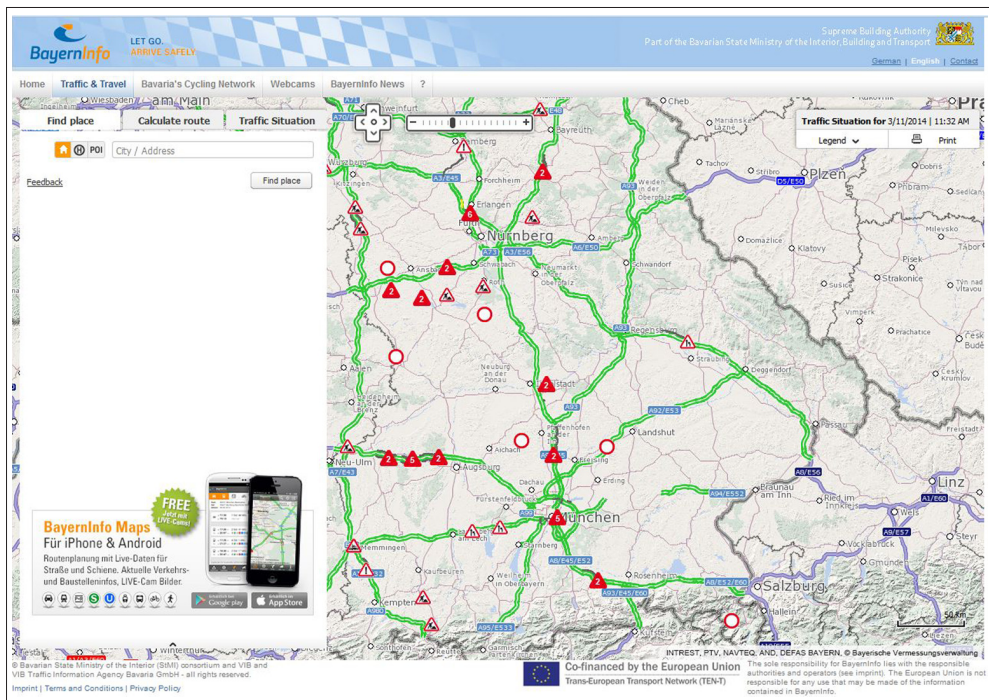


Figure 8 - “Bayern Info” page [<http://www.bayerninfo.de/planner>].

Italy

In Italy, OCTO Telematics distributes real-time speed and number of vehicles on the Italian motorways network (“autostrade” - Fig. 9) as well as in the area of major cities. Traffic data are gathered by the largest FCD fleet in Europe (i.e. hundred thousands of anonymous customers equipped with company’s GPS). Dataset may afterwards be used by navigation systems (TomTom and Garmin in Italy) contributing to the route planning optimization. This will help end-users reduce travel times, save energy and money.



Figure 9 - “OCTO Telematics” Real-time Traffic [http://traffico.octotelematics.it/traffic.tml?fr=0].

Piedmont Region area

5T, as technological partner of Municipality of Turin and Piedmont Region Government, was in charge to manage, deploy and maintain the overall ITS systems and services related to traffic in the metropolitan area of Turin (Italy) and for the whole Piedmont territory (Italy) (Fig. 10).

The involved ITS systems are:

- Traffic Operation Centre (TOC): covering the metropolitan area;
- Urban Traffic Control system (UTC): over 300 controlled intersections;
- 3,000 traffic sensors;
- 71 Traffic Control cameras;
- 100 Variable Message Signs (VMS);
- 2 speed control systems.

The services enabled by the above ITS systems are:

- traffic monitoring and control;
- dynamic traffic lights cycles optimization, on the base of real-time traffic situation;
- priority green light phase to public transport;
- traffic jams forecast through traffic supervisor software platform;
- real-time traffic information services (traffic conditions, incidents, road works, availability of parking lots, etc.).

The different involved ITS systems are integrated in order to create value added services (Fig. 11).

The heart of this architecture is the “so called” Regional Traffic Supervisor (SVR) [Arneodo et al., 2012], a software platform that implements Dynamic Traffic Assignment [Bellei et al., 2005; Gentile et al., 2007; Gentile, 2010] algorithms for traffic status forecast.

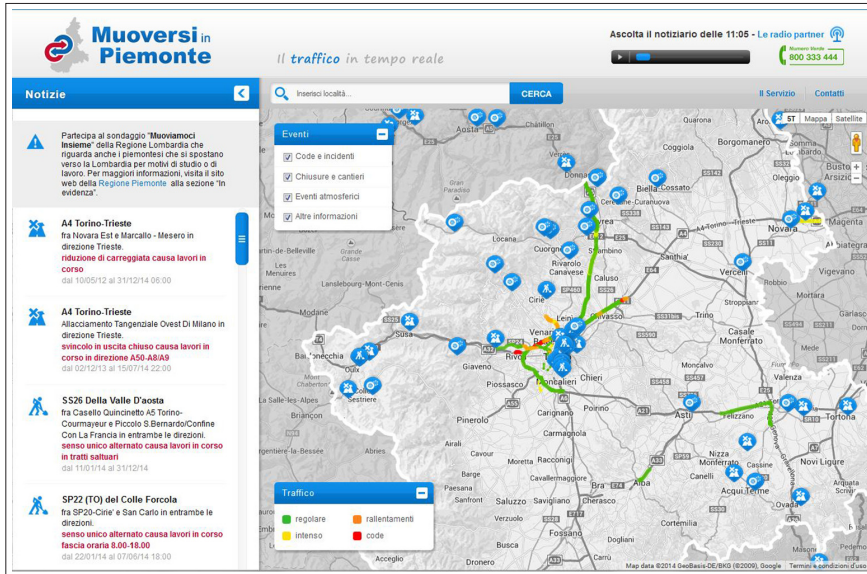


Figure 10 – Traffic in Piedmont Area [<http://www.muoversinpiemonte.it/mip/>].

As already mentioned, Geomatic techniques are used to perform traffic management; in order to improve this forecast capacity: each single vehicle, equipped with the required localization electronic devices, can generate FCD.

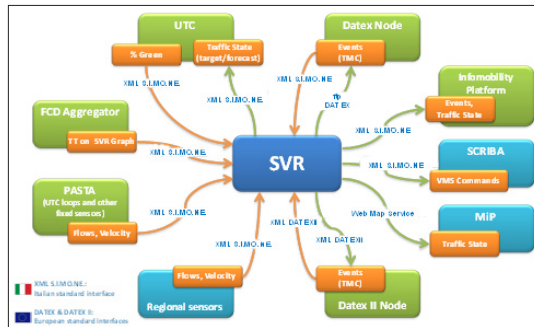


Figure 11 – Traffic operation Centre Architecture.

FCD are gathered and correctly elaborated by “FCD Aggregator” module; managed data consist of:

- over 8.000 RDPT every 5’, provided by Turin Public Transport AVM System;
- over 250 Travel Times (TTs) on TMC reference every 5’, provided by a primary private Fleet Manager;
- an average of 9.000 RD every 5’, provided by a primary private Fleet Manager;
- over 1.400 TTs on TMC reference every 5’, derived from *Floating Cellular Data* and provided by a primary Italian mobile company.

FCD Aggregator [Arneodo et al., 2009] then provides to SVR speeds and TTs on 30.000 links of the SVR regional transport graph, corresponding over 4.000 Km (daytime mean values). These TTs are calculated (Fig. 12) on basic geographic element of the Aggregator graph or on aggregation of basic geographic elements (functional classes); to perform this calculation, the module needs to have the following data:

- FCD Start and end positions over the arc (Map Matching);
- FCD Start and end timestamps;
- Calculated $\Delta T = T_{\text{end}} - T_{\text{start}}$;
- Calculated $\Delta L = L_{\text{end}} - L_{\text{start}}$.

In this way starting from FCD, first of all, speed is calculated and then it is used to determine TTs on the whole Aggregator graph arc.

The regional TOC follows the paradigm of “*open platform*”, able to exchange data and information with *private platforms*, in order to enable the growth of enhanced information services for travellers.

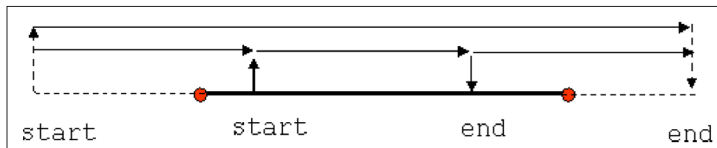


Figure 12 - TTs Calculation.

Having the current and forecast information about traffic flows it is also possible to generate forecast for CO distribution taking into account wind speed and direction too (Fig. 13).

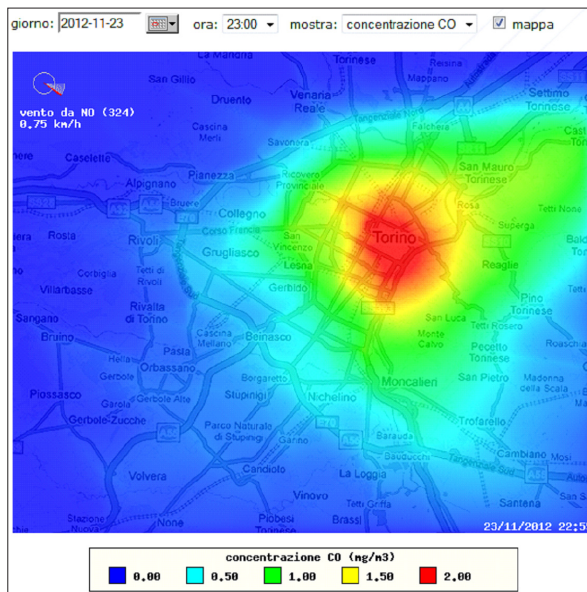


Figure 13 - CO distribution in Turin metropolitan area.

The real challenge of this implementation has been to provide a centralized reliable traffic information and management system for all different kind of areas of the region. This result has been obtained by merging fixed traffic sensors data with “virtual sensors” data coming from different Data Provider and Fleet Manager with an increase of the monitored area 8 times with minimal infrastructure update and maintenance costs.

At the same time, this has led to a reduction of traffic jams and pollution on the main regional roads and around the main cities of some percentage points, with a concurrent increase in road safety.

Wideness and complexity of the area, heterogeneous innovative traffic data and variety of providers, increased traffic monitoring and control are at the same time the main challenge and the real strength of the project that, for these reasons, outclasses any other previous similar attempt.

U.S.A.

The *Alabama* Department of Transport (ALDOT) provides hourly traffic flow through the Traffic Polling Data System. An interactive map enables the user to get traffic information over a wide range of road segments throughout the State. Historical data (1996-2006) are also available. Unfortunately, there is no real-time traffic flow since last update in January 2007.

In *Washington State*, it is possible to obtain the daily number of cars at any traffic count recorder of the road network. Data are completed by information about count quality, data completeness and sensor.

The DoT of *South Carolina* has a very user-friendly tool (the South Carolina Traffic Polling System) providing real-time traffic counts (hourly) and average speed, along with historical data.

In *Maryland*, around 70 permanent sites on line are collecting traffic data along with 3700 short-term (48h) count locations. The Maryland State Highway Administration provides traffic volume maps with historical counts from 1980 to present for Maryland state roads. The website also contains traffic trends, traffic count data reports, and traffic station history (2001-2005).

In *California*, the Company Sigalert provides live traffic information (e.g. speeds, accidents) for personalized traffic reports (Fig. 14). It covers Southern California (West/East Los Angeles County, Orange County, Ventura, Inland Empire, San Diego), Northern California (San Francisco, Sacramento), Phoenix (Arizona) plus other smaller cities. Speed data are directly collected from fixed detectors and displayed on their website in a user-friendly format.



Figure 14 - California state Sigalert live traffic system [<http://www.sigalert.com/Map.asp>].

Public Fleet Management

Italy - Piedmont Region area

5T, as technological partner of Turin Public Transport Company (GTT – Gruppo Torinese Trasporti), is in charge to support the company AVM Control room, in order to guarantee that all the information about the vehicle positions are sent correctly to enable infomobility services (like forecast arrival time at the bus stop).

The current size of the controlled Public Transport system is:

- 1,400 urban vehicles with real-time positioning;
- 300 extra-urban vehicles with real-time positioning;
- 8 tram lines with priority at intersections;
- 101 bus lines;
- 3,300 bus stops with real-time arrival information.

Figure 15 represents the architecture of the Turin Public Transport Fleet AVM system; Public Transport Service data are sent by AVM equipments installed on board on buses and retrieved by AVM Control Room. The regularization of transport service is performed automatically communicating to the drivers their current delay/advance on schedule and furthermore data are used to enable infomobility service [Arneodo et al., 2011]: in particular information about arrival time forecast at bus stop are available through dedicated VMS or via SMS.

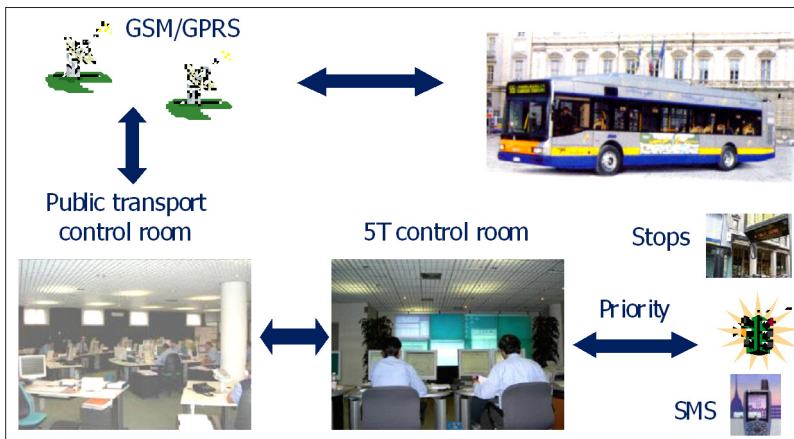


Figure 15 - Turin PT AVM system.

Electronic Ticketing

France - Paris Area

The Navigo pass is an electronic ticketing system for public transport introduced in the Île-de-France region in 2001. It is implemented as a contactless smart card using Calypso standard, and enables authenticated access at turnstiles by passing the card near an electronic reader.

This pass is available either connected to an account for residents of the Île-de-France (known simply as Navigo Pass), or can be issued to anybody at a station (Navigo Découverte). While the “account based” passes are free, a Découverte pass costs 5€ at ticket booths. The passes can be credited at ticket vending machines (TVM) for weekly, monthly or annual

use. Unlike similar cards issued in other major cities, there is no electronic purse for use on irregular journeys over a period of time.

Navigo passes can be used on vehicles of RATP, SNCF (within the Transilien network), Optile, and companies under the aegis of the Syndicat des transports d'Île-de-France (STIF), as well as with the Vélib' bicycle rental system.

Cards either bear a photograph of the holder or must be accompanied by a photo ID card.

The U.K. - London Area

Oyster card is the form of electronic ticketing used on public transport in Greater London. It is promoted by Transport for London and is valid on travel modes across London including London Underground, London Buses, the Docklands Light Railway (DLR), London Overground, trams, some river boat services and most National Rail services within the London fare zones.

A standard Oyster card is a blue credit-card-sized stored-value contactless smart card that can hold single tickets, period tickets and travel permits, which must be added to the card prior to travel. Passengers touch onto an electronic reader when entering and leaving the transport system in order to validate it or deduct credit from electronic purse. Cards may be "topped-up" through payment authority, by online purchase, at credit card terminals or by cash, the last two methods at stations or ticket offices. The card is designed to reduce the number of transactions at ticket offices and the number of paper tickets: use of electronic ticketing is encouraged by offering substantially cheaper fares.

This card was first issued to the public in July 2003 with a limited range of features and since then further functions are still introduced from time to time. By June 2012, over 43 million Oyster cards had been issued and more than 80% of all journeys on public transport in London were made using the card.

Italy - Piedmont Region area

5T, as technological partner of Piedmont Region Government, is in charge for the implementation of the regional contactless ticketing system for public transport and railway system, named BIP (Biglietto Integrato Piemonte) [Arneodo et al., 2013]. BIP project involves around 60 public transport and railway operators, nearly 3,400 vehicles and 400 railway stations, with the aim to revive the regional public transport system, on one side, by improving accessibility and favouring the modal shift and on the other side by certifying quality and quantity of the executed service. The user is able to access, through a single contactless smart card, different transport services (buses, trains, bike-sharing, car-sharing, etc.) in the region in a simple, fast and safe way. From the technological point of view, BIP project is based on three fundamental pillars:

- an electronic contactless ticketing system, based on Calypso technology;
- an Automatic Vehicle Monitoring (AVM) system, enabling real-time monitoring and off-line statement of the executed service;
- a video surveillance system for passengers safety.

Since several actors and different technological systems have been involved, the main effort of the project has been devoted to obtain a good level of integration (Fig. 16). The following picture depicts the level of integration and interoperability for the BIP project.



Figure 16 - Piedmont Region (Italy) electronic ticketing system interoperation.

To ensure a complete and correct level of integration, international standards (ISO, CEN) have been adopted:

- TCP/IP : for network communication on board of Public Transport Buses [<http://tools.ietf.org/html/rfc793>];
- WiFi – IEEE 802.11: for the communication among Fleet vehicles and the control centre [<http://www.ieee802.org/11/>];
- 3G, 4G wireless communications: for the communication among Fleet vehicles and the control centre;
- ISO 14443 A/B: for the RFID communication between smart card and terminals [<http://wg8.de/sd1.html>];
- *de- facto* Standard: Mifare [<http://www.mifare.net/en/home/>], Calypso [<http://www.calypsonet-asso.org/>];
- NeTEx (Network Timetable Exchange): for the communication and transmission of Public Transport Data like Timetable, Network description, etc [<http://user47094.vs.easily.co.uk/netex/>].

Future perspective in Location Based Services

The after-market availability of On Board Unit (OBU) with high technology at sustainable costs, able to interact in real-time with infrastructure with high market penetration rate, enables the design of new infomobility services for drivers, Fleet Management centres and Traffic Operation Centres.

Through the use of GPS vehicle position managed by the OBU, it is possible to provide information to drivers about real-time road network state, in terms of traffic jams, forecast Travel times and all possible traffic limitations due to fog, road closures, accidents, etc.

Other Location Based Services are those relevant to the mobility offer personalization (private car, park and ride, public transport), based on actual vehicle position, final destination, vehicle typology (environmental class), special limited access zone entrance authorizations. This allows to move one step beyond with respect to the current mobility services based simply on broadcasting concept (radio bulletins, Variable Message Signs, etc.)

The chance to have infomobility services providing all the necessary information, exactly when and where they are needed, will increase the on board car security (avoiding drivers lack of attention), with innovative application in ITS-enabled enforcement services (Limited Traffic Zones, exceeded speed limits detection, black spot, etc).

Actually, Traffic Operation Centres use Floating Car Data to improve traffic status forecast and to cover the areas where there are no traffic sensors (loops, infrared sensor, radar, etc.). Improving location precision of FCD, these data could be used also to enable new mobility services, in particular to deploy new mobility control actions to regulate:

- the entrance in Limited Traffic Zone without the need to use electronic gates;
- Road Pricing;
- parking payment.

The main benefits relevant to the usage of high precision localization data are relevant to:

- reduction of huge infrastructure (cameras, sensors, etc.) deployment;
- cost reduction in terms of dedicated personnel for parking check.

Concerning Road Pricing systems, the more relevant models in Europe are those in London and Stockholm, based on fixed infrastructure (electronic gates) using pre-defined tariff schemas that doesn't take into account (in fare calculation) neither characteristic and parameters of the vehicle nor the current traffic status in the zone where the Road Pricing is applied. Implementing this kind of Road pricing models would imply significant investments.

Utilizing high precision localization data, indeed, it will be possible to design a dynamic model that consider all vehicle characteristic and parameters, driver condition and/or passengers (e.g. disabled people), limited time of permanence in the road pricing area, park and ride (to stimulate use of Public Transport service), pre calculated journeys inside the area.

OBU's having precise localization can also enable the driver to access new payment services like access to Limited Traffic Zones, Road Pricing and park payment with interoperability with highways tolling systems. The OBU is the critical element of the architecture: it must be part of bigger platform that consists in an high precision localization system able to communicate from vehicle to vehicle (V2V) and from vehicle to infrastructure (V2X).

Nowadays, car makers have started to produce vehicle with sophisticated telematics platforms on board, but still very limited in the implementation of real innovative infomobility services. The introduction of "advanced" on board platforms with precise localization that guarantee V2V and V2X communications, could enable several innovative infomobility services like the following:

- *black spot*: in the road network areas with high level of accidents could communicate with the vehicle, on the base of the actual position, when it is approaching the area with high level of risk (presence of ice on the road, accident, etc.);
- *geo-fencing*: service that communicate to the driver when the vehicle is approaching a Limited Traffic Zone;
- *parking payment/booking*: service for automatic payment and parking reservation;
- *adaptive cruise control*: knowing in advance the road network status (traffic jams, travel times) it is possible to regulate the speed, limiting start and stop events;
- *hybrid navigation*: the driver receives instructions dynamically according to the real traffic conditions;

- *Virtual Variable Message Signs*: the drivers can receive messages on the on board device with suggestions for alternative routes in case of congestions.

As already told, all the potential new services described require to have a extremely precise localization mechanism, including an on board telematics platform. The following research activities must be performed to allow the realization of this approach:

- *Short range connectivity*: study and sperimentation to integrate the following devices and systems (DSRC, Wi-max, Zigbee) to enable the communication between
 - *V2V*: data and information exchange between near vehicles (chat, traffic state, travel time, accidents, etc.);
 - *V2X*: data and information exchange between vehicles and the infrastructure (traffic state, travel time, accidents, etc.);
 - *OBU*: personal devices (smartphone, etc.).
- *System resources*: computational and memory capacity have to be correctly calibrated according to the level of safety required by the deployed new services;
- *Localization precision*: a robust solution has to be identified to guarantee high level of localization precision also in critical environmental conditions (canyon effects in the urban area, etc.), using for example GALILEO satellite system, integrated with GPS and EGNOS and/or using permanent GPS station network to post process raw data with a sub-metric accuracy both in real time or in a “post-event” mode;
- *Position certification*: based on GALILEO satellite technology the information received by the vehicle will be correct, also using pseudo-satellite (so called Pseudolite) to reach more precise localization;
- *Connection with other on board units*: this is the research sector relevant to the exchange of information among the on board telematics board units over the air (wireless).

V2V and V2X communications besides localization precision and localization certifications, will be the main driver for infomobility and safety services in the near future.

With V2V communications it will be possible, for example, to create virtual radar maps, that can give promptly information to the driver about the real traffic state, about the behaviour of the near vehicles with relevant potential risks.

V2X communications, on the other hand, will enable a continuous exchange of information between the vehicle and the Traffic Operation Centre, with direct benefits on travel time reduction, traffic flows optimization, booking of parking slots.

This model requires an high level of integration and interoperability: in this perspective it is important the usage of a standard communication protocol that can guarantee the communication among different devices with real time constraints.

These new approaches could also improve map updating and/or creation of graph where they are not available at all (e.g. many megacities in emerging countries); sub-metric accuracy could definitely help the design and implementation of fully automatic routines able to allocate impedances to road graphs, to match these data with other available map layers (buildings, street numbers, infrastructures, etc.) and eventually, could be considered as a new source of ancillary data extremely useful for the improvement of map positional accuracy (dynamic Ground Control Points - GCPs, usable for maps and images warping and ortho-projection).

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