LIFE ENV 389

INTEGREEN

Action 2: Requirements

D.2.2.1

Mobile system requirements

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1 Introduction

The main objective of Action n.2 is to define the requirements of the components and sub-components that are part of the proposed INTEGREEN system architecture. The Action is structured in two different tasks, each of them covering a specific domain of the system architecture.

In Task 2.1, the components that are part of the new Environmental Supervisor Centre are analyzed and evaluated in terms of the technical and functional requirements. This task is responsible as well of the analysis of the traffic and air pollution baseline data, which is needed in order to calculate the environmental impact of the project. This functional analysis is entirely presented in deliverable D.2.1.1 [1].

Task 2.2 is in charge on the other side to define the requirements of the mobile system for INTEGREEN, which is an automotive electronic platform that allows vehicles to have traffic and environmental detection capabilities, as well as communication functionalities, in particular with the vehicle-to-centre front-end at the Environmental Supervisor Centre. The deliverables of Action n.2 are the ground layer for the following activities of the project, since most of the decisions regarding the planning, the implementation, the testing and the validation of the INTEGREEN system will be made on the basis of the functional indications defined at this level, and following the typical V-model approach [2] (Figure 1).

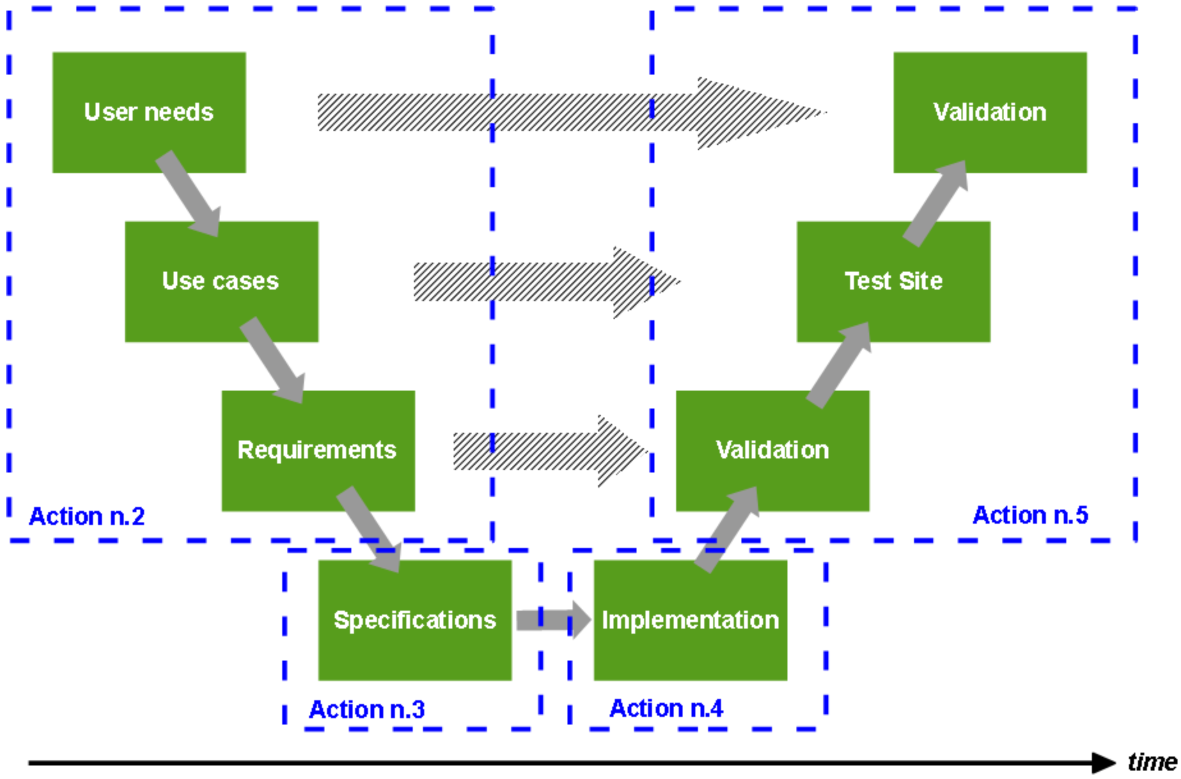

Figure 1: The V-model approach applied in the INTEGREEN project.

1.1 Purpose of the document

The document presents the requirements which are defined for the INTEGREEN mobile system. The scope of this document is thus limited to a specific part of the entire INTEGREEN architecture, as illustrated in Figure 2. The requirements are defined in order to guarantee maximum compatibility and interoperability with the set of requirements which refers to the Supervisor Centre.

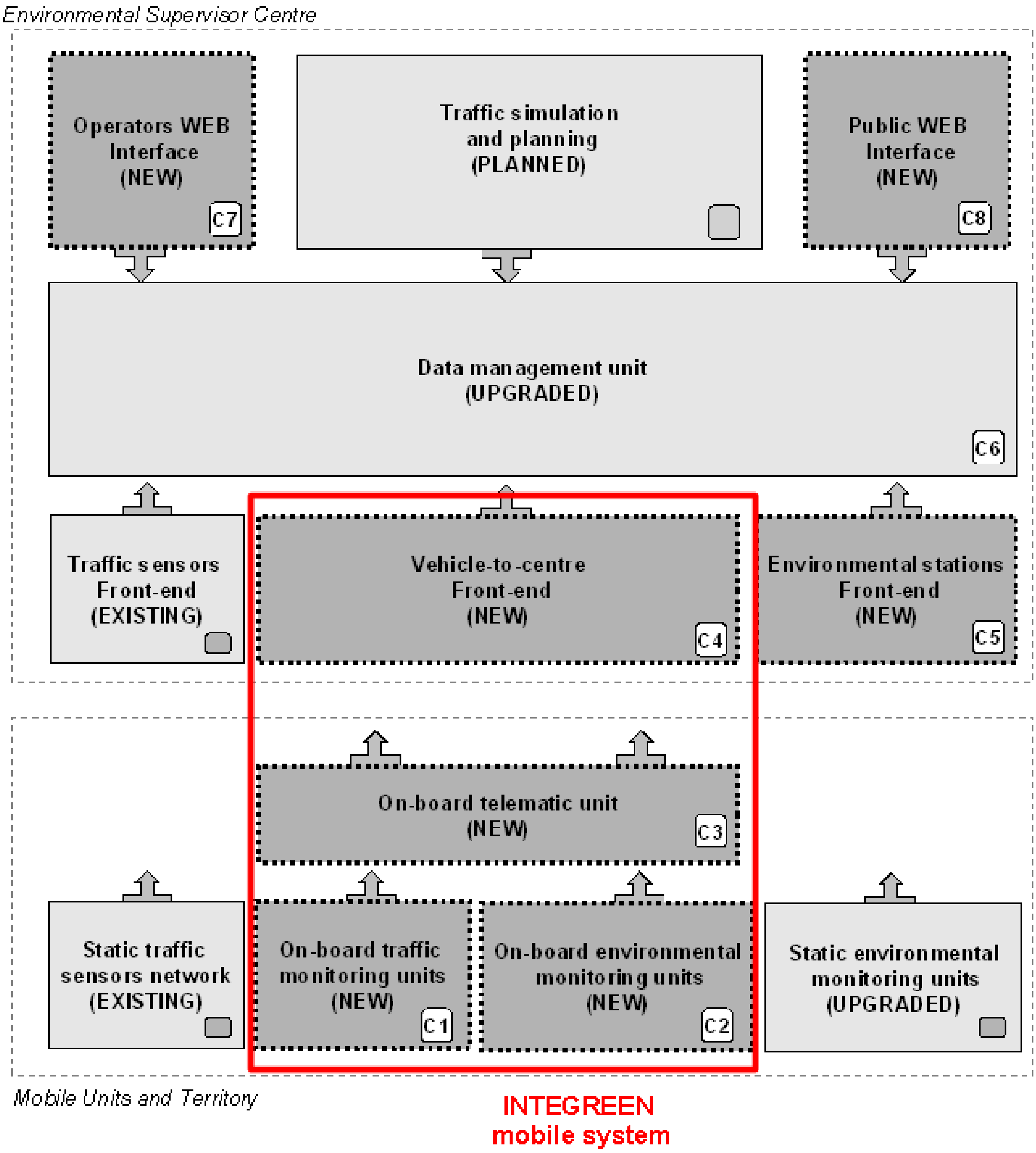

Figure 2: The reference INTEGREEN architecture and the scope of the document.

1.2 Requirement definition methodology

The methodology which is applied in this activity of requirements analysis is illustrated in Figure 3. It is composed by four sequential activities which aim (i) to assess and evaluate the reference state-of-art, not only in the mobile and environmental monitoring literature but also considering the main features of the local fleet system circulating in the city of Bolzano, and (ii) to identify the mobile system requirements which can match the local needs and exploitation opportunities.

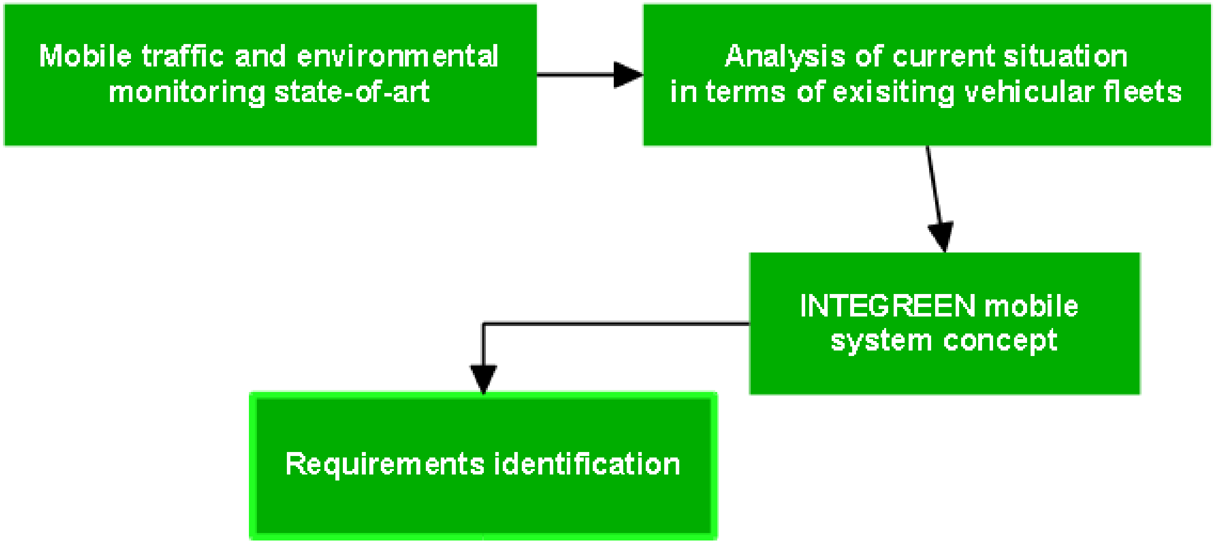

Figure 3: Adopted methodology for the analysis of the INTEGREEN mobile system requirements.

The document is structured as follows. Chapter 2 provides relevant inputs coming from the scientific literature regarding techniques and approaches in the field of mobile traffic and environmental monitoring. Chapter 3 describes the main peculiarities of the different (present and future) fleets circulating in the urban area of Bolzano, and which are of main interest in order to exploit the mobile monitoring system which the project aims to introduce. Chapter 4 introduces the three main use scenarios that the INTEGREEN mobile system will be able to accomplish. These use scenarios refer to the “root” use case 5 (UC_5) defined for the Supervisor Centre. Finally, Chapter 5 illustrates the set of requirements defined for each component of the mobile system.

2 Mobile traffic and environmental monitoring state-of-art

2.1 Mobile traffic monitoring systems fundamentals

The most important technology in the area of mobile traffic monitoring is the floating car technology. Equipped with a positioning unit and a communication unit (or a combination of both) the vehicles act as mobile sensors, i.e. they are *floating* within the overall traffic.

Nowadays more and more fleets are equipped with positioning and communication devices to organize their business and optimize their routes. As an additional value these trips can be used to estimate travel times (TT) and Level of Services (LOS) of traffic situations.

Several studies (e.g. [3], [4]) and international projects (as analyzed within this chapter) have shown the use of different types of vehicular fleets as data provider for traffic monitoring systems. The usage of different fleet types depends on several aspects of the traffic monitoring system, in particular:

- the **characteristics of the road network** (urban, highway, etc.);
- the **traffic regulations** (functional road classes, bus lanes, no truck's on Sunday, etc.) and **speed level** (Figure 4);
- the **existing equipment** (like On-Board-Units (OBU) with GPS and/or Communication Interfaces).

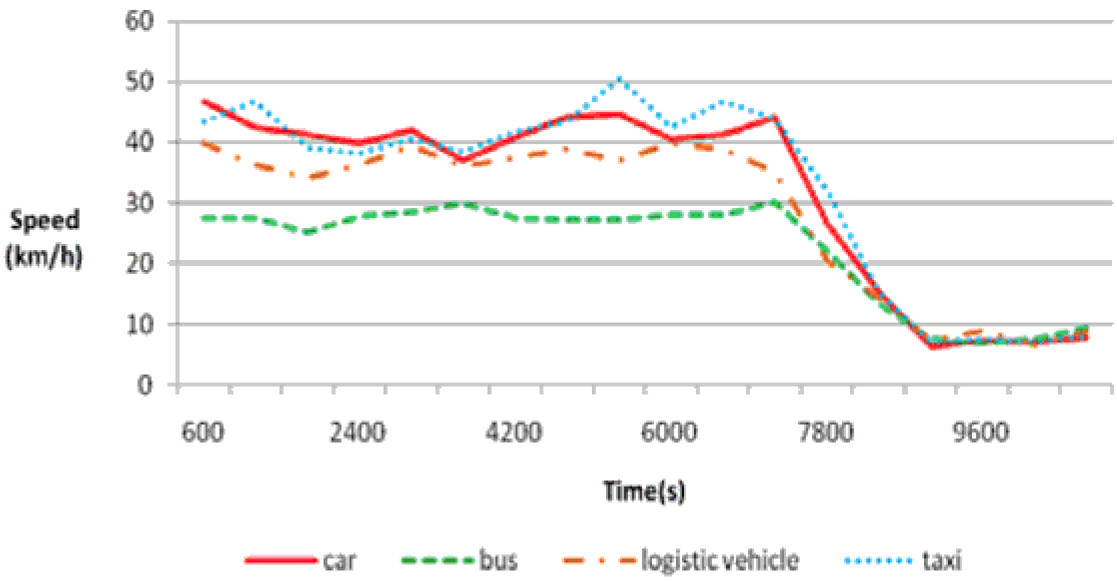

Figure 4: Speed curve of Floating Car and Vehicles on the same section [2].

To monitor the traffic situation of a certain region, a specified minimum penetration of probe vehicles (floating cars) is required. Depending on aggregation periods for estimated TT and

LOS, the correlation of penetration rate and covered network can be estimated. The diagram in Figure 5 is based on simulated data with references on taxi FCD and network characteristics from Lyon.(see Alexandre Torday, 2004).

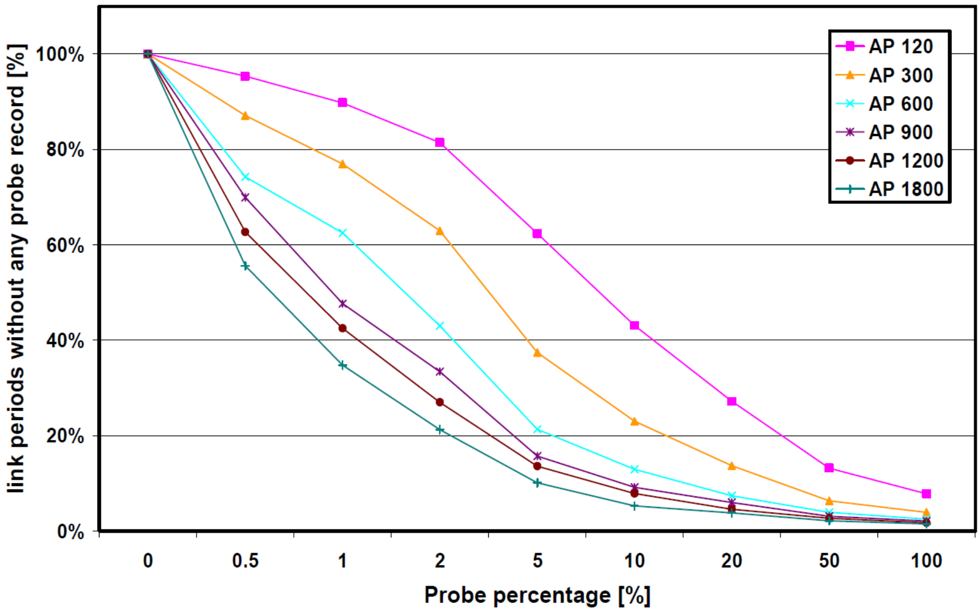

Figure 5: Correlation of Aggregation Period (AP), probe percentage and link periods without any probe records [3].

2.2 Factors Influencing the estimation of traffic state

Several factors influence the estimation accuracy of traffic state by means of floating car data technology. The most relevant factors can be summarized as follows:

- **Timing.** This factor influences mobile traffic monitoring in various ways and in particular through the following parameters:

    1. the **sampling interval**, i.e. the time between two measured position data sets. This parameter defines the method and the complexity of geo-referencing. From one side it is possible to choose high frequency position data (typically 1 [Hz], i.e. 1 position every second) with almost no need of routing between, while on the other side it is possible to prefer low frequency data (typically 1 position every minute), but with higher investments in routing algorithm needed;

    2. the **communication interval**, i.e. the interval between two consecutive data packets transmission. The choice is typically driven by technological equipment and costs availability. Mobile phone networks cover pretty much the whole European road network and mobile data packages for business are available on good terms. Therefore, communication interval is becoming shorter and shorter, and the position data available almost in real time.

Depending on the fleets system architecture, data communication can be triggered by other events than time, like the end of a trip (e.g. the end of a passenger trip in case of taxis, or the change of a vehicle state).

For the use in traffic monitoring systems the single vehicle measurements need to be aggregated in *distance* (e.g. per link) and *time* to model traffic parameters like mean travel velocities (or travel-times) for a road network. The **aggregation period** depends on data availability and data density; common values are from 5 min. (for real-time applications and short-time prediction) up to 1 hour (for mid-term prediction and historical traffic data analysis)

- **Positioning**. First applications on mobile traffic data consists of O/D (**Origin/Destination**) information, with the advantage of low data transmission, but with no information about the taken route between origin and destination. Different travel speed along the route and waiting times at intersections therefore cannot be detected reliably with this method.

  With the availability of **satellite-based positioning** in different devices, like Navigation Devices, On-Board-Units or Smartphones in combination with flat rates for mobile data, the position data quality has become significantly better.

  The position data consist at least of:

  1. the **coordinates** (latitude, longitude);
  2. a precise **timestamp**;
  3. a **vehicle** (or equipment) **identification**.

  Optionally further data, like the **actual speed**, **heading**, **acceleration** or some **quality parameters** like *Position Dilution of Precision* (PDOP) and number of satellites or vehicle data, like the state of vehicle or driving, can be available for further processing.

- **Modeling**. To process mobile traffic data for applications in the traffic monitoring domain, the previous influencing factors have to be considered in the following steps of modeling:

  1. **Geo-Referencing**, i.e. the task of referencing position data in form of latitude/longitude coordinates to a map of the road network. A key part in this process are the **map matching** algorithms, with several mapping approaches (i.e. point-to-point, point-to-line and line-to-line) [6].
  2. **Filtering** – i.e. the task of creating a reliable data set in the spatio-temporal domain by means of outlier detection techniques;
  3. **Aggregation** – i.e. the final task of estimating basic traffic parameters per link, and aggregation period.

2.3 Further aspects influencing mobile traffic monitoring systems

Other aspects which must be properly taken in consideration during the design of mobile traffic monitoring system are the following [7]:

- **Time**. Data become outdated, i.e., new messages should be considered with more weight, while older messages are less significant. However, above a threshold of elapsed time, with no coherence to the current traffic state, the data will become historical. Historical data can be treated uniformly, and only the type of day and time become important.

- **Message density**. The precision of the statement is increased by the number of samples belonging to the road element, i.e., more messages yield higher weight.

- **Speed variance**. Variance of speed depends on traffic state. High variance can be observed for free flow traffic, whereas variance is low for congested traffic. In case of no road disturbances like traffic lights, speed values are normally distributed, and outliers can be detected on the basis of the properties of the normal distribution (if a sufficient quantity of data are available). Values can be, e.g., excluded if they go beyond two times the standard deviation of speed. In case traffic lights are involved, they mainly determine the speed variance leading to bi-modal normal distributions or even skew distributions.

- **Type of Road Element**. Taking the mean speed for a longer section could lead to imprecise speed information on the individual road elements. This is particularly the case when the estimated path contains different types of streets, with both low and high normal speeds. In this case the speed of the street with low normal speed could be overestimated and analogously, the speed on a highway can be underestimated by the average speed. Hence, a method for speed estimation for one trip is proposed in the next section.

- **Additional factors**. In several cases estimations for some road elements are insufficient because of lack of data. However, travel time estimation should be given for them as well. It can be set to infinity, which means that these roads are omitted. This approach could lead to very long routes or even to the case that no routes exist. That is why it is proposed that the data is to be estimated on the basis of historical data and travel time estimated by macroscopic models.

2.4 Positioning technologies for mobile traffic monitoring

The common positioning technology which is adopted for mobile traffic monitoring applications is the **self-positioning** one [6]. This approach consists of a mobile terminal using signals transmitted by an antenna (which can be either terrestrial or satellite) to calculate its own position.

Typically, self-positioning technology applied for mobile traffic monitoring relies on a satellite technique. **Global Positioning System** (GPS), the worldwide satellite-based radio navigation system managed by the USA, is the common choice. The system is composed by three main segments (the space segment, the control segment and the user segment – see Figure 6), and provides a position accuracy which is in the order of 15-20 [m]. The GPS constellation is made up of 24 satellites which orbit at an altitude of 20.200 [km] above the Earth. At the user segment side, a mobile GPS receiver convert satellite signals into position, velocity and time estimates. The estimation is possible only if the signals are received by four different satellites.

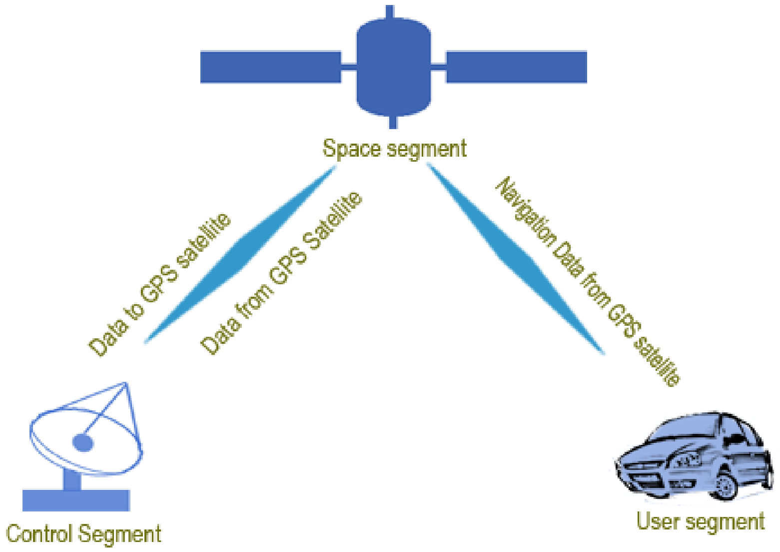

Figure 6: The architecture of the GPS system (Source: engineersgarage.com).

GPS is a very robust choice, but presents a certain number of drawbacks, in particular the limited spatial accuracy, and the difficulty to have at least four on-sight satellites in any conditions .

An improvement of conventional GPS system is the **Assisted-GPS** (A-GPS) technology. The basic idea of A-GPS is integrate satellite-based measurements with cellular networks ones, which can estimate the location of a mobile receiver down to cell/sector level (Figure 7). Typically, A-GPS receivers are able to detect and demodulate signals that are order of magnitude weaker than conventional GPS receivers, and can lead to position accuracy in the order of 1-10 [m].

Differential techniques, known as **Differential-GPS**, can further enhance the accuracy (and the cost) of a GPS system. Differential correction can be applied in real-time or in a post-processing phase, but with different levels of accuracy. The basic idea in this case to use a couple of receivers relatively close one to each other, in order to guarantee that both will experience similar atmospheric errors. One receiver is set up on a precisely known location, and acts as a reference station. The error experimented by this station is applied to the second receiver in order to improve the position estimate.

Figure 7: The architecture of the A-GPS system (Source: navigadget.com).

The future reference positioning system will however be **Galileo**, the European navigation satellite system, which is going to introduce a highly accurate global positioning system under civilian control interoperable with both GPS and GLONASS, the Russian system. Galileo is based on a constellation of 30 satellites (27 operational and 3 active spares) at an altitude of 23.222 [m] above the Earth. The large number of satellites together with the optimization of the constellation will ensure that the loss of one satellite has no discernible effect at the user side. Galileo will offer real-time positioning accuracy down to the meter range, which opens the doors for advanced location-based services where safety is crucial, in particular in the transport domain .

In some projects and publications, also **beacon-based** technologies are proposed for the positioning of floating car or probe vehicle systems (e.g. electronic tolling systems). In this case, the road side infrastructure is used for both positioning (thanks to the exact position of the beacon) and data communication (e.g. through DSRC communication technology).

Because of the very high penetration, also **mobile phone data** becomes a very interesting data source for traffic monitoring. Within the mobile phone network, active phones can be located and trajectories can be computed.

2.5 Traffic monitoring applications and reference projects

2.5.1 IN-TIME

In-Time is a Pilot Type B Project funded by the European Commission, DG Information Society and Media in the CIP-ICT-PSP-2008-2 Program. In-Time (*Intelligent and Efficient Travel management for European Cities*) focuses on **multimodal Real Time Traffic and Travel Information (RTTI) services** provided to drivers and travelers with the goal to reduce drastically energy consumption in urban areas across the different modes of transport [9].

Central part of the In-Time concept is an interoperable and multimodal Regional Data/Service Server (RDSS) which can be seen as a service-oriented middleware infrastructure providing a number of data/services, covering individual traffic, public transport, weather, location based services, inter-modal transport planning, that enables the operation of end-user applications (web based applications) as well as the B2B access from European-wide Traffic Information Service Providers (TISP) via a harmonized standardized open interface. This RDSS has been set up at 7 European pilot sites to ensure the easy access of real-time multimodal traffic data for external Traffic Information Service Providers. This model ensures the easy access to all urban traffic related data within one region resulting in the distribution to the end-users via several information channels and in parallel enhancing user acceptance.

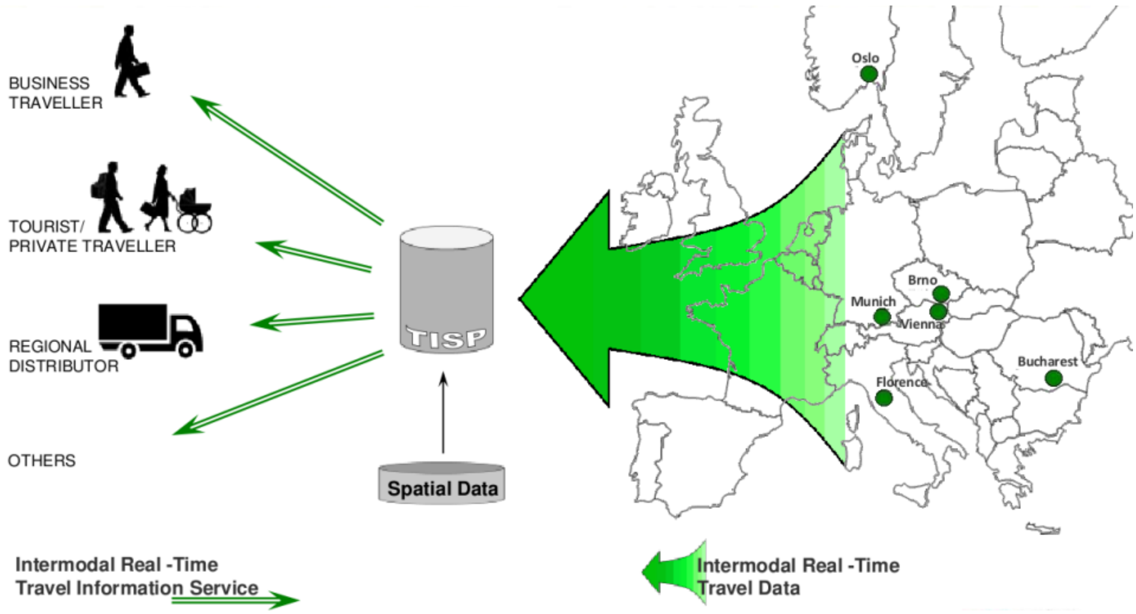

Figure 8 – The high-level approach of IN-TIME [10].

Travel Time Evaluation Methodology

One of the most interesting demonstrative services implemented in In-Time project is service 17 – “comparative dynamic multi modal journey planning”. In order to assess the accuracy of this service, the actual travel time is required. This ground truth is measured on the base of an evaluation phase split into three sub-phases:

- a first **preparation** phase which includes (i) the acquisition, installation and setup of the required technical infrastructure, (ii) the selection of test routes and test timetables as well as (iii) the recruitment of the required personnel to carry out the following phases. The output of the preparation phase was a Test Plan which summarizes all decisions taken in this activity;

- a second **data collection** phase, in which travel time information for the previously defined routes was collected from the RDSS and stored in an Evaluation Database for subsequent analysis. Simultaneously, a fleet of probe vehicles equipped with GPS trackers travelled on the same routes and measured the actual travel time.

- a third and final **data analysis** phase, which compared in a post-processing session the ground truth collected by the probe vehicles and the travel information elaborated by the RDSS.

The overall error between estimated and measured data is quantified by the *mean squared error* (MSE) or *root mean squared error* (RMSE).This overall error can be decomposed into three components [11]:

- the bias (or mean error), indicates systematic over- or underestimation;
- the variance deviation, which indicates how well the estimated data replicate variability in the observed data;
- the correlation, which describes how well estimated data are representing the ground truth.

For travel time information characterization, the correlation parameter is the most important component, as changing travel time is an important indicator of changing traffic conditions.

2.5.2 DMOTION

Dmotion (Düsseldorf in Motion) is a German research project within the VM 2010 (Traffic Management 2010) research initiative funded by the German Ministry of Economy and Technology (BMWi). The aim of Dmotion is to develop and implement an integrated traffic management system for the conurbation of Düsseldorf [3].

This system is based on a comprehensive data, information and strategy network for regional and local authorities, as well as for private service providers (Figure 9). Thus, one major objective of Dmotion is to generate a consistent and comprehensive report on traffic conditions for Greater Düsseldorf. For this reason, many different possibilities for the calculation of the current traffic state are in the focus of this research project, e.g. traffic models based on loop detectors near traffic lights and various methods based on floating car data (FCD). Methods for data fusion are used to get a consistent view of the network. This provision of an overview on the current traffic situation is a precondition for deciding on corrective actions, using roadside information systems (VMS), internet and on- and off-board navigation.

Technical Setup: Taxis and Public Transport Vehicles As Data Source

Speed calculation based on floating car data represents an alternative, respectively a supplementation to stationary sensors. Several research projects in European cities (e.g. Vienna, Berlin, Munich) have shown that measured speeds from taxis are representative of the average speed of the whole driving population [7].

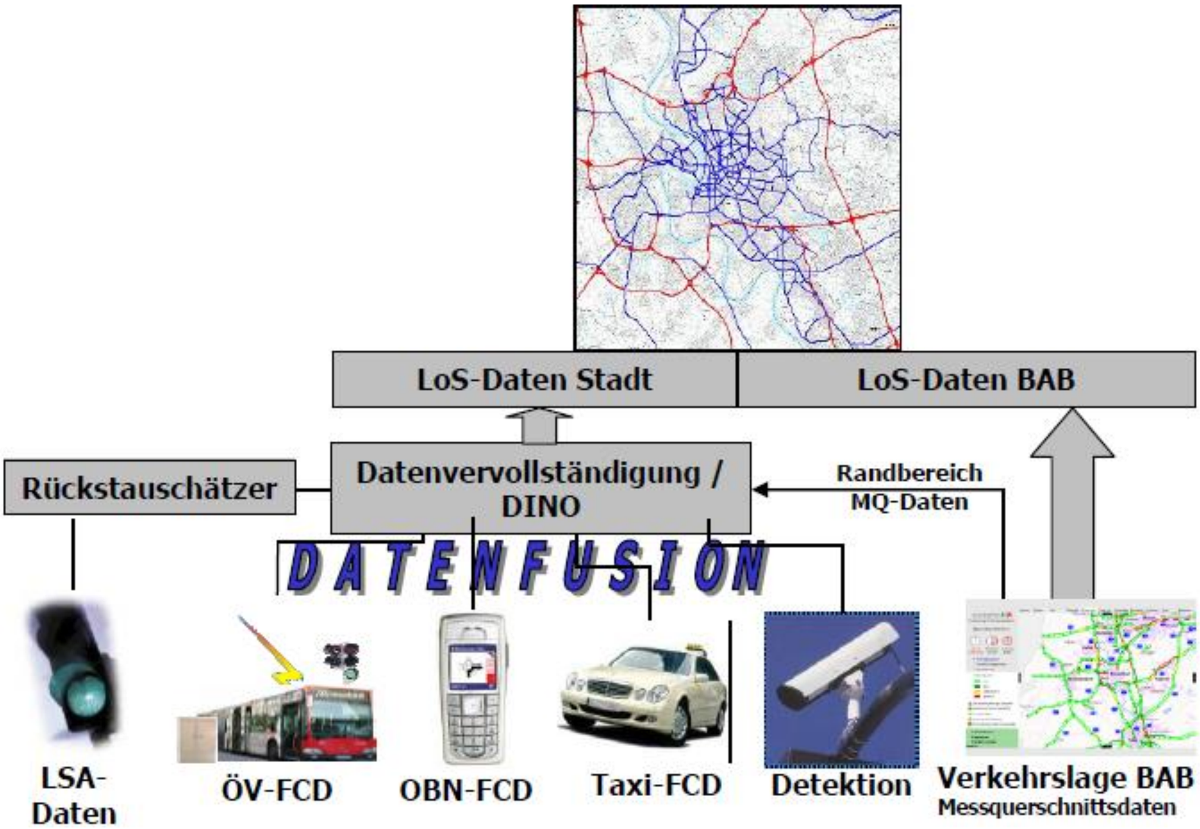

Figure 9 – The reference system architecture of Dmotion [12].

Furthermore taxi fleets mostly dispose of fleet management systems including positioning technology and communication networks. These preconditions allow for cost-effective integration of representative fleets. Typically the trips of taxis are not uniformly distributed in the city network, but they are rather concentrated to the city centre and relevant areas, e.g. conference centres, soccer stadiums, and to the arterial road network [4]. Within the research project Dmotion, data is provided by a fleet consisting of 1200 taxis. Most of the taxis provide origin - destination (OD) trip data, because the bandwidth for transmitting information from the taxis to the taxi management centre is limited. Merely a few test vehicles of the fleet transmit position information with high accuracy from their GPS receiver. Evaluation of trip length and average speed of taxi trips has shown that only trips with passengers on-board are representative for the normal driving situation. Percentage of links per time interval with available probe records on a typical working day ranges between 2 and 10 percent from midnight to 6 a.m., whereas it is higher from 6 a.m. until midnight (between 10 and 30 percent). From the percentage of links with available probe records and the aggregation period of currently 15 min, the equipment ratio (ratio of the number of trips of floating cars in relation to all trips in the network) can be estimated (see also [5]).

This estimated equipment ratio is up to 0.2 % from midnight to 6 a.m. and between 0.2 and 0.5 % from 6 a.m. until midnight. Estimating equipment ratio based on the mileage of taxis is difficult, because data on the exact mileage of taxis is not readily available.

As an additional source of information on the current traffic state, probe data from public transport vehicles is utilized in Düsseldorf. PT vehicles send online messages at fixed locations in the streets to the next traffic controller on their route to gain their right of way. These messages are then passed on to the traffic control centre. The time between different messages from the same vehicle can be interpreted as travel time, and thus it can be used to collect information on traffic state on the affected roads.

2.5.3 NAV-CAR

The project NAV-CAR (*Improved Navigation in challenging Areas by Robust Positioning*) includes the analysis of satellite based data from GALILEO system, which is still under construction [13]. In COOPERS, a European integrated research project [3], an approach to evaluate the potential of Galileo using simulation of satellite signals was taken. The whole procedure is described in detail in Deliverable D4500-2 “Evaluation of scientific test vehicle and achieved results” [14].

The data analysis is based on position data. On the one hand position data is gathered with GPS from test drives and on the other from GALILEO simulation. The drives were divided into distinct drives on different lanes to ensure a sufficient number of positions for lane-specific data analysis. Data analysis is done including following steps:

- **Selection of road sections.** The test drives for task “enhanced maps” where done on A12 (“Inntalautobahn”) and A13 (“Brennerautobahn”) in Tyrol.
- **Representation of data in form of trajectories.** A trajectory shows the path of a moving object in space. The resulting geometry is a polyline connecting the points of position data.
- **Definition of orthogonal cuts.** In order to achieve a look on the sectional view the taken trajectories are cut by orthogonal lines (cross-sections) .
- **Analysis of lateral distribution.** The resulting distances on the orthogonal line represents the lateral distribution of the trajectories on the specific cross-section on the highway (Figure 10).

The test field of mountainous region consists of road segments on A12 (“Inntalautobahn”) and A13 (“Brennerautobahn”). The data acquisition was organized to cover the triangle built by these two highways. For data analysis the test area was arranged in three sections: *east*, *west* and *south*. As illustrated in Figure 10 each section includes both driving directions and consists of three orthogonal cuts (cross-sections).

The orthogonal cut and especially the lateral distances from an estimated centre point are shown in Figure 11. The diagrams present the relative distribution of trajectories in relation to their lateral position. As expected the driving direction and for position data with best lateral accuracy (GALILEO CS) the number of lanes can be recognized.

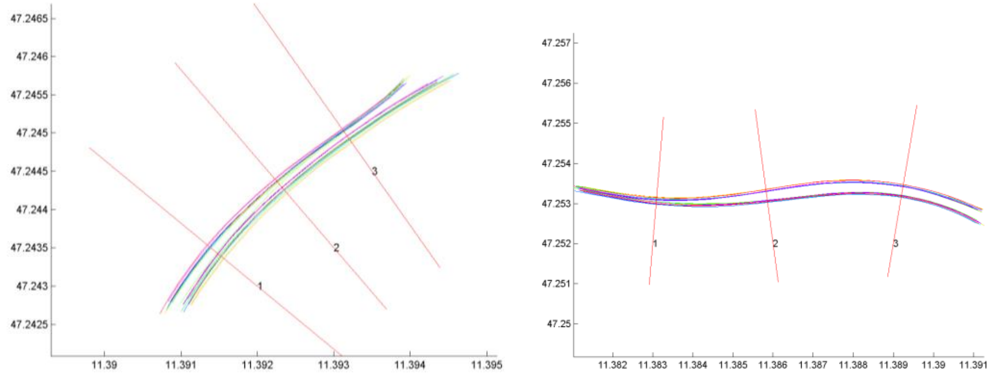

Figure 10: Trajectories of test drives and orthogonal cuts for analysis of lateral distribution

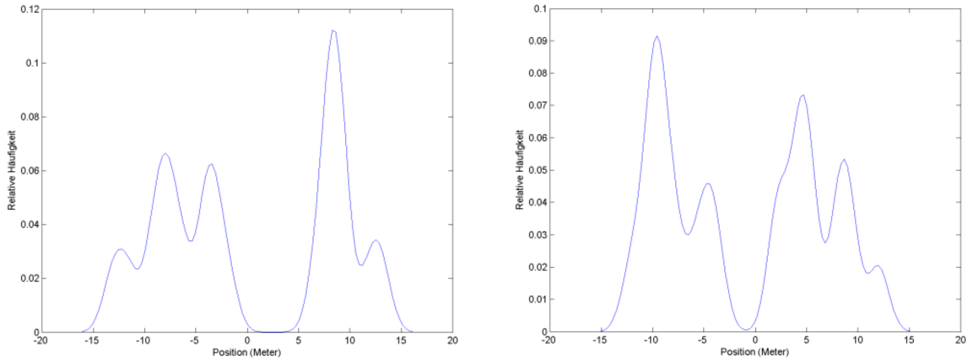

Figure 11: Samples of lateral distribution, trajectories from Galileo CS data set.

2.6 Analysis of environmental monitoring approaches for traffic applications

The distribution of environmental data is very complex. The gas concentration and the concentration of particles in the air change in the three dimensional spaces. One reason is the very local distribution of pollution producers like factories, houses and vehicles. On the other hand climatic events like wind or rain will distribute gas or particles in a very complex way.

Local environment stations can measure the concentration of pollutants at stationary locations over time. These fixed environmental stations measure the concentration of pollutants in the area nearby the sensor and subsequently it is possible to interpret the data in the surroundings if the principal pollutants and the climatic situation are known.

Within the city of Bolzano in South Tyrol (Italy), air pollution monitoring is performed by the Autonomous Province of Bolzano, and in particular by the Local Agency for Environment. For several years the agency has been measuring the principal air pollutants, in order to control if the reference levels are below the thresholds defined by law. A detailed analysis of the air pollution level is presented in the INTEGREEN deliverable D.2.1.1 in chapter 2.3 [1]. The state-of-the-art to monitor air pollutants is performed with local fixed environmental stations by mean of an Eulerian approach (see below). These fixed environmental stations are expensive, need power supply (typically with fixed cables) and data connection to a monitoring central station (with either fixed wired or wireless connection).

2.6.1 Traffic-induced environmental monitoring approaches

Three main approaches are available in the literature in order to monitor air pollution emissions and concentrations over a road network of interest [15].

- **Absolute Lagrangian approach**. In this case, a mobile probe is designed in order to monitor the pollution that it has been generating. Thanks to this approach, it is possible to correlate the emission details as a function of the internal (e.g. driving style) and external (e.g. traffic, road type, etc.) factors which influence driving, and thus to optimize driving cycles. This approach can be very precise for emission modelling purposes, but it needs a very large fleet of mobile probes in order to calculate the emissions differences as a function of the motor type. For this kind of activity, it could be useful to take in consideration the numerous databases of emission data available in the state-of-art, in particular ARTEMIS which is of public domain [16].
- **Hybrid Lagrangian approach**. In this case, a mobile probe is designed to measure the local levels of air pollution. These measures are useful in order to calibrate a calculation model, but must rely on a fleet of mobile probes which is in the condition to sufficiently cover a target area in time and space.
- **Eulerian approach**. In this case, the environmental monitoring task is performed by a network of fixed environmental stations, installed at the road side. Emission calculation models such as COPERT [17] use this data for calibration purposes, and are driven by traffic data provided by traffic counters (typically inductive loops). This approach has the advantage to easily cover wide areas, but its accuracy strongly relies on the quality of the data provided by the monitoring systems.
- **Integrated approach**. This approach aims to integrate the advantages proposed by the different approaches. In other words, a simulation modelling task performed at a central level is run on the base of traffic measurements and calibrated by environmental data provided by both mobile probes and fixed stations. In particular, the calibration follows a Lagrangian approach in the time domain and an Eulerian approach in the spatial domain.

2.7 Environmental traffic management reference projects and solutions

To overcome the complexity of performing an accurate monitoring of air quality in both time and space, different research projects are working on how to better integrate simulation models with measurement systems, in particular exploiting the increasing potential of mobile probes. Mobile environment systems can indeed be mounted on motor vehicles or bicycles, as well as carried around by pedestrians.

2.7.1 CARBOTRAF

The project CARBOTRAF is a STREP (Specific Targeted Research Project) project co-funded within the 7th EU Framework Programme, and coordinated by AIT (Austrian Institute of Technology) [18].

The CARBOTRAF project aims to introduce a method, system and tools for adaptively influencing traffic in real-time to reduce carbon dioxide CO_2 and black carbon (BC) emissions caused by road transport in urban and inter-urban areas. The system will be tested in the two European cities of Glasgow (UK) and Graz (AT).

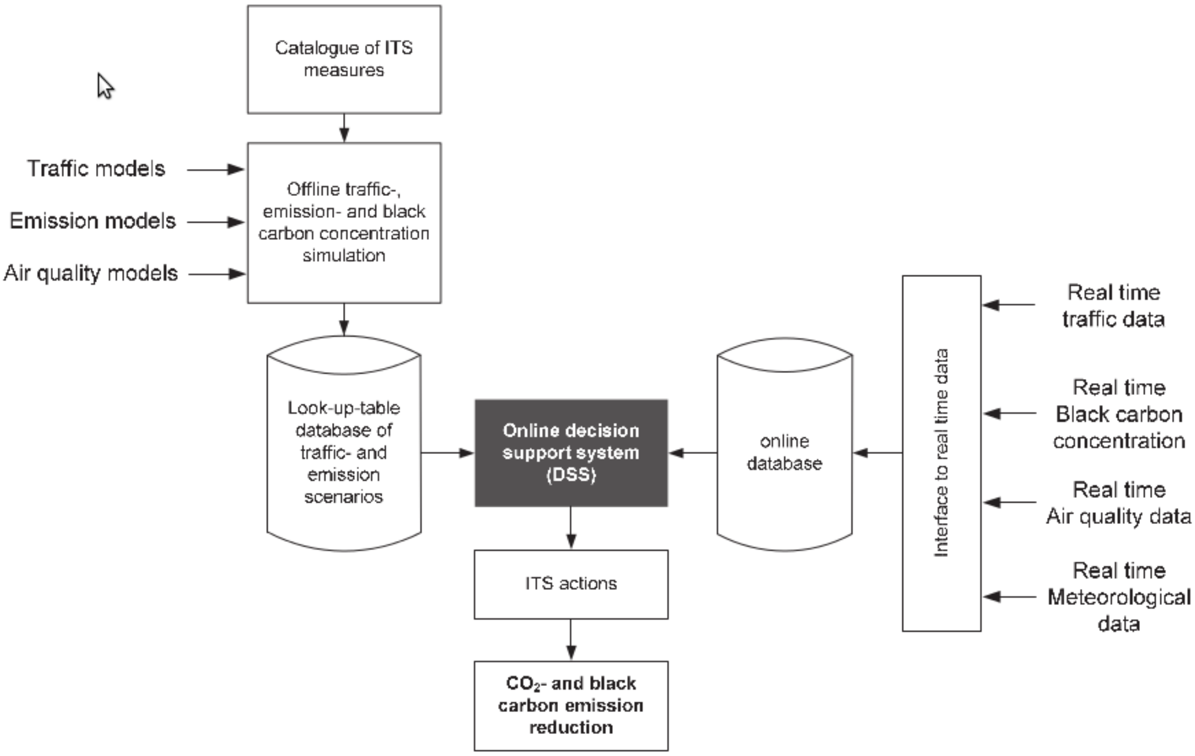

Figure 12: The reference architecture of CARBOTRAF [17].

“Stop & go” traffic conditions causes substantial CO_2 and black carbon emissions. Both pollutants contribute significantly to global warming. CARBOTRAF combines real-time monitoring of traffic and air pollution with simulation models for emission prediction in order to provide on-line recommendations for alternative adaptive traffic management options. The focus of CARBOTRAF is the creation of a simulation model to predict pollutants from traffic vehicles and on this basis to give input for improved traffic management. It takes also into account other pollutants from the available fixed environment monitoring systems and meteorological data. The method used in CARBOTRAF concentrates more on the analysis the emissions of gas and particles caused by heavy traffic conditions, rather than on providing low-cost mobile monitoring systems.

2.7.2 *iQ mobility project*

iQ mobility – "Integrated Quality and Mobility Management for Road Traffic in the Berlin Regionis a joint research project being undertaken by various partners from the federal states of Berlin and Brandenburg [19]. The project started in autumn 2004 and ended in February 2008. The project was managed by the Berlin Senate Department of Urban Development and supported by the Federal state of Brandenburg.

The aim of the research project was to improve the quality of road traffic on the existing road network in the whole region by using intelligent traffic control measures. For this purpose, the project significantly increased the capability of the local traffic management and the control centers in Berlin, Potsdam and the federal state of Brandenburg. Quality criteria were considered in order to quantify the impact of the novel systems; besides standard traffic parameters (flowing traffic, congestion phenomena, travel times), the effects on air pollution and noise as well as on road accidents were considered.

The integrated quality and mobility system iQ mobility was structured as a control loop with the following modules (Figure 13):

- the **Quality Module**, which continuously monitors and evaluates the quality of road traffic;
- the **Strategic Traffic Management**, which takes in consideration predictable events such as large scale events, the exceeding of critical values, and construction sites;
- the **Operational Traffic Management,** which early detects disturbances as they arise, and allows traffic officers to activate the proper countermeasures.

The quality module , for example, calculates the level of air pollutants for all street sections of the main road-network based on current traffic and weather data.

A field test for "**Environment Traffic Management**" was performed in Leipziger Straße in Berlin-Mitte. The efficiency of the traffic management measures, implemented for the reduction of traffic induced pollution by fine particles (carbon, particulate matters) and nitrogen oxides (NO_2) as well as noise, was analysed. For this purpose, continuous and situation-related (dynamic) operational control measures have been performed. The efficiency analysis of these measures (calculation of air and noise pollution as well as calculation and analysis of traffic quality) was based on comprehensive traffic and meteorological data that were provided online.

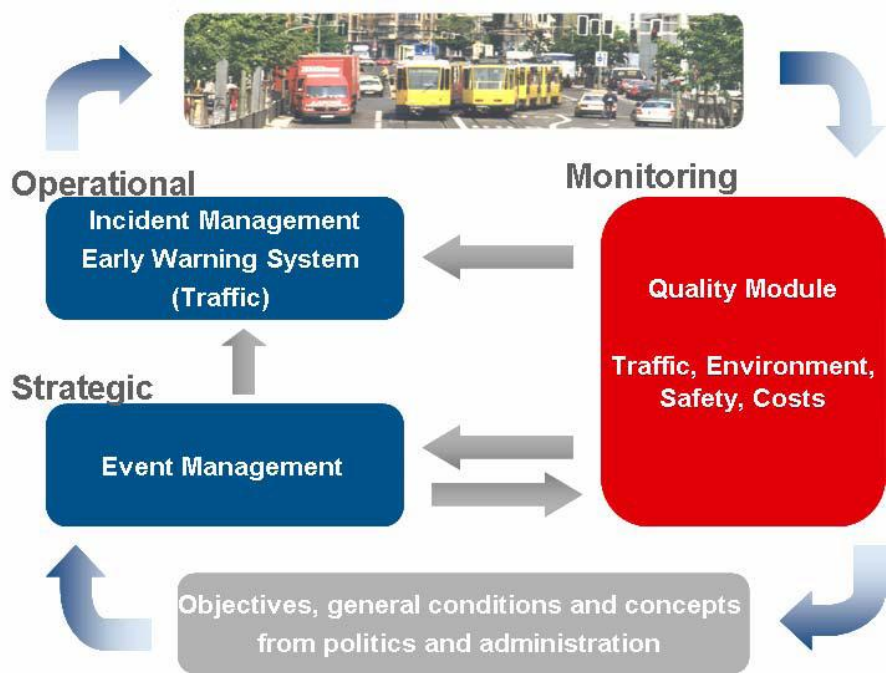

Figure 13: The reference architecture of iQmobility [19].

The result was that a reduction of traffic congestion showed a reduction of nitrogen oxides up to 10%. The particulate matters pollution from the traffic showed also a significant reduction, but, due to the relative high contribution of other pollutants the reduction of total pollution was lower than the reduction of nitrogen oxides. Since the test case in Leipziger Straße covered a small geographical area, there was no need to have mobile environmental measurements.

2.7.3 MESSAGE

The project MESSAGE (*Mobile Environmental Sensing System Across Grid Environments*) was a national project carried out in England, under the coordination of Imperial College London [20]. The project started on 14th October 2006 and ended on 13th October 2009, and was jointly funded by the Engineering and Physical Sciences Research Council and the Department for Transport of England. The project team included researchers at Universities of Cambridge, Leeds, Newcastle and Southampton.

The project developed and demonstrated the potential of diverse, low cost sensors to provide data for the planning, management and control of the environmental impacts of transport activity at urban, regional and national level. This includes their implementation on vehicles and people to act as mobile, real-time environmental probes, sensing transport and non-transport related pollutants and hazards.

Three sensor platforms were developed as part of the project. The University of Cambridge investigated the potential for personal devices (mobile phones) to support a sensing system. the University of Newcastle developed a “smart-dust” network using Zigbee (IEEE 802.15.4) motes, while Imperial College London devised a network that utilized WiFi (IEEE 802.11.g) and WiMax (IEEE 802.16) technologies for communications and positioning, and a set of novel sensor designs. All platforms were integrated with a common data processing system.

A significant result of MESSAGE was the design and implementation of a data architecture that supported large numbers of the different types of sensors and allowed the system to be dynamically scaled up as more sensors are added. Data could be stored in multiple databases incorporating the Urban Traffic Management and Centro specification. The data could be coupled with data from weather and traffic flow and fed into applications such as emission and pollution dispersion models.

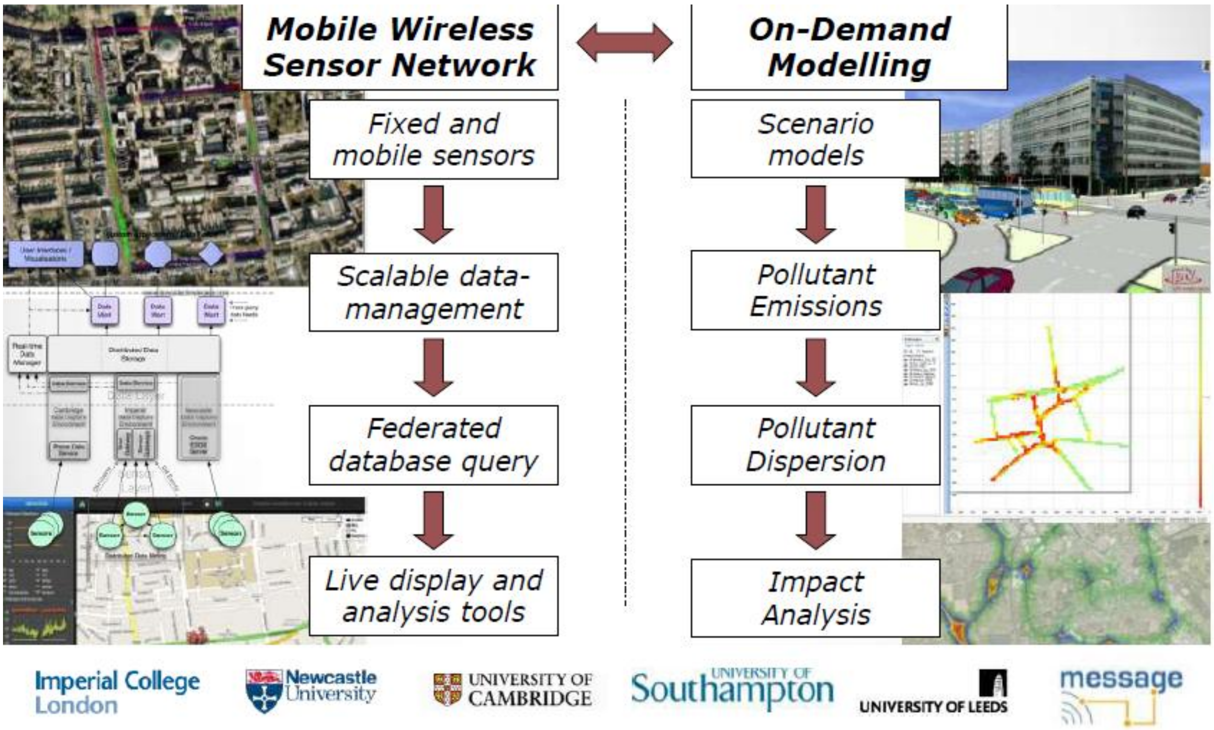

Figure 14: The reference architecture of MESSAGE [21].

The final architecture and data management processes could be used in different domains, but it addressed mainly large scale remote data collection – the system was in fact to complex and expensive for a regional or city level application. The final systems were not as low-cost as expected and the transfer from a laboratory solution to a commercial deployment remained a major challenge.

2.7.4 DUVAS

Duvas Technologies is a start-up company which was founded with the objective to commercialise the result of the MESSAGE project described here above [22]. Duvas is also a partner in the project Carbotraf. Duvas is a newly created entity that sits within the Imperial Innovations Incubator that combines the academic and engineering excellence of Imperial College London with the commerciality of the real world. It builds on the result of

10 years R&D led by Dr John Hassard, the Chairman, and the extensive resources of Imperial College. The company is jointly owned by Imperial Innovations [Aim Listed] and private capital [MDT] with significant knowledge and strong links with the aviation industry. Duvas have been actively engaging with end-users and other stakeholders in order convert a perceived technological advantage into a commercially viable business model.

Duvas is an acronym for *Differential UV Absorption Spectroscopy*. It is based on DOAS (*Differential Optical Absorption Spectroscopy*) technique used for remote sensing to retrieve volume mixing ratios of trace atmospheric absorbers over long optical paths. Further stages of noise reduction then take place on the data before the differential spectra are obtained. Reference spectra for all the species under investigation are then dynamically matched using a sophisticated non-linear algorithm. The Duvas Solver utilises a range of statistical analysis tools to aid further noise reduction whilst maintaining real-time sensitivity.

DUVAS states thanks to this technological solution it is possible to:

- measure a broad range of pollutants;
- obtain measurements with resolution in the order of parts per billion (ppb);
- set up a **mobile** (for short term measurement) or **permanently sited** (long term measurement) grid of monitors;
- provide **real time data**, with measurements taken every few seconds;
- be networked for **real-time applications**.

More in detail, the DUVAS system is characterized by the following list of specifications:

- high throughput UV spectrometer system;
- simultaneous measurement of SO_2, NO, NO_2, O_3 & Benzene to ppb levels, with a frequency update of few seconds;
- monitoring capability of the following pollutants: carbon disulphide, xylene, toluene, ammonia, ethyl benzene, formaldehyde, acetaldehyde, hydrogen sulphide,1,3 butadiene, isoprene, most VOCs and PAHs;
- H_2S and the other aromatic "smelly" gases are currently under investigation;
- CO_2 and particulates planned to be incorporated through other off the shelf and proven instruments to create "one solution in a box";
- geared for networking of multiple DUVAS units within a Sensor Grid -e-Science;
- can support 3rd -party data for correlative studies

Further Development Areas of the Duvas system taken from one of their recent presentations are the following:

- increase the scope and the sensitivity of the sensors;
- develop (mobile) data validation protocols;
- develop dynamic measurement routines;
- develop data representation tools;
- anomaly research for threat mitigation.

Figure 15: The portable DUVAS system solution [21].

The solution developed by Duvas is suitable for low-volume measurement campaign as it is rather expensive and bulky. The commercialised product is still in its infancy and still has instability issues (from unofficial sources). However, Duvas is ready to engineer ad-hoc solutions or to rent their system for a limited period of time. In the context of the INTEGREEN project, the Duvas system could be hired for a specific measurement campaign and used as second source of data to validate the measurements of the future INTEGREEN system.

2.7.5 German Institut für Automation und Kommunikation

The German Institut für Automation und Kommunikation (IFAK) worked in 2008 on the integrated acquisition of traffic and environment data [23]. In particular, IFAK developed a static monitoring system (Figure 16) consisting of a base equipment unit (1), a passive infrared detector for traffic analyzing and a detector for acquisition of environment data (2). The data are processed locally and remotely transmitted via GPRS. The power supply is performed with solar cells (3).

Figure 16: The IFAK integrated traffic and air pollution static monitoring system.

2.7.6 CISMA

CISMA (Centro di Ingegneria e Sviluppo di Modelli per l'Ambiente) was founded in 2005 by four engineers from the Department of Civil and Environmental Engineering at the University of Trento (Italy) [24]. The start-up is today a technological company based within the business incubator of TIS innovation park.

The company offers a variety of services and engineering solutions in different application fields, in particular (i) particulate pollution in urban areas and the evaluation of the health risk, (ii) implications rehabilitation of contaminated land, (iii) rubbish incinerators effluent management and (iv) analysis of the dispersion of pollutants in rivers and lakes.

CISMA designed, assembled and patented in the past years a mobile air pollution monitoring system called MASS (*Mobile Air Sampling System*) [25]. It is a device designed to be mounted on a car, intended for sampling of fine particles and coupled with a GPS antenna for geo-referencing purposes. The instrument is based on an optical particle-counter and can provide one measurement record of dust concentration every 6 seconds for 15 granulometric classes between 0.3 and 20 µm. In Figure 17 and Figure 18 the MASS system is shown.

Figure 17: The CISMA MASS system [24].

Figure 18: Detail of the CISMA air-probe and a car mounting example [24].

Figure 19 represents an example of the measurement campaigns taken with the MASS system in the areas of Bolzano / Merano, Trento, Rovereto and Verona. The results are superimposed cartography and refer to the gravimetric classes which are conventionally taken into account for the analysis of air quality: PM_{10}, $PM_{2.5}$ and PM_1; concentrations are expressed as [µg/m^3]. The values reported should be intended as instantaneous concentrations.

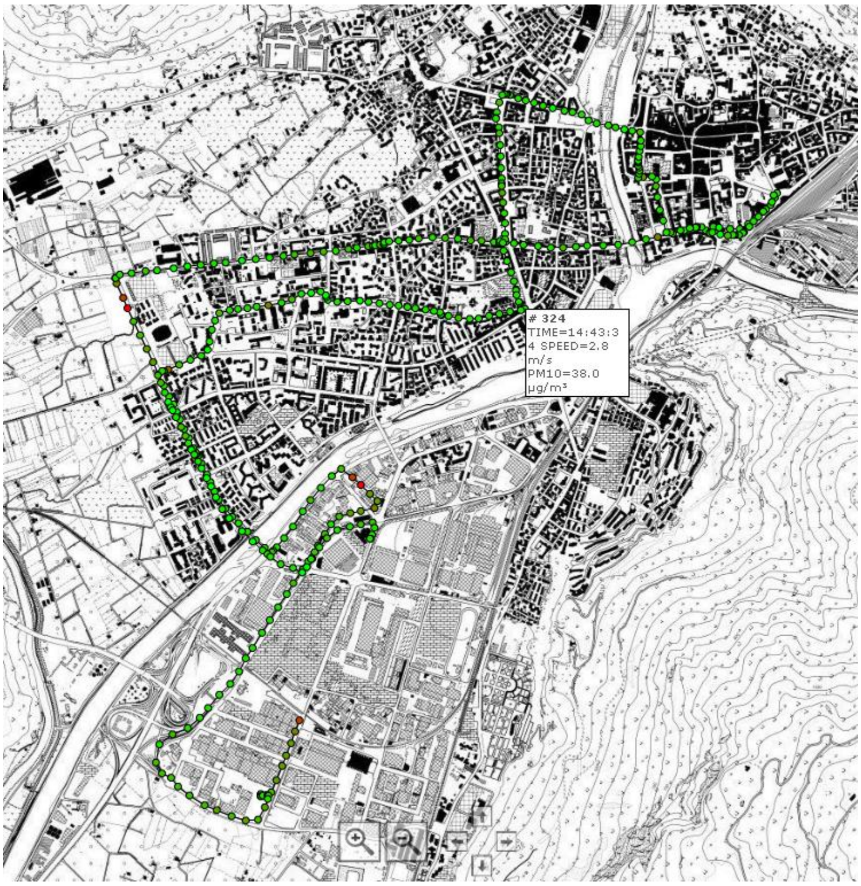

Figure 19: Sample measurements taken in Bolzano on the 31/10/2006, showing PM10 particles [24].

The solution developed by CISMA is based on integrating a portable high quality Laser Aerosol Spectrometer and dust monitoring instrument. It is not meant for large volume mobile applications but rather for measurement campaigns as shown in the figure above. It is rather expensive solution, but it would be suitable as second source of data to validate the measurements of the future INTEGREEN system.

2.8 Communication technologies

The communication between a traffic/environmental mobile probe and a central station can be achieved with different technologies. The technologies available are addressing to different industrial sectors and have different characteristics and performances.

This section will give a short overview of the communication technologies which can be used in ITS and their main characteristics will be described.

2.8.1 GSM/GPRS

The Global System for Mobile Communication (**GSM**) is the most popular standard for mobile phones in the word. Roaming between mobile phone operators is very common, so it is often possible to use a mobile phone in many parts of the word. The signaling and speech transmission is totally digital and on a good quality.

GSM is a cellular network, which means a cellular infrastructure in the vicinity of the user is necessary. GSM networks operate in four different frequency bands:

- 400/450 [MHz]
- 900 [MHz]
- 1800 [MHz]
- 1900 [MHz]

In Europe the 900 [MHz] and 1800 [MHz] bands are typically used, while In the USA and other countries also the 400/450 [MHz] and the 1900 [MHz] bands are preferred. The diameter of a GSM cell varies between 100 [m] and 35 [Km]. It depends in principal from on antenna characteristics and the propagation conditions and is designed from cell planers. For difficult indoor conditions or tunnels picocells can be built.

If the mobile moves from one cell to another cell an automatic hand-over is provided from the cell infrastructure. General Packet Radio Service (**GPRS**) is a mobile data service available to user of GSM mobile phones. It can be used for SMS (Short message Service), MMS (Multimedia Messaging Service) but also for further service, e.g. mobile Internet access. GPRS is a packet-switched service, that means the bandwidth is available for all users and only if data has to be transmitted the bandwidth is assigned to that user. Typically only the transferred data have to be paid and not the access time. With GPRS, download rates of about 60kbit/s and upload rates of 40kbit/s are possible.

2.8.2 UMTS

Universal Mobile Telecommunications System (**UMTS**) is the third generation mobile cellular technology (3G) and is based on the GSM standard. It was developed from the 3GPP (3rd Generation Partnership Project). UMTS uses a *Wideband Code Division Multiple Access* (W-CDMA) radio access technology to achieve a better spectral efficiency than GSM in order to reach higher data rates. The data rate for each user can be adapted dynamically according to the user need and network capacity.

The existing cellular base stations of the GSM network cannot be used for UMTS, so a new infrastructure had to be built. Dedicated frequency bands are foreseen from the standard. The data rate depends on the cell type and the speed of the mobile. For a microcell and a speed of up to 120 [km/h] a data rate of 384 [kbit/s] is possible. In a picocell the data rate can increase up to 2 Mbit/s.

During the lifetime of UMTS, different upgrade options for higher data rates have been developed:

1. **HSDPA**. *High Speed Downlink Packet Access* (HSDPA) was developed to achieve higher download data rates (from the mobile network to the mobile terminal). Up to 21 [Mbit/s] download rate is possible. in practice, however, typical download rates are in the order of 7.2 [Mbit/s].

2. **HSUPA**. *High Speed Uplink Packet Access* (HSUPA) is an enhancement for higher uplink data rates (from the mobile terminal to the mobile network). Some providers offer 5.76 [Mbit/s] uplink rate, further plans aim to achieve 23 [Mbit/s].

2.8.3 LTE

For higher data rates, the Long Term Evolution (**LTE**) project plans to move UMTS to 4G speeds with 100 [Mbit/s] downlink data rate und 50 [Mbit/s] uplink data rate. In order to accomplish this, a new air interface OFDM (*Orthogonal Frequency Division Multiplexing*) will be used. This enhanced data rate opens the horizon for future, advanced on-board location-based services, e.g. mobile video-streaming.

2.8.4 Bluetooth

Bluetooth is a short range wireless communication technology. It was developed to replace cable connections from portable to fixed devices like a mobile phone to a computer or to a printer. Bluetooth use the free ISM frequency band for communication. Due to other communication devices using the same frequency band, Bluetooth can be easily disturbed.

The standard was developed for networks with nearly static nodes where the topology is changing slowly, So it is not suitable for communications between moving motor vehicles with static infrastructure.

The data rate depends on the version: in version 1.2, it can arrive up to 1 [Mbit/s], while in version 2.0+EDR, this limit is increased to 3 [Mbit/s]. Typical range for data transfer varies from a few meters up to hundred meters.

2.8.5 WLAN

Wireless Local Area Network (WLAN) is a communication technology standardized by IEEE. It is placed in the IEEE 802.11 group and has several subgroups. WLAN is very popular in professional and private networks. The numerous standard groups “a”, “b”, “g” and “n” are not designed for fast moving mobile terminals.

The frequency bands of 802.11 are located in the free ISM frequency band 2.4 [GHz] and 5 [GHz]. The data rate provided by the different standard groups are summarized in Table 1.

Standard	Data Rate	Frequency band
802.11a	up to 54 Mbit/s	5 GHz
802.11b	up to 11 Mbit/s	2.4 GHz
802.11g	up to 54 Mbit/s	2.4 GHz
802.11n	up to 300 Mbit/s	2.4/5 GHz
802.11p	3 – 54 Mbit/s	5.9 GHz

Table 1: IEEE 802.11 standard groups main features.

The newest standard **802.11p** was approved from IEEE in April 2010 and published in July 2010. The standard was specifically designed in order to satisfy the requirements of future cooperative ITS (C-ITS) applications, which need a fast and reliable data exchange from moving vehicle to vehicle (v2V) and from vehicle to infrastructure (V2I).

2.8.6 WiMAX

Worldwide Interoperability for Microwave Access (WiMAX) is a standard of IEEE 802 for support of wireless metropolitan area network. It is placed in the 802.16 group. WiMAX belongs to the 4G (fourth generation) communication system.

This communication technology was introduced in order to:

- provide a wireless alternative to cable modem for “last mile” broadband access. The terminal antenna is typically fixed for example on a house roof;
- provide a mobile broadband Internet access.

The frequency band is in the range from 2 [GHz] up to 6 [GHz]. The frequencies in use are dependent of the specific regulations of the different countries. National providers have bought these licensed sub-bands and can thus operate WiMAX services.

The possible data rates are depending strongly on the provider capabilities. The system can theoretically support up to 1 [Gbit/s] for fixed stations.

2.8.7 DAB

Digital Audio Broadcast (DAB) is a technology to broadcast audio information of radio stations and other types of digital services. It is also called “Digital Radio”. DAB is transmitted in many countries in Europe but also in other countries. Communication is mono-directional, this means that data can only flow from a transmitter station to the mobile or fixed users.

The high data rate - in the range of a few [Mbit/s] – makes this technology suitable for delivering broadcast mobility services on board, especially in the case when the same information from a central station should be provided to a big number of mobile users. This opportunity is going to be further explored with the successor of DAB, **DAB+**, which is going to further increase this data rate limit by significantly reduce deployment costs, in particular at the receiver side.

2.8.8 CEN-DSRC

Dedicated Short Range Communication (DSRC) is a set of protocols and standards for ITS defined by the European Committee for Standardization (CEN). In Europe, a dedicated frequency bandwidth of 30 [MHz] in the 5.9 [GHz] band is allocated from the European Telecommunications Standards Institute (ETSI).

At present, DSRC is used mainly in electronic toll collection (ETC) and congestion charging services in Europe. The deployment of DSRC-based application typically needs an extensive infrastructure with different RSUs (*Road Side Unit*), which is not available today in the city of Bolzano.

2.8.9 CALM-IR

Communications access for land mobiles (CALM) – Infra Red is a family of standards which defines a common architecture, network protocols and an infrared air interface.

CALM-IR works in the wavelength range at 870 [nm]. The basic features of CALM-IR are:

- data rates of 1 and 2 [Mbit/s], which can be extended up to 128 Mbit/s;
- data transfer in mobile conditions, with vehicle speeds up to 200 [km/h];
- communication distance up to 100 [m];
- latencies and communication delays in the order of milliseconds.

Similarly to DRSC, CALM-IR finds today application basically only in the ETC sector, since an infrastructure needs to be available to support the communication at the road side unite side. Even in this case, such infrastructure is not available today in the city of Bolzano.

3 Analysis of current situation in terms of existing vehicular fleets

The objective of the INTEGREEN system is to demonstrate the potential of mobile probes in significantly increasing the traffic (and environmental) capability of the Traffic Management Centre of the city of Bolzano. Not only: INTEGREEN aims to involve local stakeholders that can at the end of the project (or even during its execution) exploit the system by integrating vehicles fleets which are in the condition to send data and thus to continuously feed the Supervisor Centre.

For this reason, before to enter in the design and implementation actions, it is important to know which possible fleets – and reference telematic architectures - are currently in use that can potentially exploit INTEGREEN.

The fleets which are going to be evaluated in this chapter are therefore (i) the local public transport; (ii) the local taxi fleet and (iii) the (future) car sharing service.

3.1 Public transport

Two main public transport companies are active in South Tyrol:

- **SAD**, which is responsible of the local extra-urban public transport service on both road (bus), rail (train) and funicular railway (cable car) [26];
- **SASA**, which is responsible of the urban road public transport service in the main towns of the region, namely Bolzano and Merano [27].

SAD is even responsible, under commitment of the Mobility Department of the Province of Bolzano, to manage the integrated ticketing system which allows local travelers to use the same ticketing platform and a unique tariff for multi-modal travels in the region.

At the beginning of 2012, a new contactless ticketing system based on ISO/IEC 14443 technology [28] was introduced, with the intention to (i) simplify and speed up the check-in and check-out operations and (ii) collect statistical data about travel choices, with the opportunity to further improve the public transport services on the base of the current needs.

A new contactless smart card, called “Alto Adige Pass” was delivered to local travelers, and allows them to move across the whole Province of Bolzano with all the means of the public transport service without any limitation in time or space. The new technology allowed to introduce a new pricing system as well, based on the real kilometers traveled and no more on the whole ride. In order to accomplish this, the travelers must validate the ticket during both the on-boarding (check-in) the off-boarding (check-out) phase.

3.1.1 SAD

In order to match both ticketing system and remote vehicle maintenance requirements, SAD has developed an own Automatic Vehicle Location A(VL) system capable of efficiently executing these tasks. The reference on-board system architecture which applies for all the vehicles of its fleet (Figure 21) is illustrated in Figure 20.

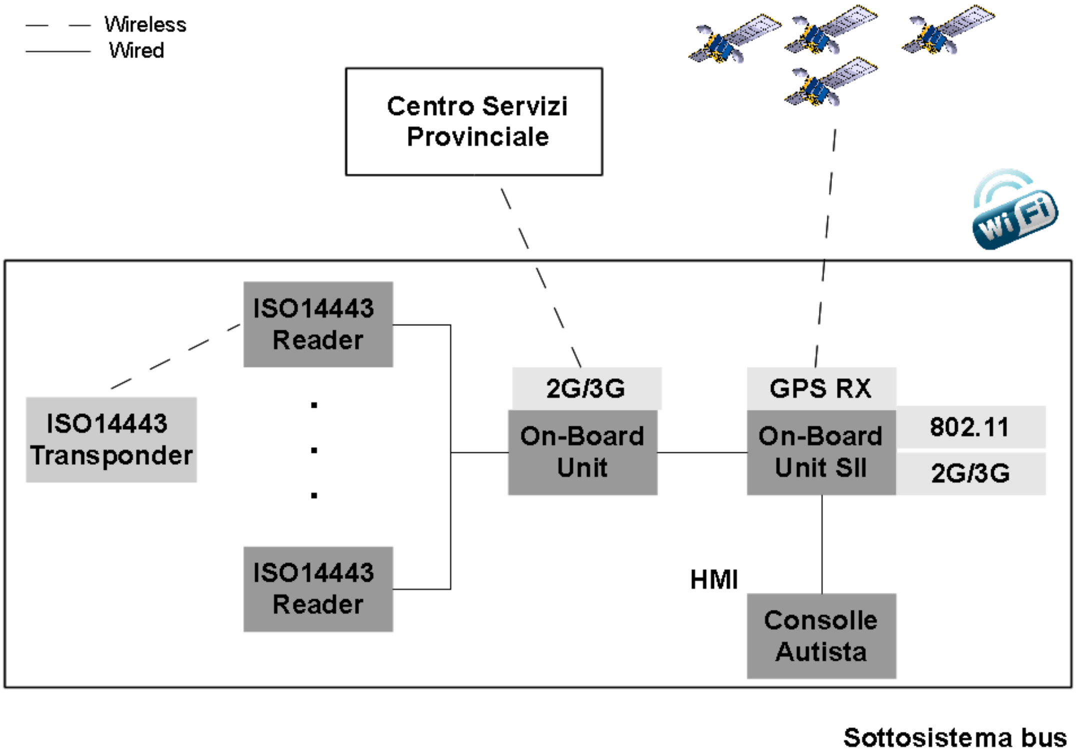

Figure 20: The reference architecture of the vehicles of SAD fleet.

Figure 21: A vehicle of the fleet of SAD.

The main system components are the following:

- **on-board ticketing system unit**, which is responsible to locally manage the data related coming from tickets' validation (performed by one or more ISO/IEC 14443 contactless readers) and to periodically deliver it to the Regional Ticketing Service Center by means of a GSM/GPRS connection.
- **on-board monitoring unit**, which is responsible to control the on-board systems (including the on-board ticketing system unit) and to send the vehicle information or notifications to the central fleet management system by means of a GSM/GPRS connection or Wi-Fi, in the case the on-board data are transferred through a short-range link to a dedicated access point (this if for example the case when the vehicles conclude their daily service). The driver can visualize basic information collected by the on-board monitoring unit on a dedicated console which can be integrated or not in the vehicle.

3.1.2 SASA

The reference architecture for the vehicles of the fleet owned by SASA (Figure 22) is actually very similar to the one already described for SAD. The only difference relies in the choice of the on-board maintenance unit, which is in this case provided by a third provider, the Swiss company **TEQ** [29].

The system is actually in function in Merano, and is going to be integrated soon even in the fleet of Bolzano. The on-board monitoring unit can be easily interfaced with other components (e.g. the INTEGREEN traffic / environmental on-board monitoring units) through standard serial data communication ports (e.g. RS232 /RS485)

Figure 22: A vehicle of the fleet of SASA.

3.2 Taxi fleet

A fleet of about 50 taxis is currently driving in the urban area of Bolzano, more or less one eight of the circa 400 among taxis and car rental services which operate in the whole Province of Bolzano. The fleet in Bolzano (Figure 23) is managed by an autonomous cooperative called **Radio Taxi Funk Bolzano-Bozen** [30]. The cooperative has had in the recent past, thanks even to the cooperation with the Municipality of Bolzano, an active involvement in several local initiatives, the most important being the activation of a collective taxi service (today no more in use), and the introduction of a Wi-Fi connection service in cooperation with Telecom Italia.

From a fleet management point of view, the vehicles (and the service requests coming from users) are controlled by a central taxi station . The technological platform, both at the centre side and on-board, is provided by the company **Microtek**, which has its headquarters in Udine, Italy [31]. Thanks to this commercial cooperation, the local cooperative is introducing some more services to their customers, the most interesting being:

- a service destined to third parties (e.g. hotels), which allows them to book a taxi for their guests/customers;
- a service based on SMS (or smartphone application) which allows local travelers to book a taxi.

Figure 23: A vehicle of the taxi fleet in Bolzano.

3.3 Car sharing Südtirol

In 2013, a local cooperative (Arche im KVW [32]) is going to create, in cooperation with other local stakeholders (in particular, Confcooperative Bolzano and Legacoopbund), a local consortium called “Car Sharing Südtirol” for the management of an advanced car sharing service in the Province of Bolzano. This future service, supported by both the Municipality of

Bolzano and TIS innovation park, will technologically rely on vehicles and car sharing management system of Volkswagen, **Quicar** [33]. This new initiative will strongly rely on the experience that Volkswagen is actually carrying out in different cities in Europe, in particular Hannover, where the system is actively in use. Quicar already offers the "***open-end***" functionality, i.e. the possibility to access to a vehicle of the fleet without previous booking. The "***one-way***" functionality, i.e. the possibility for the traveler to take a car in one point and to give it back in another location, is a premium service which is going to be probably introduced in a future step.

The access to the service will be possible through a contactless smart card, probably the Alto Adige Pass, which will thus increase the number of supported transport services.

Figure 24: The presentation of the local car sharing initiative in Bolzano.

4 INTEGREEN mobile system – use cases & concept

This chapter aims to consolidate the mobile system concept and to define the reference use cases which will guide the following design and implementation activities. The concept is defined by taking in consideration the inputs coming from the state-of-art and the parallel work of requirements analysis carried out in Task 2.1 at the Supervisor Centre [1]. Last but not least, the mobile system architecture takes in consideration the recommendations of the first C-ITS standards, and in particular the building blocks proposed for the ITS Vehicle Station (Figure 25).

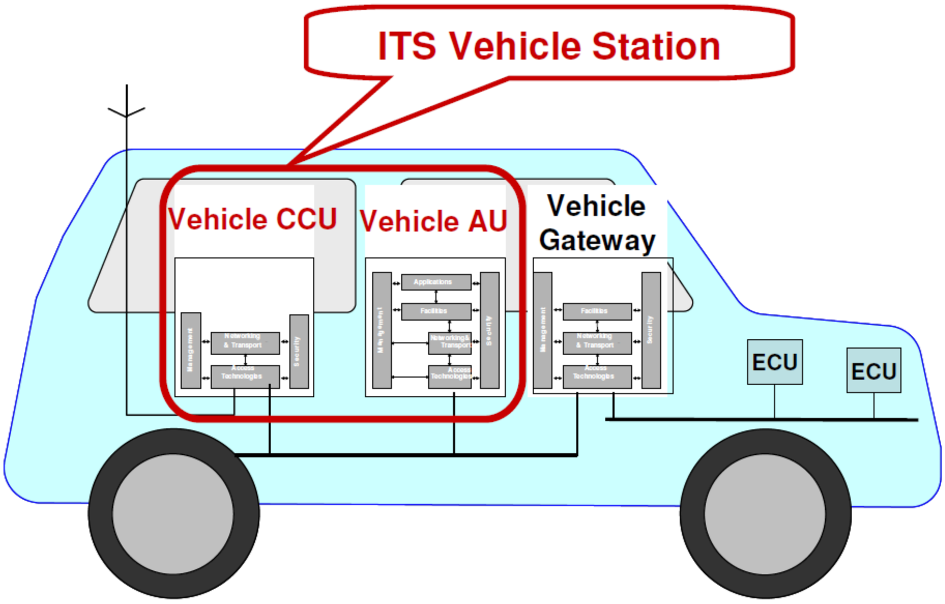

Figure 25: The ITS Vehicle Station reference architecture [34].

An ITS Vehicle Station consists of two main sub-components:

- a Vehicle **Communication and Control Unit** (CCU), which is in charge of communication with other vehicles (V2V), roadside infrastructure components (V2I) and remote centre controls. Depending on the profile, may also provide access to the Internet Domain;
- one or several Vehicle **Application Units** (AUs) realizing the ITS applications.

In order to provide vehicle specific ITS applications, the ITS Vehicle Station may require an access to the vehicle network (e.g. CAN bus) and the data produced by the automotive Electronic Control Units (ECUs) or vehicle sensors. The link to the vehicle-specific network is provided by the vehicle gateway, which is able to access the vehicle information and provide it to the ITS Vehicle Station. In the reverse direction the Vehicle Gateway may also provide data to vehicle controllers or to presentation devices integrated in the vehicle.

4.1 The mobile system concept

The mobile system architecture is illustrated in Figure 26.

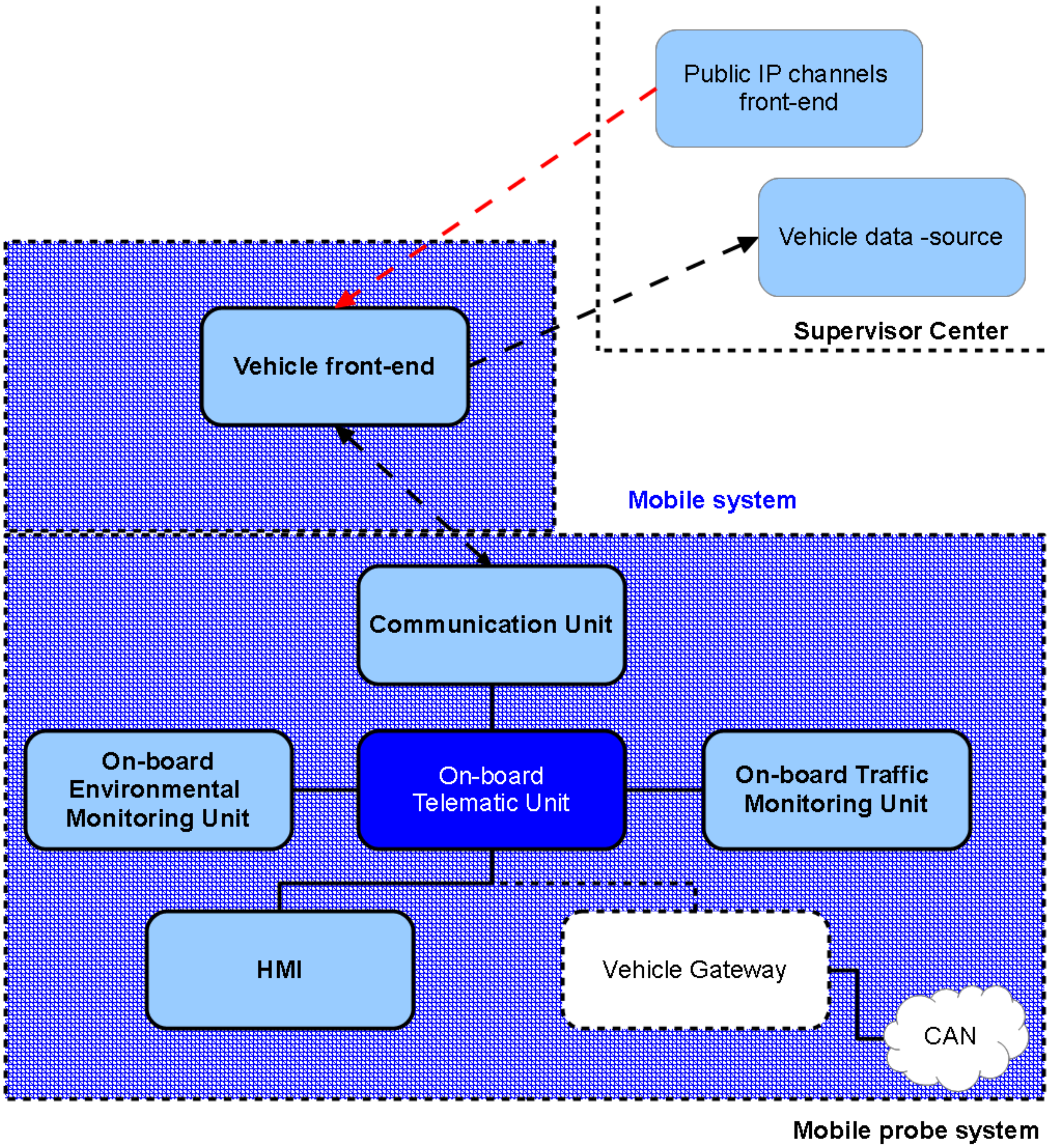

Figure 26: The reference architecture for the INTEGREEN mobile system.

The components of the mobile system are:

- the **mobile probe system**, which is composed by the following main components:

- ✓ the **on-board telematic unit**, which is the core element of this subsystem, controlling the proper functioning of the other components (in particular, the on-board traffic and environmental monitoring units); its main tasks are to:
  - ▪ receive the sensed data by the on-board traffic and environmental monitoring units, pre-process it and deliver it remotely to the vehicle front-end through the Communication Unit;
  - ▪ receive the info-mobility information from the Supervisor Centre (through the Vehicle front-end and the Communication Unit), and let it properly display on the HMI;
- ✓ the **on-board traffic monitoring unit**, whose focus is to collect data about the local traffic conditions;
- ✓ the **on-board environmental monitoring unit**, whose focus is to collect data about the local environmental conditions;
- ✓ the **communication unit**, which provides a communication service with the remote Vehicle front-end;
- ✓ the **HMI**, which offers a visualization interface of the available data/ information on-board to the driver.

- the **Vehicle front-end**, which provides a remote bi-directional data communication channel with the mobile probe system; the front-end is moreover in charge to interact with the Supervisor Centre, namely to deliver the raw data to the vehicle data-source and to get the info-mobility information from the public IP channels front-end (eventually, even by the public broadcast channels front-end).

At the mobile probe system side, it is possible to foresee an interface with the CAN network of the vehicle (even if not mandatory in the INTEGREEN project), with an architecture which is compliant with the ITS Vehicle Station one (i.e. through a vehicle gateway).

4.2 The mobile system use cases

The INTEGREEN mobile subsystem contributes to the development of use case 5 (UC_5) defined in D.2.1.1 in three different use scenarios, namely:

- **T1: Traffic state estimation;**
- **T2: Estimation of the amount of emissions caused by motorized individual transport**
- **T3: Air Quality state estimation**.

The contribution to these use scenarios are presented in the next paragraphs.

4.2.1 Traffic state estimation

The target is to enable the Supervisor Centre operator to base their decisions on reliable, actual and network-covering traffic state information. Also the distribution of this information to the drivers is of high interest to influence their driving behavior to avoid or mitigate congestions to reduce the pollutions that would be generated otherwise.

To achieve reliable information the on-site measurements provided by probe vehicles are of high value. Another advantage of the use of a mobile system is that all major parts of the road network will be covered and reduces the enormous costs for road side infrastructure. The actuality of the data is partially a technical question regarding the sampling and communication rate but also relates to a compromise with the coverage. A lower frequency rates increases the probability of a sufficient number of vehicles to calculate the actual traffic state. Typical update frequencies are in the order of 5 to 15 Minutes. That means that every 15 minutes a new traffic state for Bolzano can be calculated.

The traffic-related data that is typically collected by a mobile system is listed in ***Table 2***.

Quantity	Necessity	Measurement principle	Application
Position	Mandatory	Global Positioning System (GPS)	a) Determination of the location of the probe vehicle and special assignment of measured data b) Basis for velocity and heading calculation
Heading	Optional	Compass, Gyroscope or subsequent GPS-Positions	a) Assignment of measured data to the driving direction b) Validation of subsequent GPS data
Velocity	Optional	Subsequent GPS-Positions or access to the on-board electronic system	Velocity is one of the core traffic state quantities enabling a direct assessment of the traffic state
Acceleration	Optional	Inertial sensors or access to the on-board electronic system	Support and validation of the velocity and traffic state estimation

Table 2: List of traffic related data to be collected by the on-board module of the INTEGREEN mobile system.

As part of the INTEGREEN project the traffic state related module of the mobile system will be designed and prototypically implemented as hard- and software. It will be used to equip probe vehicles in order to collect movement data from the probe vehicle, which will provide test data for the data integration at the TMC data management and traffic elaboration unit.

As soon as vehicle fleets of reasonable size, like taxis and local public transport take part of the INTEGREEN mobile system the full potential for the traffic state estimation will be possible. The network-coverage as well as the reliability highly depends on the number and mileage of the probe vehicle fleet.

4.2.2 Air quality state estimation

The key approach of INTEGREEN is to reduce traffic based emissions and increase air quality by a combined traffic and air quality information support of the Supervisor Centre. Such a decision support enables not only to take the best traffic related choice but to optimize traffic actions regarding air quality.

To support the stationary measurement system for air quality, the mobile probes will be partially equipped with a pollution sensor system. Like for the traffic state system described above this enables an area-wide coverage beyond the fixed stations.

The air quality related data to be collected by the mobile system is listed in ***Table 3***. **The added value of mobile environmental monitoring is to address peak values, and thus to study the air pollutant profile patterns not in absolute terms but in relative terms**.

Quantity	Necessity	Measurement approach	Application
NO_2	Mandatory	Hybrid Lagrangian approach	Air pollution peaks evaluation, emission/dispersion modeling calibration.
O_3	Mandatory		
CO	Optional		
NO	Optional		
PM_{10}	Optional		
VOC	Optional		
SO_2	Optional		
Air temperature	Mandatory	Temperature sensitive resistors or semiconductor	Support the calibration of the pollutant measurements
Humidity	Mandatory	Humidity sensitive	Support the calibration of the

		electric capacity	pollutant measurements

Table 3: List of air quality related data to be collected by the on-board module of the INTEGREEN mobile system

As part of the INTEGREEN project the air quality related module of the mobile system will be designed and prototypically implemented as hard and software. It will be used to equip probe vehicles in order to collect pollution and meteorological data, which will provide test data for the data integration at the Supervisor Centre data management and air quality elaboration unit.

4.2.3 Estimation of emissions caused by motorized individual transport

The vehicle based measurement of emissions of all vehicles is practically impossible because not every vehicle can be equipped with a measurement unit.

The proposed approach for INTEGREEN is to reuse the traffic state estimation as input to a macroscopic emission model. In this case the traffic situation is characterized by a low number of discrete traffic states (like stop&go). The combination of this traffic state, the type of road and the vehicle fleet (EURO classes) are sufficient to enable the selection of according emission factors (e.g. at the handbook of emission factors, which applies results of the aforementioned ARTEMIS project). In this way the estimation of the emission can be performed.

The data to be collected for the traffic state estimation is already described in Table 2. In case, the traffic data collection is part of the emission modeling one can consider special characteristics that are very informative for this task. Especially accuracy data to derive stop&go conditions are of high value. Hence Table 2 will be updated for a mandatory accuracy measurement to Table 4.

Quantity	Necessity	Measurement principle	Application
Acceleration	Mandatory	Inertial sensors or access to the on-board electronic system	Support and validation of the velocity and traffic state estimation

Table 4: Updated list of traffic related data to be collected by the on-board module of the INTEGREEN mobile system

As part of the INTEGREEN project the emission modeling related traffic state will be estimated. The mobile system will be designed and prototypically implemented as hard and software especially considering the accuracy component. It will be used to equip probe vehicles in order to collect movement data from the probe vehicle, which will provide test data for the data integration at the Supervisor Centre data management and emission calculation unit.

5 Requirements identification

The objective of this last chapter is to finally consolidate the reference system requirements of the INTEGREEN mobile system. The reference methodology which is used in this task is the same which is applied for the requirements identification at the Supervisor Centre, described in detail in Chapter 7 of D.2.1.1 [1].

5.1 List of requirements

The complete set of requirements is listed in Table 5. It is worth noting that no requirements are defined for the vehicle front-end, since its behavior is actually driven by the requirements defined for the vehicle data-source.

Components	ID	Name	Type	Priority
On-board telematic unit	OBU_1	Computing capacity	F	M
	OBU_2	Storage capacity	P	M
	OBU_3	Storage capacity (optional)	P	C
Communication unit	CU_1	Communication technology	NF	M
	CU_2	Communication protocols	NF	M
	CU_3	Communication load	P	M
HMI	HMI_1	HMI - Information content	F	M
	HMI_2	GUI - Information content	F	C
On-board traffic monitoring unit	OBTU_1	Kinematic sensors	F	M
	OBTU_2	Kinematic sensors plus	F	M
	OBTU_3	Kinematic sensor quality	F	S
On-board traffic environmental unit	OBEU_1	Environmental sensors	F	M
	OBEU_2	Meteorological sensors	F	M
	OBEU_3	Environmental sensors plus	F	C
	OBEU_4	Environmental sensor quality	F	S

Table 5: Requirements list table.

Derived from the requirement analyses of the entire system, the technological potential of mobile probe vehicles for measurements of traffic status and environmental conditions the requirements of the INTEGREEN mobile subsystem are defined as illustrated in the following paragraphs.

5.2 On-board telematic unit requirements

ID	OBU_1
Name	Computing capacity
Description	The CPU of the on-board telematic unit requires enough computing capacity to accomplish the following tasks: • the control of the attached units; • the basic map matching and filtering of the data stream from the traffic and environmental units; • the processing of the communication protocols; • the preparation of the data to be displayed as well as the interaction with the HMI.
Rationale	System design – central processing and control of all components of the mobile probe

	system
Type	Functional
Priority	Must

Table 6: Requirement OBU_1 (computing capacity).

ID	OBU_2
Name	Storage capacity
Description	The on-board telematic unit must be equipped with enough memory to backup the recorded data of the traffic and environmental unit for at least 15 minutes.
Rationale	System design – enable to bridge temporal failures of the contact to the stationary system
Type	Performance
Priority	Must

Table 7: Requirement OBU_2 (storage capacity).

ID	OBU_3
Name	Storage capacity (optional)
Description	Further memory allocation must be considered in the case the on-board telematic unit needs to store basic map representations.
Rationale	System design – possible extension of the on-board data representation modalities.
Type	Performance
Priority	Could

Table 8: Requirement OBU_3 (storage capacity (optional)).

5.3 Communication unit requirements

ID	CU_1
Name	Communication technology
Description	The communication unit must apply standard communication technologies such as 2G, 3G, WLAN (802.11) and Bluetooth
Rationale	System design - fast and future-proofed communication technologies.
Type	Non-functional
Priority	Must

Table 9: Requirement CU_1 (communication technology).

ID	CU_2
Name	Communication protocols
Description	The communication unit must apply standard communication protocols, e.g.: • XML, GPRS (generic data) • UMTS, CALM (traffic data)
Rationale	System design – well established and standardized communication protocols.
Type	Non-functional
Priority	Must

Table 10: Requirement CU_2 (communication protocols).

ID	CU_3
Name	Communication load
Description	The communication between the mobile probe system and the receiving vehicle front-end has to transfer:

	• traffic data (position, heading, velocity and acceleration) with an update frequency of 5 [s]; • environmental data (air pollutants and meteorological data) with an update frequency of 60 [s];
Rationale	System design - all the measured data must be communicated to the stationary system
Type	Performance
Priority	Must

Table 11: Requirement CU_3 (communication load).

5.4 HMI requirements

ID	HMI_1
Name	HMI - Information content
Description	The human machine interface has to provide functionalities to display: • the status of the INTEGREEN mobile probe system, including basic analyses and configuration capabilities; • the information provided by the Supervisor Center;
Rationale	Usability – testing of the equipment as well as continuous information transfer to the driver from the Supervisor Center.
Type	Functional
Priority	Must

Table 12: Requirement HMI_1 (HMI – information content).

ID	HMI_2
Name	GUI - Information content
Description	The graphical user interface of the mobile subsystem has to provide functionalities to display elementary map representations including the current position.
Rationale	Usability – continuous geo-spatial information transfer to the user
Type	Functional
Priority	Could

Table 13: Requirement HMI_1 (GUI – information content).

5.5 On-board traffic monitoring unit

ID	OBTU_1
Name	Kinematic sensors
Description	The on-board traffic monitoring unit has to deliver at least GPS sensor data composing of: • position; • heading ; • speed.
Rationale	System design – minimum requirements for traffic state estimations
Type	Functional
Priority	Must

Table 14: Requirement OBTU_1 (kinematic sensors).

ID	OBTU_1
Name	Kinematic sensors plus

Description	The traffic data unit must also deliver acceleration sensor data
Rationale	System design – acceleration data increases the quality of traffic based emission calculations
Type	Functional
Priority	Must

Table 15: Requirement OBTU_2 (kinematic sensors plus).

ID	OBTU_3
Name	Kinematic sensor quality
Description	The GPS and acceleration sensor together with the first data stream filtering should deliver additional quality and accuracy information.
Rationale	System design – data quality is essential for the fusion of different data sources to achieve a reliable traffic status estimation.
Type	Functional
Priority	Should

Table 16: Requirement OBTU_1 (kinematic sensors).

5.6 On-board environmental monitoring unit

ID	OBEU_1
Name	Environmental sensors
Description	The environmental data unit has to deliver at least pollutant sensor data composing of: • NO_2 • O_3
Rationale	System design - air pollutants are selected according to (i) specific monitoring needs within the city of Bolzano and (ii) technological constraints.
Type	Functional
Priority	Must

Table 17: Requirement OBEU_1 (environmental sensors).

ID	OBEU_2
Name	Meteorological sensors
Description	The environmental data unit has to deliver meteorological data, related in particular to the following parameters: • air temperature ; • humidity.
Rationale	System design – the online calibration of pollutant measurements require metrological data
Type	Functional
Priority	Must

Table 18: Requirement OBEU_2 (meteorological sensors).

ID	OBEU_3
Name	Environmental sensors plus
Description	The environmental data unit can deliver additional pollutant sensor data: • NO_X • PM_{10} • VOC • CO

	• SO_2
Rationale	System design – although these pollutants are difficult to measure they are of high interest for the urban air quality
Type	Functional
Priority	Could

Table 19: Requirement OBEU_3 (environmental sensors plus).

ID	OBEU_4
Name	Environmental sensor quality
Description	The pollutant and meteorological sensors together with the first data stream filtering should deliver additional quality and accuracy information.
Rationale	System design – data quality is essential for the fusion of different data sources to achieve a reliable concentration estimation.
Type	Functional
Priority	Should

Table 20: Requirement OBEU_3 (environmental sensors plus).

Conclusions

The deliverable has presented the main requirements of the INTEGREEN mobile system. A detailed evaluation of the reference international literature has put in evidence how available mobile monitoring technologies, in particular in the environmental domain, are starting to match the increasing need to have a real-time environmental traffic management which is able to tackle the impact that road traffic has on the environment. This confirms the novelty of the approach proposed in INTEGREEN, and the concrete opportunity to share this approach with other European areas facing similar traffic-induced environmental problems.

Moreover, the existing fleets circulating in Bolzano, more specifically the public transport buses and the taxis, don't put in evidence any kind of technological limitation which can jeopardize the future possibility to use these vehicles as mobile probes. A further opportunity will be the future car sharing service, which is going to be activated in 2013.

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