Strategic Research Agenda

ICT for Intelligent Mobility

Working Group RTD

Update 2010

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Executive Summary

The long term vision for Intelligent Mobility is based on zero accidents, minimised delays, near zero environmental impact, and fully informed travellers. To reach this state will require the development of a fully integrated multimodal transport network, which will ensure efficient and safe movement of people and goods. This will require public authorities, industry, and other private organisations, in partnership, to undertake a substantial RTD effort, building on what has already been achieved, and moving forward ICT-based eSafey technologies to the point where their deployment will bring about the realisation of the long term vision.

To this end, RTD actions are needed in six areas: Sustainable Road Transport; Sustainable Urban Mobility; Road Transport Safety; ICT and the Decarbonisation of Transport; Deployment; and Horizontal Issues.

Research in the area of Sustainable Road Transport needs to address the needs of road users and road operators. It also need to be focused on the development of systems for vehicles, transport services, and logistics services, while addressing the new challenges and opportunities that arise from the use of electric and hybrid vehicles.

In the area of Sustainable Urban Mobility, a coordinated, efficient and integrated approach is required to address the development of safe and sustainable urban mobility. The research will need to address several areas: data collection and analysis of the state of the transportation network; integrated transportation networks; and urban mobility of goods.

Road Transport Safety has been, and remains, a major goal for the European Union. An additional effort should be made to achieve the targets for reducing the number of road fatalities. At the same time, investment in the development of electrical vehicles is also opening up novel areas of investigation on safety related applications. These new areas must also be addressed.

With respect to ICT and the Decarbonisation of Transport, there is a need for new ICT solutions, or for existing ICT systems to be adapted, to integrate electric vehicles fully into the urban mobility system. The main areas to address are integration with other modes, demand management, and charging.

On the matter of deployment, this, along with market development, have always been a major problem with ICT-based ITS, and, to overcome this problem, Field Operational Tests and data collection must be developed further. Modelling and simulation must also be considered. In particular, with regard to modelling, two important areas must be addressed. The first of these relates to researching traffic models, and the second relates to researching emission models.

Horizontal issues remain an important area requiring attention in future research activities. Overall these horizontal matters cover a broad range of topics. Specifically, the horizontal issues that need to be considered include assessment methods, quality standards, business models and deployment aspects, training and education, human factors and organisational perspectives, and international R&D collaboration.

Vision - 2030

It is 2030. For over 40 years, Europe's ICT for Intelligent Mobility community have been working on the development of Intelligent Transport Systems. With the recent wide take-up and deployment of research results developed within the European Commission's Framework Programme 8 (2014 to 2020), Intelligent Mobility has now moved very close to the objectives that were set back at the turn of the century: zero accidents, minimised delays, near zero environmental impact, and fully informed travellers.

This achievement has come about largely as a result of the development of a fully integrated multimodal transport network, which ensures efficient and safe movement of people and goods. In partnership, all the stakeholders—public authorities, industry, and other private organisations— have dedicated substantial efforts toward the achievement of the above objectives.

Thanks to the wide availability of low cost wireless communication systems, relevant information flows constantly and seamlessly from each source to all interested users. All road infrastructures have been digitised in detail with respect to their geometry, characteristics, speed limits, etc. Distributed monitoring of traffic conditions means that all traffic incidents can be detected, and information about these (such as road works, accidents, stationary traffic, or slow moving vehicles, etc.) can be transmitted in real time to targeted road users.

A large portion of road traffic (about 80% of new vehicles) is cooperative, and contributes to the generation of very accurate, up-to-date and precise traffic information. All vehicles are equipped with automatic emergency call systems and can signal different types of abnormalities (stationary traffic, slow moving vehicles, emergency incident, etc.). In-vehicle open platforms with flexible and integrated Human-Machine Interfaces (HMIs) provide access to onboard nomadic devices applications, as well as access to online services related to safety, navigation, entertainment, and many other telematics functions.

Most of the infrastructure (80% of critical road sections and intersections; 10% of all road networks) is also cooperative, meaning that the infrastructure is able to detect and interact with vehicles. In particular, the most important intersections in urban and rural areas are equipped, based on different decision criteria, with systems that address safety, traffic flow and environmental issues. Geo-referenced information, either static or dynamic, is widely available and very accurate in terms of both space and time. This information is provided in coordination with public authorities to manage properly any emergency situation.

Information about different kinds of mobility options is made available in an overall service-oriented transportation network, allowing connected travellers to choose between different context-aware travelling options according to their priorities and needs, and taking into account financial and regulatory incentives. Travellers in all types of vehicles (private vehicles and public transport) are also part of this mobility resource database, sharing not only position data, but also destination information and planned traffic-based route (or the most likely route based on personal habits). People share their data without any major worries concerning privacy risks.

Since mobility demand has continued to increase since the turn of the century, the average speed in urban areas in particular, has remained quite low, but the estimation of travel time has become more precise and reliable, allowing users to choose more appropriate transport modes considering their needs in term of time, flexibility, cost, and environmental impact. Security is still an issue, but technologies are used to guarantee security on public transport, and also on a large part of the road network, allowing users to choose their travel modes with fewer security constrains.

Vehicle technology has been further developed. About 30% of the new vehicles are either fully electric or are hybrids. For urban freight delivery, hybrids have become important and these constitute 80% of the overall fleet. Fully electric drive-chains are only possible on small delivery or special purpose vehicles. Incentives have pushed the diffusion of dedicated city vehicles that are used for urban mobility. These incentives include new ownership models, tax reduction, priority parking facilities, city access, and reduced road pricing. New urban vehicle concepts have also been made available. Three wheel and single passenger city vehicles are two examples of such dedicated city vehicles.

Road operators have focused on network operation, so as to manage both mobility and demand and also to control traffic flows in real-time to ensure safety, throughput, and sustainability in all conditions. Road pricing is widely accepted as a solution to manage urban and inter-urban mobility demand, and to provide incentives for more sustainable solutions. Technology now allows sophisticated pricing schemes that take into account time, position, environmental criteria, etc., for all travellers. Driving behaviour has been influenced using incentive schemes promoting safer and more efficient behaviour. Special attention has been be paid to incident management to maintain the network operation and even to prevent incidents using advanced traffic management and real time targeted traffic information.

Cooperative solutions have allowed the introduction of *supervised autonomous driving solutions*, which use dedicated lanes, both in cities and on motorways. The first applications were in *green corridors* specially designated for collective transport, including, outside cities, long distance freight transport operating in platoon mode.

Service levels in public transport have been improved, thereby increasing the competitiveness and attractiveness of this method of travel. Rapid Transit systems have become quite diffused, with driverless vehicles on both rail and on the roads (using dedicated lanes). Demand-responsive transport has also become popular, in which it is possible to identify, in real time, the specific mobility needs of given areas. Park-and-ride facilities have also become ubiquitous around cities, and these facilities all have automated booking services and good interfaces with other travel modes.

Freight transport demand has also increased, not only because of economic growth, but also owing to an increase in e-commerce for goods purchased daily, such as groceries. Also, freight logistics has been integrated into the overall transportation network, allowing new efficient solutions for freight delivery. Zero-noise night delivery has become common in cities, which allows better traffic distribution during the day.

Road safety has remained an issue, but the risk level has been greatly reduced for most user groups including Vulnerable Road Users. Impaired driving, especially under the influence of alcohol or drugs, has become nearly impossible. Speed limits are widely respected owing to sophisticated green-wave concepts and strong enforcement and reward schemes. Drivers will often accept to be supported so as to stay within the speed limits, for example, through the use of automatic speed adaptation or simply through the delivery of speed advice. Semi-automated driving, or, under very restrictive conditions, fully automated driving, are commonplace, which has helped to reduce accidents that are related to driver failures.

Drivers are supported through the use of onboard systems, which also benefit from the deployment of cooperative solutions at intersections, and these solutions also help avoid secondary events that can arise from earlier traffic incidents or abnormalities. Since a large portion of vehicles are equipped with these systems, communication with other vehicles has improved safety both on motorways and on primary roads.

Onboard speed regulation has not only imposed limits on speed, but has also enabled the implementation of speed-related vehicle safe-following distance control. Infrastructure-based systems have also contributed towards drivers staying within speed limits and have enabled safe-following distance control to become part of traffic management. Infrastructure-based systems have also enabled the introduction of standard road safety evaluation methods. Public authorities also have specific criteria to promote safe roads through the use of public funds.

Vulnerable Road Users are more protected, both physically and legally, for example through the wide use of dedicated lanes inside city areas for manually-powered transport such as bicycles. Priority at intersections for Vulnerable Road Users is normal at traffic lights. Cooperative solutions are also widely available to protect Vulnerable Road Users.

Driver education has become a lifelong task. The training of new drivers has been improved through the use of realistic driving simulators. Other road users, such as cyclists and pedestrians, are also now better trained and more safety aware.

An increasing demand to use travel time for secondary activities such as entertainment, learning, etc., resulted in specific attention being given to the driver. In-vehicle HMIs have been optimised to minimise distraction from the driving task, and these HMI have been personalised for each driver. In addition, access to entertainment services is differentiated between drivers and passengers. Unsafe behaviour, both voluntary and involuntary, is autonomously detected by means of real-time distraction monitoring systems. Immediate feedback, as well as post-trip feedback, is provided by driver-coaching systems. The use of these coaching systems is linked to economic incentives, such as tax and insurance premium reductions. Identification of the most efficient road safety measures is more precise, and is guided by new data collection and analysis methods, including large-scale naturalistic driving studies and automated site-based analysis, as well as accident and incident modelling techniques.

State of Play - 2010

Significant reductions in road traffic accidents has been the wish of European transport stakeholders for many years, and the determination to achieve this wish has been in pursued in several EU programmes. The White Paper[1], *European Transport Policy for 2010: Time to Decide*, set the policy objective of achieving a 50% reduction in accidents and deaths by 2010 (from the 2001 starting point). However, this objective has only been reached in a few countries, such as France and Italy. Mostly the reductions achieved are as a result of increased use of enforcement (in the French case) and an increase in infringement penalties (in the Italian case).

Some contribution to the achievement of the above objectives has been made by the use of specific passive safety tests which are dedicated to the assessment of risk for Vulnerable Road Users. In every new road construction or adaptation, in both urban and sub-urban road networks, road infrastructure design now also takes into account the needs of Vulnerable Road Users. However, with regard to the use of technologies and their contribution to achieving the policy objective of reducing road accident fatalities, diffusion of technologies to improve safety has only reached a high level for a few specific solutions, such as Electronic Stability Control (ESC), Anti-lock Braking (ABS), and Airbags. More advanced solutions, such as Automatic Cruise Control (ACC), emergency braking, lane departure warning, etc., are generally only available in a very limited number of vehicle models, and sales of these are

[1] European Commission, COM(2001)370, 12/09/2001

very low, both in terms of number and in terms of the proportion of total European vehicle sales.

With regard to actual reductions in road fatalities, in 2008 within the EU27, some 39,000 people were killed in road collisions[2]. This is 15,400 less than in 2001, but still far from the target figure (27,000) which the EU set for itself in its Road Safety Target for 2010. The average annual reduction since 2001 has been only 4.4%, instead of the 7.4% needed. This shortfall will delay the EU in reaching its target, possibly until 2017.

Transport authorities (especially in urban environments) also have their own policy objectives, and these are, in typical order of priority: lessening the environmental impact of transport; improving road safety; reducing congestion; and enhancing accessibility. City authorities are introducing demand management measures to restrict car-based journeys in the city centre, through access restrictions, environmental and low emissions zones, parking policy, and to a lesser extent, road use pricing. Specific strategies and measures are being developed to minimise the impact of the transport of goods in urban areas through the use of small electric delivery vehicles and quiet night deliveries. Improved attractiveness of public transport, potentially leading, in cities, to a shift from car usage, is a policy objective of many city authorities, and this is often accompanied by policies to encourage a reduction in transport demand. All these measures have implications for the mobility needs of the European population.

With respect to the development of cooperative driving, in Europe this was first promoted and addressed in the EUREKA PROMETHEUS[3] Programme (1987-1994) and later on, by the DRIVE I project supported by the European Commission (EC) in Framework Programme 2 (FP2) and by the DRIVE II and the TAP EC Programmes. Activities have focused on studies and applications of bi-directional Vehicle-to-Infrastructure communication (V2I), followed later by Vehicle-to-Vehicle (V2V) communication.

Initially the technology was not able to fulfil the needed requirements for cooperative driving, and therefore the focus of the European automotive industry turned to stand-alone vehicle safety systems such as ESC and ACC. However, the development of intelligent vehicle safety systems is spiral-like: the same topics are revisited over time, but on each occasion on a new and higher level to reach the goals set in the late1980s. With the progress that has been made in communication technologies, the European industry has looked again in recent years at the opportunities offered by applications such as incident detection, traffic information systems, and guidance and cooperation among vehicles.

Using available real time information, bi-directional communication with vehicles can, on the one hand, inform drivers of static and dynamic facts related to transport and traffic safety, and on the other hand, enable vehicles to act as *mobile sensors* collecting information concerning surrounding traffic conditions, like for example, local weather information. New applications for safety, as well as enforcement and information, have proven to be very effective in delivering, in some cases, 50% reduction in fatalities.

The aim of cooperative driving solutions is now mostly focused on supporting foresighted driving and early detection of dangers and hazards allowing the driver to adapt the vehicle speed accordingly, thus increasing the distance between vehicles in those instances. This is realised by means of communication-based systems that extend the drivers' horizon and warn of potentially dangerous situations ahead. The main expected application areas for cooperative driving are:

- Traffic information exchange between vehicles and background systems;

[2] CARE - European Road Accident Database
[3] Programme For A European Traffic with Highest Efficiency and Unprecedented Safety

- Early hazard warning systems;
- Driver support for merging into traffic flows;
- Platoon driving within a dedicated infrastructure (lanes);
- Cooperative intersections.

On the matter of standardisation, this has received a considerable push forward through the allocation in Europe of a dedicated frequency band for vehicle safety communication. 30 MHz have been reserved, between 5.875 and 5.905 GHz, for the exclusive use of communication of safety relevant information. This frequency allocation is quite in line with the frequency band that has been reserved in the USA for Dedicated Short Range Communication (DSRC), thus allowing the same chip set to be used in both regions, and also building on the IEEE standard 802.11p, both of which will generate scale effects and thus make equipment cheaper once deployment starts. Additionally, a band of 40 MHz has been reserved between 5.855 and 5.875 GHz and 5.905 and 5.925 GHZ for traffic related applications, but there is no exclusive use of this for C2X communication.

Commonly agreed standards for V2V and V2I communication in Europe are under preparation by the ETSI Technical Committee, ITS. The Car2Car Communication Consortium (C2C-CC), the non-profit organisation initiated by European vehicle manufacturers and open to suppliers and other research organisations, was established to increase road traffic safety and efficiency by means of inter-vehicle communications. The consortium promotes solutions for common European standards for C2X communication. With regard to technical development activities, both CALM (an ISO activity) and the C2C-CC, have worked on architectures and protocols that are mostly complementary.

Additionally, a number of research projects have been carried out in Europe, but also in Japan and the USA, to integrate different Advanced Driver Assistance System (ADAS), cooperative driving systems, and safety functions, into a single platform by means of sensor data fusion. Prototype applications such as the systems demonstrated by the PReVENT sub-projects WILLWARN (Wireless Local Danger Warning) and INTERSAFE, clearly show the potential of cooperative systems, but these systems are not yet providing solutions for commercial use. Moreover, agreement still needs to be achieved between the road operators on the one side, and car manufacturers on the other side, concerning the communication technologies, procedures and services to be used between infrastructure and vehicles and its fallbacks.

Valorisation of existing mature GSM/UMTS technologies is being addressed which will allow road operators to avoid the investment in a specific network for the road infrastructure. A more modern communication infrastructure is also being considered which will better support the action of motorway operators using private devoted networks, for example, WIMAX type networks. Operated just by road operators, this will give them the possibility of maintaining a close relationship with their customers, the road users. Beside the technical questions, the roles of the partners in the value chain for the implementation and provision of V2I and I2V also need to be defined. A qualification process regarding the information given to drivers, needs to be set up from the source, right up to the in-car delivery.

Harmonisation activities have been undertaken in the EC funded support action COMeSafety and in the projects CVIS, SAFESPOT and PRE-DRIVE C2X, in support of enabling the interoperability of safety systems. Intelligent Transportation Systems and Services (ITS) and Intelligent Vehicle Safety Systems (IVSS) will in the future play a key role in improving safety on European roads. However, as of 2010, there is still a moderately slow market introduction, and safety applications are still high cost items, and they tend to be limited to a small part of the premium car market segment. Future safety systems must therefore be made more affordable so as to penetrate all vehicle segments, since small and medium-size cars constitute the largest part of vehicles in use on Europe's roads.

One activity that is being addressed consists in increasing the sensing capabilities to perceive obstacles, anomalies and hazards, both for vehicles and traffic monitoring systems. Cameras (video, FIR and NIR), radar technologies (77 & 24 GHz) and laser technology to sense the surrounding space as well as the objects around the vehicles, still need to be developed for mass-market use so as to enable monitoring and prediction of vehicle trajectory, driver behaviour, and traffic flows.

New driver information and support application technologies making use of GPS-enabled location functions and services are also emerging: these functions and services range from consumer-oriented offerings in Asia, business-oriented and consumer-oriented applications in North America, and personal navigation and traffic information services in Europe. The number of nomadic devices and personal navigation devices (PND) and smart phones (3G phones) is increasing. The associated technology for nomadic devices is mature, and useful functions for travellers can be developed with open interface solutions when connecting mobile terminals to vehicle systems. Mature wireless communication and positioning technologies providing functions and services to aftermarket and nomadic devices, can already enable some cooperative driving-type functions: mobile phones and portable navigators are channels which are able to provide personalised information for Travel and Traffic Information (TTI) provision. Infrastructure-based systems such as Variable Message Signs (VMS) are an option in densely built-up areas, while TV and teletext are channels that are only viewed before a journey. Digital content and broadcast technologies could however be used in multiple ways to provide information.

In general there is however, no single channel that can provide complete and comprehensive information to all types of travellers. The issue is still how to create business cases around these technologies that would speed up the market penetration of intelligent traffic services.

From the road operators' perspective, there is still a difference between various classes of roads in terms of both road equipment and the number of staff devoted to operation and technology deployment. There are also typically two or three road authorities responsible for different categories of road in an urban area: the highways authority generally has responsibility for the motorways entering urban areas; the city or transport authority manages the vast majority of non-motorway roads; and local (secondary) roads are managed by smaller administrative units (for example boroughs). In some cases a metropolitan or regional transport authority exists (for example in London and Brussels). However, institutional cooperation among the different parties is developing so as to achieve a more regional approach to traffic management since there is growing recognition that journeys do not stop at administrative boundaries.

In the case of some roads, the time is ripe for a new approach to the operation that could deliver further benefits in terms of efficiency of the road transport system, safety of road users, and environmental sustainability. This is especially true for the secondary road network and the urban road network, but is also the case for many motorways which are part of the Trans-European Road Network. Road operators have reasonably accurate and timely knowledge of what is happening on the primary road networks in terms of road works and incidents, but a correct understanding of traffic conditions and behaviour needs to be gained in a wider range of cases. This requires the infrastructure to be equipped with traffic monitoring systems able to gather information on the number and type of vehicles flowing in each road section, per lane and direction, giving moreover, real-time information related to accidents and other perturbing events occurring on the road network.

Furthermore, new central data processing systems will need to be developed for control centres, both for dealing with new sets of information, and new volumes of data related to the quantity of data that will be received from the most congested sections at peak hours, both in urban and inter-urban environments. Control centres will have to be able to process all the information from traffic control systems. In addition they will also need to be able to process large volumes of data provided by vehicles that are capable of communicating with the infrastructure. Based on foreseen traffic management plans, control centres will need to be able to supply traffic information to travel information systems and services, as well as directly to consumers in their vehicles, so as to maximize the traffic throughput and flow, and to minimize the travel times of road users.

There is a growing desire among road authorities for traffic management systems to become proactive, and to move away from reactive systems. This means being able to, for example, predict traffic flow and volume, and then to take pre-emptive measures to avoid incidents such as traffic build-up, air pollution peaks, etc. This will require a far more intelligence infrastructure than that which exists in 2010, notably in terms of data collection, fusion and analysis, short-term traffic forecasting, modelling, and decision support systems.

ICT-based mobility services for goods are also part of the global picture. There are significant inefficiencies inherent to freight transport, mainly owing to loading rates: the sectors fragmentation translates into high empty running rates (percentage of truck-km run empty), which range between 40% and 60%[4]. Process-related inefficiencies include: useless trips; unwanted stops; lack of synchronization between transport modes; and lengthy administration processes. Collective goods transport solutions are also attempted via logistic brokers. These are asset-less logistic services providers who act as intermediaries between transport demand and supply, providing services to optimise loads and routes. Inter-modal freight transport is promoted and supported as the way to ensure that the most competitive and efficient transport solution, or a combination, can be employed for the entire journey. The unabated growth of road freight testifies to the difficulties encountered by logistic users in managing door-to-door consignments over multimodal transportation networks. Related information management costs and burdens are too high for the majority of small logistic companies.

Finally, turning to the matter of Human-machine Interfaces (HMIs), in-vehicle HMIs are increasingly integrated and mapped in a many-to-many way, to applications. HMIs however are still mainly used for onboard (native) applications although some provisions for basic integration of nomadic devices (e.g. media players and phones) are offered by most vehicle manufacturers. At the same time, as described above, the number of applications that can potentially interact with drivers is increasing rapidly, including online services and cooperative systems. These mainly run on nomadic devices, and here the situation is still relatively far from an open interface by which means drivers can access all applications via a single HMI. The proliferation of applications also implies a potential distraction problem and there is a lack of design guidelines concerning how to achieve safe integration of a large number of applications into a single HMI, and also concerning how to safely fix nomadic devices in vehicles.

Recommendations for Future R&D

Recommendations for future R&D are presented in the following pages, under the headings of:

[4] European Environment Agency, Environmental issue report No 12.

- Sustainable Road Transport
- Sustainable Urban Mobility
- Road Transport Safety
- ICT and the Decarbonisation of Transport
- Deployment
- Horizontal Issues

1. Sustainable Road Transport

1.1 Road Users

Road transport user requirements are clearly connected to better planning capabilities. Delivery on this requirement needs a strong effort from all service, transport and road operators to redefine their systems so as to improve access to information and other mobility services, and to facilitate user and stakeholders' interaction. This can be achieved with real-time, multimodal travel advice, which is adapted to user preferences. This advice must demonstrate to users, real benefits in terms of monetary, environmental, and time savings. Associated with the development of this next generation *of real-time traveller information systems*, will be research on ambient intelligence to connect databases and different data sources, so as to provide the fore mentioned capabilities.

In addition, users require facilities for reserving and paying for mobility services, for example, Internet-based facilities, e-tickets, etc. and new ICT applications will need to be developed to meet these requirements. Moreover, users in Europe are also increasingly becoming older and so, to ensure social inclusion for an aging population, the development of new mobility concepts is needed for keeping people mobile and active. Examples could be advanced car sharing, new taxi services, autonomous vehicles, and advanced public transport.

A single technical platform is also desirable from the user perspective. Such a platform should provide a full range of public and private-sector mobility services, including real-time information, reservation facilities (car-share, parking space, park-and-ride, bicycle hire), payment mechanisms (public transport, etc.), incentives, and personalized information (favorite places, promotions, etc.). Such services will also need to be developed to run on this platform.

For the user, the underlying technical paradigm should be Many-to-Many (M2M) connectivity, where travellers can be connected to databases and other information sources concerning their mobility and travel as a whole, including choices while on the road. This should be a long-term social goal for traffic management and mobility support.

In addition to onboard applications, there are already a proliferation of third-party applications and services accessed through wireless communication (telematics, V2V, V2I) or via nomadic devices. Many of these applications interact with drivers and this implies the need for integrated, flexible, Human-machine Interface solutions. This raises both technological and human factors challenges. The technological challenges concern the HMI architecture, in particular, information prioritisation and protocols for mediating the driver-system interaction. Human factors issues mainly concern the development of interaction design principles for integrated HMIs. While these issues are critical for the deployment of cooperative systems, they have not been sufficiently addressed in previous collaborative research.

1.2 Vehicles

Vehicles are a major component of the overall transport system, and in this area, major developments are underway which are related with multiple objectives, such as increased energy efficiency, higher safety levels, and lower environmental impact, including a reduction in CO2 emissions. To achieve these objectives, vehicle manufacturers are introducing assisted and partially autonomous driving which are expected to improve the efficiency of vehicles of different types (buses, cars and trucks) as well as drive train modes (conventional, hybrid, electric).

To achieve integrated safety systems, it is necessary to improve the sensing capabilities of vehicles. Sensors are often too expensive, bulky, not robust, and too many different types of sensor are needed. So, it is necessary to develop more generic sensors, reduce their size and cost, and improve their performance, so as to accelerate the penetration rates of Intelligent Vehicle Safety Systems (IVSS) and to ensure European leadership in this area.

The introduction of Green Vehicles in the Transport System requires information systems as well as systems for interfacing and exchanging between transport modes or types of clean vehicles. Demand management information and control, and interfaces among various levels of *environment zones* (traffic and network information, management systems) are also required. Moreover, improved facilities are required for the safe and secure transport of goods on road networks, along with inter-modal transport systems, both offering data-security, vehicle tracking and monitoring, safe resting places and appropriate routing, and monitoring of users for security in cases of crime.

1.3 Transport Services

Different transport services need to be coordinated so as to assure the best services to travellers of the future. Coordination of different services has to be ensured, along with the information that is made available for traveller planning and cooperation among the different transport services. To achieve this, ICT is needed to promote the efficient use of all modes through improved interfacing and by means of better transport hubs. The development of new mobility concepts will also contribute to safer, more sustainable, and better individual and collective transportation services.

Integrated payment and ticketing systems for public transport, demand management systems (parking and road pricing), other mobility services (car share, public bikes), and non-mobility products and services (for example retail) should be developed. New combined systems offering information about real-time and forecasted parking availability, and reservation and payment, should be offered to users.

New energy efficient transport of goods, freight distribution, and improved logistics will have to be developed. This will be associated with development of complementary modularisation principles and architectures for goods carriers and vehicles so as to facilitate improved transport and energy efficiency. Furthermore, an open ITS framework for goods logistic systems, along with and cost and time databases for different modes of transport, need to be developed.

Incidents in the transportation of hazardous goods create the risk of a high negative impact in terms of public security and environmental damage. The minimisation of these risks requires research focused on new technologies and solutions that can achieve a very high level of driving safety (driving monitoring, safe distance enforcement, etc.) and also the development of systems for initial as well as continuous driver monitoring. Vehicle tracking along its route to detect any anomalies in space and time will also help to reduce risks, as will the monitoring of the condition of freight. Risks can also be minimised along the route, by performing safest, securest, and environmentally conscious routing and re-routing.

Armed robbery of, and from vehicles, has become a challenge to the logistics industry. For economic reasons, in case of theft, but also in terms of public security in those cases where large vehicles are misused as weapons, for example, in a terrorist attack, the development of appropriate countermeasures requires research focused on solutions which detect criminal acts automatically, in real time, and without the involvement of the driver. New solutions should either result in avoidance of damage, or lead to minimal related damages, by triggering appropriate measures, for example, automatic stopping of the vehicle. Such systems should also allow police intervention before the freight can be transferred to another vehicle.

1.4 Logistics Services

Comprehensive and integrated usage of new technologies (such as RFID, wireless sensor networks, advanced ICT platforms, and common application architectures) must be directed at optimal management of freight transport chains, to reduce environmental impact and increase efficiency for the community of users and logistics services providers. Several key developments are expected.

The first of these is *platforms for collaborative and interoperable freight management.* ICT solutions addressing the process-related inefficiencies that arise from the high degree of fragmentation in the logistic sector need to be developed. These solutions should address empty running, useless trips, unwanted stops, lack of synchronization between transport modes, and lengthy administration processes. These solutions must also support process models that simplify relationships and information exchanges among the involved stakeholders, along with clear and unambiguous concepts for governance, cohesive policies, and decision-rights. Processes to be supported include inter-modal freight traffic management based on sharing of transport demand and supply data. Here available transport services should be easily identifiable and there should be capabilities for automatically combining these into efficient, environmentally friendly door-to-door transport alternatives. In addition, monitoring and efficient management of complex multimodal flows should be supported, enabling individual logistic users to integrate their ICT systems with carriers and logistic operators for seamless door-to-door transport management.

Cargo mobility information services is another expected development, allowing cargo to connect itself to logistic service providers, users, and authorities, so as to provide information services whenever required along the transport chain. The goal should be to integrate intelligent packages and containers, and vehicle and field devices, through a ubiquitous infrastructure which provides basic information services, for example, identification, track and trace, proof of delivery, and all with very low integration costs. Furthermore, the infrastructure should be open for companies and providers to integrate their own advanced services, for example, eco-friendly route selection across modes, real-time monitoring, and load optimization across operators.

Finally, *data infrastructures for energy-efficient logistics* should be developed enabling distributed and centralized decision support based on intelligent analysis of efficiency related information, cross-referencing environmental data, and other relevant sources from public and private stakeholders. This will provide the means for carbon footprint estimation across several dimensions (for example sector, supply chain, transport mode, company) and enable evaluation of environmental impact reduction policies, to support authorities, government agencies and other public decision makers. An additional purpose of the data infrastructures will be assessment of energy-efficiency strategies from the business perspective, providing the private sector with the means to evaluate the impact of sustainability policies in business and market-related terms.

1.5 Road Operators

Road operators are the organisations who will be mainly responsible for reducing congestion and improving environmental conditions. The main means to achieve this will be by delivering better mobility and safety conditions. To pursue these objectives, congestion management will need to be treated as a separate issue. Very different methods will be required to address this. Above all, traffic policymakers and the private sector should work together and use ICT, in addition to demand management measures, to alleviate congestion.

A real-time knowledge of network status will require full road network monitoring covering all road users (public transport, commercial vehicles, cars, pedestrians, cyclists, etc.). The implementation of cost-effective traffic data collection covering the whole network (combining UTC and other data, for example, vehicle floating data) will be mandatory, as will data mining, filtering, fusion and processing and connection of databases. This will assure the attainment of full road network monitoring and management, and will allow the development of an intelligent road infrastructure with embedded sensor networks.

The definition of cost-effective data transmission and standardised reliable communication channels is also fundamental to make viable, equipping the whole road network. In addition, the development of open ITS frameworks will be required to allow system compatibility and interoperability leading to efficient area-wide and regional traffic management associated with new advanced traffic control to support environmental zones. Vehicle identification, tracking and monitoring will also be required to establish the environmental footprint and occupancy level, and subsequent traffic strategies and supporting systems need to be defined and evaluated.

Efficient traffic management and reliable real-time traffic information should be provided to users, based on:

- Reliable, real-time multimodal travel and traffic management and information that can be accessed anytime and anywhere;
- Evolution of traffic information platforms to multimedia content centres for cooperative and co-modal content and services for the end user;
- Development of open ITS frameworks that allow for system compatibility and interoperability leading to efficient area-wide traffic management within dense urban areas, on roads with highly fluctuating traffic densities, and across jurisdictional boundaries to inter-urban roads and adjacent urban areas;
- ITS applications recommending routes, in coordination with traffic authorities, for high fuel efficiency and low environmental impact;
- Applications assessing the impact of ITS on greenhouse gas emissions; and
- Models for route planning and re-routing that combine safety, cost-efficiency, environmental protection and personalisation of service.

Next generation traffic management systems that are multimodal and designed to move people and goods efficiently and safely, need to be designed, developed and tested. New (and integrated) monitoring technology is needed to provide a good indication of the people and goods (volume and destination) circulating on a road network (in cars, public transport, commercial vehicles, soft modes, etc.). New strategies and systems need to be defined to manage people and goods movement (rather than vehicle movement) against a variety of different objectives (efficiency, safety, reduced emissions, etc.). Moreover, traffic management strategies and systems will need to become proactive, that is to say, they will require a short-term traffic forecasting function which enables incident prediction and appropriate management interventions to be made.

Improved monitoring of people and goods movement covering the whole road network is required, along with tools for real-time local incident prediction based on vehicle-by-vehicle or flow data. Furthermore, appropriate technology for disseminating traffic information and recommended routes (especially in the event of an incident) to all road users (including incentives and penalties) has to be developed. Definition of appropriate decision-support systems also has to be tackled and more automation needs to be brought into traffic management, that is to say, self-managing (less intervention of traffic controller), self-learning (learn from incidents) and self-correcting (systems adapt themselves to new situations and knowledge) capabilities should be provided.

Concerning the accessibility for the end-user, more research in the field of ICT can improve the accessibility of digital content. On the other hand, as demonstrated in several EU funded ICT projects, the development of ICT applications in infrastructure gives possibilities and opportunities to increase the accessibility of multimodal transport systems (for example, cooperative systems (CVIS, SAFESPOT, COOPERS), and e-Inclusion of the elderly and disabled (ASK-IT, etc.)).

2. Sustainable Urban Mobility

Urban mobility is concerned with the mobility of people and goods in the urban environment, facilitated by the management of the urban mobility network. The increasing availability of real-time multimodal transport and traffic information together with better interoperability between services and systems in the transportation networks, enable the provision of personalized urban transport services to all users. Emerging technologies, systems, and solutions also allow the use of scarce resources in the most optimal way and with minimal environmental impact.

The research required for the development of safe and sustainable urban mobility will be based on a coordinated, efficient and integrated approach. This will need to address several areas: data collection and analysis of the state of the transportation network; integrated transportation networks; and urban mobility of goods.

With regard to the first area, data collection and analysis of the state of the transportation network, new technologies are required for sensing, data collection, processing and distributing, for all traffic, on all road networks, and for all modes. Soft modes and public transport should also be included in this. The objectives should be to estimate and inform on the status of the transportation network; and to predict the impact and consequences of incidents, infrastructure works, special events, communication infrastructure failures, including the behavioural changes of travellers as referred in sections 1.1 and 6.

Concerning integrated transportation networks, the integration of multiple networks management is the key for a coherent development of urban mobility, focussed on the reduction of social exclusion and provision of access for all. The integration of stand alone traffic and travel information is required. These systems must also be able to send and receive information from contiguous service providers from other transport modes and road operators, as well as local and national authorities who can contribute most significantly to the development of urban mobility. To assure the total interoperability of all these systems and services, a strong standardisation effort should be made, focussed on flexible architecture.

The definition of digital map specifications also needs to be addressed to allow the interoperation of data from different sources in all digital map types, independent from suppliers, as well as to facilitate the sharing of map information among different stakeholders. This is expected to be a major element supporting urban mobility development. Also, traffic information for route planning and guidance, considering environmental impacts and restrictions, for example in Low Emission Zones, needs to be further studied and developed.

The definition of Business Models and PPPs in ICT/ITS systems for transportation networks may lead to new urban mobility solutions using multi-criteria (safety, security, efficiency, environmental protection) and routing schemes optimisation. An example could be interoperable road tolling, parking, and public transport payment and management systems.

On the matter of urban mobility of goods, future urban logistics will go beyond traffic monitoring and enforcement, aiming at the implementation of real-time cooperative freight transportation systems. Here there are two significant issues to be addressed. The first is transparent data acquisition and use, allowing effective monitoring and coordination of urban freight traffic while safeguarding privacy and commercial sensitiveness of crucial logistics information. The second is cooperative real-time demand management solutions, allowing cargo owners (consigners or consignees), logistic operators, and control authorities to apply consolidation strategies for urban goods deliveries and pick up, as well as advanced cooperative routing.

3. Road Transport Safety

Road safety has been, and remains, a major goal for the European Union. The objectives mentioned earlier in this document were not met, and as a result an additional effort should be made to recover the situation and address the resulting delays in attainment of the objective of reducing road fatalities. At the same time, investment in the development of electrical vehicles is also opening up novel areas of investigation on safety related applications, which are related to new aspects associated with electrical vehicles (for example, charging batteries).

The safety and security of new hybrid and electric vehicles should be considered in the research of the safety of alternative propulsion systems, namely integrated safety for the electrified vehicle (explosion, fire, high-voltage, gas, EMC, noise), new HMI concepts, new body design and enhanced low-weight materials, and distributed drive train architectures.

Increased utilisation of electric vehicles will generate additional opportunities for different control systems within the vehicles to increase safety and for easing navigation, entertainment, life assistance, besides environment control systems that will allow the vehicle colour selection according to the driver’s mood or the weather conditions, etc. Safety impact assessment methods for electric and hybrid vehicles, and the review of assessment and definition of safety standards, should be performed, as well as impact studies of self-driven vehicles in urban and inter-urban environments.

Electric vehicle driver assistance and cooperative systems research for interaction and exchange of safety relevant information, for example, for Vulnerable Road Users (acoustic perception, sensors and actuators adapting to the object crashed into) is also needed. Moreover, concerning new high voltage systems and components, there will be a need for elements that address regular use (instructions), maintenance, and repair, together with information and database systems for the rescue and emergency services and intervention, namely post-crash automatic intervention (safe batteries, high-voltage systems risks).

Research on crash mitigation for electric and low-weight vehicles (complete vehicle crash behaviour) is also required, as well as collision avoidance and intelligent vehicle dynamics and adapted structural architectures that will improve significantly, safety on the roads. Better human body modelling for improving computer simulation of advanced protection systems and virtual safety testing is needed, and in addition, driver behaviour modelling for computer simulation of driver behaviour in critical situations should be covered. This can be used both for parameter optimisation during development and general safety benefits estimation. Functional safety and reliability through remote diagnosis of vehicles, aimed at the prediction of vehicle faults, is another area requiring attention. Contributions to the development of the road environment will also be welcome in view of facilitating the functioning of vehicle ICT systems.

Research concerning safety of smart intersections, offering different applications using several communication channels to users, and liability in the event of a systems failure, needs to be tackled. Public authorities are currently responsible, but this would change if other systems, not under their full control, are implemented.

The new Many-to-Many (M2M) services paradigm will become more significant and this is creating a shift from product-centric to services-centric *smart services*. However, a broader approach is needed where traffic participants are connected enabling journey planning and decisions on alternative means of transport as well as keeping those on the road aware of traffic and incidents ahead. From a technical perspective, what is needed is a system where all travellers and other stakeholders may be connected through systems applying the principles of M2M communication.

V2V and V2I communication along with driver information support will allow the connection of independent safety-systems, vehicles and roads, in an integrated and fail safe cooperative system, optimised for energy efficiency and light weight vehicle usage. Also enabled, will be driver safety information, with V2V and V2I communication systems and post-crash information, for example, on possible fire hazards for rescue operations. V2V and V2I communication and driver information support will also allow ICT/ITS for safe and ecological driving, providing dynamic routing to avoid traffic congestion and to improve traffic fluidity, thus reducing CO2 emissions. In this context, cooperative systems, C2X communications, and the reliability of sensor and communication information is important.

HMI solutions to enable safe interaction with a large number of onboard, nomadic and infrastructure based applications, including online services and cooperative systems need to be developed. This also includes the seamless integration of nomadic devices, and this is an important goal to pursue. HMI design guidelines need to be developed for general HMI integration as well as for information, warning, intervention, and automation strategies for specific safety functions. The development of such guidelines should to be guided by an enhanced understanding of the basic mechanisms whereby distraction causes crashes. This understanding could be obtained by means of combining naturalistic driving studies (see section 5 below) with simulator studies and driver modelling efforts.

4. ICT and the Decarbonisation of Transport

There is a need for new ICT solutions, or for existing ICT systems to be adapted, to integrate electric vehicles fully into the urban mobility system. The main areas to address are integration with other modes, demand management, and charging.

With regard to Integration with other modes, since large-scale deployment of electric vehicles will probably also occur in captive fleets (car clubs, public cars, etc.), solutions will be needed to facilitate the transition to other modes so as to maximise inter-modal transport. From an ICT perspective, solutions will be needed in terms of integrated information, ticketing, billing and payment, etc. On the matter of demand management, there is an important role for ICT to assist the electric vehicle driver (passenger or freight) in selecting the most energy efficient route, or a destination, or both, which offer charging facilities. ICT solutions should be developed in the areas of traffic management (priority, access to restricted zones, etc.), real-time information (for example traffic conditions, charging station, parking availability, etc.) and route guidance. Integrated charging systems are needed, and key here are payment and billing where there are a whole range of options that should be explored, for which ICT solutions will be needed, including *in situ* payment (via Smartcard or mobile phone), or remote payment (for example to an energy supplier), which can be integrated with payment and charging systems across all modes on the network.

Transport system integration[5] needs to be investigated, focusing on exploration of the potential of ITS for energy efficiency, and providing convenient transition between modes. Application of sensors and C2X for autonomous driving, promotion of the green image of electric vehicles, development of best practice for implementation of road infrastructure measures supporting rapid uptake, reviewing the effects of large scale deployment on future infrastructure developments, and EU wide signage of roads and vehicles, also needs to be considered.

In the area of customer systems, customer-based ICT solutions are needed. These should provide services such as location identification, routing and availability of charging stations (including information on queue times, energy cost and payment means), advanced charging management systems, and driver alerts on remaining battery charge. With regard to the charging systems, the charging station is the interface between the power grid and the vehicle and as such it forms the starting point for metering, as well as further customer services and billing processes. These all require advanced ICT solutions, notably a system architecture involving functions such as vehicle identification, authorisation, and payment and billing solutions. The use of electric vehicles for urban delivery is being increasing adopted in cities. This will place an additional burden on the charging system.

Integrating electric vehicles into the grid is a key issue. The access of electric vehicles to the power grid and their optimised integration in the grid's infrastructure and operation is an important element of the electrification of the transport system. Energy loads purchased by electric vehicles may contribute to an additional stress on the power network, but may provide wide potential for advanced ancillary services for network management as well, that is to say, bidirectional vehicle-to-grid (V2G) interactions. This is determined by the charging station, the battery system and operating converter, and by the applied control architecture in terms of appropriate ICT solutions. Ancillary services include the provision of balancing

[5] ERTRAC/EPOSS/SMARTGRIDS European Roadmap 'Electrification of the transport systems (November 2009)

power, voltage and frequency control, and the reliable supply of energy from renewable energy systems. Grid integration will require:

- Development of adaptive onboard and plug-in charging, as well as contact-free charging, along with the creation of systems to provide information on charge status;
- Development of simulation, monitoring and management tools;
- Development of protocols and devices for V2G communication;
- Investigation of quick charging technologies and the creation of a network of quick charging stations;
- Development of bidirectional charging technologies and the establishment of business models for bidirectional trading;
- Establishment of a first generation charging infrastructure along with the creation of business models for charging, and the connection of regions by highways with charging stations;
- Standardised billing concepts.

Information Exchange Standards are also important and these need to be identified. The development of new concepts such as *smart grid* or *vehicle-to-grid* has created the need for an appropriate communication protocol for electric vehicle charging. These standards need to be focused on a number of critical areas:

- Vehicle identification and billing, allowing payment for charging at public charging stations, but also individual billing of used energy to the user's account when the vehicle is charged at any outlets connected to a smart meter;
- Charge cost optimization by choosing the most appropriate time window when electricity rates are the lowest;
- Grid load optimization by controlling charger capacity as a function of grid demand and external parameters such as costs;
- Further advanced ancillary grid services by using electric vehicles connected to a grid dispersed storage unit, with highly flexible generation and consumption characteristics (vehicle-to-grid);
- Appropriate billing and user compensation functions for vehicle-to-grid operation.

Eco-technologies have been making their way into the auto industry for many years and include everything from onboard trip computers to powertrain control solutions designed to improve the efficiency of a motor vehicle. Eco-telematics leverages many of the technologies and shared resources already being deployed in cars, like HMI, navigation, powertrain control, and connectivity. Eco-telematics is considered a necessity for OEMs taking a position on sustainability. An increasing regulatory environment creates an economic incentive for further development.

Fleet managers need to be able to compare all their drivers' fuel consumption and CO2 emission records on a single chart. Company drivers should be able to upload information onto a company system, which will give them and their fleet managers instant access to their driving styles. This should allow comparisons with other company drivers so that fleet managers can identify and reward efficient drivers and identify and train the least efficient.

Several other research topics related to electric vehicles also need to be considered. First among these is a smart ICT tool simulator that allows simulation of the impact of electric vehicle introduction on the electrical network, including planning of charging points, electrical network growth, and smart management of mobile charging, etc. Second there is modelling of the battery charge and discharge cycle. Algorithms for electric vehicle battery pack management, optimizing the useful life of batteries and the onboard information of the battery status, should be developed. Third, development of control systems for the vehicle electric distribution network should be investigated along with smart control of vehicle electrical devices to optimise battery life. Finally, the development of data communication interfaces between the green car and the infrastructure, including transmission of information (protocol definitions) to feed the demand management models, has to be considered.

There are also several ICT Topics related to efficiency that require attention. These include ICT for advanced and eco-efficient logistic applications, and new control and traffic management models oriented to energy efficiency (reliable real time traffic information accessible from anywhere, eco-routing and eco-navigation, etc.). Novel methodologies or systems for verification of high occupancy traffic lanes, new systems and software to facilitate ride sharing and parking reservation, automatic information about arrival and ticketing, and information to the driver about environmental costs, as well as ecologic insurance policies, are also relevant.

Secondary research on electro-magnetic compatibility, user acceptance, business models, and standardization requiring demonstrations, validations and field tests is also needed, along with research on testing and simulations of components (e.g. batteries, tanks) to work on specific risks present in electric or hybrid vehicles.

The road itself could play a role in the reduction of Green House Gas emission, in different ways. One way this could be achieved is through the reduction of energy loss occurring at the point of interaction of the vehicle tyres with the road surface. A second way is through optimisation of the speed profile, based on road geometry and traffic conditions. A third contribution could arise from optimisation of traffic distribution, in particular commercial vehicles, to extend the life of the road surface, increasing the time between road surface maintenance interventions. Finally, there are specific infrastructure matters such as green corridors where vehicle platoon operation would be possible, and where electric vehicles could be charged while moving.

Road user behaviour has a clear influence on the energy spent on road mobility. Driver behaviour that is more environment-friendly could not only be based on driver education, but also on a series of supports that can help drivers to adopt *eco-behaviour*. Such behaviour should take into account speed adaptation, based on real traffic, green route planning, safe platoon mode, and optimisation of energy use (for hybrid vehicles).

5. Deployment

Deployment and market development has always been a major problem with ICT-based ITS and, to overcome this, Field Operational Tests must be developed further. FOTs are large-scale test programmes, using ordinary drivers, covering a wide range of driving conditions, undertaken over an extended period of time. They enable the collection of data that cannot be produced by conventional test and demonstration methods associated with RTD activities. The data collected from FOTs can then be used for socio-economic and technical evaluations, leading to concrete information concerning the costs and benefits of advanced ICT-based systems in vehicles, and their impacts on driver behaviour, traffic safety, the environment, and transport efficiency. FOTs can be undertaken, in principle, with any type of road vehicle fitted with relevant ICT-based systems: cars, trucks, buses.

5.1 Field Operational Tests and Data Collection

Larger scale FOTs, including all types of drivers (that is to say private and professional drivers) and vehicles (that is to say, cars, trucks, and buses) for after market and close-to-market functions, or innovative functions in prototype form, encompassing ecological functions and covering more countries, are needed so as to prepare the European market and its relationship with other regions. FOTs need to be undertaken that consider urban traffic environments, intersections and the larger road network, motorways and corridors (testing various penetration rates), cooperative systems including CO2 emissions, and new ITS services and new low carbon vehicles or services.

The ideal should be to move from FOTs involving 20 to 200 vehicles, to FOTs involving a much larger number of vehicles, with the exact scale and scope taking into account the results of the first FOTs undertaken in Europe. Such a major change also requires a revaluation of the assessment methods used in FOTs because of the alteration in scale. These large scale FOTs may be combined with naturalistic driving studies with the purpose of studying accident causation (as done in the US SHRP2 project). For these new type of FOTs, there is also a need for standardization and harmonization of the test bed infrastructure.

Given that people do not change their travel habits and behaviour easily, it will be necessary to find ways to support and motivate travellers to adopt sustainable travel. FOTs can play a role here. Various ICT measures need to be studied and evaluated. Even though environmental impacts such as pollution and possibly noise could be solved, congestion remains and will increase. To tackle this, effective measures are needed, where various ICT-based solutions can be of help (pricing, pay-as-you-drive and others). Experiments with these, and other even more innovative approaches, are needed, and may be undertaken using FOTs.

The introduction of any innovation requires the monitoring of a lot of new data. This should be collected according to the requirements of new challenges, and not be based on following old models, modelling schemes, and methodologies. Innovation and market introduction need to be done smoothly and in a phased way. Therefore, experiments and observations concerning new applications or services should be done in such a way that different market segment reactions may be captured and understood. A full understanding of the behaviour mechanisms inducing these reactions needs to be achieved before full deployment in the market.

It must be considered that FOTs are an essential tool to test several ICT systems in real traffic, and thus FOTs provide the opportunity to evaluate the impacts on driver behaviour and the transport system. Data collection should be concerned with data warehousing, micro scale traffic data, reliable dynamic Origin Destination matrices, CO2 estimation and traffic data needs, naturalistic driving observations, safety and eco driving data for professional drivers, eco-green driving advisory HMI data, and data for modelling and simulation.

FOTs aim to support the decision-making of industrial stakeholders and public authorities responsible for transport and mobility. Therefore, European FOTs should bring together industry and public authorities, including local governments, so as to ensure that the necessary relevant partners are contributing to the evaluation of systems.

From the previous paragraphs, it should be clear that the use of real-life data is extremely important. There are, however, large differences between Member States in the availability of data. Consequently there is a need for a number of actions.

First, there should be an analysis of the data needs for accurate simulations that include situation-sensitive and human behaviour sensitive emission models. Second, good empirical data on the system level impacts are required at several levels: at road section/intersection level, at corridor level, and at network level. Third, available traffic databases (public and private) in the various Member States should be analysed. Fourth, access tools are required for the various traffic databases (possibly with a conversion to a standardised format). Fifth, real-world driving data has to be generated enabling the characterisation of the influence of detailed traffic conditions and human driving behaviours on emissions, as well as the development of appropriate emission models. Sixth, mobility should be supported by rapid and user-centred information systems providing travellers with information on their choices, real-time travel conditions, and the carbon foot-print that their choices create.

Data related matters are crucial and there is a lack of basic data for setting up accurate simulations. Information on roads (curvature, slopes, traffic-calming measures) and on rules and regulations in the network (for example, speed limits) has to be collected. Specific modes can have a considerable impact on the results of the simulations. Therefore, easy access to several types of data would be useful. These data include public transport schedules, and the information systems used by public transport operators to maintain their schedules. Freight movement data is also important. Data on commercial vehicle movements generated by logistic systems could therefore be extremely valuable, but such information is normally confidential. Acceptable ways need to be designed for gaining access to such confidential data.

The optimisation of mobility from the environmental perspective is subject to intensive study and experimentation. Large scale tests like FOTs can produce valuable data. This data should be fed back into traffic databases and made available for future work.

With respect to FOTs, it should also be remembered that improvement of transport and services for disabled people (not only PMR) focusing on evacuation issues, need to be considered. Moreover, for the evaluation and assessment of FOTs addressing HMIs, IVIS, ADAS and cooperative systems, it is necessary to have available accident and pre-accident data, which should be scientifically collected and structured. There is also a need to have real accident data such as that obtained by Japanese NPA through the equipping of a test bed of 300 digital cameras at intersections or merging areas. In addition to data collection, there is a strong need for improved methods for analysing FOT and naturalistic driving data. A particular critical issue here concerns the identification of valid surrogate crash measures (for example crash relevant events) and models for relating these to actual crash risk.

To cope with new challenges and new ITS services, there is a need to confirm the validity of analysis methodologies. There are several aspects to the validation issue. Important aspects include transport demand changes, traffic behaviour and routing changes, and safety benefits. Providing a standardised way of quantifying the reduction in CO2 emissions attributable to a specific ITS implementation (already installed) is also important for validity, as is the estimation, before implementation, of the costs and benefits of a proposed ITS strategy, for example and in particular, the trade-off between safety, efficiency, and environmental factors as well as the relationship between the system performance or service quality level on one hand, and the benefits and costs on the other hand.

5.2 Modelling and Simulation

There are two important areas relevant to modelling. The first are issues concerning traffic models and the second are issues that relate to emission models.

With regard to traffic models, simulation seeks to provide an accurate representation of (potential) real-world systems. Current technology needs a careful calibration to be able to provide reliable data. This means that sets of calibration data must be available to verify or tune simulations to different circumstances. Such circumstances include environmental conditions (weather, road surface) and details of driving behaviour.

Probably the most challenging factor is simulating human behaviour. Current models do not always take into account the type of driver behaviour relevant to CO2 emissions or energy consumption, or both, and tend only to consider a few parameters. It is necessary to establish to what extent it is feasible to develop validated driver behaviour models taking into account elements such as drivers' responses to traffic signals, driving advice, etc., regional differences in driving behaviour, variable external conditions (for example, the weather, road condition, visibility), representative distribution of driving behaviours as well as their evolution or sensitivity to typical ITS measures, and interaction between individual vehicle behaviour and traffic flows.

Present simulation models do not enable the study of the effects of intelligent systems on safety. There is a need to develop new modelling tools including the human being as one of the units simulated, and the occurrence of different kinds of driver errors so as to have the possibility of real safety simulation. Both intra-individual and inter-individual differences and variation need to be taken into account in the models.

When traffic management strategies interact with driver behaviour, an accurate model of the traffic management strategy is important. Details of the actual traffic control strategies operating in the simulated environment are therefore needed. These should include direct interaction with the simulated driver or vehicle behaviour when the traffic control strategy uses cooperative technology. Also required is an interface (preferably universal for all simulation environments) between simulation models and simulated traffic control strategies.

It is necessary to have transport demand models which not only consider modal choices, but also consider dynamic route planning and trip timing. On the other hand, a definition of models optimizing the urban transport of people and goods (distribution, routing and pick-up) regarding efficiency and environmental impact should be studied and defined, making use of demand and access management systems. In particular, modelling and analysis tools should be developed that will allow integration and cross-reference analysis of collected data from transport networks with operational data from logistics operators, thus providing comprehensive performance evaluation.

Improved network forecasting, simulation and modelling tools, as well as decision support systems for the implementation of advanced network management strategies, should contribute towards foreseeing incidents in advance, so that these can be better researched and understood.

With regard to emission models, and especially instantaneous emission models, these are continuously being improved. Current models however, do not provide, for the most part, satisfactory treatment of the vehicle (engine) response to the details of driver behaviour, microscopic approaches validated for the assessment of ITS applications, and appropriate scales and parameters for combination with the traffic models. Appropriate models are therefore needed, taking into account the driving behaviour and conditions at the required scale (consistent with traffic models). Such models should be based on real-world driving data with a sufficient range of driving conditions and behaviours.

To set up a representative simulation it is necessary to know the mix of vehicles that constitute the simulated demand. For this it is useful to be able to derive vehicle characteristics from measured data. The most accurate way is to gather vehicle registration data and retrieve vehicle characteristics from the various European vehicle registration databases. It is also useful to be able to compile a database with representative vehicle mixes for the situations to be simulated. This database should enable predictions to be made for future vehicle mixes (in which hybrid and electric vehicles will play a bigger part).

Modelling fuel consumption on a larger scale is also necessary. Fuel consumption depends upon the details of driving behaviour which, in turn, depends upon the traffic management. To set up a simulation able to show the impact of traffic management on a useful scale (area, city or region), a great deal of modelling is required. To perform a detailed simulation of a single (complex) controlled intersection can require several days work. Extrapolating this to a city scale (several hundred intersections), would amount to years of effort, which is clearly not a practical proposition! To effectively simulate CO2 emissions for a large network, approximation or extrapolation is therefore essential.

Models and tools for driver behaviour simulation on different time scales and granularity, informed by FOTs and other sources of driver behaviour data are also necessary, as is an accurate model of driver behaviour in response to the infrastructure and traffic management measures.

Simulation development also needs to be addressed. In this respect, there is a need to use distributed interactive simulation to design and evaluate cooperative ITS, and to undertake driver modelling and simulation for ITS design.

6. Horizontal Issues

Horizontal issues remain an important area requiring attention in future research activities. Overall these horizontal matters cover a broad range of topics. Specifically, the horizontal issues that need to be considered include assessment methods, quality standards, business models and deployment aspects, training and education, human factors and organisational perspectives, and international R&D collaboration.

Assessment methods are an important horizontal topic area. A better understanding is needed of the impact that ITS can have upon green, clean, safe and more efficient transport. To this end, it is necessary to further develop methods and procedures to assess the contribution (impact) of ADAS and ICT/ITS systems. Additionally, traffic information for route planning and guidance, considering environmental impacts and restrictions (for example in Low Emission Zones) needs to be further studied and developed as referred in section 1.2. Concerning ITS and climate change, the most carbon friendly solutions need to be identified, while in ITS and impact assessment, large scale assessments of new technologies are required to understand their benefits (at all levels)—hard evidence is needed.

Related to the above is the matter of quality standards. The development of methods and procedures is required to assess the impact of vehicle and infrastructure related ITS functions with a view to possibly developing certification procedures and exploring the relationship between the technical performance and the impacts of the function. Also, European benchmarks and trends in infrastructure-vehicle technologies aimed at traffic information and traffic management require additional standardisation work, and the same applies to vehicle and infrastructure-vehicle technologies aimed at improving road safety.

Business model and deployment aspects are also an area requiring attention. In relation to this, technologies and the definition of standards to promote new insurance models based on vehicle usage and driver safe behaviour need to be developed. Additionally, outline deployment road maps, business models, business partnership aspects of ADAS and cooperative systems, need to be considered as part of the overall business model for ICT systems. Moreover, research should incorporate scenarios and use cases to determine the effects of the implementation of dynamic traffic management, where there is a high degree of uncertainty about whether or not applications will be used and to what extent. For political decision making processes, such evidence is important.

Legal (data protection and privacy) and liability issues must also be considered. A special need for research arises as a result of the scope of ADAS features, and also because of RTTI systems and data collection techniques, which requires the processing of personal data. Owing to improvements in terms of telecommunication possibilities and computing power, it is now possible to develop V2V and V2I communication as well as security functions, IVIS, and comfort related functionalities that require not only processing of personal data, but also the storage of such data. It may even prove necessary to transmit personal data to achieve the goal of an enhancement of safety for other drivers, once a danger has been detected by another vehicle. Consequently, aspects related with data protection, public acceptability, and privacy within data collection and analysis, must continue to be researched so as ensure the correct deployment of research results.

Training and education must also be addressed. There is a need to develop European training curricula for drivers and riders considering new ITS systems and drivers' information processing capabilities. Adequate training tools for driver and rider behaviour and specific ITS functionality must also be considered. Migration from theoretical training and road testing, towards interactive multimedia training and driving simulators should be explored, examining the potential of ITS to train drivers and riders, including testing the usability of such systems. With regard to such ITS based training systems, the development of Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR) driving simulators have to be investigated, where the user interacts with real vehicle environments and receives visual feedback from a Virtual Environment (VE). ITS training modalities also need to be adapted to specific populations such as riders, novices, professionals, the elderly, and the disabled. Moreover, the developed training methods and tools need to be validated and results analysed.

It would also be very helpful to develop a multidisciplinary pan-European training course on the subject of ITS and cooperative systems, either as mandatory, or as additional training for obtaining a driving licence. On the matter of driving licences, the possibility of electronic driving licences, with possible restrictions and control for responsible use of vehicles, should also be studied in more depth.

Strategies targeted at raising public awareness through pan-European campaigns that will promote driver and rider training in ITS, should be designed. Additionally, driver-coaching for achieving behavioural change through feedback must also be considered. This may be related to both ecological and safe driving and may involve direct feedback on driving performance through the in-vehicle HMI, as well as post-trip feedback to the driver or other stakeholders. A key research issue here concerns the identification of suitable incentive schemes linked to multi-stakeholder business models.

There is a need also to consider instruments aimed at covering large scale development and deployment including various types of, but not limited to, FOTs, during the different stages of research, development, and deployment. This could be an ELSA (European Large Scale Action). However, as for innovation, research has to be cooperative with various types of stakeholders (and also stakeholder driven). Hence it is necessary to think in terms of clusters of big research projects, which could be industry or operator driven, or both, through a PPP. Or these could be policy driven through a PPP or a JRI. Another possibility is an academic driven approach through a JRI, especially in nurturing frontier research in focused areas useful for future projects that could then be covered in PPPs. An academic driven approach could also be useful for reliable data collection.

General human factors and organisational issues in the implementation of ICT-based solutions for enhanced mobility need to be considered. In addition to technical challenges related to system interoperability and reliability, the efficiency and impact of new ICT-based mobility solutions ultimately depends on their ability to support the various different users to achieve their goals. This is not simply an issue of good Human-machine Interface design, but also involves more general, system-level and organisational issues. For example, a traffic management system must be understandable for the traffic managers as well as for the road users. Moreover, the willingness of people to use a system, and to comply with instructions and recommendations, depends on users' motivation to do so. This motivation may be changed by various incentive schemes, which may involve many different stakeholders, with potentially different motives. Hence, research efforts are needed to identify, from the human factors and the organisational perspectives, the most efficient ways to implement ICT-based solutions.

Finally, turning to international R&D collaboration, several areas have been identified for international cooperation and these are mainly aimed at cooperation with stakeholders in the Americas, in Asia and in emerging economies. Innovation and research on these topics is advancing fast in other areas of the world and international collaboration is necessary to allow Europeans (industry and public authorities) to exploit research results quickly and to adapt them to regional requirements. International collaboration would allow, in some cases, experience from European cities to be used by industry to develop systems adapted to the needs of emerging countries. In relation to international R&D collaboration, there are three important areas that need to be considered: harmonisation of accident statistics; transportation of hazardous goods; and business models.

With regard to harmonisation of accident statistics, an understanding of accident causation is essential for the development of safety and support functions, in particular, for the assessment of their impact. Existing national accident databases are often structured differently, which makes aggregation of data difficult. There is a general need for global harmonisation with the goal to obtain comparable data from different regions. The main target regions are North America, Japan and Australia.

International R&D collaboration—especially in ICT research for transport—is inevitable in a global economy, and is especially important when it comes to the matter of the transportation of hazardous goods. Cargo monitoring is not limited to regions or continents, but has to be available for cross-continent transport as well. To achieve this there is an urgent need to harmonise communication protocols for international cargo monitoring. Growing demand for the transport of goods generates an emerging market for low-power and low-cost devices for tracking and tracing goods, and there is a need for global harmonisation of the communication interfaces used by such devices.

Business model are a key issue for the deployment of ICT systems, namely, integrated models for micro and macro mobility based on data for people and goods, rather than data for vehicles. Business models for public-private partnership in urban freight transport services need to be sustainable and friendly on the community side, while on the business side they should be commercially viable. A key issue concerns how reduced *costs* in terms of such benefits as lives saved and CO2 reductions achieved, can be re-allocated in monetary terms to the stakeholders making the investments.

Glossary

ADAS:	Advanced Driver Assistance Systems
C2X:	Car-to-X
CBA:	Commonwealth Broadcasting Association
EMC:	Electro-Magnetic Compatibility
FOT:	Field Operational Tests
HMI:	Human-Machine Interface
ICT:	Information and Communication Technologies
ITS:	Intelligent Transport Systems and Services
IVIS:	In-Vehicle-Information-Systems
IVSS:	Intelligent Vehicle Safety Systems
NPA:	Nippon
OD:	Origin-Destination
PMR:	Private Mobile Radio
PPP:	Public-Private Partnerships
RTTI:	Real-time Travel and Traffic Information
R&D:	Research and Development
TMP:	Traffic Management Plans
US SHRP2:	United States Strategic Highway Research Program 2
UTC:	Universal Time Coordinated
V2I:	Vehicle-to-Infrastructure
V2V:	Vehicle-to-Vehicle