EUROPEAN COMMISSION

Brussels, XXX
STTP
[…](2012) XXX draft

COMMISSION STAFF WORKING DOCUMENT

Preliminary Descriptions of Research and Innovation Areas and Priority Fields

Accompanying the document

Communication

Research and Innovation for Europe's Future Mobility

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1. INTRODUCTION

1.1. Rationale of this document

The Communication "Research and innovation for Europe's future mobility"[1], further 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 R&I areas, ten priority fields with a clear EU added value on which research and innovation should focus. They offer, based on expert judgement, a significant potential for contributing to the White Paper's objectives by 2030, or for some fields by up to 2050, and take into account the specificities of the individual modes and multimodal issues. They represent neither a final position nor a list of priorities for future research and innovation programmes. The ten priority fields have been identified by matching on 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].

Based on the priority fields described in this paper, the Commission will launch a process to further specify the objectives, timing, resources and instruments that are necessary to bring each of the priority fields towards large-scale deployment. This will be done through the definition of roadmaps, which will be developed in close collaboration with relevant stakeholders. Existing work, for example roadmaps produced by European Technology Platforms, will be used as a starting point.

The roadmaps will identify the challenges along the full innovation chain and the solutions to address them. 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 research and innovation priority fields

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

This definition allows for a broad understanding which not only addresses technological solutions from a conventional engineering and/or scientific perspective, but also their use in the transport system. This brings in 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.

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1 Add reference

2 Scientific Assessment of Strategic Transport Technologies, EC Joint Research Centre (2011)

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

1.3. Clustering of Research and Innovation Areas

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

- In the R&I area of transport means, progress is needed on clean, safe, efficient and silent 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.

Clustering these priority fields is necessary for structuring and managing the future work. However, drawing clear boundaries between the fields is difficult and counterproductive as some issues overlap between different fields and the overlaps may be exploited in a search 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 manner horizontally, considering the specific needs of each priority field (see Figure 1). These include:

- Information and communication technologies: intelligent ways to connect transport means with each other and with infrastructure will help fighting congestion, improve safety, security and resilience in the transport system and increase reliability and punctuality in transport operations.
- Safety and security: safety and security can be enhanced through improved design and operations of transport means and infrastructures (including terminals). Passive and active safety, preventive safety, and enhanced automation and training processes to reduce the impact of human errors are crucial in this respect.
- 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. Modelling tools for improving analytical competences behind policy development will also be important. Other issues that require attention include internalising the negative externalities from transport, including taxation and pricing issues; and assessing the needs for skills and new jobs in the transport sector.

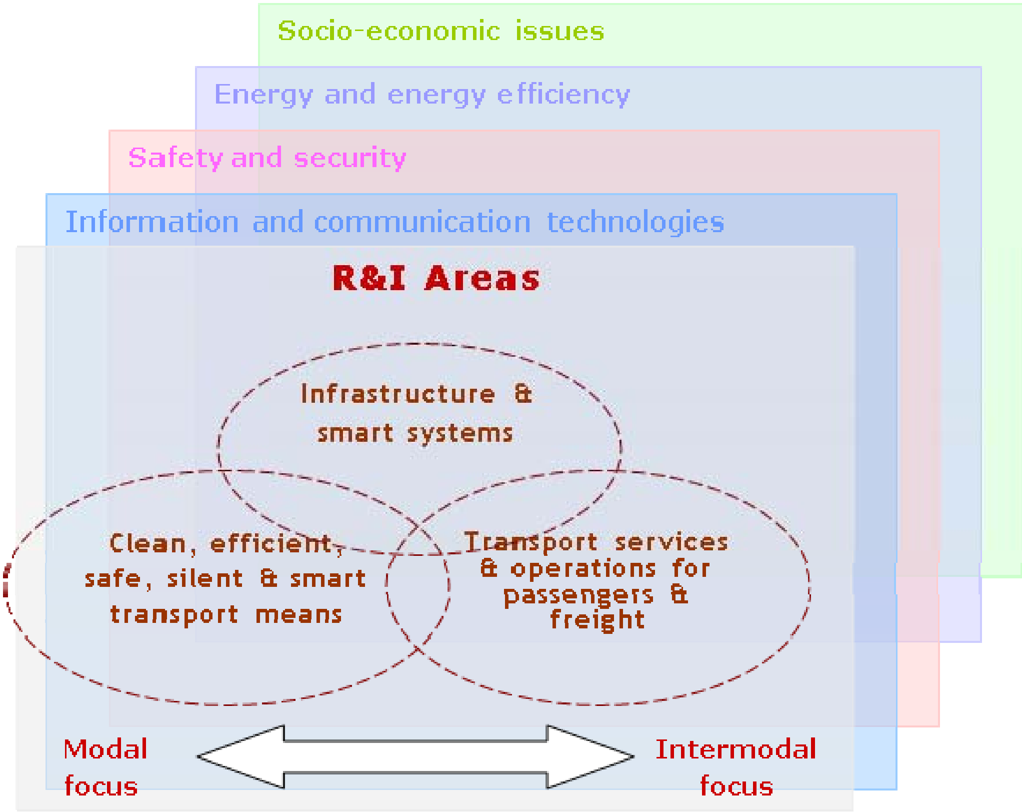

Figure 1: a graphical presentation of the R&I areas and cross-cutting issues.

1.5. The structure of this paper

With regard to the structure of the remainder of this paper, the presentation of each of the R&I areas opens with a short description of the policy objectives which it addresses. It then outlines the priority fields within each area, elaborating on the current level of development, technology needs and, in some cases, already puts forward a list of actions envisaged.

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

2.1. Strategic Objective

The White Paper sets the ambition of reducing greenhouse gas emissions from the transport sector by 60% by 2050 with respect to 1990 levels. In order to achieve this objective, improvements in energy efficiency of transport operations and vehicles across all modes of transport are essential but not sufficient options. The carbon intensity of transport fuels must also be lowered. This will also contribute to reducing the transport sector's excessive reliance on oil products. Therefore major efforts are necessary to work on alternative fuel propulsion systems in all modes of transport but particularly in road and air transport.

Vehicles also have major implications for safety, another central concern of transport policy. Specifically for road transport, the White Paper sets 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 adapt the regulatory safety framework to accompany the

development and deployment of new technologies in air transport (SESAR) and developing SafeSeaNet into the core system for all relevant maritime information tools needed to support maritime safety and security and the protection of 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 priority fields:

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

2.2. Priority field 1: Clean, efficient, safe, silent and smart road vehicles

As road transport accounts for the largest share of greenhouse gas emissions caused by transport, the development and deployment of innovative, clean and efficient vehicles are essential to reducing transport related emissions. The preferred policy option of the Impact Assessment of the White Paper makes the assumption that average emissions will reach 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, a 40% improvement in the fuel efficiency of trucks could be achieved. The further developing standards to limit air pollution are also included in the White Paper modelling of future scenarios.

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

Energy efficiency and alternative fuel propulsion systems

The future propulsion systems and their technological aspects are varying greatly with regard to their level of maturity and adaptation to vehicles. The internal combustion engine can be considered a mature technology that will still undergo incremental improvements that can lead to significant emission reductions. The internal combustion engine is likely to remain the dominating propulsion technology in the market at least until the 2030 time-horizon.

With regard to alternative fuel uptake, differences are likely to persist between different kinds of vehicles. For passenger and light duty vehicles on the 2020 time horizon, blends of bio-ethanol or biodiesel appear to be most promising alternatives. In medium and long term (2030-2050), electricity and hydrogen are expected to gain larger shares[4]. In terms of research and innovation needs, electro mobility requires technological development to improve performance and economic efficiency (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

[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.

number of recharging cycles for batteries, technical performance data versus operating hours for fuel cells; temperature sensitivity for both systems). As discussed further in priority field 6, infrastructure availability for electro mobility is also a key issue. In addition, bio-methane, synthetic fuels (BtL/GtL), and biofuels are prospective on a medium and long term horizon.

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

For heavy duty vehicles biodiesel blend will be 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. Specifically for long distance heavy duty vehicles, synthetic fuels and methane in liquid form (LNG) may become important in the medium term. Hydrogen has high potential for zero-emission heavy and light duty vehicles in short distance operation in urban areas, in particular for buses. Synthetic fuels require research on bio-pathways, as well as pilot plants for production.

Greater energy efficiency can also be achieved through the development and wide-scale deployment of extreme downsizing of engines, multi-fuel engines, homogeneous charge compression ignition engines, advanced combustion and after-treatment for trucks (i.e. novel combustion modes with efficient after-treatment, non-precious metal catalytic systems).

In terms of materials, enhanced use of lightweight materials and new nanomaterial applications contribute to improvement in energy efficiency. Furthermore, concepts and materials facilitating the optimisation of end-of-life recovery and resource efficiency, new materials for semi-conductors are important. Vehicle design is important from an energy efficiency point of view, including the optimisation of aerodynamic designs, new vehicle concepts adapting to the design boundaries of innovative propulsion technologies:

- New fully automated vehicle concepts, automated driving and impact of nomadic devices (smart phones, ubiquity etc.);
- Built-in flexibility in vehicle design for optimised load capacity for trucks (incl. optimised chassis control);
- Assessment of safety, environmental impact and effects on intermodal competition of vehicles with possible subsequent demonstration of such vehicles;
- Innovative trailers and loading platforms to increase flexibility, speed and loading capacity.

Safety

Achieving the targets set out in the White Paper will require a universal deployment of Intelligent Transport Systems (see priority field 7), based on an exchange of information between vehicles and the road infrastructure: infrastructure to infrastructure (I2I), vehicle to infrastructure (V2I) and vehicle to vehicle (V2V) communications based on new ICT (Information and Communication Technologies) infrastructure. These will enable ubiquitous communication between infrastructure and vehicles, among the vehicles and among

infrastructures. On-board automatic collision avoidance systems can minimise the probability of collision also with pedestrians, cyclists or objects.

Applications for active and integrated road safety and security aim at giving drivers and users of the road transport networks and services the necessary information that would help them avoid an accident or mitigate its consequences should it occur. Research and development activities must be based on the consideration of 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 are those with combined effects to all three of these contributors and that build upon the strengths and interactions between them. Market uptake and deployment must be rigorously pursued in the future and would require new standards, increasing user awareness to stimulate demand for such systems, providing appropriate policy frameworks, and appropriate incentives for more investment in road safety related systems and services.

The main technology objectives should target enhanced road vehicle *passive* safety design, including features for the protection of vulnerable road users; a*ctive* safety technologies; technologies for the provision of emergency services (e.g. e-call) and technologies performing automated road-side checks and law enforcement.

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

- provision of highly accurate navigation services, monitoring and assisting the drivers’ manoeuvring by providing information at the lane level;
- Micro-routing, i.e. the provision of highly detailed route guidance information, which includes information aids for the surrounding environment; including routing for pedestrians and cyclists and indoor routing.
- Strategic routing, i.e. enhanced routing functionalities that take into account some pre-defined strategies;
- Receiving of alerts and/or notifications related to road safety directly from other vehicles (vehicle to vehicle - V2V) and possibly from other road users;
- Receiving of information related to signal timing when approaching signalised intersections, with appropriate instructions regarding the optimal speed of the vehicle, so as to reach the intersection when signals turn green (infrastructure to vehicle - I2V);
- Continuous increases in computational capability for route guidance and navigation services.

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

In aviation, technological advances help reducing aviation fuel consumption and associated carbon emissions as well as noise and other emissions (e.g. NOx) with a negative environmental or health impact. On a per-flight basis, efficiency is expected to improve continuously through 2050 and beyond. The White Paper preferred scenario presumes 60% improvement in energy efficiency of aircraft by 2050 compared with 2005.

In 2011 the High Level Group on Aviation Research presented a high-level outlook "Flight path 2050 – Europe's Vision for Aviation" which sets out the main challenges to address in order to maintain global leadership as well as serving society's needs. There is also a vigorous programme of Aeronautics and Air Transport research in Europe, which is already delivering important benefits for the aviation industry towards the European "Vision 2020" objectives.

This includes EU collaborative research in 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 industrial programmes.

Currently there is an on-going transition where maturing R&D is brought to the market and a new innovation cycle for next aircraft generations is starting. The results of completed research will realise significant improvements (e.g. fuel efficient engines, lighter materials; fuel-saving design features such as winglets have become standard). The possible role of unmanned and remotely piloted aircraft for civil applications is being explored. Automation and high-tech will make flying still safer.

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 contribute to the overarching industry goal to cut aviation emissions globally by 50% by 2050[5]. On a short term future, the reduction of drag and the increased use of lightweight material will continue to bring fuel savings. On medium and long term perspectives, the inclusion of light electrical actuators, of active flow control technologies, morphing wings and new aircraft architectures with a better integration of engines (e.g. blended wing body) have the potential to bring important gains. As discussed further under priority field 7, optimised air traffic management has the potential to bring benefits with the existing fleet (e.g. continuous climbing and continuous descent approach, green taxiing etc.).

In the short term, further technological progress can enhance the performance of existing gas turbine engine (e.g. improved aerodynamics, increased use of lightweight turbine and compressor materials) and reduce the fuel consumption and associated CO_2 emissions. A progressive move towards low NOx combustors will also improve the environmental friendliness of engines. Similarly to the airframe, engine noise can be tackled with 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 to reduce the noise perceived by the public is also needed. This calls for technological solutions such as passive shielding and active noise control on the many aircraft components generating noise (landing gear, flaps, slats etc.). The design of low noise aircraft / engines configurations is also a possibility to reduce noise at its source.

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

The design and manufacturing of the aircraft, its operation and its recycling should be approached in a full cycle analysis in the view of maximising the efficiency of the 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 statistics are showing a good record. Safety must continue to be a permanent concern when designing and testing vehicles and their components as well as the air traffic management system. Lessons learned from extreme weather events and other hazards should be continuously integrated. The European Aviation Safety Agency (EASA) will need to critically review all the standards, which have been developed over the last sixty years and more. The certification methodologies should evolve, integrating modern design and testing techniques and gain in time and cost efficiency allowing a fast cost effective development of regulatory standards needed to integrate new technologies with the highest level of safety. A strong EU leadership and coordination of safety-related research in Europe would be beneficial.

The main objectives should target technologies to:

- Better predict, measure, and react to extreme weather events and other hazards;
- A coherent approach to safety analysis at early design and development stages and integration of advanced design and testing technologies into the certification process;
- New technologies ensuring safety with an increased level of automation.

Given the long life cycles in the field of aeronautics (an aircraft operates during ~30 years), and the high capital commitments needed for the development of new generation aircraft, systems and equipment, there is a need of continuity in technological research and support in all phases: upstream and applied technological research, integration of technologies in systems and demonstration. Such support is crucial in order to promote the international competitiveness of the aviation sector in front of significant investments seen in other parts of the world.

2.4. Priority field 3: Clean, efficient, safe, silent and smart vessels

The preferred scenario of the Impact Assessment accompanying the White Paper assumes 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 the achievement of the White Paper's goals for the waterborne sector (covering both maritime and inland waterways transport).

Ships are typically used for a minimum of 20-30 years. This implies that a change of mind set and the accelerated introduction of new technologies are needed to meet the overall reduction goals for the whole shipping fleet by 2050. Retro-fitting of new technology into existing ships often proves cumbersome and costly, thus more efficient retro-fitting concepts as well as a new generation of far more efficient ships need to be developed, tested and coming into operation during the next 10-20 years. Attention thereby has to be paid to modular building and equipment with a standardisation of modules. This could facilitate more efficient assembly, repair, retro-fitting and eventually vessel recycling at the end of its service life.

Energy efficiency and environmental impact

Using more efficient and cleaner energy will enable the maritime sector, to reduce emissions conventional pollutants and greenhouse gases, and to become more resilient to the fluctuations of fuel prices and reduce emissions. In particular an extensive use of Liquefied Natural Gas (LNG) is expected to reduce the environmental pressure of waterborne traffic in the next years. Fuel cells, hybrid ships, the use of superconductors and electricity storage (and to a certain extent also use of wind power) will need some further developments to represent a

real alternative for maritime transport. The potential of shore side electricity (cold-ironing) should be further assessed. This can develop a great potential especially is ports where there can be easy access to renewable energy. Powering shore side electricity with renewable energy and highly efficient conversion devices such as fuel cells fed on renewable hydrogen or on ship waste water can make it even more efficient.

In inland waterway transport, the improvement of conventional engine technologies can be based on the full or partial substitution of fossil fuels (marine diesel, gas oil) by natural gas (LNG) or by fuel gained from renewable energy sources.

Build-up of infrastructure for LNG in ports can serve three types of transport carriers: maritime vessels, inland waterway barges, and trucks using ports as major destinations.

In terms of vessel design and materials, new hull materials such as hybrid materials and fibre/carbon will replace steel plates and reduce ship weight and thus emissions. A more effective integration among the on-board sub-systems and optimised energy use will contribute to increase the ships' efficiency. More effective and more environmentally friendly hull coating and monitoring systems as well as optimised propellers, optimised hull shapes, hybrid propulsions and the use of air bubble lubrication, air cavity systems and turbulence control systems will lead to reduced water resistance and reduced power demands. Consequently further opportunities for reducing the ships' fuel consumption and thus their externalities will emerge. Ballast water free ships will eliminate the introduction of alien invasive species into fragile marine environments.

The economy of inland waterway vessels is especially sensitive to changing parameters of infrastructure like water depth and stream flow rate. Predicted climate changes could alter the usual parameters, especially those on free-flowing rivers. Innovations have to address corresponding adaptation measures (e.g. intelligent ship designs to match extreme nautical conditions like light-weight constructions, adapted main dimensions).

Economic efficiency and information technologies

New ship concepts (such as, for example, "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 used for ships and on-shore will render navigation safer, enable more efficient routing, tracking and tracing, piracy detection and deterrence and optimised 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 not only make navigation 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 by using accurate inland ship positioning data (from GPS and Galileo), including heading data allowing for automated docking assistance, path keeping and auto-piloting, automatic collision detection and emergency manoeuvring.

In summary, with the aim of developing new generations of innovative and efficient ships and barges adopting the technologies previously mentioned a combination of research and innovation activities, market uptake and deployment activities and policy-driven activities might be required for the following points:

- 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 ships’ concepts
- New information and communication technologies

2.5. Priority field 4: Clean, efficient, safe, silent 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 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 the vision, technological improvements should be made within the rail system (including rail vehicles) but technical solutions should always be seen in the light of their contribution to the commercial attractiveness of rail transportation, as well as in view of the efficiency gains when transporting freight by rail.

Innovations often result in system effects supporting both approaches; this is especially true for the railway system with its strong interdependencies among different sub-systems. Key topics for research and innovation related to rolling stock should be:

- *Braking* technology improvements are especially important in order to facilitate the operation of longer and heavier trains (management of longitudinal forces) as well as to achieve noise reduction. Conceptual design of brake systems for rail as well as new materials for brake components are key aspects of innovation and development. Better braking technology can also contribute to better operational performance in high-speed and regional passenger networks.

- *Innovative electric power supply/management and propulsion systems* can help to reduce energy consumption and to better make use of regenerated energy in the rail system. This may also include temporary energy storage solutions on board or on ground. Further should be addressed the power supply on freight wagons ("electrification of freight trains"). There is an increasing demand to have 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 severely limits rail's possibilities to enter into certain market segments. The development of cost-efficient dual-power/hybrid-locomotives would be an enabler for new production methods in single wagonload as well as intermodal and trainload operations.

- *New high-strength and light-weight materials* help to further improve the payload-deadweight ratio in rail traffic and to 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 horizontal issues):

- *Train formation technologies/coupling* (automatic central couplers). The introduction of automatic central couplers would have a number of highly desired system effects, as

possibility to operate longer and heavier trains, rationalisation of the train formation process, and easier realisation of on-board power supply on freight trains. In prolongation it would also enable new production methods, like Train-Coupling- and Sharing (TCS). Research and innovation should help to specify a concrete technical solution for an Automatic Central Coupler as well as to outline possible migration strategies.

- *Process innovation in service and maintenance* of complex rolling stock and infrastructure is important to improve reliability, productivity and to reduce life-cycle costs. Continuous process innovation and provision of such services by the railway suppliers is also a means to ensure the competitiveness of European rolling stock manufacturers, especially towards new market entrants from China/Asia. Standardisation of components should play an important role in rationalising vehicle maintenance. Research should also address the question of mutual recognition of inspections and better international cooperation in the field of accreditation of Certified Bodies; this would result in a better functioning of a Single European Railway Area.

- *Signalling* (ERTMS Level 3). ERTMS is a cornerstone in the Commissions strategy to improve interoperability in the European railway system. There is a need to further develop Level 3 of the ERTMS. The possibility to replace/complement GSM-R by UMTS-based data transmission should be investigated as well. See also priority topic 7.

- *Automation* becomes relevant in combination with the aforementioned points (automated coupling, automatic brake testing) as well as with regard to terminal handling of wagons and intermodal loading units; remote-control of locomotives running in the middle or at the rear of trains would support the introduction of long trains. A breakthrough of automated operation of metropolitan railway systems is already underway, while automated or semi-automated operation of trains in mainline services could become reality within the time horizon of the White Paper and STTP. Research and innovation should also cover the socio-economic implications and impact on working conditions. A further area of automation should be the detection of derailments. The use of IT will play an important role in connection with the automation of train operations.

- *Development and better use of information technologies* should pave the way for intelligent freight wagons and trains, enabling both improved traffic management, operational performance and productivity and addressing passengers and freight customers' needs for information in order to optimally integrate rail into advanced and demanding logistic solutions and travel chains.

- *Security* plays an important role for widening the market for rail towards high-value goods and to maintain customer confidence for transport of damage-sensitive goods by rail. Research and innovation should also target solutions for international transport with third countries.

- *Transhipment technologies*, with special focus on transhipment rail-rail are important for implementation of new production methods for intermodal traffic and become also crucial for development of rail traffic along the Europe-Asia axis, which has to cope with two different gauges. Further, transhipment technology needs also to become more efficient in intermodal terminals with connection rail with road traffic, maritime traffic (e.g. direct transhipment ship – train in connection with innovative main-port – dry-port connections) and air traffic (enabling the introduction for high-speed rail freight services). An important aim must be to reduce energy-consumption of transhipment processes in order to further strengthen the environmental competitiveness to intermodal transport solutions.

3. R&I AREA: INFRASTRUCTURE AND SMART SYSTEMS

3.1. Strategic Objective

The White Paper sets the benchmarks of creating a fully functional and EU-wide multimodal TEN-T 'core network' by 2030, with a high quality and capacity network by 2050 and a corresponding set of information services. A transport system that is articulated around a multimodal backbone and that relies on optimal modal choices to enhance its efficiency must benefit from multimodal terminals strategically located along the network. Multi-modal infrastructure interfaces are an important enabler for cross-modal optimisation, both for passenger and freight transport. Along the same lines, the White Paper calls for connecting all core network airports to the rail network by 2050, ensuring links between core seaports and rail freight and the inland waterway system, where possible.

Transport infrastructure must also contribute to low carbon transport through the provision of relevant recharging and refuelling facilities for innovative low-carbon vehicles and vessels according to established distribution standards. The 'core network' should test best practices and innovative technologies with a view to minimising the environmental impact of transport.

The availability of reliable, updated and interoperable data and information flows regarding nodes and links are essential for an efficient integration of transport modes. ICT solutions are also needed to optimise the use of existing infrastructure with relatively low levels of investment and environmental impact compared to the building of new infrastructure. The deployment of the modernised air traffic management infrastructure (SESAR) in Europe by 2020 has been emphasised among the ten goals of the White Paper. Similarly, the White Paper foresees the deployment of equivalent land and waterborne transport management systems, including the European Rail Traffic Management System (ERTMS) and rail information systems based on TAF-TSI and TAP-TSI, maritime surveillance systems (SafeSeaNet), long-range identification and tracking of vessels, River Information Services (RIS), Intelligent Transport Systems (ITS) with strong road transport basis, as well as that of the European Global Navigation Satellite System (Galileo). The preferred scenario modelled for the Impact Assessment accompanying the White Paper envisages a reduction in congestion and higher energy efficiency thanks to the deployment of those intelligent transport systems.

The White Paper also makes a strong commitment to moving towards full application of "user pays" and "polluter pays" principles and private sector engagement to eliminate distortions, including harmful subsidies, generate revenues and ensure financing for future transport investments. In the future, transport users are likely to pay for a higher proportion of infrastructure construction costs than it is presently the case. This would contribute to less distorted modal choices and judicious decisions on organisation and localisation of activities. The recuperation of construction costs should be done over a period that is consistent with the economic life of the facility. To illustrate the role of this policy, the preferred scenario of the Impact Assessment accompanying the White Paper assumes a full internalisation of external costs for heavy duty vehicles, passenger cars, motorcycles, passenger and freight rail, inland navigation and aviation by 2050.

In addition, the White Paper proposes the development of a validated framework for urban road user charging and access restriction schemes and their applications. This would include the development of interoperability standards for equipment, which will reduce production costs and contribute to users' acceptance, and careful examination of how to avoid negative impacts on accessibility.

This R&I area covers three priority 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. Priority 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 is an enabler for a coherent, more efficient and safer transport system. Parts of the European transport networks already face congestion problems, especially in urban road networks, airports, port hinterland connections and bottlenecks in terminals for all modes. In the light of the future transport demand projections and the limited funding for the required significant infrastructure investments, new ways to improve the management of existing transport infrastructure will be necessary. At the same time, infrastructure maintenance and renewal can impose an important financial burden for 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 reduce the vulnerability of the networks to climate change and limit the environmental impact of construction, maintenance and operation.

Several promising technologies are already mature or are expected to be available in the medium term. The priorities are the development of integrated solutions that exploit technological improvements in related fields and the promotion of innovative applications that lead to interactive technologies and systems, with improved infrastructure interfaces needed for efficient intermodal and cross-modal applications and the development of new materials and construction methods to reduce resource use and maintenance. Synergies with other priority fields should be sought wherever possible, especially for those under this R&I area (e.g. applications to support the integration of the navigation use of inland waterways with other uses of rivers and canal infrastructure in a synergetic way).

The main actions in the future should target all transport modes and should combine research, demonstration and implementation activities:

- Design and implementation of 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 relevant interfaces with neighbouring countries;
- Development of coordination mechanisms and structures that would allow operators to ensure seamless services with a minimum number of interruptions and adequate resilience to handle their impact, using integrated information and communication systems;
- Creation of multimodal centres allocated throughout the European transport network and deployment of eco-innovations in existing terminals, e.g. new terminal design concepts in ports to facilitate interaction between modes;
- Activities aiming to reduce the consumption of natural resources, including specific targets with respect to embodied energy in construction materials, raw materials, waste reduction and recyclability of construction materials. Technologies focusing

on innovative materials and technologies for the recycling and reuse of construction waste that are likely to have an impact on the logistic system;

- Innovative solutions to improve safety, such as technologies and infrastructures for informing drivers on road hazards, self-explaining and forgiving road infrastructures;
- Research and Development activities to extend the life-span of existing infrastructures, to achieve a better understanding of degradation and ageing processes, and to reduce disruptions from network congestion.

3.3. Priority field 6: Europe-wide alternative fuel distribution infrastructures

As already outlined in the priority 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, dealt within this priority field, depends partially on the availability of alternative fuels, with regard to both production and refuelling infrastructure.

All fuel options need to be considered according to their specific readiness level in the research and innovation chain and deployment scope, including both transport mode and geographic scope and coverage. 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 enterprises' and consumers' acceptance.

A level playing field and stable regulatory framework for all fuel alternatives is required to reduce long-term risk on investments. EU regulation on CO_2 emissions and carbon content of all fuels in the European fuel mix fixing increasingly stringent targets and clear roadmaps beyond 2020 for all modes is a correct signal for industry to make sound investment plans in alternatively fuelled transportation technologies. The Renewable Energies Directive (2009)[6] is an important framework to promote the use of renewable energy sources also in transport. The EU is worldwide the only region with binding sustainability criteria for biofuels and biomass which should influence production on the global market.

For *liquid biofuels*, the petroleum based fuel infrastructure can be used. Research and innovation activities could address modifications to existing infrastructure and a dedicated distribution system for higher-blends biofuels (above 10% ethanol and 7% biodiesel), and development and implementation of standards for refuelling equipment and components.

With regard to *synthetic fuels* (HVO, Fischer-Tropsch fuels, with priority from sustainable biomass), they provide an important alternative and should be promoted (a) to bring research results closer to market, (b) to enhance efficiency and economic viability of production processes, and (c) to lower the costs of initial investment by certainly a stable regulatory framework but also incentive schemes. Especially the supply of alternative fuels for aviation depends 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 which would promote CBG as an economically viable alternative. These fuels

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

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, even with globally harmonised requirements. Further development is required for transport and storage of hydrogen. Build-up of a European hydrogen filling network could start by linking existing pre-commercial infrastructure networks to strategic corridors.

Liquefied Natural Gas (LNG) is a viable technical alternative for medium and long distance road and waterborne transport should be supported at EU level to move from research and demonstration to close-to-market readiness via the support to targeted infrastructure pilots. Investing in additional LNG refuelling infrastructure in ports and along main axes of the European road and ports networks is needed to exploit the potential of LNG as a fuel alternative for maritime, inland waterways and long-distance road transport.

For *electricity*, the power grid is available but recharging infrastructure needs to be built and the grid needs to be strengthened. Optimising electrical architecture for electrified vehicles, Grid Integration and charging infrastructure, including fast charging, wireless charging, bidirectional charging should also be on the research and innovation agenda.

Well-to-Wheels/Well-to-Wake (WTW)/Life-Cycle Analysis (LCA) would need to be further developed 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 taking place in the EU or elsewhere.

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

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

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

- Open standard electronic platforms for on-board units for the exchange of information with ground stations or other vehicles, on: location, speed, date, time, network class, security and safety-related issues;
- Technologies allowing the collection of data (in real time, as well as short term forecasting) and synthesising it into information on the infrastructure condition and capabilities, the traffic conditions and instructions to users to reduce congestion;
- Creation of the technical standards for the transfer of traffic and travel information and data, as well as standards for the management of 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 eventually establishing a single common data registry for Traffic information and management data by mode and across the modes.

Taking Air Traffic Management (ATM) as an example, the strategic objective is to achieve a fully functional Single European Sky (SES) promoting seamless air travel. SES legislation aims at tripling capacity, reducing ATM cost per flight by half, 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. SESAR aims at developing the new generation of air traffic management system 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 the competitiveness of its industry worldwide allowing the EU to have a strong voice in standardisation bodies. For the aeronautical supply industry, the market perspectives for ATM modernisation are worldwide.

For the years following 2020, the Flight path 2050 report sets a goal for a European air traffic management system that provides a range of services to handle an increased (25 million flights per year in 2050) amount of traffic of all types of vehicles (fixed wing and rotorcraft) and systems (manned, unmanned and autonomous) in an round the clock operation of airports. In 2020-2030 safe, efficient and high-performance 4-D trajectory operations will need to be implemented based on distribution and use of best available information. Increased levels of automation will be fundamental to cost-effectively meeting the number and range of services to be provided.

Descriptions for the corresponding systems in other modes will be developed in the later stages of preparing the STTP. The descriptions shall take into account capacity management aspects. The priority is the development, demonstration and implementation of electronic tolling (or fee) systems, used for road tolls or road/rail pricing schemes. Concession schemes might be considered, as well as pre-financing through congestion charges in case of extension works. The technologies applied should offer the possibility of “smart” charging i.e. according to the characteristics of the user, location, time and traffic conditions. Interoperability is crucial for e-toll systems and should allow users to circulate across Europe with a single electronic tolling device.

The focus in the short and medium term should be on the deployment of (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 (using barcodes, RFID, plate recognition, GNSS (Global Navigation Satellite Systems), etc.);
- Automated vehicle classification (using video cameras, sensors, or storing the vehicle class in the customer record).

[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.

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) will be developed in the second phase of 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 foresees halving the use of ‘conventionally-fuelled’ cars in urban transport by 2030; and phasing them out in cities by 2050. Public transport has to gain a higher share than today in the transport mix, its accessibility to all must be improved, and it must be fully integrated with non-motorised modes.

The White Paper also emphasises the need to optimise the performance of multimodal logistics chains in long-distance transport. Particularly, it sets the benchmark of shifting 30% of road freight over 300 km 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 service offering of the alternative modes must meet the customers' expectation.

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 through universal access and data exchange across regions and borders, enabled by feasible business models.

This R&I area covers three priority fields:

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

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

Deployment of traffic information systems has so far been largely “unimodal” in scope and extent, 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 one developing their own platforms and standards. The current lack of integrated cross-modal approaches could potentially hamper the further development of interoperable systems and technologies.

Integrated traffic information and management will provide continuous and reliable traffic and travel data and information of relevance to all modes and networks through universal access to such information and data exchange across regions and borders, enabled by feasible business models. 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 door-to-door transport chain (by 2050 within 4 hours for 90% of travellers), 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 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 others personalised information, environmentally aware routing, and 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 highest degree of reliability;
- Smart integrated and interoperable electronic reservation and ticketing systems available through user friendly interfaces over the web, and covering all available public transport modes and their interfaces, including smart and eco-pricing.

Main actions 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 actions 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 users' 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 the transmission and processing of data and information in traffic management and operations control;
- Innovative approaches to operations to address the environmental and health impact of transport, including noise.

4.3. Priority field 9: Seamless logistics

Setting up seamless and efficient multimodal freight transport services will require parallel action on cleaner, safer, smarter and more silent transport means (for all modes of freight transport, see priority fields 1 to 4 above); the optimisation of freight streams; seamless connections with interurban freight transport and distribution services, including efficient terminal operations and consolidation centres; and data collection and monitoring to help users and planners make better decisions.

The main focus for research and innovation supporting the optimisation of freight streams, deliveries and services, arising from the new White Paper, the ITS Action Plan[8], the ITS Directive[9], and the Logistics Action Plan[10], is in summary the following:

- Fleet management with the objective of optimising the utilisation and scheduling of a fleet of freight vehicles (or wagons or vessels) while reducing the negative impacts;
- Delivery management, including restricted access zones, silent night-time deliveries, dedicated infrastructure for loading and off-loading, and parking management;
- Exploiting possibilities for modal shift in freight distribution, deliveries and services towards more efficient and low impact options, including towards innovative, new systems for good distribution.

These objectives should be seen in combination with other priority fields outlined above, and against the background of the development and implementation of the next generation of 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 related to the identification of 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 with 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.

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

9 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.

10 Freight Transport Logistics Action Plan. Communication from the Commission. COM (2007) 607.

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

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, is a strategic necessity for the future. Several tracking and tracing related applications are currently 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 actions in logistics services and operations could address the following topics:

- Technologies for multimodal management of freight transport, including technologies for goods vehicles pre-trip planning; intelligent fleet and transport management systems; navigation and in-vehicle routing with real time data, aiming at optimising travel times and protecting environmentally sensitive areas from freight traffic.
- Intelligent cargo applications, especially at the consolidation and distribution terminals to enable multimodal freight operations, including gathering, storing, analysing, and providing real time cargo data to help users and planners make better decisions and support bundling of freight deliveries.
- Development of intelligent freight distribution services, new service concepts (such as home delivery); application programmes and technologies for optimisation of deliveries in urban areas (both time, and environmental footprint optimisation); 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:

- On-line tracking and tracing of freight vehicles or individual cargo, and provision of detailed information to the relevant stakeholders;
- Adaptation of the regulatory and safety framework to suit the development of new technologies for tracking and tracing;
- Developing interoperability and integration of monitoring tools used by all relevant authorities in all sectors, ensuring the full interoperability between tracking and tracing systems.

4.4. Priority field 10: Integrated and innovative urban mobility and transport

European towns and cities are facing today the considerable challenge of meeting their businesses', industries', and citizens' demand for mobility and transport services, while 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, safety and security. Integration of urban transport with regional, inter-urban and long-distance transport is crucial for addressing the challenges. The White Paper calls for increasing the share of public transport, necessitating major improvements in the quality of its services. Quality, reliability, safety, cost, security and accessibility, notably for persons with reduced mobility,

will be essential to the greater uptake of public transport. Integration with non-motorised modes is also critical.

To bring about the necessary transformation of urban transport systems requires new transport technologies, innovative policy-based measures and integration into local strategies, defined in duly validated sustainable urban mobility plans.

Public transport could be boosted by a wider range of options, some based on existing concepts (trolleybuses) or on new ways of operating the service (Bus Rapid Transit; use of smaller buses outside rush hours; ‘transport-on-demand’ through advance reservation systems, automated operation of metropolitan rail systems). Information on the available choices and the ability to purchase tickets is being revolutionised through personal mobile communication devices but uptake may vary in different demographic groups. Perceived waiting times can be drastically reduced. The higher share of travel by collective transport can allow increasing the density and frequency of service and the reinforcement of urban-rural links, thereby generating a virtuous circle for collective transport modes.

With regard to integration of urban and long-distance transport systems, airports and other relevant nodes need to be fully integrated in the land-transport services. A seamless approach to security could avoid multiple and redundant checks and associated time penalties and expenses. New technologies making use of digital solutions and non-intrusive inspection methods also have the potential to enhance time and cost efficiency for the overall passenger experience. In parallel, with an increased use of ICT based information, management and control systems, the risk of misusing digital information will increase and therefore requires highly secured information transmission systems.

R&D effort in this context has been supported by the European Commission, among others, through the CIVITAS Initiative since 2002. Future actions shall target:

- Testing of integrated packages of new technologies and innovative concepts for urban mobility and transport under real-life conditions, in categories: clean fuels and vehicles, car-independent lifestyles, collective passenger transport, demand management strategies, mobility management, safety and security, transport telematics, and urban freight logistics.
- Informed policy making: development of frameworks for impact and process evaluation;
- System design; development of integrated local strategies for better and sustainable urban mobility and transport;
- Better involvement of civil society (awareness raising; changing mobility patterns and social norms; citizen engagement, "design for all" principles and standards).