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Preliminary Descriptions of Research and Innovation Areas and Fields

Accompanying the document

Communication

Research and Innovation for Europe's Future Mobility

{COM(2012) 501 final}

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1. INTRODUCTION

1.1. Rationale of this document

The Communication on 'Research and innovation for Europe's future mobility'[1], hereinafter referred to as 'the communication', makes proposals on how research and innovation can make a more substantial contribution to achieving European transport policy goals.

The communication identifies three initial Research and Innovation areas (R&I areas) and, within these areas, ten fields with a clear EU added value on which research and innovation (R&I) should focus. The ten fields have been identified by matching the current state and future development of key transport technologies as outlined in the report 'Scientific Assessment of Strategic Transport Technologies'[2] with the policy requirements set out in the 2011 White Paper on Transport[3]. According to expert opinion, these ten fields have significant potential for helping achieve the White Paper's objectives by 2030 — or by 2050 in the case of some fields. They also take into account the specific characteristics of the individual modes of transport as well as multimodal issues. However, they represent neither a final position nor a list of priorities for future research and innovation programmes.

Based on the fields described in this paper, the Commission will now begin work to further assess and specify the objectives, timing, resources and instruments that are necessary to bring each of the fields to large-scale deployment. This will involve drawing up roadmaps, in close collaboration with relevant stakeholders. Existing work, for example roadmaps produced by European Technology Platforms, will be used as a starting point. The roadmapping exercise and its outcome will take account of existing Commission proposals and activities and not supersede them.

The roadmaps will identify the challenges all along the innovation chain and the solutions they require. Processes, roles and structures will need to be designed. Indicative budgets will need to be identified and adaptive management and monitoring procedures will need to be put in place.

1.2. Scope of the research and innovation fields

For the purpose of this paper, a field is defined as 'a comprehensive set of technologies, methods and practices with a shared focus on addressing societal challenges and competitiveness. It encompasses all elements of the research and innovation chain (from research and demonstration to market uptake and deployment)'.

This broad definition not only covers technological solutions from a conventional engineering and/or scientific perspective but also their use in the transport system. It thus embraces the user and his or her priorities. It may include related elements by which deployment can be facilitated, such as management tools, business models, service design, regulation, standardisation, public procurement, awareness raising, etc. It may also include market entry barriers, longer-term sustainability and life-cycle issues which are at the core of the later phases of the innovation chain.

1.3. Clustering of Research and Innovation Areas

The three R&I areas presented in the communication cover the following fields:

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[1] Add reference to STTP communication.

[2] *Scientific Assessment of Strategic Transport Technologies*, EC Joint Research Centre, EUR 25211 EN, 2012.

[3] *Roadmap to a Single European Transport Area — Towards a competitive and resource efficient transport system*, COM(2011) 144 final .

- In the R&I area of means of transport, progress is needed on clean, safe, efficient and quiet vehicles, aircraft and vessels, including components, propulsion systems, materials and enabling technologies. The anticipated shift towards alternative fuels will lead to important new requirements.
- In the R&I area of infrastructure, progress is needed on smart, safe, green, low-maintenance and climate-resilient infrastructure, including alternative fuel distribution infrastructure, modal information and traffic management systems, demand management and other solutions related to infrastructure usage.
- In the R&I area of transport services and operations, progress is needed on seamless and efficient services for passenger and freight transport, including public transport, logistics and smart terminals, as well as integrated travel and freight information services.

In order to structure and manage the future work, these fields have to be clustered. However, drawing clear boundaries between the fields is difficult — and, indeed, counterproductive as some issues overlap between different fields and the overlaps can be exploited when looking for synergies.

1.4. Cross-cutting issues

Some technologies or issues stretch across all three R&I areas and will need to be addressed in an integrated and cross-cutting manner, considering the specific needs of each field (see Figure 1). These include:

- Information and communication technologies: intelligent ways to connect transport means with each other and with infrastructure will help reduce congestion, improve safety, security and resilience in the transport system and make transport operations more reliable and punctual.
- Safety and security: these can be enhanced by improving the design and operation of transport means and infrastructures (including terminals). Crucial in this respect are passive and active safety, preventive safety, and enhanced automation and training processes to reduce the impact of human errors.
- Energy and energy efficiency improvement technologies: greater energy-efficiency and reduced oil-dependency can be achieved through a holistic approach to transport means, energy storage and energy supply infrastructure (including vehicle-to-grid interfaces and innovative solutions for the use of alternative fuels) and transport operations (e.g. eco-driving).
- Socio-economic issues: the interaction between transport policy and other policy sectors, such as environment, land use, urban planning, employment, health, accessibility etc. It will also be important to have modelling tools for improving the analytical capacity needed for policy development. Other issues that require attention include internalising the negative impact of transport (for example, through taxation and pricing) and understanding the drivers of user behaviour and how to use behavioural science to develop smarter tools.

Strengthening the skills base in Europe to meet transport research and innovation objectives, to create jobs and to support economic growth.

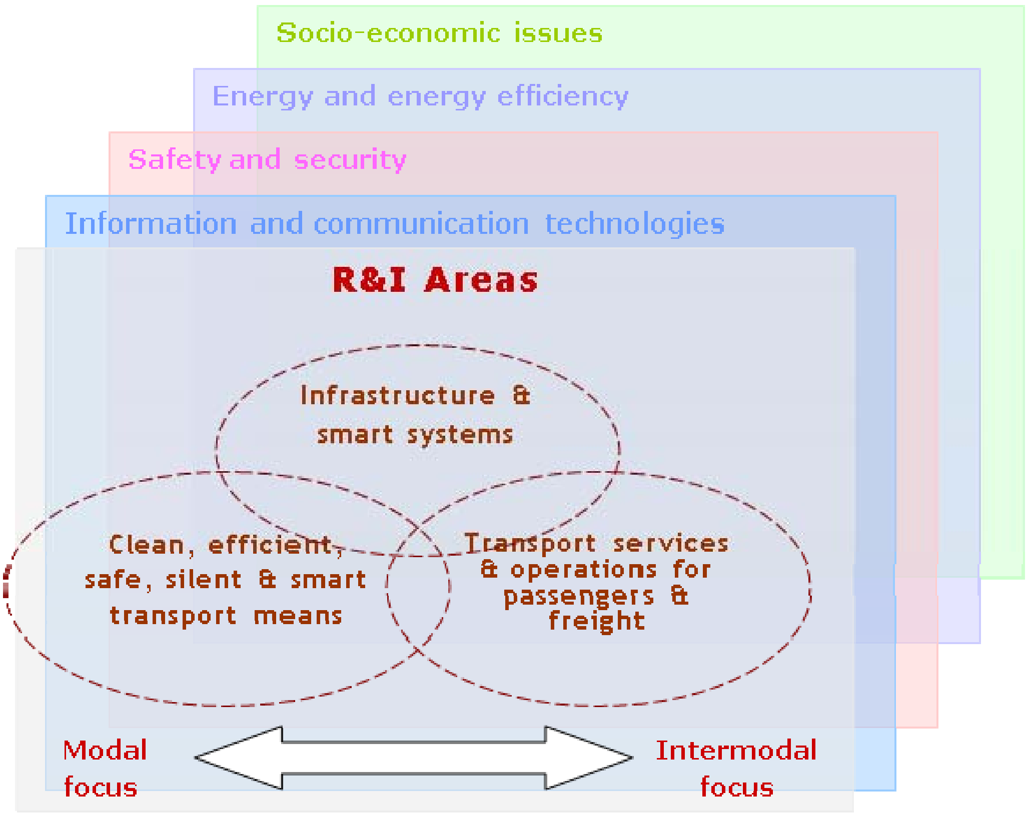

Figure 1: a graphical presentation of the R&I areas and cross-cutting issues.

1.5. The structure of this paper

In the rest of this paper, the presentation of each of the R&I areas opens with a short description of the policy objectives which that area addresses. It then outlines the fields within each area, describing the current level of development and the technology needs. In some cases, the presentation already puts forward a list of the measures to be taken.

2. R&I AREA: CLEAN, EFFICIENT, SAFE, QUIET AND SMART TRANSPORT MEANS

2.1. Strategic Objective

The White Paper sets the EU the goal of reducing greenhouse gas emissions from the transport sector by 60% by 2050 with respect to 1990 levels. To achieve this objective, it is essential to improve the energy efficiency of transport operations and vehicles across all modes of transport. However, this will not be sufficient. The carbon intensity of transport fuels must also be lowered. This will also help reduce the transport sector's excessive reliance on oil products. Much more must therefore be done to develop alternative fuel propulsion systems for all means of transport but particularly for road vehicles and aircraft.

Vehicle design also has major implications for safety, another central concern of transport policy. Specifically for road transport, the White Paper sets the EU the strategic objective of halving the number of road casualties by 2020 and moving close to zero fatalities by 2050. Similarly, the White Paper emphasises the need to bring safety rules into line with the development and deployment of new technologies in air transport (SESAR). It envisages developing SafeSeaNet into the core system for all the information tools needed to support maritime safety and security and to protect the marine environment from ship-source pollution. Intelligent devices are also important for safety in road and rail vehicles.

This R&I area covers four fields:

- Clean, efficient, safe, quiet and smart road vehicles
- Clean, efficient, safe, quiet and smart aircraft
- Clean, efficient, safe, quiet and smart vessels
- Clean, efficient, safe, quiet and smart rail vehicles

2.2. Field 1: Clean, efficient, safe, quiet and smart road vehicles

Road transport accounts for the largest share of transport-related greenhouse gas emissions. In order to reduce those emissions, therefore, it is essential to develop and deploy innovative, clean and efficient vehicles. The preferred policy option set out in the White Paper's Impact Assessment assumes that average emissions will be reduced to 20 g CO_2/km for new cars and 55 g CO_2/km for new light commercial vehicles by 2050, through the use of emission standards. Furthermore, the fuel efficiency of trucks could be improved by 40 %. The White Paper's modelling of future scenarios also includes stricter standards for air pollution.

Research and innovation will continue to play an important role in optimising the performance and cost competitiveness of future vehicles. Overall vehicle efficiency needs to be further improved through advanced engine design, alternative fuel propulsion systems, lightweight materials, increasing the recovery of waste energy and system optimisation. Vehicles will also have to be improved in order to fully exploit the potential of future drive train concepts and new infrastructure systems. Conventional light and heavy-duty vehicle designs can be further improved especially in terms of aerodynamics, low resistance tyres, etc. The unexploited potential is particularly great for trucks.

Energy efficiency and alternative fuel propulsion systems

Future propulsion systems and their associated technologies vary greatly in terms of their level of maturity and their suitability for road vehicles. The internal combustion engine is a mature technology that will undergo further incremental improvements leading to emission reductions. The internal combustion engine is likely to remain the dominant propulsion technology in the market at least until 2030.

With regard to alternative fuel uptake, differences are likely to persist between different kinds of vehicles. For passenger and light duty vehicles, blends of bio-ethanol or biodiesel appear to be most promising alternative fuels until 2020. In the medium and long term (2030-2050), electricity and hydrogen are expected to gain larger shares[4]. In terms of research and innovation needs, electromobility requires technological development to improve its performance and economic efficiency. (The latter is measured in terms of energy density/cost per unit of energy stored for batteries, power density/cost per unit of power for fuel cells, ageing versus number of recharging cycles for batteries, technical performance data versus operating hours for fuel cells, and temperature sensitivity for both systems). As discussed further in field 6, another key issue is the availability of infrastructure for electric vehicles. In

[4] According to the reports from Member States on their Renewable Energy Action Plans, on the contribution of the different forms of energy towards the 10 % target set by the Renewable Energy Directive, the estimated shares by 2020 are (total EU): 9.3-9.5 % of liquid biofuels, 1.0 % of electricity from renewable sources, up to 0.2 % of bio methane supplied through the gas grid and 0.001 % of hydrogen from renewable.

addition, there is a good outlook for bio-methane, synthetic fuels (BtL/GtL) and biofuels in the medium to long term.

Specific issues for non-pluggable hybrid vehicles include further optimisation and adaptation of the combustion engine to HEV (hybrid electric vehicle) architecture, full integration of the power train with the hybrid system (including waste heat recovery, after treatment and control) and further optimisation of current battery technologies, adapting them to different degrees of hybridisation. There are also specific issues relating to plug-in hybrid electric vehicles (PHEVs) and battery electric vehicles (BEVs). For example, standards are needed for the recharging infrastructure, vehicle-to-grid communication and billing. The standards for health- and safety-related aspects such as electromagnetic interference, user protection and emergency handling need to be reviewed. We also need to test protocols for battery testing (including safety), to consider well-to-wheel emissions in emission regulations and to investigate the impact of large-scale electrification on grid quality and stability.

For heavy duty vehicles, biodiesel blends are expected to become more important in the short and medium term, whereas 2nd and 3rd generation biofuels are expected to gain in importance in the long term. In terms of research and innovation needs, biomass pathways must be optimised. Synthetic fuels and methane in liquid form (LNG) may become important in the medium term, specifically for long distance heavy duty vehicles. Hydrogen has high potential for powering zero-emission heavy- and light-duty vehicles carrying out short distance operation in urban areas, and in particular for buses. Synthetic fuels require research on bio-pathways, as well as pilot plants for their production.

Greater energy efficiency can also be achieved by developing and deploying on a wide scale extremely compact engines, multi-fuel engines, homogeneous charge-compression ignition engines, and advanced combustion and after-treatment for trucks (i.e. novel combustion modes with efficient after-treatment, using non-precious metal catalytic systems).

In terms of materials, energy efficiency can be improved by making greater use of lightweight materials and new nanomaterial applications. It is also important to develop concepts and materials that help optimise end-of-life recovery and resource efficiency, as well as new materials for semi-conductors. Vehicle design is important from an energy-efficiency viewpoint, including the optimisation of aerodynamic designs and new vehicle concepts that take into account the design limits of innovative propulsion technologies. For example:

- New fully-automated vehicle concepts, automated driving and the impact of nomadic devices (smart phones, ubiquity etc.);
- Built-in flexibility in vehicle design to optimise the load capacity for trucks (including optimised chassis control);
- Assessing the safety and environmental impact of new types of vehicle and their effects on intermodal competition, and perhaps subsequently demonstrating such vehicles;
- Innovative trailers and loading platforms to increase flexibility, speed and loading capacity.

<u>*Safety*</u>

Achieving the targets set out in the White Paper will require the universal deployment of Intelligent Transport Systems (see field 7), based on exchanges of information between vehicles and the road infrastructure. These exchanges fall into three categories: infrastructure-to-infrastructure (I2I), vehicle-to-infrastructure (V2I) and vehicle-to-vehicle (V2V) communication. They are based on new ICTs (Information and Communication

Technologies) which enable ubiquitous communication of all three kinds. On-board automatic collision avoidance systems can also minimise the risk of collision with pedestrians, cyclists or objects.

Active and integrated road safety and security applications aim to give drivers and other road users the information they need to help them avoid an accident, or to mitigate its consequences should it occur. Research and development activities must take into consideration the three main factors that affect transport safety: the *driver*, the *vehicle* and the *infrastructure /* traffic *environment*. The optimal Intelligent Transport System (ITS) for safety applications will be one that takes into account the effects of all three of these contributors and builds on the interactions between them. Market uptake and deployment must be rigorously pursued in the future. It would mean setting new standards, creating a more robust understanding of driver behaviour, raising user awareness to stimulate demand for such systems, setting up appropriate policy frameworks and providing incentives for more investment in road-safety-related systems and services.

The main technology objectives should include improving the *passive* safety design of road vehicles, including features for protecting vulnerable road users. But they should also include a*ctive* safety technologies, technologies for providing emergency services (e.g. e-call) and technologies for automated road-side checks and law enforcement.

Objectives in the field of tracking, tracing and navigation services include:

- Providing highly accurate navigation services that monitor how the driver is steering the vehicle and assist the driver by providing lane information.
- Micro-routing, i.e. providing highly detailed route guidance information. This includes information on the surrounding environment, routing for pedestrians and cyclists and indoor routing.
- Strategic routing, i.e. enhanced routing functionalities that take into account certain pre-defined strategies.
- Receiving road safety alerts and/or notifications directly from other vehicles (vehicle to vehicle — V2V) and possibly from other road users.
- Receiving information on the timing of traffic lights when approaching light-controlled junctions, and giving the driver appropriate instructions about the optimal speed at which he/she should drive in order to reach the junction when the lights turn green (infrastructure to vehicle — I2V);
- Continuously increasing the computational capability of route guidance and navigation services.

2.3. Priority field 2: Clean, efficient, safe, quiet and smart aircraft

In aviation, technological advances are helping reduce aviation fuel consumption and associated carbon emissions, as well as noise and other emissions (e.g. NOx) that have an adverse effect on the environment or health. On a per-flight basis, efficiency is expected to improve continuously through 2050 and beyond. The White Paper’s preferred scenario assumes a 60 % improvement in aircraft energy efficiency by 2050, compared with 2005.

In 2011, the High Level Group on Aviation Research presented a report entitled ‘Flight path 2050 — Europe’s vision for aviation’. This sets out the main challenges Europe must address in order to maintain its global leadership as well as serving society’s needs. Europe also has a vigorous programme of aeronautics and air transport research, which is already delivering important benefits to the aviation industry, helping it move towards the ‘2020 Vision’ objectives. This research includes EU-wide collaborative projects under the Framework Programme, the Clean Sky Joint Technology Initiative, SESAR (Single European Sky Air traffic management Research), national programmes in many Member States and research establishments as well as various industrial programmes.

Aeronautical research is currently in a transitional phase where maturing R&D is being brought to the market while a new innovation cycle for next-generation aircraft is beginning. The results of the completed research will deliver significant improvements, such as fuel-efficient engines and lighter materials. Fuel-saving design features such as winglets have already become standard. As automation and high technology make flying ever safer it may become possible to use unmanned and remotely-piloted aircraft for non-military operations.

Energy efficiency and environmental impact

Current RTD aims at 50 % fuel burn improvements (compared to 2000) for aircraft entering the market from 2020. More significant savings are on the longer-term agenda and will help the industry achieve its overarching goal of cutting global aviation emissions by 50 % by 2050[5]. In the short term, reducing drag and increasing the use of lightweight materials will continue to bring fuel savings. In the medium and long term, important gains may come from light electrical actuators, active flow control technologies, morphing wings and new aircraft architectures (such as the blended wing body) where the engines are better integrated. Even with the existing fleet, potential benefits can come from optimised air traffic management (e.g. continuous climbing and continuous descent approach, green taxiing etc.), as discussed further under field 7.

In the short term, further technological progress (e.g. improved aerodynamics, increased use of lightweight turbine and compressor materials) can enhance the performance of the existing gas turbine engine and reduce its fuel consumption and associated CO_2 emissions. Steadily moving towards low NOx combustors will also improve the environmental friendliness of engines. As with the airframe, engine noise can be tackled using active or passive noise reduction technologies. In the medium term, new engine core concepts with optimised heat management, use of heat resistant materials and of active control, etc. can bring substantial improvement. In the longer term, innovative architectures such as open rotor or recuperative engines have the potential to bring significant fuel savings.

More research and innovation are also needed to reduce the noise perceived by the public. This calls for technological solutions such as passive shielding and active noise control on the many aircraft components that generate noise (landing gear, flaps, slats etc.). The design of low-noise aircraft/engine configurations is another way to reduce noise at its source.

A further goal set by the White Paper is to increase the share of low-carbon sustainable fuels in aviation to 40 % by 2050. Further research and development is needed to produce suitable low-carbon aviation fuels that can guarantee the same level of safety currently obtained with kerosene. This includes similar lubrication properties, a similarly low freezing temperature and high flash point, the capacity to relight the combustor at high altitude under severe weather conditions, etc. Furthermore, to encourage the market uptake of aviation biofuels we need international standards and appropriate business models. Major efforts need to be made to accelerate the large-scale production of such fuels.

The design and manufacture of the aircraft, its operation and its recycling should be subject to a full-cycle analysis with a view to maximising the efficient use of resources and minimising the impact on the environment.

[5] Together with optimised ATM and operations and biofuels.

Safety

The safety standard in air transport in Europe is very high and it has a good track record. Safety must continue to be a priority when designing and testing aircraft, their components and the air traffic management system. Lessons learned from extreme weather events and other hazards should be continuously integrated into the process. The European Aviation Safety Agency (EASA) may need to review the standards which have been developed over the last sixty years or more. The certification methodologies should evolve, integrating modern design and testing techniques and becoming cheaper and more efficient. This will allowing the swift and cost-effective development of regulatory standards needed to integrate new technologies with the highest level of safety. It would help if the EU showed strong leadership, coordinating safety-related research in Europe.

The main technological objectives should be to:

- better predict, measure, and react to extreme weather events and other hazards;
- adopt a coherent approach to safety analysis at early design and development stages and integrate advanced design and testing technologies into the certification process;
- develop new technologies that ensure safety while providing an increased level of automation.

The life cycles in aeronautics are long (an aircraft operates for around 30 years) and developing new generation aircraft, systems and equipment is a very expensive business. Consequently, continuity and support are needed at all stages of technological research, including upstream and applied research, integrating new technologies into aviation systems and demonstrating them. Such support is crucial to keep Europe's aviation industry competitive, given the major investment in this field in other parts of the world.

2.4. Field 3: Clean, efficient, safe, quiet and smart vessels

The preferred scenario of the Impact Assessment accompanying the White Paper assumes a 45% improvement in energy efficiency for ships by 2050 compared with 2005, as a result of emission standards. Technology will play a significant role in achieving the White Paper’s goals for the waterborne sector (which covers both maritime and inland waterways transport).

Ships are typically used for a minimum of 20-30 years. Europe therefore needs a change of mindset and the accelerated introduction of new technologies if it is to meet its overall goals for the whole shipping fleet by 2050. Retro-fitting new technology into existing ships is often cumbersome and costly. More efficient retro-fitting concepts and a new generation of far more efficient ships therefore need to be developed, tested and brought into operation over the next 10-20 years. Modular building techniques using standardised modules could make for more efficient assembly, repair and retro-fitting, and could make it easier to recycle the vessel at the end of its service life.

Energy efficiency and environmental impact

In maritime transport, using more efficient and cleaner energy will enable shipping companies to reduce their emissions of conventional pollutants and greenhouse gases, and to become more resilient to fluctuations in fuel prices. In particular, an extensive use of Liquefied Natural Gas (LNG) is expected to reduce the environmental impact of waterborne traffic in the coming years. More work needs to be done on fuel cells, hybrid ships, superconductors and electricity storage (and to a certain extent the use of wind power) if these are to become real alternatives for maritime transport. The use of shore side electricity (cold-ironing) should be further assessed: it could have great potential in ports with easy access to renewable energy. Shore side electricity can be made even more efficient by using highly-efficient conversion devices such as fuel cells fed on renewable hydrogen or on ships' waste water.

In inland waterway transport, conventional engine technologies can be improved by fully or partly replacing fossil fuels (marine diesel, gas oil) by natural gas (LNG) or by fuel gained from renewable sources.

Building up the infrastructure for LNG in ports can serve three types of transport carriers: maritime vessels, inland waterway barges and trucks that frequently come to ports.

In terms of vessel design and materials, new hull materials such as hybrid materials and carbon fibre will replace steel plates and reduce ship weight and thus emissions. Ships can also be made more efficient by better integrating their on-board sub-systems and optimising their energy use. Water resistance and thus fuel consumption can be reduced by more effective and more environmentally-friendly hull coatings and monitoring systems, optimised propellers, optimised hull shapes, hybrid propulsion and the use of air bubble lubrication, air cavity systems and turbulence control systems. Moreover, eliminating ballast water from ships will prevent them from introducing alien invasive species into fragile marine environments.

The economy of inland waterway vessels is especially sensitive to changing infrastructure parameters such as water depth and stream flow rate. Predicted climate changes could alter the usual parameters, especially in free-flowing rivers. Innovations are therefore needed to adapt vessels to such changes. For example, ships may need to be re-designed in terms of their shape and size, and be made of new, light-weight materials.

Economic efficiency and information technologies

New ship concepts such as 'super large container ships' for maritime transport and 'barges resilient to fluctuating water levels' for inland navigation will also increase the system's efficiency.

New information and communication technologies both on board ships and on shore will make navigation safer, enable more efficient routing, tracking and tracing, help detect and deter pirates and optimise co-modal logistics chains. Ships optimised for sailing new and much shorter Arctic routes will reduce travelling distances and thus save time and energy.

In inland waterway transport, more advanced equipment on board will make navigation not only more efficient and environmentally friendly but also safer. Innovation should be focused on sophisticated but affordable stowage systems, automatic ballasting systems, remote control solutions and further automation of on-board processes.

Safety

Navigational support can be improved by using accurate inland ship positioning data (from GPS and Galileo), including heading data that enables automated docking assistance, path keeping and auto-piloting, automatic collision detection and emergency manoeuvring.

In summary, to develop new generations of innovative and efficient ships and barges equipped with the abovementioned technologies, Europe must combine research and innovation with market uptake and deployment. Policy-driven action might be needed in the following areas:

- LNG and other alternative energy sources for propulsion
- Energy management
- Hull/water interaction and propulsion optimisation

- New materials and designs used for ship construction
- New ship concepts
- New information and communication technologies

2.5. Field 4: Clean, efficient, safe, quiet and smart rail vehicles

Rail is today the only transport mode which is largely independent of oil as a primary source of energy. Although rail already addresses the key challenges for the transport sector, the preferred scenario of the Impact Assessment accompanying the White Paper makes the assumption of a 40 % improvement in energy efficiency for trains by 2050 compared with 2005, as a result of emission standards.

The overall vision for the future of rail transport is to increase its role in the European transport system by providing seamless and integrated high-speed passenger services and long-distance freight services, as well as efficient metropolitan and urban mass transport. To attain this, technological improvements will need to be made within the rail system (including rail vehicles).

Key topics for research and innovation related to rolling stock should be:

- *Braking* technology. Improvements are needed especially to facilitate the operation of longer and heavier trains (management of longitudinal forces) and to reduce noise. New designs for braking systems and new materials for brake components are both important aspects of innovation and development. Better braking technology can also improve the performance of high-speed and regional passenger networks.

- *Innovative electric power supply/management and propulsion systems.* These can help reduce energy consumption and make better use of regenerated energy in the rail system, for example by temporarily storing energy on board or on the ground. Improvements should also be made to the power supply for freight wagons (‘electrification of freight trains’). There is an increasing demand for access to electric power on freight wagons, both for railway-internal use (e.g. activation of brakes) and — mainly — for heating/cooling of reefer-containers/reefer swap bodies carried on trains. The lack of power supply on freight wagons makes it much more difficult for rail operators to enter certain market segments. The development of cost-efficient dual-power/hybrid-locomotives would enable new production methods in single wagonload, intermodal and trainload operations.

- *New high-strength and light-weight materials.* These help further improve the payload-deadweight ratio in rail traffic and enable new vehicle designs.

The following research and innovation topics should address the rail system more broadly (interplay between rolling stock and infrastructure, smart systems or cross-cutting issues):

- *Train formation technologies/coupling* (automatic central couplers). The introduction of automatic central couplers would have a number of highly desired system effects, such as making it possible to operate longer and heavier trains, rationalising the train formation process and making it easier to supply on-board power to freight trains. By extension, it would also enable new production methods, such as Train Coupling and Sharing (TCS). Research and innovation should help create the right technology for an Automatic Central Coupler and to outline possible migration strategies.

- *Process innovation in servicing and maintaining complex rolling stock and infrastructure.* This is important for improving reliability and productivity and for reducing life-cycle costs. Continuous process innovation and the provision of such services by the railway suppliers will also help ensure that European rolling stock manufacturers remain competitive, especially *vis-à-vis* new market entrants from China/Asia. Standardising components should greatly help rationalise vehicle maintenance. Research should also address the question of mutual recognition of inspections and better international cooperation in accrediting Certified Bodies. This would enable the Single European Railway Area to function better.

- *Automation.* This is clearly important in relation to automated coupling and automatic brake testing. It is also important when applied to the terminal handling of wagons and intermodal loading units. Moreover, remote-controlled locomotives running in the middle or at the rear of trains would make it easier to introduce long trains. A breakthrough in the automated operation of metropolitan railway systems is already under way, while automated or semi-automated trains operating mainline services could become a reality within the time horizon of the White Paper. Research and innovation should also cover the socio-economic implications of automation, and its impact on working conditions. Automation should also be applied to the detection of derailments. Automated train operation will rely heavily on information technologies (IT).

- *Development and better use of information technologies.* Better IT should pave the way for intelligent freight wagons and trains, making it possible to improve not only traffic management but also operational performance and productivity. Better IT will also address passengers' and freight customers' needs for information in order to optimally integrate rail into advanced and demanding logistic solutions and travel chains.

- *Security.* This is important for enabling high-value goods to be carried by rail and for maintaining customer confidence in rail's ability to transport damage-sensitive goods. Research and innovation are also needed to improve rail transport links with countries outside the EU.

- *Transhipment technologies.* Rail-rail transhipment in particular is important for implementing new production methods for intermodal traffic. It is also becoming crucial for developing rail traffic along the Europe-Asia axis, which has to cope with two different gauges. Furthermore, transhipment technology needs to become more efficient in intermodal terminals that connect rail with road, sea and air transport. For example, direct transhipment between ship and train is important for innovative main-port to dry-port connections, and good links with airports are needed for the introduction of high-speed rail freight services. An important aim must be to reduce energy consumption in transhipment processes, in order to further strengthen the environmental competitiveness of intermodal transport solutions.

3. R&I AREA: INFRASTRUCTURE AND SMART SYSTEMS

3.1. Strategic Objective

To further the EU's aim of creating a Trans-European Transport Network (TEN-T), the White Paper sets certain benchmarks. The key targets are to create a fully functional and EU-wide multimodal TEN-T 'core network' by 2030, leading to a high-quality and high-capacity network by 2050, with a corresponding set of information services.

A transport system with a multimodal backbone and that relies on optimal modal choices to enhance its efficiency must have multimodal terminals strategically located along the network. Multi-modal infrastructure interfaces are essential for cross-modal optimisation, both for passenger and freight transport. Along the same lines, the White Paper calls for all core network airports to be connected to the rail network by 2050, and for core seaports to be linked to the rail freight system and the inland waterway system, where possible.

Transport infrastructure must also contribute to low-carbon transport by providing appropriate recharging and refuelling facilities for innovative low-carbon vehicles and vessels, and these facilities must meet established distribution standards. The 'core network' should test best practices and innovative technologies with a view to minimising the environmental impact of transport.

Efficiently integrating the different modes of transport requires the availability of reliable, updated and interoperable flows of data and information regarding transport nodes and links. ICT solutions are also needed to optimise the use of the existing infrastructure. This will be cheaper and have less environmental impact than building new infrastructure. Thus one of the White Paper's ten goals is the deployment of the modernised air traffic management infrastructure (SESAR) in Europe by 2020.

Similarly, the White Paper calls for the deployment of equivalent land and waterborne transport management systems, including the European Rail Traffic Management System (ERTMS) and rail information systems based on the Technical Specification of Interoperability (TSI) relating to telematic applications for passenger services (TAP) and for freight (TAF). Also to be deployed are maritime surveillance systems (SafeSeaNet), the long-range identification and tracking of vessels, River Information Services (RIS), Intelligent Transport Systems (ITS) with a strong road transport basis, and the European Global Navigation Satellite System (Galileo). The preferred scenario modelled for the Impact Assessment accompanying the White Paper envisages lower congestion and higher energy efficiency thanks to the deployment of these intelligent transport systems.

The White Paper also makes a strong EU commitment to move towards fully applying the 'user pays' and 'polluter pays' principles, and calls on the private sector to eliminate distortions (including harmful subsidies), to generate revenues and to help finance future investment in transport. In future, transport users are likely to pay for a higher proportion of infrastructure construction costs than it is presently the case. This would make for less distorted modal choices and more judicious decisions on organisation and localisation of activities. The pay-back period for construction costs should be consistent with the economic life of the facility. By way of illustration, the preferred scenario of the Impact Assessment accompanying the White Paper assumes that the external costs of operating heavy goods vehicles, passenger cars, motorcycles, passenger and freight rail services, inland navigation and aviation will be fully internalised by 2050.

In addition, the White Paper proposes setting up a validated framework for charging urban road users and for applying access restriction schemes. Interoperability standards would have to be drawn up for the equipment, to reduce production costs and improve users' acceptance, and there would have to be a careful examination of how to avoid negative impacts on accessibility to urban centres.

This R&I area covers three fields:

- Smart, green, low-maintenance and climate-resilient infrastructure
- Europe-wide alternative fuel distribution infrastructures
- Efficient modal traffic management systems (including capacity and demand management)

3.2. Field 5: Smart, green, low-maintenance and climate-resilient infrastructure

Infrastructure in the form of roads, airports, waterways, ports and rails/stations along with the relevant multi-modal interfaces make for a coherent, more efficient and safer transport system. Parts of the European transport networks already face congestion problems, especially on urban roads and near ports and airports, and there are bottlenecks at terminals for all modes. Given the likely future demand for transport and the limited funding available for major spending on infrastructure, new ways must be found to improve the management of Europe's existing transport infrastructure. At the same time, infrastructure maintenance and renewal can impose a considerable financial burden on authorities and infrastructure managers, raising the need for more cost-effective construction and maintenance materials and techniques. New materials and monitoring systems can also help make the networks less vulnerable to climate change and limit the environmental impact of their construction, maintenance and operation.

Several promising technologies are already mature or are expected to be available in the medium term. The priorities are to develop integrated solutions that exploit technological improvements in related fields and to promote innovative applications that lead to interactive technologies and systems. At the same time, steps must be taken to improve the infrastructure interfaces needed for efficient intermodal and cross-modal applications, and to develop new materials and construction methods to reduce resource use and maintenance. Synergies with other fields should be sought wherever possible, especially with those in this R&I area (e.g. applications to help integrate, in a synergetic way, inland waterway shipping activities with other uses of rivers and canals).

The main action in future should combine research, demonstration and implementation work on all transport modes:

- Design and create efficient infrastructure networks for improved mobility, specifically targeting transport network systems and stressing the importance of interoperable and inter-modal networks and interfaces across Europe, including interfaces between neighbouring countries.
- Develop coordination mechanisms and structures that would allow operators to provide seamless services with a minimum number of interruptions. The structures and mechanisms must be sufficiently resilient to handle the impact of these services, using integrated information and communication systems.
- Set up multimodal centres throughout the European transport network and deploy eco-innovations in existing terminals, e.g. new terminal design concepts in ports to facilitate interaction between modes.
- Take steps to reduce the consumption of natural resources. Set specific targets for the energy embodied in construction materials and raw materials. Reduce waste and make construction materials more easily recyclable. In particular, develop innovative materials and technologies for recycling and reusing construction waste that are likely to have an impact on the logistics system.
- Find innovative ways to improve safety, such as technologies and infrastructures for informing drivers about road hazards, and road infrastructure that is ‘self-explanatory’ and ‘forgiving’.
- Carry out R&D to extend the life-span of existing infrastructures, to achieve a better understanding of degradation and ageing processes and to reduce disruption caused by network congestion.

3.3. Field 6: Europe-wide alternative fuel distribution infrastructures

As already outlined in fields 1 to 4, alternative fuel propulsion systems are going to be central to the development of road vehicles, vessels, aircraft and trains. The large-scale uptake of such vehicles, addressed by this field, depends partly on the availability of alternative fuels, in terms of their production and of the refuelling infrastructure.

All fuel options need to be assessed according to how far they have progressed along the research and innovation chain and how ready they are for large-scale deployment. in the various transport modes. Major transitions in fuel infrastructure need support and fostering to meet the stated objectives. Today's lack of harmonised alternative fuelling infrastructure slows down development, reduces opportunities for economies of scale and, subsequently, increases costs and hampers acceptance by businesses and consumers.

A level playing field and a stable regulatory framework for all fuel alternatives is required, to reduce the long-term risk for investors. EU legislation on CO_2 emissions and on the carbon content of all fuels in the European fuel mix need to set increasingly stringent targets and clear roadmaps beyond 2020 for all modes of transport. This will give industry the signal it needs to make firm plans for investing in alternatively-fuelled transportation technologies. The Renewable Energies Directive (2009)[6] is an important framework to promote the use of renewable energy sources, including in transport. The EU is the only region of the world with binding sustainability criteria for biofuels and biomass, and this should influence global production.

Without prejudging on-going and future work on alternative fuels for transport, the following fuels represent potential according to experts.

For *liquid biofuels*, the petroleum-based fuel infrastructure can be used. Research and innovation activities could look at ways of changing the existing infrastructure and setting up a dedicated distribution system for higher-blend biofuels (above 10 % ethanol and 7 % biodiesel), and should develop and implement standards for refuelling equipment and components.

Synthetic fuels (HVO, Fischer-Tropsch fuels, and especially those obtained from sustainable biomass) provide an important alternative and should be promoted (a) to bring research results closer to the market, (b) to enhance the efficiency and economic viability of production processes, and (c) to lower the initial investment costs by having not only a stable regulatory framework but also incentive schemes. The supply of alternative fuels for aviation is particularly dependent on the availability of synthetic / 2nd generation / advanced sustainable alternative fuels. Synthetic fuels should be fully fungible with conventional fossil fuels, and therefore would not require specific new infrastructure.

For *gaseous methane fuels*, efforts should be put into developing harmonised standards for bio-methane or Compressed Bio-Gas (CBG) injection in the existing Compressed Natural Gas (CNG) grid, as this would promote CBG as an economically viable alternative. These fuels should preferentially be fed into the existing gas grid. Captive fleets may be fuelled from exclusive CBG facilities such as sewage treatment plants.

For *hydrogen* (fuel cell electric vehicles), standard development is well advanced, and there are even globally harmonised requirements. The transportation and storage of hydrogen still need further development. Building up a European hydrogen filling network could start by linking existing pre-commercial infrastructure networks to strategic corridors.

Liquefied Natural Gas (LNG) is a technically viable alternative fuel for medium- and long-distance road and waterborne transport. The EU should help it move from research and demonstration to close-to-market readiness by supporting targeted infrastructure pilot

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6 Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources.

schemes. To exploit LNG's full potential, more investment is needed in additional refuelling infrastructure in ports and along the main corridors of the European road and ports networks.

For *electricity*, the power grid is available but a recharging infrastructure needs to be built and the grid needs to be strengthened. The research and innovation agenda should include optimising the electrical architecture for electric vehicles and integrating the grid with the charging infrastructure – which should include fast charging, wireless charging and two-way charging.

Well-to-Wheels/Well-to-Wake (WTW) and Life-Cycle Analysis (LCA) need to be further developed if they are to be used as a common basis for assessing the carbon footprint and the environmental, economic and social impacts of conventional and alternative fuels in all transport modes. Sustainability criteria should be applied consistently, including indirect effects in the EU and elsewhere.

3.4. Field 7: Efficient modal traffic management systems (including capacity and demand management)

To fully achieve its strategic objectives in the field of modal traffic information systems, the EU needs *advanced traffic management systems* in all modes. This means developing sub-roadmaps for each of the modal initiatives (SESAR, ERTMS, RIS, ITS and SafeSeaNet). A combination of technological and organisational solutions can help improve the efficiency of infrastructure use, manage transport demand and support decarbonisation. Most of the elements needed for deployment and market uptake are already in place, but interoperability is still a key issue and further progress is necessary here.

The following areas should be further developed and effectively deployed in the future:

- Open standard electronic platforms for on-board units for exchanging information (with ground stations or other vehicles) on location, speed, date, time, network class, security and safety-related issues.
- Technologies allowing data to be collected (in real time, as well as short term forecasting) and synthesised into information on the infrastructure condition and capabilities, the traffic conditions and instructions to users to reduce congestion.
- Technical standards for sending traffic and travel information and data, and standards for managing traffic on a network, including the development of any necessary communications infrastructure.
- The full interoperability of these standards, allowing the free exchange of such information, and a single common data registry for storing traffic information and management data by mode and across the modes.

The framework for accelerating the development and deployment of Intelligent Transport Systems (ITS) in *road transport* has been set out Directive 2010/40/EU adopted on 7 July 2010. Under this Directive the European Commission has to adopt within the next seven years specifications (i.e. functional, technical, organisational or services provisions) to address the compatibility, interoperability and continuity of ITS solutions across the EU. The first priorities will be traffic and travel information, the eCall emergency system and intelligent truck parking.

The European Rail Traffic Management System (ERTMS) is a cornerstone of the Commission's strategy to improve interoperability in the *European railway system*. Europe is currently host to more than 20 different ground systems. Deployment of ERTMS will enable trains to carry a single European system on board, thus reducing costs for infrastructure managers. Equally suited to high-speed and conventional railway lines, the system will significantly enhance network safety. ERTMS Level 3 needs further development, and research should also investigate whether GSM for railways (GSM-R) can be replaced or complemented by data transmission using the Universal Mobile Telecommunications System (UMTS).

In *maritime transport* administrative procedures are complex, time-consuming and, even today, are often done on paper. Major European ports have advanced information systems, which deliver considerable quality and efficiency gains. However, the interoperability between port information systems is limited. SafeSeaNet is to develop into the core system for all the information tools needed to support maritime safety and security and to protect the marine environment. Furthermore, the e-Maritime initiative aims to foster the use of advanced information technologies to promote interoperability in its broader sense. It aims to stimulate coherent, transparent, efficient and simplified solutions in support of cooperation, interoperability and consistency between Member States and transport operators.

The *inland navigation* sector needs to create a common architecture that offers sufficient consistency and synergy across applications. Over the past few decades a significant number of services and systems have been developed for shipping traffic and transport management. River Information Services (RIS) are information technology related services designed to optimise the resource management of the waterborne transport chain by enabling information exchange between vessels, lock and bridges, terminals and ports. The development of RIS, in combination with cost-effective and environmentally friendly logistics operations, enhances the competitive edge of inland waterway transport in the supply chain.

In the case of *Air Traffic Management* (ATM), the strategic objective is to achieve a fully functional Single European Sky (SES) promoting seamless air travel. SES legislation aims at tripling capacity, halving the ATM cost per flight, improving safety by a factor of 10 and reducing the environmental impact of each flight by 10 %. The Single European Sky ATM Research (SESAR) Programme is the technological pillar of the SES. It aims to develop the new generation of air traffic management systems, capable of ensuring the safety and fluidity of air transport worldwide over the next 30 years[7]. The timely development and deployment of SES technologies and procedures will boost Europe's innovation capacity and its global industrial competitiveness, giving the EU a strong voice in standardisation bodies. ATM modernisation will give Europe's aeronautical supply industry a world-wide market.

For the years following 2020, the 'Flight path 2050' report[8] sets an ambitious goal for European air traffic management. By 2050, Europe's ATM system should be able to provide a range of services, round the clock, to handle 25 million flights per year by all types of aircraft — fixed wing and rotorcraft — whether manned, unmanned or autonomous. In 2020-2030 safe, efficient and high-performance 4-D trajectory operations will need to be implemented,

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7 SESAR is composed of three phases: The definition phase (2005-2008), the development phase (2008-2013) and the deployment phase (2013-2020). The SESAR Programme is now in its development phase managed by the SESAR Joint Undertaking (SJU). The deployment phase (2013-2020) covers the large scale production and implementation of the new ATM infrastructure. This infrastructure will be based on the new technologies and procedures resulting from the development phase and will contribute to achieving SES objectives that will lead to high performance in European air transport. The cost of deployment is estimated at 30 billion Euros over the period 2008-2025. One of the key results of the SESAR definition phase is the European ATM Master plan, which constitutes a commonly developed roadmap, endorsed by the EU Council and recognised by all stakeholders, to achieve deployment of new generation of ATM technologies and procedures within the next 10-15 years. The Master plan steers the work programme for the development phase and similarly will be a key tool to govern the SESAR deployment phase. .

8 'Flightpath 2050 Europe's Vision for Aviation' Report of the High Level Group on Aviation Research, 2011. http://ec.europa.eu/transport/air/doc/flightpath2050.pdf

based on the distribution and use of the best available information. In order to cost-effectively provide the number and range of services needed, increased automation will be essential.

More elaborate descriptions of the corresponding systems for all modes of transport will be drawn up during the road mapping phase. These descriptions will take into account capacity management aspects. The priority is to develop, demonstrate and implement electronic tolling (or fee) systems to be used for road tolls or road/rail pricing schemes. Concession schemes might be considered, as well as pre-financing through congestion charges in the case of extension works. The technologies applied should offer the possibility of 'smart' charging i.e. varying the charges according to the type of user, the location, the time of day and traffic conditions. Interoperability is crucial for e-toll systems and should allow users to travel across Europe with a single electronic tolling device.

The focus in the short and medium term should be on deploying the following (subject to modal specificities):

- Smart fee collection systems that charge for the use of infrastructure depending on the level of congestion and external costs.
- Automated vehicle identification technologies that use barcodes, radio-frequency based identification (RFID), plate recognition, GNSS (Global Navigation Satellite Systems), etc.
- Automated vehicle classification using video cameras or sensors, or storing the vehicle class in the customer record.

The following issues should also be considered:

- transaction processing (prepaid or post-paid systems);
- violation enforcement (physical barrier, plate recognition, police at toll gates, etc.);
- technical interoperability of on-board equipment;
- procedural interoperability for contractual agreements;
- treatment of non-equipped users;
- protection of personal data.

One roadmap per mode (air, inland navigation, maritime, rail and road) is planned to be drawn up during the second phase of the work.

4. R&I AREA: TRANSPORT SERVICES AND OPERATIONS FOR PASSENGERS AND FREIGHT

4.1. Strategic Objective

The third research and innovation area emphasises the role of services in bringing together the application of technologies into a sustainable, resource-efficient and safe transport system for passengers and freight. The uptake of new transport technologies and solutions depends to a large degree on whether these can be used for developing services that satisfy user needs.

Given the expected continuation of urbanisation, as well as the ageing of Europe's population, delivering mobility and transport services in urban areas is of particular importance. The White Paper refers to a move towards 'zero-emission logistics' and sets the goal of achieving essentially CO_2-free logistics in major urban centres by 2030. The White Paper also recommends halving the use of 'conventionally-fuelled' cars in urban transport by 2030 and phasing them out in cities by 2050. Public transport's share of the transport mix has to increase, its accessibility to all must be improved and it must be fully integrated with non-motorised forms of mobility.

The White Paper also emphasises the need to optimise the performance of multimodal logistics chains in long-distance transport. In particular, it sets the benchmark of ensuring that 30 % of road freight 300 km are shifted to other modes by 2030, and more than 50 % by 2050. If cargo owners and freight forwarders are to make greater use of non-road modes, the services provided by the alternative modes must meet the customers' expectations.

Major research and innovation efforts are required to establish the framework for a European system of multimodal transport information, management and payment services by 2020. A European Integrated Multimodal Information and Management Plan should provide continuous and reliable traffic and travel data and information of relevance to all modes and networks. It should do so via universal access and data exchange across regions and borders, enabled by feasible business models.

This R&I area covers three fields:

- Integrated cross-modal information and management services
- Seamless logistics
- Integrated and innovative urban mobility and transport

4.2. Field 8: Integrated cross-modal information and management services

Deployment of traffic information systems has so far been largely 'unimodal' in scope and extent (see Field 7), leaving wider cross-modal applications for the future. Application of ICT in the various transport modes has gone ahead in a rather fragmented way, each mode developing its own platforms and standards. The current lack of integrated cross-modal approaches could hamper the further development of interoperable systems and technologies. Although developing modal traffic management systems is crucial for each of the modes, achieving the objectives of the White Paper of an integrated European transport system, information flows must also support cross-modal operations and services for passengers and freight. Online information, electronic booking and payment systems integrating all means of transport would facilitate multimodal travel. For example, the recent 'Flight path 2050'report has set an objective for the door-to-door transport chain (less than 4 hours for 90 % of travellers by 2050), which would need 'perfect' organisation and integration of transport services, including ICT.

To achieve an EU-wide integrated and cross-modal system, the key technology objectives are:

- Integrated management within networks and between different modal networks across borders, with the emphasis on seamless transfers from one mode to another. Also seamless interfaces between long-distance and local (e.g. urban) networks, for both freight and passenger transport.
- Integrated and real-time information provision to all users of the transport system, cutting across the modes and borders and offering cross-modal usage information. The strategic coordination between traffic and travel information and network management is an important enabler of seamless mobility.
- Smart navigation and routing systems and services providing (among other things) personalised information, environmentally-aware routing and a full presentation of the implications of the different travel choices. Also, systems providing optimal routing strategies, as opposed to today's routing suggestions, for routes with the lowest degree of travel time uncertainty and the highest degree of reliability.

- Smart integrated and interoperable electronic reservation and ticketing systems available through user-friendly web interfaces, and covering all available public transport modes and their interfaces, including smart-pricing and eco-pricing.

The main action for the future should include:

- Expanding standardisation and achieving interoperability of standards and services.
- Greater coordination between information services and network management tools.
- Intelligent operational decision-support systems in the management of transport networks.
- More refined and sustainable business structures for the provision of traffic information and management services.
- Implementation measures for the uptake of integrated electronic tickets and smart cards.
- Applications analysing real-time data on users' behaviour, to improve system management and planning.
- Development of smart information devices and communication systems that provide real- time data on public transport schedules, tailored to each user's specific needs.
- A comprehensive approach to security in the design and operation of transport infrastructure and services (in all modes), including non-intrusive detection methods and highly-secured networks for sending and processing the data and information needed for traffic management and operations control.
- Innovative approaches to operations to address the environmental and health impact of transport, including noise.
- A more robust understanding of what drives user behaviour and behavioural testing of information systems to identify what works.

4.3. Field 9: Seamless logistics

Setting up seamless and efficient multimodal freight transport services will require parallel action to create cleaner, safer, smarter and quieter transport means (for all modes of freight transport, see fields 1 to 4 above). It will mean optimising freight streams and ensuring seamless connections with interurban freight transport and distribution services, including efficient terminal operations and consolidation centres. It will also mean collecting and monitoring data to help users and planners make better decisions.

Research and innovation (R&I) is needed to support the optimisation of freight streams, deliveries and services, as set out in the new White Paper, the ITS Action Plan[9], the ITS Directive[10], and the Logistics Action Plan[11]. This R&I should focus mainly on the following:

- Fleet management, aiming to optimise the utilisation and scheduling of a fleet of freight vehicles (or wagons or vessels) while reducing its negative impacts.
- Delivery management, including restricted access zones, quiet night-time deliveries, dedicated infrastructure for loading and off-loading, and parking management.

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[9] *Action plan for the deployment of Intelligent Transport Systems in Europe. Communication from the Commission*. COM(2008) 886 final. .

[10] Directive 2010/40/EU on the framework for the deployment of Intelligent Transport Systems in the field of road transport and for interfaces with other modes of transport. .

[11] *Freight Transport Logistics Action Plan. Communication from the Commission*. COM(2007) 607. .

- Exploiting the opportunities for shifting freight distribution, deliveries and services towards more efficient, low-impact options, including innovative distribution systems.

These objectives should be seen in combination with the other fields outlined above, and against the background of developing and implementing the next-generation freight transport environment known as e-freight. This will see the introduction of cargo item intelligence, interaction between the item and the agents throughout the transport chain and the emergence of new applications for the management of transport operations from order capture to payment and invoice control.

Tracking and Tracing, together with *Navigation services* in general, involves the use of technologies for identifying the position of a vehicle or load unit in real time and across all modes and stages of transport. These technologies also provide instructions as to the optimal route to one's destination, using the concept of 'connected traveller — connected well'.

The use of existing GPS positioning systems is fundamental to tracking and tracing. The key European technology in this area is the Galileo satellite navigation system which will provide a highly accurate, guaranteed global positioning service under civilian control.

It will be inter-operable with both GPS and GLONASS, the other two existing global satellite navigation systems.

One strategic necessity for the future is the universal coupling of navigation services with real-time traffic data (invariably enhanced with historical data sets and short-term traffic predictions) so as to provide route guidance based on real-time traffic conditions. Several tracking- and tracing-related applications are currently being tested in real-life environments, e.g. cooperative systems, intersection management and control, freight fleet management with real-time loading and delivery space booking, various routing applications, etc.

Research and innovation work on logistics services and operations could address the following topics:

- Technologies for the multimodal management of freight transport, including: pre-trip planning technologies for goods vehicles; intelligent fleet and transport management systems; navigation and in-vehicle routing with real-time data, to optimise travel times and protect environmentally-sensitive areas from freight traffic.
- Intelligent cargo applications, especially at the consolidation and distribution terminals, to enable multimodal freight operations. These applications include gathering, storing, analysing and providing real-time cargo data to help users and planners make better decisions and support the bundling of freight deliveries.
- The development of intelligent freight distribution services; new service concepts such as home delivery; application programmes and technologies for optimising deliveries in urban areas (reducing both the time and the environmental footprint); seamless connection with the interurban freight transport systems; environmentally-friendly city logistics.
- Enforcement of restrictions (e.g. parking, loading / unloading, entering restricted zones / streets, etc.).

Technology objectives for future tracking and tracing research and development relate to:

- Tracking and tracing freight vehicles or individual cargo on line, and providing detailed information to the relevant stakeholders.

- Adapting the regulatory and safety framework to suit the development of new technologies for tracking and tracing.
- Developing interoperability between, and integration of, the monitoring tools used by all relevant authorities in all sectors, ensuring full interoperability between tracking and tracing systems.

4.4. Field 10: Integrated and innovative urban mobility and transport

European towns and cities are today facing a considerable challenge. They need to meet the demand for mobility and transport services from their businesses, industries and citizens while at the same time mitigating the negative effects of transport. In many of Europe's urban areas, the challenges are manifold: congestion, urban sprawl, air quality, noise, limited accessibility, insufficient safety and security. To address these challenges it is essential that urban transport be integrated with regional, inter-urban and long-distance transport. The White Paper calls for increasing the share of public transport and this will necessitate major improvements in the quality of its services. To ensure that more people use public transport, operators will have to provide quality, reliability, safety, security and accessibility (especially for persons with reduced mobility) at an affordable price. It will also be critical to ensure integration with non-motorised forms of mobility.

To bring about the necessary transformation of urban transport systems requires new transport technologies and innovative policy-based measures. These measures must be integrated into local strategies, set out in urban mobility plans that are duly validated and sustainable.

Greater use of public transport could be boosted by providing a wider range of options. Some could use existing concepts (such as trolleybuses) or involve new ways of operating the service (e.g. the Rapid Transit Bus; using smaller buses outside rush hours; 'transport-on-demand' via advance reservation systems; automated operation of metropolitan rail systems). Information on the choices available and on how to purchase tickets is being revolutionised through personal mobile communication devices, but the uptake may vary from one demographic group to another. Perceived waiting times can be drastically reduced. If a greater percentage of travellers use public transport, this could allow operators to increase the number and frequency of their services and to reinforce urban-rural links, thereby generating a virtuous circle for public transport.

When it comes to integrating urban and long-distance transport systems, it is essential that airports and other important nodes be fully integrated with road and rail transport services. A seamless approach to security could avoid multiple and redundant checks and thus save time and money. New digital technologies and non-intrusive inspection methods also have the potential to save passengers time and money. In parallel, however, an increased use of information and communication technologies (ICT) for management and control systems increases the risk of misusing digital information and therefore requires highly-secured data transmission systems.

The European Commission has been supporting R&D in this field, for example through the CIVITAS Initiative since 2002. Future action will target the following:

- Testing integrated packages of new technologies and innovative concepts for urban mobility and transport under real-life conditions, in the following categories: clean fuels and vehicles; car-independent lifestyles; public transport of passengers; demand management strategies; mobility management; safety and security; transport telematics and urban freight logistics.

- Informed policy-making: developing frameworks for assessing impacts and processes.
- System design: developing integrated local strategies for better and sustainable urban mobility and transport.
- Greater involvement of civil society (awareness raising; changing mobility patterns and social norms; citizen engagement, ‘design for all’ principles and standards).
- Support for urban, regional and national authorities through technical assistance to increase their capacity to deliver change and to elaborate Urban Mobility Plans fully aligned with their Integrated Urban Development Plans, as defined in the 2011 White Paper on Transport[12].

[12] *Roadmap to a Single European Transport Area — Towards a competitive and resource efficient transport system*, COM(2011) 144 final .