

Intelligent Transportation Systems

Automatic Vehicle Location and Monitoring Systems





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EXECUTIVE SUMMARY

Throughout the field of transportation and vehicle systems some general trends can be universally observed.

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The demand for transportation, for example, is increasing for all modes of transportation and types of vehicles.

This need for mobility of persons and goods and the corresponding increase in traffic causes serious **congestion, safety and environmental problems** in all modes of transportation as described, e.g., in the "*White Paper—European Transport Policy for 2010*" (European Commission, 2001).

For economical and ecological reasons or simply due to a lack of space, expansion of traditional transportation infrastructure cannot be the only answer to this problem.

The scientific-technical community attempts to address and solve these problems in an intelligent way, i.e., via employment of **new technologies** and advanced methodologies.

By integrating technologies for **INFORMATION** and **COMMUNICATIONS (ICT)**, **INTELLIGENT TRANSPORT SYSTEMS (ITS)** enable authorities, operators and individual travelers to make better informed and coordinated decisions.

The main goal of this document is an analysis of the possibility for using ITS focusing on a particular applications: the Automatic Vehicle Location and Monitoring Systems (AVL and AVM).

This will be done first introducing the main characteristics and the policy background for ITS and then by presenting two examples of low budget research projects



developed at regional level and selected among the projects registered on the PRESS4TRANSPORT platform.

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This fiche is produced within the **PRESS4TRANSPORT** (*Virtual Press Office to improve EU Sustainable Surface Transport research media visibility on a national and regional level*) project. The overall aim of the project is to assist EU, National and Regional funded projects communicate their surface transport research results to the media.

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AUTOMATIC VEHICLE LOCATION AND MONITORING SYSTEMS

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The scope of the Topic

Automatic Vehicle Monitoring (AVM) and Automatic Vehicle Location (AVL) systems are applications in the **Advanced Public and Private Transportation Systems (APTS)** category. Those systems represent an electronic means of gathering data and performing commands and control over a land vehicle fleet. While data on vehicle location are required for effective control, such systems are totally dependent upon reliable dedicated communications systems. Generally the vehicle's location is determined using Ground Positioning System (GPS);

after collecting positioning and monitoring data, these are transmitted using a wireless communications systems.

GPS utilizes the signals emitted from a network of 24 satellites, which are picked up by a receiver placed onboard the vehicle. The accuracy and reasonable cost of GPS makes it the most appealing, though it too has some problems. Foliage, tall buildings, and tunnels can temporarily block the satellite signal, and at times satellite signals do not reach specific locations. In recent years, competing terrestrial positioning technologies have emerged as viable alternatives to GPS. One such technology is Europe's **Global Navigation Satellite System (GNSS)**, also known as **GALILEO**, that should be operational by 2013. Galileo could eventually allow Europe to discontinue its dependence on the US GPS and Russian GLONAS systems. Galileo will be under civilian control and will allow positions to be determined



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accurately for most places on Earth, even in high rise cities where buildings obscure signals from satellites low on the horizon. This is because there will be twice as many satellites available from which to take a position. By placing satellites in orbits at a greater inclination to the equatorial plane than GPS, Galileo will achieve better coverage at high latitudes. This will make it particularly suitable for operation over northern Europe, an area not well covered by GPS.

The design and implementation of AVL and AVM systems includes acquisition and transmission of a vehicle's location information along with on board apparatus status information to the monitoring server. Additionally, the system can also provides a **web based interface** to display all transmitted information to the end user along with the location of the vehicle on a map.

All the information can be available to authorized users of the system via a website on the

internet. As a general example **Figure 1** illustrates the system architecture of the general Automatic Vehicle Location and Monitoring System developed in one of the two projects that will be described in the next paragraphs.

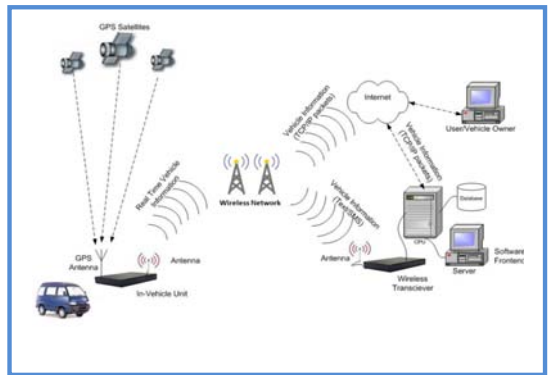


Figure 1: *Automatic Vehicle Location and Monitoring system architecture.*

The main components generally included in these systems are the following:

Remote devices. In order to track the location of remote vehicles or people, some kind of device is needed in the remote location. It typically consists of a



(GUI) for building more complex tracking queries.

Persistence component.

All these components and applications need some persistence for their data, as they need to store the locations they receive or generate for further analysis. Usually, this persistence is provided by a **data base manager**. These components can be combined in order to build different systems. They should be able to solve different kinds of problems and act as distributed GPS data collectors, local area control centers or headquarters control, or provide distributed management of the same GPS data.



POLICY BACKGROUND

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Measures to satisfy the mobility needs of the European economy and society

In order to satisfy the mobility needs of the European economy and society **three major challenges** have to be overcome:

- 1. Road traffic congestion is estimated to affect 10 % of the road network, and yearly costs amount to 0.9-1.5 % of the EU GDP.*
- 2. Road transport accounts for 72 % of all transport-related CO₂ emissions, which increased by 32 % (1990-2005).*
- 3. Whilst road fatalities are in regression (-24 % since 2000 in EU27) their number*

(42 953 fatalities in 2006) is still 6 000 above the intended target of a 50 % reduction in fatalities in the period 2001-2010.

The main **policy objectives** arising from these challenges are for transport to become:

- cleaner,*
- more efficient, including energy efficient,*
- safer and more secure.*

These challenges require innovative solutions to achieve rapid progress and ITS can play an important role in enabling tangible results to emerge. In 2001, the Commission presented a **White Paper** proposing various measures to overhaul the EU's transport policy in order to make it more sustainable and avoid huge economic losses due to congestion, pollution and accidents.



- The **Kyoto Protocol** came into force, generating emission reduction commitments for Europe;
- Transport networks experienced particularly deadly terrorist attacks.

In order to adapt to these changes, the Commission proposes a number of new tools to achieve its objective of sustainable transport:

Decoupling transport growth from its negative effects

In stark contrast with the 2001 White Paper, no reference to curbing transport demand is made in the revised paper, which instead stresses the need to disconnect mobility from its negative consequences.

The 'modal shift'

Although the Commission maintains that this remains a priority, the focus has been shifted towards '**co-modality**' - or the *optimized*

use of all modes of transport – rather than 'inter-modality'. Co-modality can be achieved by facilitating the passage from one transport mode to another via the harmonisation of standards and the integration of the various transport modes into efficient logistics chains. This has been the aim of a Commission logistics action plan later adopted in 2007.

Energy Efficiency

In accordance with the EU's energy much more attention is paid to increasing energy efficiency in the transport sector. A strategic technology plan for energy use in transport has been presented in 2007 and a programme on 'green-powered vehicles' has been launched in 2009.

Intelligent Transport Systems.

The use of new technologies in all transport modes will cut costs, boost energy efficiency



and improve security by providing new services to citizens, such as real-time management of traffic flows and tracking possibilities.

Urban transport

Mobility in urban areas is an everyday problem for Europe's citizens. In order to encourage local authorities to better tackle congestion, pollution and accidents, the Commission launched a Green Paper on Urban Transport in 2007.

Smart charging

The Commission presented a model for infrastructure charging based on the assessment of all external costs accompanied by an impact analysis of the internalization of external costs for all modes of transport.

On 16 December 2008, the European Commission took a major step towards the deployment and use of Intelligent Transport Systems (ITS) in road transport adopting

the Action Plan for the Deployment of Intelligent Transport Systems in Europe. According to the Plan, ITS can create clear benefits in terms of transport efficiency, sustainability, safety and security, whilst contributing to the EU Internal Market and competitiveness objectives. This Action Plan proposes an approach for a coherent and faster deployment of ITS across Europe, building on policy objectives and suggesting the following **six priority action areas**:

- 1. Optimal use of road, traffic and travel data;**
- 2. Continuity of traffic and freight management ITS services on European transport corridors and in conurbations;**
- 3. Road safety and security;**
- 4. Integration of the vehicle into the transport infrastructure;**



5. Data security and protection, and liability issues;

6. European ITS cooperation and coordination.

Moreover a proposal for a directive on the deployment of Intelligent Transport Systems (ITS) in the field of road transport has been recently approved on May 2010. The objective of the draft directive is to accelerate and coordinate deployment of interoperable ITS in road transport, including interfaces with other transport modes, by creating the necessary conditions and mechanisms through a coherent EU-wide framework. To foster the deployment of ITS, the directive reduces to four the priority areas and defines the priority actions within those areas. The Commission will have the task of adopting specifications for the actions planned in the priority areas. The **priority areas** and corresponding **main actions**

outlined in the draft directive include:

- *optimal use of road, traffic and travel data priority actions: EU-wide multimodal travel and real-time traffic information services as well as road safety related minimum universal traffic information services;*
- *continuity of traffic and freight management ITS services (actions: e.g. ensuring information flow; tracking and tracing of freight);*
- *ITS road safety and security applications priority actions: EU-wide eCall services as well as reservation and information systems services for safe and secure parking places for trucks and commercial vehicles;*
- *linking the vehicle with the transport infrastructure (actions: e.g. systems for exchange of data or information between vehicles, infrastructures and between vehicle and infrastructure).*



RESEARCH CONTEXT AND PROGRAMMES

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Key research areas and actions at EU and National levels

In order to classify and define the key research areas where it could be vital to invest in, we can identify **five primary categories** :

1. *Advanced Traveler Information Systems (ATIS);*
2. *Advanced Transportation Management Systems (ATMS);*

3. *ITS-Enabled Transportation Pricing Systems;*
4. *Advanced Public and Private Transportation Systems (APTS);*
5. *Fully Integrated ITS Systems (VII and V2V Systems).*

This classification is not inclusive of all possible ITS applications but includes the most prominent ones arranged by their primary functional intent and considering that many ITS applications can serve multiple functions or purposes. The five categories are summarized in **Table I** and shortly described below.



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ITS CATEGORY		ITS APPLICATIONS
1	AdAdvanced Traveler Information Systems (ATIS)	Real-time Traffic Information Provision
		Route Guidance/Navigation Systems
		Parking Information
		Roadside Weather Information Systems
2	AdAdvanced Transportation Management Systems (ATMS)	Traffic Operations Centers
		Adaptive Traffic Signal Control
		Dynamic Message Signs
		Ramp Metering
3	ITS-Enabled Transportation Pricing Systems	Electronic Toll Collection (ETC)
		Congestion Charging
		Fee-Based Express (HOT) Lanes
		Vehicle-Miles Traveled (VMT) Usage Fees



		Variable Parking Fees
4	Advanced Public and Private Transportation Systems (APTS)	Real-time Status Information for Public Transit System
		Automatic Vehicle Location and Monitoring (AVL - AVM)
		Electronic Fare Payment (for example, Smart Cards)
5	Vehicle-to-Infrastructure Integration (VII) and Vehicle-to-Vehicle Integration (V2V)	Cooperative Intersection Collision Avoidance System (CICAS)
		Intelligent Speed Adaptation (ISA)

Table I : *General Classification of Intelligent Transport Systems*



Advanced Transportation Systems

ATS help to make public transport a more attractive option for commuters by giving them enhanced visibility into the arrival and departure status (and overall timeliness) of buses. This category also includes **electronic fare payment systems** for public transportation systems, which enable transit users to pay fares contactlessly from their smart cards or mobile phones using near field communications technology. Advanced public transportation systems, particularly providing “next bus” or “next train” information, are increasingly common worldwide.

Advanced Transportation Management Systems

Advanced Transportation Management Systems (ATMS) include ITS applications that focus on traffic control devices, such as traffic signals, ramp metering, and the dynamic

message signs on highways that provide drivers **real-time messaging** about traffic or highway status. Centralized traffic management centers rely on **information technologies** to connect sensors and roadside equipment, vehicle probes, cameras, message signs, and other devices together to create an integrated view of traffic flow and to detect accidents, dangerous weather events, or other roadway hazards. Adaptive traffic signal control refers to dynamically managed, intelligent traffic signal timing. Giving **traffic signals** the ability to detect the presence of waiting vehicles, or giving vehicles the ability to communicate that information to a traffic signal, could enable improved timing of traffic signals, thereby enhancing traffic flow and reducing congestion. Another advanced transportation management system that can yield significant traffic management benefits is ramp metering. Ramp meters



are traffic signals on freeway entrance ramps that break up clusters of vehicles entering the freeway, which reduces the disruptions to freeway flow that vehicle clusters cause and makes merging safer.

ITS-Enabled Transportation Pricing Systems

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ITS have a central role to play in funding countries' transportation systems. The most common application is electronic toll collection (ETC), also commonly known internationally as "road user charging," through which drivers can pay tolls automatically via a on-board device. As described in the Thematic Analysis Fiche about **Congestion Charging**, an increasing number of cities throughout the world have implemented congestion pricing schemes, charging for entry into urban centers, usually at certain peak hours, as a means to not only reduce congestion but also to generate needed resources to

fund investments in public transportation and to reduce the environmental impact of vehicles. The Thematic Analysis Fiche describes and compares tested methodologies and results from two European cities: **London** and **Stockholm**.

Those are just 2 of the cities in the world that have put congestion pricing systems in place to reduce traffic congestion, smog, and greenhouse gases. By charging more at congested times, traffic flows can be evened out or reduced. As half the world's population now lives in urban areas, some economists believe that urban congestion and emissions will be virtually impossible to reduce without some form of congestion pricing. For example, in Europe, urban areas account for 40 percent of passenger transport but 53 percent of all transport-related emissions. Stockholm's congestion pricing scheme yielded immediate results, reducing traffic by 20 percent in the first month alone as many



Vehicle-to- infrastructure Integration (VII) and Vehicle-to- vehicle (V2V) Integration

Vehicle-to-infrastructure integration is the archetype for a comprehensively integrated intelligent transportation system able to deploy and enable a communications infrastructure that supports vehicle-to-infrastructure, as well as vehicle-to-vehicle communications for a variety of vehicle safety applications and transportation operations. DSRC-enabled tags or sensors, if widely deployed in vehicles, highways, and in roadside or intersection equipment, would enable the core elements of the transportation system to intelligently communicate with one another, delivering a wide range of benefits. For example, it could enable **Cooperative Intersection Collision Avoidance Systems (CICAS)** in which two (or more) DSRC-equipped vehicles

at an intersection would be in continuous communication either with each other or with roadside devices that could recognize when a collision between the vehicles appeared imminent (based on the vehicles' speeds and trajectories) and would warn the drivers of an impending collision or even communicate directly with the vehicles to brake them. Combining both vehicle-to-vehicle and vehicle-to-infrastructure integration into a consolidated platform, would enable a number of additional ITS applications, including adaptive signal timing, dynamic re-routing of traffic through variable message signs, lane departure warnings, curve speed warnings, and automatic detection of roadway hazards, such as potholes, or weather-related conditions, such as icing. Another application enabled by vehicle-to-infrastructure integration is **Intelligent Speed Adaptation (ISA)**, which aims to assist drivers in keeping within the speed limit by correlating information about the



National and local program in Italy

An example of local program in LAZIO Region.

The program “**Projects and plans for the Technological Frontiers**” is one of the tools used by the Lazio Region to promote regional development and innovation processes and for financing and promoting SME innovation, technology transfer and social entrepreneurship. These measures are included in the **Single Programming Document (SPD)** of the Regione Lazio to promote the development of research, technological innovation and, in particular, easy access to research results in order to allow enterprises to increase their degree of competitiveness in the period 2007-2013. The program has a total budget of **36 M€**.

In particular the program finances:

1. Small and medium enterprises, based in Lazio, that present requests for research projects together with universities and research centres and, in general, all public and private organizations conducting research activities;
2. Universities and research centres, based in Lazio, and, in general, all public and private organizations conducting research activities for scholarships or other forms of financing for new personnel in small and medium enterprises operating in Lazio.

16 M€ of the budget are dedicated to Sustainable Energy and Mobility projects and 6M€ to ICT projects.



The national “*Industria 2015*” program.

One of the most important research program in Italy is the so called “**Industria 2015**” proposed by the Italian Ministry of Economic Development.

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The program has established the strategic lines for the development and competitiveness of the future production systems in *Italy*. The aim of the program is to stimulate industrial innovation

projects to create new cross-sector industries (which integrate manufacturing, advanced services and new technologies) to encourage the development of specific types of products and services with a high content of innovation in strategic areas for the country: energy efficiency (**200M€**), sustainable mobility (**180M€**) and new technologies for the made in Italy (**190M€**). The actors involved, in addition to the production sectors, are national and local administrations, universities and research institutions.



RESEARCH RESULTS

Benefits from key projects

Research in ITS: the example of two pilot projects

Research in ITS in Europe has two main concerns:

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- *Investigating the merits of introducing new technologies;*
- *identifying and piloting developments that are necessary for ITS implementation and regulation;*
- *identifying and promoting successfully pilot research projects and best practices that can be 'transferred' and reproduced at European level.*

The development of new technologies can contribute to the development of new services, helping to improve mobility, transport management, quality and efficiency of transport using different communication technologies and protocols. AVL and AVM systems represent an example of introducing new technologies and two projects have been selected among the ones registered in the **PRESS4TRANSPORT** platform to illustrate different applications of those systems. The selected projects are the following:

- *Project 1: **Automatic Vehicle Monitoring and Location System for the Island of Ventotene;***
- *Project 2: **Monitoring system for freight truck fleet.***

The two projects are characterized from having a **low budget** and for involving **public-private partnerships**. Project 1 aims to improve the



mobility on a small Italian island testing AVM and AVL on the Municipal fleet; Project 2 has the goal of testing the functionality of a fleet monitoring tool developed for a freight truck distribution fleet. Moreover the

two projects are an example of a local application having a potentially transferability at European level.



Automatic Vehicle Monitoring and Location System for the Island of Ventotene

The project aims to develop and test an Automatic Vehicle Monitoring and Location System on the small island of **Ventotene** in Italy, in order to determine geographic positioning and provide information about a Municipal fleet of electric and hybrid vehicles circulating on the island and transmitting the information to a remotely located server. The project has been financed by the Lazio regional government with the participation of the Municipality of Ventotene and it has been developed by the Pole for Sustainable Mobility (POMOS) and various private partners. The project has a duration of six months split up in two

periods of 3 months corresponding to the 2009 and 2010 summer seasons. The monitored fleet was initially

composed by 7 electric vans. These are commercial **Piaggio Porters** using a pure electric drive train which only consumes electric energy. The Van uses a 10.5 kW electric motor and uses 14 heavy-duty lead-acid battery packs (6V-180A) as sources of energy. Moreover a selection of other commercial electric and hybrid vehicles and prototypes developed by POMOS has been also tested on the island as well as the use of different kind of batteries.



Figure 2: Main mask of the multimedia software.



traveler information and entertainment, vehicle component monitoring, and data collection. All the experimental results and data coming from the first research period have been also used to learn more about what is needed to support electric vehicles as they become more common on the island and helping the understanding of things such as how the system works, how consumers want to use it, driving and charging patterns, and interconnection with the electricity grid. Experimentation continued in summer 2010 also introducing other prototypal electric and hybrid vehicles in the fleet.

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Monitoring system for freight truck fleet

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The main objective of this project was to **test the functionality of a fleet monitoring tool** developed for a freight truck distribution fleet. The project has been developed by the Centre for Transport and Logistics (CTL) and mainly funded by a private company. The pilot project was initially implemented on two vehicles of different brands (one MAN and one IVECO) but of equal gross weight and used for the same service. It started in January 2008 and was concluded in July 2009. The tool has been tested with respect to the following services:

- *Remote real time reading of the **tachograph** on specific events (e.g. when the legal driving limits are exceeded ...) or whenever the fleet managers requires it;*
- *Remote real time reading of fuelling, to identify time and place of the fuelling and quantity of added fuel to be checked against the real time data coming from the pumps;*
- *On board storage and automatic wireless download (when back at the depot) of the vehicle working data: cost-control, driver behavior monitoring, dynamic maintenance and emission measurements.*

The main results obtained were:

- a. main differences exist between the consumption of the two vehicles;
- b. fuel is not dispersed by the two vehicles as the data from the pump coincide with those consumed by the vehicles;



CONCLUSIONS: key outcomes from the two projects

In this Thematic Analysis Fiche a general idea of the possibilities for using ITS has been presented focusing on a particular application: the **Automatic Vehicle Location and Monitoring Systems**. This has been done first introducing the main characteristics of ITS and then by presenting *two examples* of projects developed at regional level.



RESULTS

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Results from the two projects shown that **introducing ITS technologies for the monitoring and location of a fleet of vehicles can be an optimal solution to improve system performance, transport safety, efficiency, productivity, level of service, energy consumption and costs for a Municipality as well as for a private company.** Considering the possibility of the reproducibility of the projects to a national and European level, the developed systems should be consistent with the National and European ITS architecture (when existing).

Both the analyzed projects experienced various **technical and institutional problems.** It can be observed that the biggest challenge in implementing AVL and AVM today is the potentially lengthy procurement and installation period (particularly

software development and integration of technical components). For this reason, public or private subjects procuring an AVL system may want to use an existing design, with customization capabilities instead of developing a dedicated one because such an approach would substantially limit potential risks and problems and the development of new software or extensive customization of existing software can result in many possible problems. It is also important to consider that often *institutional relationship* may be difficult and could slow down the progress of the projects. Another aspect that emerged from the analysis concerns the *operations of the systems*: in order to correctly use the innovative components new technical expertise is usually required and some existing staff maybe reluctant to learn the new technology. A **training program** for the staff need to be considered in the programs and it is essential to



exploit all the potential of the systems.

Cost as always is the major concern: the cost of the development and of the installation of AVL and other advanced transportation system components is dependent on the size of the system, its level of sophistication, and the components to be included. Systems can range from those with fairly basic features (GPS, computer-assisted dispatching, mobile data terminals, silent alarms, and limited automated passenger information) to very comprehensive systems. There is a significant cost for the equipment and software that reside at the operations/dispatch center. The per-vehicle cost of large fleets is less than for smaller fleets, assuming similar features, because the cost of this major infrastructure is distributed over a larger number of vehicles. Comparing the two projects has emerged that to accelerate and stimulate the diffusion of ITS in Europe a

public financing is indispensable. Although the good results of Project 1, the continuing of the experimentation at the end of the 6 months period it is strictly dependent on the decision of the regional Municipality. In Project 2 the company is asking for a state funding to apply such a system on the fleet; the initial investment cost required discourage from a direct investment, but if start up funding should be granted the company is willing to proceed.



EUROPEAN POLICY IMPLICATIONS

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What next?

The selection and deployment of ITS applications and services shall be based upon an evaluation of needs involving all relevant stakeholders, and shall comply with the following *principles*.



These measures shall:

1. **Be Effective** – make a tangible contribution towards **solving the key challenges affecting road transportation** in Europe (e.g. reducing congestion, lowering of emissions,

improving energy efficiency, attaining higher levels of safety and security including vulnerable road users);

2. **Be Cost-efficient** – **optimize the ratio of costs** in relation to output with regard to meeting objectives;
3. **Be proportionate** – provide, where appropriate, for different levels of achievable service quality and deployment, taking into account the local, regional, national and European specificities;
4. **Support continuity of services** – **ensure seamless services across the Union**, in particular on the trans-European network, and where possible at its external borders, when ITS services are deployed. Continuity of services should be ensured at a level adapted to the characteristics of the transport networks linking countries with countries, and where appropriate, regions



with regions and cities with rural areas;

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5. **Deliver Interoperability**
– ensure that systems and the underlying business processes have the capacity to exchange data and to share information and knowledge to enable effective ITS service delivery;
 6. **Support backward compatibility** – ensure, where appropriate, the capability for ITS systems to work with existing systems that share a common purpose, without hindering the development of new technologies;
 7. **Respect existing national infrastructure and network characteristics** – take into account the inherent differences in the transport network characteristics, in particular in the sizes of the traffic

volumes and in road weather conditions;

8. **Promote equality of access** – do not impede or discriminate against access to ITS applications and services by vulnerable road users;
9. **Support maturity** – demonstrate, after appropriate risk assessment, the robustness of innovative ITS systems, through a sufficient level of technical development and operational exploitation;
10. **Deliver Quality of timing and positioning**
– use of satellite-based infrastructures, or any technology providing equivalent levels of precision for the purposes of ITS applications and services that require global, continuous, accurate and guaranteed timing and positioning services;



11. Facilitate Inter-

modality – take into account the **coordination of various modes of transport**, where appropriate, when deploying ITS;

12. Respect

Coherence – take into account **existing Union rules**, policies and activities which are relevant in the field of ITS, in particular in the field of standardization.



parking, continuity in traffic management, etc.)

Also research topics related to the electrification of vehicles and the integration of electric vehicles in the transport system needs to be investigated giving particular attention to **vehicle to grid integration (V2G)** and to charging infrastructure (charging which adapts to the needs of the user and to the restrictions of the grid, charging at enhanced speed, and smart charging with bi-directional energy and information transfer capabilities).

Moreover, research actions will be needed on *intelligent roads*. They will allow the development of new road infrastructure and related communication tools, encouraging the use of electric vehicles and also the integration of electric vehicles with other modes of transport. Research could also include low-cost and low-emission maintenance and

construction of roads (including life cycle analysis), the development of automated driving systems, based on active safety systems and car-to-car communication or to energy harvesting systems on roads.

Research actions should also focus on **advanced vehicle concepts** and **technologies** (including innovative solutions for improving the aerodynamic performance of vehicles, rolling resistance, the efficiency of its constituent sub-systems also in terms of the potential for energy recovery, flexible and modular truck-carrier concepts). At the same time, GHG emissions from freight transport will be further reduced through measures optimizing vehicle flows and implementing efficient and innovative logistics schemes and concepts.



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