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Scientific Assessment of Strategic Transport Technologies

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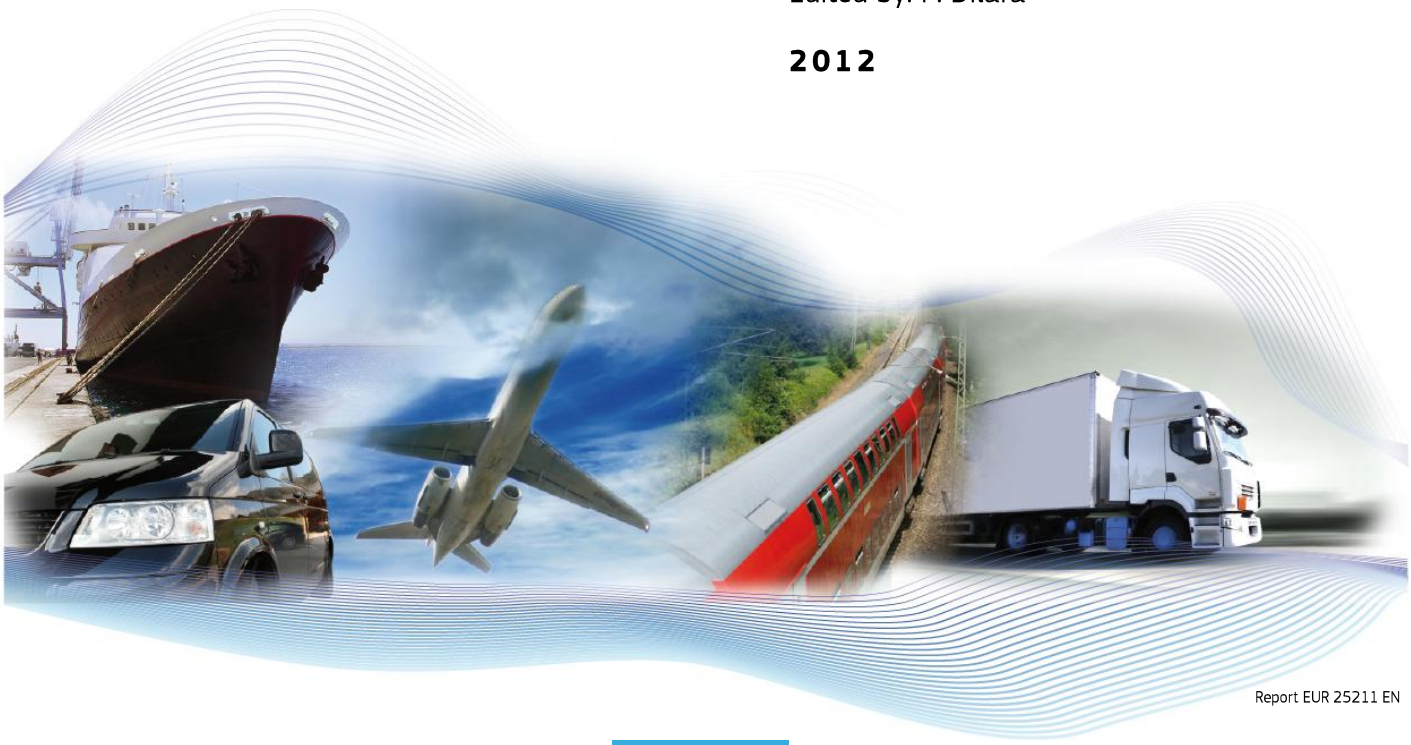

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EXECUTIVE SUMMARY

Introduction

The European Commission's vision for a more competitive and sustainable transport in Europe has been outlined in the recent Transport White Paper (WP)[1]. The Transport WP sets out to remove major barriers and bottlenecks in key areas across the fields of: transport infrastructure and investment, innovation and the internal market. The aim is to create a Single European Transport Area with more competition and a fully integrated transport network which links the different modes and allows for a profound shift in transport patterns for passengers and freight. To this purpose, the Transport WP puts forward 40 concrete initiatives for the next decade, including technological as well as non-technological measures. The Strategic Transport Technology Plan (STTP)[2], addressing the technology pillar of the White Paper, is hence designed to contribute to these objectives in the mid-term.

The European Commission's Joint Research Centre (JRC) undertook the responsibility to produce this scientific assessment, as a contribution to the STTP preparation. The assessment took place from *November 2010 to August 2011* and covered all transport sectors and issues. The magnitude of the work required the collaboration of 3 JRC Institutes (Institute for Energy, Institute for Prospective Technological Studies and Institute for the Environment and Sustainability) located in 3 different JRC sites (Petten, Ispra and Seville) and that of at least 10 JRC experts in the field.

The Scientific Panel was formed on the explicit request of Commissioner Kallas, in order to contribute and validate the scientific assessment done in preparation of the STTP. Members of the Panel were chosen in order to cover all transport fields, assuring independence but also geographical and gender balance in the group. Most of the members come from the academia (see ANNEX I: The STTP Scientific Panel for its members). Authors are listed within each chapter.

The Scientific Assessment took into account the answers received to questions prepared by the JRC for the stakeholder hearings held during the preparation of the STTP as well the Visions and Roadmaps already created by the technology platforms and partnerships in the transport field. The assessment was also extensively reviewed by the STTP Scientific Panel and by several Commission experts in DG MOVE, INFSO and DG RTD.

On the basis of the description of the status and vision for all transport modes and cross-modal aspects, a prioritisation exercise also took place under the responsibility of JRC staff and with the participation of the members of the Scientific Panel. The analysis of the results of the prioritisation was a valuable (but not the sole) input in the final selection of the Research and Innovation Areas for the STTP.

Analysis of Modes

The broad overview of modes and cross-modal aspects contained in this document is structured along the following chapters:

[1] "White Paper. Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system", COM(2011)144 final of 28 March 2011. Available at http://ec.europa.eu/transport/strategies/2011_white_paper_en.html

[2] http://ec.europa.eu/transport/research/sttp/sttp_en.htm

- Road transport
- Rail
- Aviation
- Waterborne transport (maritime/inland)
- Fuels and energy
- Urban mobility
- Logistics
- Intelligent transport systems across modes

The chapters are structured in order to give a short overview of the current status of the sector, define the vision and the ways to achieve it. Especially the vision part, was structured into vehicles/vessels, propulsion, fuels, ITS, infrastructure and safety for the sectorial chapters, since this split was thought to facilitate the full coverage of all issues within a particular sector.

The analysis of the sectors is too broad to be summarised in the executive summary, but can be found in its full extend within each chapter.

Scoring Exercise

The scoring methodology is the result of collegial work. It has been designed by the JRC and validated/refined through input of the Scientific Panel. The scoring methodology applies to the list of identified technology areas as these were identified in the previous sections.

Consistently with the inclusive design of the STTP, additional input has been sought and collected via outcomes of the meetings with the stakeholders and the public Internet consultation as well as information provided by the Seventh Framework Programme for Research and Technological Development (FP7) Transport Programme Committee and the STTP Scientific Panel. All input data at succeeding steps of elaboration have been submitted to the consistency check of: all involved Commission's services, the Scientific Panel, and the FP7 Transport Programme Committee.

The scoring methodology was designed along four axes (contribution to EU policy objectives, EU added value via research, demonstration and deployment support). Each axis was judged against a set of defined criteria.

The first axis included in the selection and prioritisation methodology evaluated the contribution of identified research and innovation areas to the following European policy objectives: decarbonisation of the transport system, reduction of oil dependency, cost-efficient and seamless mobility, consumer protection, security and safety, transport and industry competitiveness, territorial and social cohesion. The first axis served as a screening mechanism to select the set of research and innovation areas best serving the objectives of the above-mentioned European policies.

The remaining three axes in the selection and prioritisation methodology are designed to position each research and innovation area along the innovation chain based on technology maturity level and closeness to market uptake. The objective was that of assessing where in the innovation chain EU intervention is expected to produce the highest added value.

The second axis considers the value added per research and innovation area of EU intervention at the level of support to research. Criteria considered were sectorial

research intensity, potential for cost reduction, distance from technological maturity, nature of innovation (incremental vs. radical) and potential as enabling technology.
The third axis moves on along the innovation chain and focuses on the value added per research and innovation area of EU intervention at the level of support to demonstration. Criteria considered were: scale-up potential, financing barriers, pre-normative standardisation, ability to match/meet consumers' needs and competitive advantage.

The fourth axis moves closer to market uptake of innovation and focuses on the value added per research and innovation area of EU intervention at the level of support to deployment. Criteria considered were: entry barriers, distance from obsolescence/leapfrogging, access to resources, need to develop infrastructure, required standardisation and added value by consumer awareness.

Conclusions

This document serves as a comprehensive view in the year 2011 of the current status and mid-term potential for technological developments in all fields of transport. It was designed to serve as a background document for the STTP, and as such, it evaluates the potential of a series of technologies for contributing to the EU policy objectives, as well as where most of the benefit would come by EU intervention.

It is clear, that this document does not identify any winners or losers, but it aims at providing a scientific based input to the decision on the research and innovation areas in which the STTP will focus during the coming years.

1. INTRODUCTION – BACKGROUND INFORMATION ON THE STTP AND THE SCIENTIFIC ASSESSMENT

1.1. Context

The "Europe 2020 Strategy"[3] includes the Flagship Initiative "Resource efficient Europe"[4], under which the Commission is to present proposals aiming at cleaner, more efficient and more sustainable transport. This is to be achieved through a mix of measures including research and innovation, setting of common standards and developing the necessary infrastructure support as well as regulatory measures such as pricing.

Furthermore, under the Flagship Initiative "Innovation Union"[5], the Commission is to develop a strategic research and innovation agenda including, inter alia, transport. The Flagship Initiative "An industrial policy for the globalisation era"[6] calls for promoting technologies that reduce the use of natural resources and for the commercialisation and take-up of key enabling technologies, while the Flagship Initiative on a "Digital Agenda for Europe"[7] promotes the use of Intelligent Transport Systems for efficient transport and better mobility.

The Commission's vision for a more competitive and sustainable transport in Europe has been outlined in the recent Transport White Paper[1].The Transport WP sets out to remove major barriers and bottlenecks in many key areas across the fields of: transport infrastructure and investment, innovation and the internal market. The aim is to create a Single European Transport Area with more competition and a fully integrated transport network which links the different modes and allows for a profound shift in transport patterns for passengers and freight. To this purpose, the Transport WP puts forward 40 concrete initiatives for the next decade, including technological as well as non-technological measures. The Strategic Transport Technology Plan (STTP), addressing the technology pillar of the White Paper, is hence designed to contribute to these objectives in the long term.

1.2. The role of Scientific Assessment

The European Commission's Joint Research Centre (JRC) undertook the job to produce this scientific assessment, as a contribution to the STTP preparation. The assessment took place from November 2010 to August 2011 and covered all transport sectors and issues. The magnitude of the work required the collaboration of 3 JRC Institutes (Institute for Energy and Transport, Institute for Prospective Technological Studies and Institute for the Environment and Sustainability) located in 3 different JRC sites (Petten, Ispra and Seville) and that of at least 10 JRC experts in the field.

The Scientific Panel was formed on the explicit request of Commissioner Kallas, in order to contribute and validate the scientific assessment done in preparation of the STTP. Members of the Panel were chosen in order to cover all transport fields, assuring

[3] http://ec.europa.eu/europe2020/index_en.htm

[4] http://ec.europa.eu/resource-efficient-europe/index_en.htm

[5] http://ec.europa.eu/research/innovation-union/index_en.cfm

[6] http://ec.europa.eu/enterprise/policies/industrial-competitiveness/industrial-policy/index_en.htm

[7] http://ec.europa.eu/information_society/digital-agenda/index_en.htm

independence, but also geographical and gender balance in the group. Most of the members come from the academia (see Annex I for its members).

The Scientific Assessment took into account the answers received to questions prepared by the JRC for the stakeholder hearings held during the preparation of the STTP as well as the Visions and Roadmaps already created by the technology platforms and partnerships in the transport field. The document was also extensively reviewed by the STTP Scientific Panel and by several Commission experts in DGs MOVE, INFSO and RTD. Authors of each chapter are listed within.
On the basis of the description of the status and vision for all transport modes and cross-modal aspects, a prioritisation exercise took place under the responsibility of JRC staff and with the participation of the members of the Scientific Panel. The analysis of the results of the prioritisation was a valuable (but not the sole) input in the final selection of the Research and Innovation Areas for the STTP.

2. STATUS AND VISION OF MODES AND CROSS-MODAL ASPECTS

The broad overview of modes and cross-modal aspects contained in this document is structured along the following chapters:

- Road transport
- Rail
- Aviation
- Waterborne transport (maritime/inland)
- Fuels and energy
- Urban mobility
- Logistics
- Intelligent transport systems across modes

The chapters are structured in order to give a short overview of the current status of the sector, define the vision and the ways to achieve it. Especially the vision part, was structured into vehicles/vessels, propulsion, fuels, ITS, infrastructure and safety for the sectorial chapters, since this split was thought to facilitate the full coverage of all issues within a particular sector.
Finally, additional aspects deserving further development, but not of equal relevance as those listed above, have been included in the Annexes.

2.1. Road transport

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2.1.1. Current Status

The Road Transport Sector is the largest corporate R&D investor in transport in Europe. European companies are among the world leaders in manufacturing road vehicles and components. R&D investments and more generally innovation are seen as essential to maintain its competitive position. While a lot of the R&D investments are directed towards incremental improvements of products and services along the regular product/service renewal cycle, some of the R&D contributes to potential market deployment of step-change technologies that could significantly change the future performance and operational aspects of the road transport system, but bear higher deployment risks. Innovation is a key factor for maintaining the competitiveness of the European road transport sector. Innovation and deployment need to be supported by a common European strategic framework for research and innovation as well as regulatory framework conditions through standardisation and/or regulation, including at international level, to avoid technological fragmentation, but also to enable European businesses to fully benefit from the entire European market, and to create worldwide market opportunities. Recent initiatives of the Commission such as CARS 21 elaborate related recommendations.

2.1.2. Vision and how to achieve it

The European Road Transport Research Advisory Council (ERTRAC), in its Strategic Research Agenda (SRA) outlines the following quantitative objectives for relevant policy fields for 2030:

Table 1. Goals for Road Transport

Overall goal	Indicator	Objective
Decarbonisation	Energy efficiency in urban passenger transport	+80% (pkm/kWh)*
	Energy efficiency in long-distance freight transport	+40% (tkm/kWh)*
	Renewables in energy mix	Biofuels: 25% Electricity: 5%
Reliability	Reliability of transport schedules	+50%*
Safety/ Security	Fatalities and severe injuries	-60%*
	Cargo lost to theft and damage	-70%*

*versus 2010 baseline

The main fields that have the technology potential to contribute in reaching the European policy goals of decarbonisation, safety/security, competitiveness, and seamless mobility, including the above mentioned quantified objectives, are: (i) Vehicles, (ii) Propulsion technologies (especially electrification of road transport including hydrogen fuel cell applications), (iii) biofuels, (iv) intelligent transport systems (ITS), (v) improvement of infrastructures and (vi) Safety.

2.1.2.1.Vehicles

R & D in vehicle design and new materials will continue to play an important role for optimising the performance and cost competitiveness of future vehicles. Regarding decarbonisation, further activities in lightweight design are needed in order to reverse the past trends of a continuous increase in weight from vehicle generation to vehicle generation. Further optimisation of the overall vehicle efficiency through reducing the resistance to motion, increasing the recovery of waste energy, and system optimisation, is needed. Vehicle adaptations to future drive train concepts and new infrastructure systems will assist in fully exploiting their potential.

There are several pathways that are currently pursued in order to develop more efficient vehicle designs. The first direction is towards decreasing the energy required to power the vehicle. Developing lightweight bodies either from steel or synthetic materials is a priority for the passenger car sector. Current industrial targets are weight reduction of 25-35% compared to existing bodies. The second pathway aims at improving aerodynamic efficiency by improving the vehicle design or using adjustable components that decrease resistance at high speed. Recently, this also became the target for heavy duty vehicles where aerodynamics improvement was not considered a priority. Rolling resistance decrease is yet another area where efficiency gains can be obtained, by using low-resistance tyres and improved transmission systems, further to the mandatory use of tyre pressure monitor systems. Incremental efficiencies of up to 2-3% can be achieved this way.

For energy savings, new concepts appear for powering the peripheral systems of the vehicle. Efficient (electrically driven) air-conditioning systems, use of solar power to keep a constant temperature in the cabin while parking, energy efficient lighting systems, are examples of systems that can reduce the overall energy consumption of the vehicle. Such measures may be promoted through the “eco-innovations” initiative of Regulation 443/2009. Energy savings may also be obtained by reducing or even better recuperating part of the waste energy. Start-stop systems reduce the energy consumption while at stand-still. Energy recuperation systems include regenerative braking and waste heat recovery systems. The range of improvement that can be obtained from such vehicles depends on the vehicle operation conditions but combination of several of these methods may lead to overall efficiency improvements beyond the range of 10-15%.

Standardisation and safety regulations are important to promote the wide implementation of such novel techniques. These are needed to improve quality and reduce the development and manufacturing costs of such systems which are a prerequisite for their wide implementation. Moreover, holistic vehicle design that will take into account mobility patterns, new propulsion technologies, and better infrastructure (including ITS) can provide synergetic improvements which are not independently achievable by any of the systems. Therefore procedures and methods for system integration and optimization will have to be improved.

The main opportunities for improving the chassis of freight vehicles lie in increasing carrying capacity, ‘lightweighting’ and aerodynamic profiling (McKinnon et al., 2010). Capacity increases will require some relaxation of regulations governing vehicle size, and possibly weight, limits. As trucks significantly longer, heavier and taller than the standard European 5-axle, 40 tonne, 4m high articulated vehicles have operated for many years in some EU countries, there is limited need to design new higher capacity vehicles for cross-border movement. The diffusion of longer and heavier vehicle (LHV) technology is currently being constrained by regulation. If this were relaxed, technical

adjustments would be required to adapt LHVs to infrastructural constraints in particular countries.

By reducing the tare (or empty) weight of a vehicle through redesign or the use of lighter materials it is possible to increase carrying capacity and cut fuel consumption. The development of new materials for the construction of freight vehicles will offer greater scope for 'light-weighting'.

Major advances have been made in the aerodynamic profiling of freight vehicles over the past two decades and there has been wide uptake of the more cost effective forms of this technology, particular over-cab spoilers. For the foreseeable future, most of the savings from improved streamlining of vehicles are likely to come from wider diffusion of existing technology. In the longer term, however, vehicle manufacturers will have to adopt radically new truck designs to achieve the improvements in energy efficiency that will be required to meet carbon reduction targets. Streamlining airflow at the front and rear of trucks, while maintaining their current carrying capacity, will require some relaxation of vehicle length restrictions.

R&D focus on the powertrains and aerodynamics of freight vehicles has diverted attention from the energy used by ancillary equipment such as pumps, fans, air compressor, heating, air conditioning, refrigeration and power steering. It has been shown that running this equipment on separate batteries rather than the vehicle engine can significantly cut fuel consumption (Greszler, 2009). More holistic assessment and management of vehicle power requirements could lead to more energy-efficient designs.

2.1.2.2.Propulsion technologies

It is widely acknowledged that the **internal combustion engine** will probably remain the dominating propulsion technology in the vehicle market at least until the 2030 time-horizon and possibly beyond. R & D activities in the internal combustion engine concepts and operation will continue to provide incremental improvements in the efficiency of vehicles. For example, efforts in low-temperature combustion may provide combined benefits to both air pollutants and greenhouse gas emissions.

In the same direction, improved intake systems and stratified combustion may better exploit the limits of conventional combustion. Engine downsizing and turbo-charging may also increase efficiency by reducing inertial and friction losses and maintaining the engine at more efficient modes during real-world operation. Gas turbines have also made some ground as road vehicle power producers, mostly as range extenders. New developments in power train technologies need to ensure capability to use future fuels such as high blend biofuels.

Also, versatility in the fuel quality, i.e. where an engine can be tuned to operate with fuels of different specifications may introduce substantial benefits when then well-to-wheels cycle of a fuel is concerned. The role of after-treatment to achieve fuel consumption benefits when combined with engine retuning should also not be forgotten, in this process. R&D activities on these technologies are also supported by the European Green Car Initiative (EGCI).

Several recent European and North American studies have assessed the potential for improving the energy efficiency of trucks. One US study suggests that about two-thirds of future energy efficiency gains in trucks will come from improvements to engine and exhaust systems, with much of the benefit accruing from turbocharging (National Academy of Sciences, 2007).

Electrification of road transport represents a potential step change technology requiring new vehicle drive trains as well as infrastructure. This is because of the higher efficiency of electric motors compared to internal combustion engines, the absence of tail-pipe emissions, as well as the potential to decarbonise the well-to-tank pathway via a parallel decarbonisation of the electricity generation mix. This path opens the possibility to use alternative energy sources to secure mobility and make road transport less dependent on crude oil (security of energy supply). The electrification of road transport is synergistic to the deployment of renewable electricity generation as demand management for vehicle charging could facilitate an increase in intermittent electricity generation. Fully electrified road transport will probably be limited to urban vehicles for the medium term. Projections for the deployment of battery electric vehicles (BEV) and plug-in hybrid electric vehicles (PHEV) cover a large range, ranging from 0.5 to 2.5 million annual sales in Europe in the 2020 to 2025 timeframe.[8] Germany alone has set the target of introducing 1 million electric vehicles on the street until 2020. Niche market small scale production BEVs are already available for some time to suit customers who make regular urban short journeys over a known route such as commuting to work and recharge at home over night. A number of large automotive manufacturers have recently launched or have announced to launch BEVs and PHEVs in the 2010 to 2012 timeframe. The first such vehicles, including Nissan Leaf, Opel Ampera, Mitsubishi i-MiEV, Peugeot iOn, Citroen C-Zero are being deployed to the European market. Hybrid Electric Vehicles (HEVs) without plug-in capability reduce the fuel consumption by approx. 15% and are seen as a bridging technology towards further vehicle electrification (e.g. PHEVs, BEVs). Various levels of hybridisation are already commercially available and contribute now and in the future to the decarbonisation of road transport. For the foreseeable future, BEVs are considered to be limited in range as the energy density of batteries is low and is expected to remain low compared with other energy carriers (gasoline, diesel, biofuels, hydrogen).

Pressure to decarbonise road freight operations will also promote the 'electrification' of short-range, multiple drop and collection trips by vans and small rigid vehicles. Most of the main European truck manufacturers are currently developing hybrid rigids and they will soon be going into full production. Prototype hydraulic hybrid vehicles, which offer even greater energy and CO_2 savings, are currently being trialled in the US. The development and adoption of fully electric freight vehicles will depend on advances in battery technology, but remain confined to local delivery rounds. The use of battery-power in heavier, long distance trucks is likely to be confined to ancillary equipment. Research in Sweden has suggested that on heavily-trafficked corridors in a country generating very low carbon electricity, a cost-benefit case could be made for electrifying the highway and running 'trolley trucks' (Ranch, 2010).
The engines propelling the movement of freight by road have been substantially redesigned over the past 20 years to meet tightening controls on the emissions mainly of NOx and particulate matter (PM10). In the road freight sector, where reductions, respectively, of 87% and 95% in NOx and PM10 emissions have been achieved since the early 1990s for new vehicles (to meet the Euro 5 emission standard), future 'cleaning' of diesel engines is likely to be marginal, particularly as greater priority will be given to the minimisation of fuel consumption and CO_2 emissions. Significant advances have also been made in the use of traps to filter emissions of particulate matter from diesel exhausts, with trucks again ahead of the other freight modes in the application of this technology.

[8] SETIS (2010): Final report of the SET-Plan workshop on Electrification of Road Transport (see http://setis.ec.europa.eu/)

A number of issues remain as significant obstacles for the faster penetration of battery-electric vehicles in the market: (i) high cost of energy storage system leading to high cost penalty for the vehicles, (ii) range limitations,(iii) inadequate standardised charging infrastructure, (iv) slow recharge times, and (v) limited battery lifetime. Further work on areas such as drive-train optimisation and system integration, and vehicles-to-grid integration is needed in order to increase the competitiveness of electrified vehicles over the well-proven 'conventional' vehicle concept.

In relation to this area, ITS has a critical role to play in the advancement and operation of electric cars and buses (either plug-in hybrids and fully electric) through providing information on available charging points throughout the road network; management of the supply of such points and helping to balance the electricity supply (electric grid integration); integration of the electric cars into the traffic stream (especially in urban areas) mainly from the safety point of view, monitoring of vehicles (in particular in public fleets), management of parking and charging points, provision of interfaces for the payment of electro-mobility related services and with the grid.

The need to develop new value chains for batteries, with separate organisations taking responsibility for sale, maintenance, recharge and exchange of batteries should also be addressed. It is not simply a technical issue – new business models may be required to promote more development and wider application of battery technology. Also the production and supply of lithium for battery, and rare earths for electric motor manufacturing, will have to be ramped up to meet the projected demand for such systems. As there are few major sources of such materials globally and they are often extracted with environmentally damaging practices, there is a need for a full risk assessment of their supply chain. Finally, there is also the possibility of electrifying highways for the direct transmission of low carbon electricity in trolley busses. At EU-level the Public Private Partnership (PPP) "European Green Car Initiative" (EGCI) these barriers and challenges are addressed through a mix of R&D funding and other instruments. Furthermore, roadmaps for electrification of road transport, long distance trucks and logistics and co-modality were elaborated within EGCI.

Electrification of road transport for applications requiring longer operation ranges and for captive fleets (buses, utility vehicles) can be achieved via fuel cell vehicles (FCV) operating on hydrogen, which are seen as a complementary technology to BEVs. A small number of FCV prototype vehicles currently operate in field tests. The Honda Clarity is probably the first fuel cell vehicle that can be purchased by private owners in California. Several other manufacturers plan the launching of fuel cell vehicles in the period 2015 and later. Fuel cells may not only be used as prime vehicle movers but also as auxiliary power units. Major technology and infrastructure challenges have still to be overcome for fuel cell vehicles to become widespread. Hydrogen production with a minimal carbon footprint and at an affordable cost is still an open issue. Furthermore, the wide-scale deployment of hydrogen fuel cell vehicles requires infrastructure investment to develop the hydrogen transport and refuelling network. Safety and handling practices have also to be developed to make hydrogen an equally safe fuel as gasoline and diesel, for the everyday driver. At EU-level, the PPP "Fuel Cells and Hydrogen Joint Technology Initiative" tackles these challenges.

Advanced electric drive vehicles such as hybrid-electric vehicles, plug-in hybrid electric vehicles, fuel cell electric vehicles, and pure electric vehicles, require power electronics and electrical machines (PEEM) to function. PEEM technologies must be compatible with high-volume manufacturing and must ensure high reliability, efficiency, and ruggedness. These technologies must also reduce cost, weight, and volume.

2.1.2.3.Fuels

Biofuels can have a positive impact towards the reduction of CO_2 not just from new vehicles but by the entire vehicle fleet, through their introduction at low blending in conventional fuels. This is promoted by the Directive on Renewable Energy Sources (2009/28/EC) and supported by the Fuel Quality Directive (2009/30/EC). Current regulations allow up to 10% vol. blending of bio ethanol in gasoline and up to 7% biodiesel in diesel, which can be used in any gasoline or diesel vehicle respectively, without the need for engine modifications. Higher blending ratios are possible but will need specifically designed vehicles. For example, 85% ethanol blends in petrol are today commercially available as automotive fuels and can be used in flexi-fuel vehicles which can recognize the actual ethanol/gasoline mixture in the tank and proportionally adjust the engine operation parameters. Higher ethanol blends make start up difficult due to the low vaporization of ethanol and are not appropriate for wide use. Higher blends of biodiesel or neat biodiesel can be used without particular combustion problems in diesel engines. However, pollutant formation issues, fuel systems sensitivity, and lube oil degradation caused by biodiesel introduce limits for the highest allowable blending ratio of biodiesel in today's engines. Dedicated engines and strict biodiesel quality specifications and monitoring will be required before higher biodiesel blends become widely available.

Currently available "first generation" biofuels are controversial from a sustainability point of view. The main criticism focuses on the rather limited actual CO_2 reductions achieved over the lifecycle of the fuel production and use, the impacts of their production on the environment, biodiversity and water resources, competition with food supply sources and impacts on regulated an unregulated pollutants upon combustion. "Second generation" biofuels appear as more promising options from an environmental perspective. Such fuels can be produced with advanced chemical processing techniques from agricultural and urban wastes. Small-scale production of such biofuels is today attempted in case studies. Because of the advanced processing, second generation biofuels have a very well determined chemical character, negligible or zero impurities and seem as ideal fuels to achieve advanced performance of internal combustion engines. Because of this, second generation biofuels are considered as one of the most probable technology options to decarbonise the long haul road transportation sector.
Apart from the technical challenges that remain for the production of 2nd generation biofuels, their cost is a key barrier. Within the SET-Plan the recently launched "European Industrial Bio Energy Initiative" aims amongst others to bring to commercial maturity the most promising technologies, in order to permit large-scale, sustainable production of advanced biofuels. Chapter 2.5 on Fuels and Energy covers biofuels in more detail.

Other fuels with the capacity to offer lower CO_2 emissions include methane (fossil or biogas) and hydrogen as an internal combustion engine fuel. Methane can offer CO_2 advantages due to the highest H:C ratio from all fossil fuels available. However, methane can only be used in a spark-ignition engine which has a lower efficiency than a combustion ignition one. Hence the benefits offered by the higher H:C of methane compared to other fuels is counterbalanced by the lower efficiency of the engine compared to diesel. Diesel natural gas busses for example emit less CO_2 than natural gas ones, for the same level of performance. Hydrogen on the other hand can burn in an internal combustion engine in much the same way as gasoline, and produces only water as the main combustion product. Small dedicated stocks of internal combustion hydrogen vehicles have been produced for demonstration. While no tailpipe CO2 emissions are produced by such vehicles, NO_X production issues and the lack of a cheap and carbon-free method for hydrogen production are limiting factors.

It is needless to say that fuel research will be one key area in the effort to produce carbon-free fuels, decrease conventional pollutants and increase the energy security of Europe. In the future, one will have to more and more consider the whole well-to-wheels chain of the fuel/vehicle combination to assess the true benefits of refuelling a significant part of the stock. In this process, developing robust methodologies to measure impacts will be necessary. Also the engine and fuel technology should be seen as an integrated system where GHG benefits will have to be achieved synergistically rather than independently in each of these two areas.

2.1.2.4.ITS in road

Intelligent Transport Systems (ITS) should be seen as a special infrastructure component with a significant potential in achieving energy efficiency improvements and CO2 reductions. Also, ITS implementation could positively contribute to the EU road safety objectives through enabling active safety systems but also by monitoring law enforcement.
ITS can contribute in reducing carbon emissions from passenger road transport in a multitude of ways. For example, by improving traffic conditions through traffic light adjustment, diverting traffic through non congested routes and proposing fuel efficient routes, enabling vehicles to travel at more fuel efficient speeds, etc. More advanced ITS application, such as vehicle platooning could massively improve infrastructure throughput.

In the case of freight transport, ITS can improve the efficiency and quality of both long haul movements and local distribution. It can also help companies to co-ordinate the movement of goods at different geographical scales. Interoperable ITS devices can promote harmonisation of automatic tolling devices and thereby incentivise more effective use of vehicle capacity. ITS can facilitate the intermodal transfer of freight helping to Commission to realise its goals for co-modality. Chapter 2.8 covers in more detail ITS applications across freight modes, while the wider application of ICT across logistics and supply chain management are covered in Chapter 2.7 and Annex III.

In the area of ITS to improve traffic management in urban and interurban transport networks several applications exist for road. Of the most common applications deployed today are: Intelligent traffic signal control, incident detection and management, priority to specific types of vehicles such as emergency, and public transport vehicles, intelligent Lane control, speed limits enforcement, longer distance diversions re-routing, data collection (with floating cars and other methods), real time public transport information, Automatic Vehicle Identification and real time information to the bus stops, priority for buses and other public transport vehicles at intersections, flexible bus lane control (to allow utilization of the bus lanes by other types of vehicles too), and so on. Some significant keywords for the next generation of traffic management systems with large-scale implementation of ITS are: traffic predictive control methods, intelligent autonomous intersections.

In the field of Navigation services, ITS includes technologies related to the identification of the position of a vehicle or load unit (positioning) and providing instructions as to the optimal route to one's destination. The positioning part of navigation services is handled through the existing GPS positioning systems such as the European Galileo (to be operational after 2014), and the GPS and GLONASS ones. A most important feature of ITS navigation systems is the 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.

Electronic Fee Collection systems offer the possibility of smart charging for the use of transport infrastructure (mainly roads) by using technologies such as automated vehicle identification technologies (using barcodes[9], RFID[10], plate recognition[11], GPS[12]); automated vehicle classification (using video cameras, sensors, or storing the vehicle class in the customer record); transaction processing (prepaid or postpaid systems); violation enforcement (physical barrier, plate recognition, police at toll gates, etc). Interoperability is a key issue for a successful implementation of Electronic Fee Collection (EFC) in Europe, especially at tolls (Directive on *Interoperable Electronic Road Toll Systems in Europe*[13]).

ITS can have significant contributions towards improved safety. While stand-alone intelligent communication technology based safety features are commonplace in today's vehicles (e.g. ABS, ESP), advanced sensor-based technologies like lane departure warning, traffic sign recognition, or blind spot detection are also beginning to be deployed by a number of manufacturers. Truly cooperative systems like vehicle to vehicle or vehicle to infrastructure communication , including demand management for charging EVs, can magnify the societal benefits of ITS. They are still in an R&D stage.

In the area of ITS for safety and security there are many examples of cooperative – active or passive - systems:

- *Advanced Driver Assistance*: (Speed adaptation (V2I and I2Vcommunication), Reversible lanes due to traffic flow (V2I and I2V), Local danger / hazard warning (V2V), Post-crash warning (V2V), Vehicle lateral and rear area monitoring (LRM), Lane Departure Warning/lane keeping (LDWS), Collision Avoidance Systems (CAS), including lane change support, Longitudinal control systems: Cruise Control and Advanced Cruise Control (ACC), Collision Warning and Avoidance (CWS/CAS), Intelligent Speed Adaptation (ISA), Night vision enhancement, Object detection, Pedestrian and other VRU protection.
- *Advanced Rider Assistance (*Frontal Collision Warning, Speed Alert Curve, Warning Intersection support, Lane Change Support, Advanced Rider Assistance Systems – HMI, Vibrating Glove or Seat, Smart Helmet, Blind spot warning mirror)
- *Road Intersection safety (*Cooperative collision warning at intersections, Integrated intelligent intersection safety system (e.g. project IRIS), other intersection safety features (e.g. project SAFFESPOT))

For a broader deployment of ITS in road transport, technical challenges still remain, as well as cost and infrastructure issues. The fault tolerance and reliability of safety critical sensors, actuators, controllers, and communication devices needs to be improved in order to reach more autonomous driving functions and vehicle systems. Standardization is a prerequisite in the effort to widely deploy such systems.

Research in Human Machine Interface (HMI) aspects and design is also very important in the context of increased ITS use. Data security and privacy issues need to be

[9] Optical systems proved to have poor reading reliability
[10] Via Dedicated Short Range Communications (DSRC), proved excellent accuracy, but with a high cost
[11] Used in the Toronto Electronic Toll Route
[12] Used in the truck tolling system in Germany
[13] Directive 2004/52/EC had set the framework for a European Electronic Toll Service (EETS). The detailed definition of the EETS, including technical, procedural and legal issues and a schedule for implementation, has been set in a European Commission decision adopted in October 2009.

addressed. Liability aspects and other legal aspects of systems with higher autonomy need to be studied. Adequate business models for technically promising ITS applications and functions need to be found. International standardised communication interfaces between infrastructure, vehicles and other modes are needed. The ITS Action Plan[14] addresses most of the above listed issues and aims at accelerating the deployment of intelligent vehicle systems in Europe. This has been following and complementing the "Intelligent Car Initiative"[15] which tried to care for some of those problems using a mix of research and communication instruments. The PPPs ENIAC (European Nanoelectronics Joint Undertaking) and ARTEMIS (Embedded Systems Joint Undertaking) both support, amongst others, the development of enabling technologies for ITS.

2.1.2.5.Infrastructure

Infrastructure in the form of roads and multi-modal interfaces are an enabler for a more efficient and safer road transport system, but also a current and future bottleneck in the light of the future transport demand projections on the one hand and the limited funding for infrastructure investments on the other hand. Besides the infrastructure aspects of vehicle to infrastructure communication and vehicle to grid integration, a number of dedicated infrastructure related measures exist. These focus on increasing the durability and reducing the necessary maintenance efforts for European roads as well as improving the traffic flow through dynamic demand management (e.g. congestion charging) and integrated mobility planning. Multi-modal infrastructure interfaces are an important enabler for cross modal optimisation, addressed in more detail in the chapter 2.8 on ITS across modes. Electrification of road transport will require dedicated infrastructures for electric charging and hydrogen distribution and refuelling. In Annex V, the issue of intermodal infrastructures is further analysed.

2.1.2.6.Safety

The protection of vulnerable road users including two-wheelers has gained high attention in Europe. Analyses of accident data and traffic safety as well as the use of crash models including improved biomechanical model components are an important enabler to further steer R&D work in passive and active safety systems. Safety related features include self-explaining roads and forgiving infrastructure which follow design recommendations for simplicity and clarity as well as simple measures that enable passive feedback of the road infrastructure to the driver such as three-dimensional markings, variable length and spacing of centre lines for different speed limits. Other ICT applications were explained in the sub-chapter on ITS above.

[14] COM(2008) 886 final - Action Plan for the Deployment of Intelligent Transport Systems in Europe

[15] http://ec.europa.eu/information_society/activities/intelligentcar/index_en.htm

2.2. Rail

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With contributions from: K. Tanczos

2.2.1. Current status

Rail is one of the most energy efficient transport modes at moderate speeds and at usual operation has among the lowest emissions of greenhouse gases in transport, provided that the occupancy rates are sufficiently high and the demand is high enough to justify rail's high infrastructure investment costs. Electrified rail transport has outstanding performance with respect to energy use and emissions. Not surprisingly, modal shift from other modes to rail (as part of an inter-modal chain) has been advocated by European policy makers since the early 1990s.

The excellent energy and emissions performance of rail is the main argument for the EU to bet on this strategy: The average emissions from rail transports was 25 g CO2 per tonnes kilometre and 47 g CO2 per passenger kilometre in average by rail in Europe 2005 and has decreased by 30% for freight and 15% for passenger transport since 1990 (UIC 2008).

In spite of these advantages, rail has been losing market share in most European countries for many years. Since the 1990s, and more decisively in the last decade this trend has changed in some countries, due to a combination of technological development (like high speed rail services), increased co-operation with other transport modes (intermodal solutions for passenger and freight transport, and for urban mobility), and reform of the regulatory framework, separating rail operation from infrastructure management and opening up the market of rail services to competition. The regulatory reform is expected to affect the market in two ways: There will be new operators so customers have a choice and existing operators will be more efficient because of competition.

In the Central and Eastern European (CEE) countries the improvement of the railway network fell behind. The main problems are the bad condition of the rail tracks and related infrastructure, as well as the rolling stock, which altogether induce low service quality. The high percentage of single-track, non-electrified lines and speed limits are further problems. Financial difficulties, due to the severe recession, are further obstacles to the modernization of the railway industry in these countries. In comparison to other transport modes, suburban traffic is the most competitive in these states.

The recent EC Transport White Paper[1] pay much attention to development of the rail system by a vision of tripling the length of the HSR network by 2030, maintain a dense conventional rail network and connecting all core airports to rail. There is also a vision to establish a fully functional EU-wide multimodal TEN-T core network by 2030 and connect all core seaports sufficiently to rail. This emphasizes the need of technical development of the rail system.

To increase the share of rail in overall EU transport, the following main actions are needed: improving the performance of the rail system; decreasing infrastructure and maintenance costs, which constitute the main barrier for the development of the rail network, and increasing the cooperation with other transport modes, focusing rail services in corridors with high traffic demand, whereas improving intermodal connection can make the whole door-to-door transport chain efficient and competitive vis-à-vis uni-modal solutions.

2.2.2. Vision and how to achieve it

ERRAC's vision for the future of rail in 2020 aims to increase the railways' role in the European transport system by providing seamless and integrated high speed passenger services and door-to-door freight services as well as efficient metropolitan and urban mass transport. Technical solutions should always be seen in the light of their contribution to the commercial attractiveness of rail transportation[16].

To attain this vision, technological contributions may operate from different, complementary perspectives:

- Within the rail system, by increasing energy efficiency and lowering emissions per tonne and passenger-km. The community of European Railways (CER) has committed to an overall reduction of in GHG emissions per passenger and tonne kilometre by 30% from 1990 to 2020. In the TOSCA-project (http://www.toscaproject.org/) analysis has shown that it is possible to reduce GHG in rail operation by 40-50% from 2009 to 2050 and by another 60-80% for electric trains in GHG-emissions in the mix of electric energy production. Additionally, full integration of national networks will require further technological developments, beyond the deployment of the European traffic management and information system (ERTMS).
- By modal change, transferring passengers and freight from current uni-modal solutions to inter-modal alternatives based on rail as the backbone of the land transport chain. This implies the development of appropriate technological solutions to reduce the costs and increase the reliability of intermodal chains, particularly at transfer points.
- By reducing the high costs linked to rail infrastructure construction and maintenance, which act as a key barrier to the modernisation and expansion of the European rail network.

2.2.2.1.Vehicles (including rolling stock)

Rail transport includes passenger and freight main-line operations as well as local railways, metros and trams. The most promising technological measures within the area of vehicle design are: *'Energy recovery'* (electricity regeneration when braking), *'Space efficiency'* in passenger trains,' *low drag',* which will be likely introduced in passenger trains, (full implementation in freight trains may require accompanying measures, such as legislation);*'Low mass'* which is important in stopping trains (commuter and metro trains) and may also require additional incentives.

High-speed trains are expected to have the lowest specific energy use per passenger kilometres and GHG emissions, due to their superior aerodynamics and few stops. Still there is a speed penalty to pay and there is also a noise issue.

The combination of these technologies results in energy and GHG reductions of 40–50 % with the same GHG content of electricity as in 2009. With GHG emissions reduced by 60–80 % for future average European electricity, the specific GHG emissions are

[16]European Rail Research Advisory Council (ERRAC) (2007).Strategic rail research agenda 2020.

estimated to be 4–10 g CO2-eq per pass-km and 2–5 g CO2-eq per tonne-km, which is very favourable (75% - 90% reduction in CO2 relative to today's GHG emissions).

For ***freight trains*** a number of technological developments would improve the energy efficiency of rolling stock :

- Lighter wagons of lighter materials to increase pay-load
- Running gear to allow higher axle loads and speeds by lower dynamic track forces
- Technology for less noise and vibration by better brakes and wagon design
- Electronically controlled braking systems for shorter braking distances and lower maintenance costs
- Intelligent freight wagons and freight trains by development of ICT: Wagons can be equipped on board for communication and position determination and a computer system for monitoring the wagon and its load. An intelligent freight train makes use of information from all the wagons and the whole train. In the long term the systems can be satellite-based and integrated with the new safety and traffic control system ERTMS/ECTS. Remote-controlled locomotives to long haul, heavy unit trains, with locomotives can be placed at the front, in the middle, or at the rear of trains up to 3,000 metres in length.
- Automatic coupling. Manual screw-couplings and side-buffers are still used in Europe. The disadvantages are that the coupling requires manual handling, which drives costs, is hazardous, and also takes time. Manual coupling also limits the trains' weight and makes it impossible to connect power, signalling and air lines automatically. Automatic couplings have great advantages: simpler, faster coupling, faster shunting, less risk, and heavier, longer trains. A modern automatic coupling could in principle be able to be remote-controlled. A decision to introduce automatic couplings must be made at European level. Once the decision has been taken, careful planning and extensive preparation will be needed. If the economic issues can be solved, automatic couplings could have a significant positive impact on freight traffic. Studies have indicated a pay-off period of 5-10 years.

For ***passenger trains*** there are a number of promising technological developments concerning vehicle design:

- Running gears for smoother ride and higher speeds with low dynamic forces is one way to increase speed on existing track or to reduce maintenance costs for vehicles and tracks. Special features as ALS (Automatic Lateral Suspension) can reduce forces to the customers in curves and tilting device in combination with radial steering of the axles can increase speed in curves.
- Space-efficient trains: Changing from locomotive-hauled trains to multiple unit trains and to double-decker trains or wide-bodied trains. With a consequent use of space-efficient train interiors - including intelligent seat design 10–15 % of energy per seat-km could be saved compared with ordinary trains.
- Modular trains: Today many trains operate with a constant length dimensioned for capacity during peak hours. If trains are made in shorter self-propelled modules these modules can quite easily be de-coupled. A half-size-train would save some 40 % of energy compared with a full-size one.

Finally, there are problems with noise both from freight, conventional and high speed trains. The technique to reduce the noise at the source on the vehicles must be developed to avoid building costly barriers along the infrastructure.

2.2.2.2.Propulsion/ energy supply

Almost 50% of the rail network in Europe is electrified but 88 % of passenger-km and 85 % of tonne-km are estimated to be carried out with electric operations; the rest is diesel-hauled.

The rail system is mainly using electricity, with still some diesel engines operating where the infrastructure and electrification has not yet advanced. It is clear that electricity is a very clean energy. However it also has to be stated, that electricity can be a very clean energy, but it is essential to prefer electricity pathways with low-GHG balance.

An efficient way to reduce GHG for diesel traction is electrification of diesel-operated lines. The advantages are that electric traction is more energy efficient than diesel traction and electricity is also possible to produce with different primary sources, some of them non-carbon. Furthermore, by regenerating braking, electricity also can be produced by the trains so the net consumption will be lower.

Electrification is rather expensive and that is also the reason why not all lines are electrified. As many diesel operated lines have low dense traffic, there is a case to discuss whether it could be more efficient to rely on other transport modes (mainly road transport) to provide accessibility in these areas. There are however some exceptions, mainly in the U.K and some new MS, of non-electrified lines with heavy traffic densities.

If there is a case to maintain non-electrified lines beyond 2030, the improvement of energy performance and emissions of rail diesel engines could be a relevant area for technological development. For example, to some extent diesel engines are also used on electrified lines for freight when feeder trains and shunting movements have to go to non-electrified lines, sidings and yards. In many countries electric tractions is used by night time to move the wagons between the yards and diesel engines are used in day-time to distribute and pick up wagons from the yards. That means that using *dual mode locomotive* with both electric and diesel-electric traction can reduce both emissions and costs.

For main-line diesel operation, both for freight and passenger trains, also *biofuels* is a way to reduce green-house gases and for shunting also *hybrid locomotives* are possible to use. In this case the development is not unique for rail because it is in many ways the same technology that has to be developed for trucks, buses and ships.

Top speed for high speed trains in regular service has increased successively in Europe from 270 km/h 1981 to 350 km/h 2010 with speed record of 575 km/h for conventional rail in 2008. Nevertheless higher speed creates special technical problems to be solved. One is the interaction between the pantograph and the overhead contact wire. Another is braking from high speed without energy losses. A third one is to get enough acceleration especially in higher speeds.

The electric traction can be developed by permanent magnetic motors with higher efficiency, lower maintenance costs and better acceleration in higher speeds. In the whole electric system from the overhead contact wire to the traction motor there is still a potential for technical improvements. There is also a potential to reduce losses in wires from generating electricity via transformers to the over-head wire.

2.2.2.3.Rail infrastructure

Building of rail infrastructure is very costly today, particularly for high speed rail. Also for conventional rail it is important to reduce investments and maintenance costs. It is

also important to develop cheaper tracks for lower density traffic and industrial sidings which is a crucial factor in wagonload traffic.

The implementation of rail-freight corridors across borders throughout Europe could be facilitated by the development of appropriate technologies in order to harmonize standards and allow for longer trains, higher axle loads or larger loading gauge. As all these will increase the capacity and reduce costs:

- Higher axle loads: The permitted axle load today is 22.5 tons on most parts of the European network, but improvements are under way to increase to 25 tons in specific lines in some countries. In US the normal axle load is 35 tons. An increase of axle load from 22.5 to 25.0 tons means a decrease in cost per ton of 9% and to 30.0 tons 23%.
- Better running gear and better checks and measuring methods might allow higher axle loads to be permitted on existing track. Bridges can be a critical link when upgrading to higher axle loads.
- Larger loading gauge[17]: A larger loading gauge is of great importance for volume freight and trailers and the transportation costs can be reduced by 20-30%. The greatest effect is obtained by combining larger gauge with higher axle loads.

Conventional intermodal traffic that handles trailers, containers and swap-bodies requires large terminals which are expensive to build and operate. Efficient train operation requires relatively large trains that run directly between one terminal and another. This limits the market to just a number of fairly distant destinations. In the conventional intermodal system, the highest costs are in the handling at the terminals and the feeder runs. New solutions must therefore be sought primarily in terminal technology and feeder traffic. To expand the market and reduce costs, the principle is to have a liner train system with many small, simple terminals closer to the customers.

Terminal technologies for automatic transfer of unit loads. In order to make terminal handling more efficient, an automatic horizontal transfer system is needed. There will be an advantage if the system can handle unit-loads horizontally under over-head wire. That will make it possible for inter-modal trains to make an intermediate stop and quick-change load during a short stop. If the system can be fully automated, it could be used in unmanned terminals, warehouses, and ports.
Longer wagons – inter-modal platforms can be developed to be flexible and able to load different kind of unit loads and trailers.

Self-propelled shorter trains: Multiple units for freight, which can be used for train-coupling and train sharing systems, in long term full automated system as a conveyor for the industry.

The normal length of a freight train in Europe is 500-750 metres. Trains of double that length, 1,500 metres, have been proposed by the New Opera projects by joining together two trains and controlling the second locomotive from the first via radio. This would halve the number of trains but is a valid method only when frequency is already high and require prolonged yards, sidings and passing loops.

Fewer freight trains will release capacity for passenger services or increased freight transportation on rail. Faster freight trains mean improved capacity utilization and slots for more trains, freight or passenger. Together this will decrease rail freight transportation costs, meaning more attractive supply for the customers.

[17] Loading gauge: clearance around the track at tunnels, bridges and railway stations etc

The largest benefits for society arise in case the capacity on a section is very constrained. Higher productivity gained by heavier/faster freight trains could postpone the construction of multiple tracks.

Magnetic levitation train

There is today one magnetic levitation train in commercial operation in the world, the line from Shanghai airport to the city. The world high speed train record is 575 km/h, not so far from magnetic levitation train record 581 km/h. Operating speed for magnetic levitation trains is still higher, 430 km/h, but operating speed for high speed trains have successively been improved and are today 350 km/h.

The cost for building magnetic levitation track today is higher than conventional track, but it is possible to have steeper grades and smaller curve-radius than at conventional HSR. The energy consumption of magnetic levitation trains is estimated to be in the same order as conventional high speed trains today. The rolling resistance will disappear, but on the other hand there is a need for energy to lift the vehicle over the beam. The air-resistance will still be there and is dominating the energy consumption in speeds over 100 km/h. For the foreseen future, the idea of eliminating air resistance in a vacuum tube train (vactrain) is not feasible, since it entails significant technical and safety problems.

2.2.2.4.ITS applications, including rail traffic management

The vast majority of the rail network in Europe is equipped with different national legacy control and command systems. ERTMS is a European system which is designed to replace the existing partly incompatible safety and signalling systems throughout Europe and to enable interoperability throughout the European rail network. This is managed using the two components of ERTMS which include the European Train Control System (ETCS) and the Global System for Mobile communications-Railway (GSM-R).

Regarding ERTMS, following an intense phase of research and development, validation of the ETCS system was carried out with real scale projects. The Commission adopted an ERTMS Deployment Plan in 2009 setting out the deadlines for the implementation on key corridors. The plan provides for 25,000 km of lines to be equipped by 2025 linking the main European ports and freight terminals.

Estimates show that ERTMS will benefit European railways. Compared with today's mixed safety and signalling system, ERTMS will contribute to:

- Increased capacity on existing lines;
- Interoperability on railway networks;
- Higher speeds;
- Lower maintenance costs;
- Support for eco-driving by better information;
- Highest level of safety (for passengers, employees and transport goods);
- Reduction of travel time
- Increase of reliability

ETCS is developed in 3 Levels. There are only minor differences in capacity between Level 1 and Level 2. Level 3 enables 40-60% higher line capacity than a standard application of Level 1, and 35-40% higher capacity than a standard Level 2 system.

Therefore it is very important to speed up the development of the level 3 system[18] so it can be implemented directly on the rail network in order to improve capacity.

Driving advice or automatic operation: Driving can be optimized by training for skilled driving, by on-line computerized support and advice to drivers or by automatic train operation. At a later stage this technology may be integrated with ERTMS and traffic flow management.

In 2011 the European Commission formally adopted the Telematics Applications for Passenger Services Technical Specifications for Interoperability (TAP-TSI), designed to ensure key timetable and ticketing information can be exchanged between EU rail companies and ticket vendors. TAP TSI requires the provision of computerised fare and timetable data for services on the trans-European rail system. Many operators already provide this voluntarily, encouraged by UIC, and TAP TSI sets out protocols for harmonised data on the type of service, when and where it calls, accommodation types, available unreserved seats and tariff structures. Its full implementation will allow a 'new generation of European rail journey planners and ticketing systems to become fully functional, operators will soon need to bring their IT systems and practices into line so that the standardised data can be exchanged and used.

For an overview of measures to reduce GHGs and make rail more efficient please look at ANNEX IIb.

[18] ERTMS Level 3, still in its conceptual phase, allows for the introduction of a “moving block” technology. Under ERTMS level 1 and 2, movement authorities are determined using “fixed blocks” - section of tracks between two fixed points which cannot be used by two trains at the same time. With ERTMS level 3, accurate and continuous position data is supplied to the control centre directly by the train, rather than by track based detection equipment. As the train continuously monitors its own position, there is no need for “fixed blocks” – rather the train itself will be considered as a moving block.

2.3. Aviation

Main Authors: P. Dilara, D. Schmitt

2.3.1. Current Status:

Aeronautics and air transport is a vital sector of our society and economy. It is also of great importance for the EU Member States. It is a sector in which European public and private stakeholders provide world leadership and helps to meet society's needs by:

- ensuring suitable and sustainable mobility of passengers and freight
- generating economic wealth and growth
- significantly contributing to the balance of trade and European competitiveness
- providing highly skilled jobs and innovation
- fostering Europe's knowledge economy through substantial R&D investment
- contributing in many ways to global protection, security and self-reliance.

Aviation's economic and societal contribution is substantial: in 2009 it generated around €220 billion[19] and provided 4.5 million jobs[20]. The value of this contribution is illustrated by the economic impact of the disruption to the European air transport system of 2010's volcanic eruption in Iceland which amounted to approximately €3.5 billion in the first week[21].

Over the past 40 years, the European aeronautic industry has, through collective European efforts encompassing public and private, major companies, thousands of small and medium enterprises (SMEs), academia and research laboratories, successfully raised from a niche sector to a world leading industry. Its products include aircraft, rotorcraft, engines, avionics and systems as well as leading operations and services. Aeronautics therefore continues to be a highlight of an integrated high tech research, development and manufacturing sector.

On average, 12% of aeronautic revenues, representing almost €7 billion per year for civil aeronautics alone, are reinvested in Research and Development (R&D). Every Euro invested in aeronautics R&D creates an equivalent additional value in the economy every year thereafter. Aeronautical technologies are catalysts for innovation and spill-over into other economic and technological sectors, thus contributing to the growth of the European economy as a whole. Around 20% of aerospace employees work on R&D.

Aviation is a vital facilitator of European integration and cohesion by providing essential transport links. It is an important enabler of prosperity and wealth creation for the Member States and their peripheral regions by stimulating development, opening new markets, boosting international trade and encouraging companies to invest.

Europe is home to approximately 150 scheduled passenger airlines and 450 airports, which in 2009 supported 751 million passengers[22]. World-wide, traffic is predicted to grow at a rate of close at 4-5% per year with even higher growth rates[23] in the Middle East and Asia.

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[19] The economic and social benefits of air transport 2008, Air Transport Action Group (ATAG)

[20] Delivering a bright future for European Aviation and Passengers. 5 year Strategic Plan 2010-2014. Association of European Airlines

[21] Flightpath 2050, Europe's vision for Aviation.

[22] Source: Eurostat

[23] Source: Airbus Global market forecast 2010-2029

The aviation sector is also fully aware of its responsibilities towards Europe's citizens: protection of the environment, security and safety. It is meeting these challenges successfully enabling its continued contribution to European economic and societal well-being.

Especially for what concerns the environment, aviation contributes less than 2% of global anthropogenic CO2 emissions, but is also the transport sector with the highest growth rate in GHG emissions with a global fuel consumption increase between 3 and 3.5% per year (ICAO Environmental Report 2010, pg. 18). At the same time, emissions of GHGs at high altitudes have different climate change impacts and issues such as the climate change impact of NOx at high altitudes or cirrus cloud formation are still open.

2.3.2. Vision and how to achieve it

The air transport and aeronautics sector in Europe is currently working towards two main goals: meeting Society's needs and winning global leadership. The vision developed is for a safe, reliable, affordable and quiet future air transport system with a zero emission balance, with well-informed customers and linked with other transport modes, in order to provide seamless transport to the European citizen. New entrants in the global market along with traditional competitors will require that Europe steps up its investments and coordination in order to capture part of the growing market and remain competitive.

This sector has put a lot of effort during the last decade to create a vision and strategic research agendas through the ACARE (the Advisory Council for Aeronautics Research in Europe[24]). ACARE has established in common agreement with private and public stakeholders a revised Strategic Research Agenda (SRA) and a Vision beyond 2020 (Towards 2050), which details the foreseen evolution of the sector.

Recently the Commission has published the "Flightpath 2050: Europe's Vision for Aviation"[25], a report of the High Level Group on Aviation Research. The vision for the European aviation in 2050 is extensive, holistic, highly ambitious and built on the parallel objectives of:

Maintaining global leadership:

- Providing the best products and associated services in aeronautics and air transport
- Ensuring the competitiveness of European industry, supported by a strong research network and balanced regulatory framework, in the face of fierce competition from both established and emerging rivals
- Maximising the aviation sector's economic contribution and creating value:
    - directly from aviation manufacturing, equipment, systems and services;
    - indirectly by creating demand up the supply chain, involving SMEs and based on cutting-edge research and education;
    - catalytically by providing the connectivity needed by other globalised industries and trade.
- Attracting the best people and talents

[24] http://www.acare4europe.com/

[25] http://ec.europa.eu/transport/air/doc/flightpath2050.pdf

- highlighting and publishing the innovation and success of the sector to create and sustain excitement around the European Aviation Vision and thus motivate young and ambitious talents.

Serving society's needs

- Meeting societal and market needs for affordable, sustainable, reliable and seamless connectivity for passengers and freight
- Supporting the integration and cohesion of the European Union, its neighbours and partners
- Addressing societal needs with non-transport aerial applications enabled by new flight control technologies
- Protecting the environment and ensuring sustainable energy supply
- Ensuring complete and non-intrusive security
- Ensuring safety
- Providing opportunities for highly qualified and skilled jobs

Many technological developments need to take place in the coming years to achieve such an ambitious vision. These can be broadly grouped under **innovative and efficient aircrafts, ATM improvements and infrastructure improvements**.

The ACARE SRA goals have had a clear influence on current aeronautical research. There is strong evidence of a vigorous programme of Aeronautics and Air Transport research, which is already delivering important initiatives and benefits for the aviation industry, including: EU collaborative research in Aeronautics and Air Transport (EC's Framework Programme research), the Clean Sky Joint Technology Initiative, the SESAR Joint Undertaking, national programmes in many Member States and research establishment as well as private company programmes.

Technological advances (like use of light-weight material and improved engine designs) and improved operations (including efficiency improvements in air traffic management) can help in reducing aviation fuel consumption and associated carbon emissions. The Commission, has and should continue to fund targeted research, in accordance with the ambitious Flightpath 2050 document.

On a per-flight basis, efficiency is expected to improve continuously through 2050 and beyond. However, even under the most aggressive technology forecast scenarios, the expected gain in efficiency from technological and operational measures does not offset the overall emissions generated by the expected growth in traffic.

The Flightpath 2050 has set a goal for an 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 be in operation, 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.

2.3.2.1.Vehicle design and Propulsion technologies

The aircraft have not changed much its external shape over the last 50 years. This indicates that a fairly good compromise between all conflicting disciplines like aerodynamics, structures, flight mechanics etc. has been found in today's vehicle design concept. There are however several alternative configuration options, which may push for a new vehicle concept. Especially the development of further propulsive efficiency will drive the aeronautical industry to investigate the concept of "Open rotor propulsion systems" which will provide the next technological step in fuel reduction (up to 15-20%), but will also lead to a new vehicle configuration. This new "open Rotor concept" may already be needed for the next Single Aisle aircraft (A320 replacement, EIS 2030 ?) and major technological investigations about the viability of such a new configuration have started in the JTI "Clean Sky" and may need a follow-up JTI for the validation of the entire vehicle concept before the industry will be able and confident to bring such a new and promising vehicle concept to the market.

Alternative configurations have been proposed and investigated over the last 30 years. Promising candidates have been identified and analysed in several research projects (Blended Wing Body (BWB), Low noise configurations, Joint Wing concepts, Morphing airframe, etc), which partly have already shown interesting improvement potential. These concepts and all their accompanying technologies in all different technical domains will have to be further analysed and elaborated.

More Electrical Aircraft (MEA) concepts are a constant challenge in the aircraft industry with a potential to deliver a 5 to 10% fuel efficiency improvement till 2020[26]. With the further development of electrical car vehicles and concepts, electrical energy storage devices (batteries), some good spin-off is expected to also increase the electrical power system on-board the aircraft, push for more electrical energy recovery from wind and sun and develop new electrical energy architectures for a better overall aircraft efficiency. The fuel driven APU (Auxiliary Power Unit) is the first candidate for the introduction of such new and innovative concepts.

In 2050, the diversity of air vehicles operating in common blocks of airspace is expected to be many-fold, including: a range of next generation wide and narrow body (including Blended Wing Body (BWB)), commercial aircraft, executive/business aircraft, advanced rotorcraft of all types including tilt-rotors and contra rotating systems, specialised aircraft (quiet short-take-off and landing (QSTOL), private flying machines and remotely controlled unmanned aircraft systems (UASs). A proportion of these vehicles will be pilotless and some are autonomous. Non-transport aviation missions will have increased significantly and will be undertaken by remotely controlled and autonomous vehicles, particularly where missions are simple and repetitive, dangerous or require long endurance.
Still the foreseeable vehicle (and engine) changes till 2020 are only expected to bring about 25 to 30% fuel burn improvements[26], while more significant savings (up to 50%) might be expected with post-2020 technologies.

2.3.2.2.Fuels

A promising approach toward reducing GHG emissions is the development and use of sustainable alternative fuels for aviation. Today such fuels are not available in sufficient quantities to meet the overall fuel demand for commercial aviation.

[26] The IATA Technology Roadmap Report, 3rd edition, June 2009.

Sustainable drop-in alternative fuels produced from biomass or renewable oils offer the potential to reduce life-cycle greenhouse gas emissions and therefore reduce aviation's contribution to global climate change. However, feedstock availability and the complete life-cycle assessment (Well or Field to Wake) are still major issues.
Alternative fuels can be produced through other alternative ways and feedstocks, but more research is needed to identify novel feedstocks and processes. Raw or intermediate products from biomass could be fed into current refineries together with petrochemical oil; a new plant could be established (most likely near to the feedstock source or near infrastructure) or it could be integrated in other industrial plants. Today it is commonly agreed that only so-called "drop-in" fuels (i.e. fuels with similar characteristics like today's Kerosene, but produced in a low carbon way) have a chance to rapidly replace petrochemical jet fuel, i.e. those that can be used for current aircraft engines and fuel distribution infrastructures without modifications, and be blended with current jet fuel. For the implementation of non-drop-in fuels (e.g. hydrogen, liquefied gas) there are considerable challenges to overcome[27], such as significant costs for their implementation.

Currently, ASTM has approved the Fisher-Tropsch synthetic paraffinic kerosenes (FT-SPK) for use as alternative fuels for aviation. These are made of coal (CTL), gas (GTL) or biomass (BTL), all of which are now approved for commercial use in blending ratio up to 50% with Jet A.1 fuel. Hydroprocessed oils (HO), producing synthetic paraffinic kerosene from plant oils or animal fats (often referred to as Hydroprocessed Renewable Jet (HRJ)), are presently following the same track and have already undergone numerous flight demonstrations. Especially the biomass-derived fuels (BTL and HRJ) have the best potential to significantly reduce life-cycle GHG emissions, although a major issue is still the indirect land use change (iLUC) for which currently no methodology or certification approach exists. Algae appears as a promising candidate, since they promise higher yields than terrestrial crops and have modest requirements on land quality, avoiding a direct competition with food. Research is however required to confirm at industrial scale the high performances obtained at lab or pilot scales and to reach competitive cost.

The cost and availability of sustainable drop-in alternative fuels for aviation are barriers to their large-scale adoption. In the SWAFEA analysis [27], it has been concluded that reducing aviation emissions by 50% in 2050, compared to 2005 levels would call for an excessive allotment of the potentially available biomass, while achieving carbon neutral growth by 2050 seems more feasible without considering very radical innovation.

The testing and certification of new fuels and the establishment of new production facilities require significant capital investment. It is also feared that since aviation consumes currently less than 5 per cent of the world's liquid fuel, it is possible that alternative fuel producers may initially target larger markets. However, adoption of alternative fuels by aviation might be simpler than for other sectors due to the relatively small number of fuelling locations and vehicles and that aviation is a unified and committed industry buyer due to the single type of fuel used by its turbine powered equipment that will continue to use liquid fuel for the foreseeable future.

[27] SWAFEA Final Report D.9.1. 2011.

2.3.2.3.Air Traffic Management

With the development of a Single European Sky[28] and the SESAR Joint Undertaking[29], new technologies will be developed which will allow for more automation in the system and a better use of already existing and proven technologies for a future air transport system. The continuous increase of air transport can only be handled in the future with the implementation of the SESAR objectives. In addition a continuous political will in Europe will be needed to install and implement the new European ATM system with the capability to further improve safety and efficiency.

The capabilities of GALILEO[30] will also be required and used to change the ATM system drastically from the old system with a fixed glideslope and the technologies of the fifties to a new standard. The integration of GALILEO navigation capabilities with the new SESAR concepts will define the new ATM system of the future. This new ATM standard will have to be developed on a global basis, but will also provide the opportunity to export technologies developed in Europe to other countries and continents.

The main goal in this field is to achieve a fully functional Single European Sky promoting seamless air travel. Although the European Aviation Sector holds a very competitive role, recent events, such as the volcanic ash crisis, have proven how urgent it is to move towards an integrated EU airspace. The Single European Sky (SES) Legislation aims at tripling capacity, reducing ATM cost per flight in 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 air traffic management system capable of ensuring the safety and fluidity of air transport worldwide over the next 30 years. It is a three phase Programme that has defined, is developing and will deploy a high quality, new generation of ATM technologies, systems and procedures compliant with SES objectives and requirements.

SESAR is composed of three phases:

The definition phase (2005-2008) has defined the roadmap for the achievement of ATM performance levels and the establishment of a high level work plan that defines the content of the next generation of ATM systems identifying the necessary elements for its realisation. The definition phase was carried out by a consortium of 30 organisations representing a wide range of ATM stakeholders, under the technological coordination of Eurocontrol. The total cost of this phase was 60 million EUR financed in equal parts by the EU and Eurocontrol.

The development phase (2008-2013) is developing the necessary elements on the basis of the results of the definition phase. The management of the development phase is entrusted to the SJU. The estimated cost of the development phase is 2.1 billion EUR and is financed by the members of the SJU combining public and private funds.

[28] http://ec.europa.eu/transport/air/single_european_sky/single_european_sky_en.htm

[29] http://www.sesarju.eu/

[30] http://www.esa.int/esaNA/galileo.html

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

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 Council of the EU and recognised by all the 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 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. SESAR has enabled the EU to enjoy today a strong position internationally and has become a reference programme in the domain of ATM modernisation. This has facilitated the launching of several cooperative projects and agreements with third countries, which entail significant opportunities for European industry and employment reinforcing European leadership in this sector.

2.3.2.4.Intermodality issues and airports

In 2050, the European air transport system is expected to be integrated in a complete logistical transport chain and part of a fully interconnected, global aviation system that is based on a multilateral regime rather than on a series of bilateral agreements. Interoperability between Europe and the other regional components of the global network is complete. Commercial air transport services are provided mainly by airlines organised as a few global alliances. Europe leads the world in the implementation of international standards covering all aviation issues, including interoperability, the environment, energy, security and safety. European leadership ensures that the global regulatory system enables, rather than hinders, market access and free, fair and open competition.

Even with the advent of high-speed rail, the distance involved means that passenger air transport remains the only viable direct way of connecting Europe’s regions for a day trip. Aviation offers the most efficient means of transport, even for shorter distances in some difficult geographical areas, air transport is the principal way of conveniently satisfying the growing demand for diffused, flexible point-to-point connections. The number and quality of aviation market services has increased significantly mainly because of passengers demand to plan and predict their journeys in real time whilst at the same time staying connected to work, relatives and friends.
During the development of the ACARE SRA1 in 2002, a challenge of a 15 min transfer time between arriving at the airport and entering the aircraft has been defined. But this challenge has never been fully implemented by the airports in Europe. Security checks have further increased this time delay. However most of the passengers are expecting a better interconnection compared to today’s standard. Some additional efforts, ideas and improvements are needed.

Seamless connections need to be developed for reaching the airports without delays from city centres and to provide a door-to-door service. Furthermore, there is a current

trend to put emphasis in the commercial side of airports, increasing their business portfolio as social event managers, which are offering shops, restaurants, hotels, meeting facilities and even general exhibitions and leisure events. There is a need to develop technologies and design concepts, which can address the needs of a variety of users: those valuing short time connections and those valuing the shopping and leisure experience.

There also seems to be a big potential for a more efficient logistics system for Europe by developing an efficient future cargo transportation system, using all modes, including aviation, in the most efficient way. This aspect deserves further research efforts in order to identify the strengths and weaknesses for each mode and identify possible solution for a future cargo transportation network for Europe with open links to intercontinental regions. Further details on this, can be found in the Chapter 2.7 on Logistics.

In the past air freight was mainly transported by passenger aircraft, filling the free cargo capacity of passenger aircrafts. This meant that all air freight handling had to be at the same place and the airport had to handle both. There are however also some small examples of specialised airports (Luxembourg, Leipzig,) where freight is playing a stronger role due to a typical cargo airline, which has its main hub at this airport. Connections do exist with road, but rarely there is a rail connection for freight in current EU airports.

2.3.2.5.Safety and Security

The safety standard in air transport in Europe is very high and statistics are showing a good record. However safety is a continuous effort and can never be neglected. Safety standards are defined by international authorities. Europe has the JAR regulations, which are since some years further developed and implemented by EASA. This authority will need to critically review all the standards, which have been developed over the last sixty years and more. Also the continuous development of new technologies needs the parallel development of the regulatory standards. It is felt that some more research needs under the leadership of EASA may help Europe to further improve safety standards. The same can be applied to security issues. An independent European view on security should be developed, taking into account the EU political dimension and the continuously changing technological challenges.

Safety standards are different between the commercial air transport and the General Aviation sector. The review of safety standards has therefore to take into account this situation and all process improvements have to be adapted to the different users.

2.3.2.6.Other (Mainly regulatory issues, Standardization, ..)

The competitiveness of the European aeronautical industry has been a major focus during the last 20 years of EU aeronautical research (FP4 – FP7). The situation has not changed drastically. A big success story is the development of Airbus from a small aircraft manufacturer to a major player in this field, being at the same commercial level as the US manufacturer Boeing. Also the situation of the European engine manufacturers (Rolls Royce, Snecma, MTU et al) has changed considerably over the last decade. Therefore the competitiveness of the EU industry still has to be kept as a major element of the European STTP Research Agenda.

New regulations and standards like the proposed ETS System for air transport have to ensure that they will not only be applicable for European airlines but also for all airlines operating into European terrain. More stringent regulations for the air transport sector for further improving the environmental repercussions may be seen as a good political instrument. It is however indispensable, that the similar political effort has to be done on an international rule making process to keep the European industry, the operators and the service providers at a similar playing level as the non-European actors.

2.4. Waterborne transport (maritime/inland)

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The waterborne transportation sector includes international shipping, sea motorways, short-sea shipping and inland navigation, which represent three almost completely different contexts although owning obvious similarities. Furthermore, from a technological point of view, opportunities offered and constraints imposed by the land proximity, make the inland navigation, substantial different from maritime transport. The vision of the European waterborne sector is to keep its leading role (in both the European and the global market) while reducing its externalities (see table 2 in Annex II) and increasing its efficiency in the maritime transport and to attract traffic flows of goods and passengers from the other land-based transportation modes for what concerns the inland navigation.

This vision can only be achieved if the system is able to move away from the current status, adopting new technical/technological and organizational strategies. In particular, the organizational aspect is very important. A key role is expected from a more efficient integration of the waterborne transportation system in a broader intermodal system. This is of course not straightforward and requires several steps in order to efficiently exploit the capacity of the different transport modes involved. The "Motorways of the Sea" concept goes in this direction. It was introduced by the 2001 Commission White paper on transport with the aim of improving access to markets throughout Europe. For this purpose, fuller use will have to be made not only of the maritime transport resources, but also in rail and inland waterway, as part of an integrated transport chain.
For the purposes of the STTP scientific assessment the present section analyses separately the technological options of maritime transport and inland navigation.

Maritime transport

2.4.1. Current Status

Maritime is and will continue to be by far the most important cargo transport mode. Indeed, maritime transport accounts for approximately 90% of EU external trade and for 40% of EU internal trades. World-wide seaborne trade has quadrupled in the past 40 years and container shipping, in particular, has expanded by 11.5% a year since 2000 (excluding the economic crisis years – 2008 – 2010), expected to a 6-fold increase by 2020[31]. The prime reason for that is the growing share of the international trade in the global output.

This situation has caused, in recent years, public concerns on the increase of the environmental impacts of maritime transport. Indeed, in spite of the higher efficiency of maritime transport (in terms of emissions and safety) with respect to other transportation modes, the analysis of the main impacts of maritime transport activities on air quality highlights the fact that the sector is responsible for a notable amount of total CO2 emissions and air pollutants. This is especially worrying in areas where ships concentrate (i.e. around ports, which are usually close to densely populated areas).

In addition, the existing trends suggest that the situation will worsen in the future (e.g. Miola et al, 2010; IMO, 2009; Lauer et al, 2009) as ships are likely to need to comply with less restrictive standards then the other land-based emission sources. As a result the whole sector is required to increase its efficiency and reduce its impacts (Notteboom, 2011). In addition, despite the efforts carried out in the past, the system is also called to further increase its safety and security, as well as its competitiveness at the European level (Waterborne, 2010). Europe, indeed, plays (and aspires to play in the future) a leading role in the globalized maritime market from both the industrial and operational perspective.

2.4.2. Vision

New technologies are now available, ready to use, and with proven results. All of these, together with the use of alternative "greener" fuels, can help reduce emissions of NOx by up to 80%, PM by up to 90%, SOx by up to 90% and CO2 by up to 70% (IMO, 2009). The estimation of the costs of such technologies is fundamental to assessing the feasibility of their application in the sector.
In the tables 2 and 3 a summary of the available technological options for the maritime transportation sector and their estimated abatement potential and cost-effectiveness is reported (source Miola et al., 2010).

The definition, in the near future, of an Energy Efficiency Design Index (IMO, 2009b), which the new ships will be required to comply with, should foster the promotion and the introduction of technologies for ships' resource efficiency. However, due to the long ships' life, it is expected that this will actually contribute to increase the overall energy efficiency of the maritime transport sector only in the long run. Other actions are therefore necessary in the shorter term.

In the following some additional details about the available technological options in the different components of the maritime transportation system are provided. It is

[31]Michel, K., Noble, P. (2008). Technological Advances in Maritime Transportation.The Bridge.National Academy of Engineering of the National Academy of Science. Washington DC.

worth knowing that the introduction of many of the following technological options has been envisaged by different sources (e.g. the European Technology Platform WATERBORNE, which includes all the principal stakeholders of the European waterborne transportation sector Waterborne, 2010).

2.4.2.1.Ship design

A more efficient design of ships may contribute to reduce the total energy required by ships' activities. Several options are available.

Increasing the size of some ships may turn in an efficiency of scale, in particular where the traffic demand of freight and passengers is very high, however most of the existing ports are inadequate in hosting such bigger ships (Malacca-max ships).

Other promising options include the use of lighter materials in ship construction, new shapes that reduce their motion resistances (which is to some extent constrained by the shape of the cargo), and the introduction of air lubrications systems, which use air to reduce the friction between the water and the hull (Eide et al., 2010).

All the previously mentioned options apply for new ships. Existing ships, which will continue to represent the majority of the ships for the next 15-20 years, would also need retrofitting measures in order to increase their efficiency. A possible option, whose effects have been proven, regards the minimization of the resistances associated to transverse thrusters' openings of the ships' hull. Optimising the design of those openings which increase the manoeuvrability of big vessels will result in a significant increased efficiency. The resistances reduction can be achieved, for example, by adding grids to the openings (Hazeldine et al., 2009).

2.4.2.2.Propulsion

The energy absorbed by the propulsion system accounts for a very high proportion of the total energy required by a ship (ranging from 60 to 90% depending on the ship type). Increasing the propulsion efficiency/effectiveness is therefore a topic of great interest in the field. Several strategies can be adopted with this aim, such as introducing: i) optimised interaction between propeller and hull, ii) propeller-rudder combinations, iii) advanced propeller blade section, iv) propeller tip winglets, v) propeller nozzle, vi) propeller monitoring, vii) contra-rotating propellers (Buckingham, 2010). Almost all these strategies can be applied to both new and existing ships (apart from the last one). All can be applied to tankers, bulk ships and containers, while only some of them can be applied to the other ship types. Their payback period is generally short. Overall, these strategies can contribute to a 15% increase in efficiency.

Another important option to reduce the role played by the propulsion on the ships' fuel consumption is to exploit renewable sources of energy like that made available by the wind. Different possibilities for harnessing this energy exist (Buckingham, 2010). One option would be to install sails on the deck or to attach a kite to the bow of the ship (the potential effect of this system is still controversial, but the more optimistic sources consider an increase in efficiency of up to 20% for all kind of ships) while another would be to use vertical rotors which can convert wind power into thrust, exploiting the so-called Magnus effect. The latter, can only be applied to tankers and ro-ro ships and can potentially improve efficiency by up to 3% (Buckingham, 2010). A medium payback time characterizes both options (Wartsila, 2009). According to Faber et al. (2009), rotors placed on ship decks can help to reduce fuel consumption by between 3.6% (for a crude oil tanker with deadweight (dwt) < 200,000 tonnes) and 12.4% (for a bulk carrier with dwt< 99,000 tonnes). In the scenario of using a towing

kite to use the wind energy, the optimal configuration is achievable only with vessels of a minimum 30m in length and a minimum speed of 16 knots. Therefore, only tankers and bulk carriers are considered as potential users (IMO, 2009).

2.4.2.3.Machinery

Machinery is another sector in which the research in energy efficiency and in the use of alternative energy sources is very dynamic. Different technological options are available. However it is important to underline that, due to the high power requested by the propulsion system, the only energy source able to substitute the current internal combustion engines is the nuclear one for ships involved in maritime traffic. In general, for big vessels a possible alternative is the use of hybrid systems, composed by different sub-systems (e.g. fuel cells, diesel engines, batteries) that are dynamically controlled in order to maximize the overall efficiency.

Efficiency improvements can also be achieved on internal combustion engines. Buckingham (2010) reports, for example, that the use of Isoengines may contribute to a reduction in fuel consumption of about the 20%.

Another option to increase the efficiency of the energy production is to reduce the waste of potentially usable energy sources. Among the possible options, the conversion of the thermal energy in the exhaust gases is a promising option. Also the use of wind power (already mentioned before) and solar power are interesting possibilities for those ships having considerable free surfaces able to host wind turbines or solar panels (Buckingham, 2010).

In order to reduce ships externalities when they stand at berth the possibility to switch off the (auxiliary) engines and to take electric energy from the shore is attracting the attention of manufacturers and policy makers. The main aim is to move polluting emissions away from the ports, which are usually situated in proximity of densely populated areas. In addition the higher efficiency of land-based electricity generating plant with respect to the ships' engine would produce also globally a reduction in the emissions. However, this technology still presents significant barriers, in particular for the necessity to make available, in port areas, significant amounts of electric energy power and for the international standardisation that the port-to-ship electrical connections will require. Also the use of "stationary" fuel cells on board ships is considered for auxiliary power applications.

Finally, in order reduce ships' impact on the environment it is possible acting on the products emitted, rather than preventing their production. For air emissions scrubbers and other comparable systems can be used. For garbage, there exist waste compressors or plasma technologies able to transform the waste. For black and grey water systems (like membrane bioreactors) are able to clean the polluted waters allowing its direct release in the sea. The use of scrubbers is particularly envisaged for existing ships, in order to reduce the environmental burden they produce already in the short term.

2.4.2.4.Operation, traffic management, intermodality and the role of ICT

More efficient use of the waterborne transport is enabled by a more extensive application of information and communication technologies to the sector. In maritime traffic, a clear example is the possibility to modify (even slightly) the ship routes in order to minimize the fuel consumption (weather routing). A debated option to reduce fuel consumption and emissions from ships is speed reduction (emissions from a vessel are indeed roughly related to its third power). This strategy might be preferred by ship operators in the event of the introduction of CO2 trading schemes. The problem

is the type of strategy adopted to preserve the scheduled frequency. Should the time lost be recovered through reduced in-port turnaround time, then the abatement of CO2 emissions is likely to be even higher. On the other hand, should additional ships have to be added, the reduction will be less significant (in this case this option would lead to a dramatic increase in operating costs and thus it is unlikely that ship operators would accept it).

Slower speed can also be coupled with larger vessels, especially changing the maritime transportation system configuration from multi-porting to hub port. In this way, very big (Malacca-max) and slow ships can travel among few and efficient hubs. Passengers and goods may reach the other ports via more efficient vessels for short-sea shipping (Nottebom, 2010).

Classified as operation option, even if of totally different nature with respect to the previous ones, is the hull monitoring and cleaning activities. With the time passing, the ships' hull starts being covered by algae and organic material. This can significantly contribute to increase the ship's resistance. Decisive factors for hull performance are the age of the ship, the time spent in port, service speed, water temperature, the effectiveness of sacrificial anodic protection and the changes in the draft and duration of loading conditions. Options that are readily available to help improve the ship's performance include maintenance, surface pre-treatment, coating and repeated dry-dock interventions (Kane, 2009). Frequent cleaning can help improve efficiency by about 3%.

The interface between ship and shore, i.e. the loading and unloading methods and equipment, need also to be addressed. Various methods, such as block methods for the container ships, ship own cargo handling systems, work between hull and shore etc., should be developed to increase effectiveness and decrease ship's loading and unloading operations time.

2.4.2.5.Fuels

Different options are available and can contribute to reduce air emissions from vessels. Low-sulphur fuels (containing less than 0,1% of sulphur) will be soon (2015) mandatory in sulphur emission control areas (SECAs, Baltic Sea, North Sea, English Channel, US and Canadian coastlines and probably, in the near future, also Mediterranean Sea and Black Sea). In addition, in 2020, the maximum content of sulphur in the fuel will be set to 0.5% globally (today the average figure for the sulphur content in marine fuel is 2.7%).

Water emulsified fuels also represent a possible option, producing a reduced quantity of nitrogen dioxide, hydrocarbons and particulate matter. Alternative fuels, such as LNG (liquefied natural gas) and biofuels, are also attracting a lot of attention due to the absence of pollutants and the reduced emissions of carbon dioxide (-15%). Their introduction has, however, to face some barriers. Biofuels have first of all to reach a large-scale availability. Availability of LNG is, instead, already good. The problem of LNG is its volume. Indeed, in order to cover the same trip, the volume required to bunker LNG is three times that required to bunker conventional fuels and it requires an LNG fuel supply network. As a consequence, at the moment, it seems suitable for short sea but not for transcontinental shipping.

Switching much of the shipping fleet from heavy, high sulphur bunker fuels to lighter diesel fuels will require investment in new refining capacity. The resulting increase in the cost of marine diesel fuel will put ship owners under greater pressure to improve fuel efficiency and, when translated into higher cargo rates, may slacken the growth in

demand for shipping services. It may also encourage the development of on-board 'scrubber' technology to reduce/eliminate sulphur emissions from vessels still burning dirty bunker fuel. An appropriate regulatory and funding scheme able to foster the introduction of the new technologies without affecting the sector competitiveness will thus be needed.

2.4.2.6.Infrastructure

A further problem that the growth of maritime trades poses regards their main infrastructures, the ports. Ports are the trade gateways to the world. Actually, 3.5 billion tons transit through the EU ports each year, representing 90% of the international trade and 40% of the internal market. Although there have been massive investment projects, especially in Mediterranean and other EU seas basins, container terminals may represent a bottleneck in the near future.

Europe's coasts are very densely populated leading to a fierce competition for coastal zone use and accentuating any environmental, safety and security issues. Indeed, ports are most often close to densely inhabited areas, even integral parts of coastal towns, so their interaction with the regional social tissue and territory is a key consideration.
Although no major breakthrough is expected in port technologies, improvements in port reception facilities can increase significantly the efficiency and lower the overall environmental impact of shipping. Of great importance is the ability of some ports to receive "super large" containerships, which could have an important economy of scale. Adaptation implies creating the necessary draught in order to host this type of ships (up to 21m) and to have more efficient system to load and unload their cargo in a reasonable time. Another infrastructural improvement for ports is the possibility to directly supply ships with shore-side electricity.

A further point which requires a careful sustainability analysis, is the construction of a number of so-called multi-purpose islands in front of the European coasts. Such islands could represent an option for coastal defence, for providing a place of safe refuge for ships encountering structural problems during their journeys and also for hosting the super large ships mentioned before. Further studies are however needed to understand the feasibility of their realization, from a technical, environmental, social and economic point of view.

2.4.2.7.Safety and Security

Both security and safety are relevant issues for the whole waterborne transportation sector.
Ports are very important transport network nodes and border checkpoints. The challenge faced, to which technology is called to provide an answer, is to achieve reasonable security levels while maintaining (even enhancing) the port system efficiency and productivity. In this light, the EU has opted for a strategy in which all exports and imports will undergo a multilayered risk management process, which will trigger research for identification of best screening technologies and algorithms.

Ships' accidents are fortunately rare events. However when they occur, their consequences can be catastrophic both for passengers and the surrounding marine ecosystem. The International Maritime Organization (IMO) has defined an international regulatory framework aimed at increasing the safety of the maritime transportation system. Basing on the IMO one, the EU has defined its own regulatory framework. Furthermore the EU has underpinned a series of action aimed at facilitating the monitoring and the control of the safety of the entire system. Furthermore, the EU will assess the possibility for the creation of an EU register and an EU flag for maritime

and inland waterway transport as a means to provide EU ships with a sort of quality label, certifying safety, security and environmental friendliness

Finally, the Commission has recently launched a pilot project in order to reduce the administrative burden, which currently hampers the spreading of short-sea shipping in the internal market. The project (aiming at the creation of a “blue belt” around European coasts) is based on the application of the SeaSafeNet information system. The system will allow the identification of those ships exclusively engaged in internal traffic, allowing for them to be treated in a smarter way (EMSA, 2011).

Inland navigation

2.4.3. Current status and vision

The inland waterway transportation sector is one of the most underutilized transport modes in Europe. According to the latest statistics it accounts for the 5.2% of total land-based transport in Europe. However, it has an enormous potential of growing, in particular thanks to the relatively small residual capacity for the other land-based transport modes but also to the overall low costs of its services and its low carbon footprint/energy consumption. The realisation of this potential, however, is hampered by several organizational/technological barriers. Actions and investments are thus required for the development of the system. In this light, the Commission adopted an action programme on the promotion of inland waterway transport NAIADES (Navigation and Inland Waterway Action and Development in Europe[32]), including the set-up of the PLATINA (Platform of implementation of NAIADES).

High investments are necessary in order to improve the connection of the inland waterway transport to the other transport modes. Indeed, since the inland waterway network has a limited geographical scope (and it is not expected to grow significantly), it is not possible to see an increase in the use of this transportation mode without its efficient integration within a wider logistic system (Blaauw et al., 2006). An important role towards a more efficient and effective use of inland waterway transport is expected from the integration of the different river information systems (RIS) that have been established in different regional contexts.

From a technical/technological point of view, the system is expected to benefit more from the introduction of alternative fuels/energy sources than the maritime sector. Due to the relative small size of the inland navigation vessels, LNG, bio-fuels, fuel cells and electricity (and their integration) may represent a realistic alternative to fossil fuels in the short/medium run (EBU et al., 2011) and would allow the sector to contribute to the improvement of the air quality.

Another point, which is attracting the attention of researchers, regards the vulnerability of the inland waterway to climate changes. Extreme conditions (both due to extreme cold or extreme hot weather) may indeed affect the system reliability and its efficiency. This point is expected to become extremely relevant in the next year and will call for the implementation of adequate adaptation strategies (Koetse and Rietvled, 2009).

In the following some additional details are provided with regard to the technological and technical options available for an inland navigation to become safer, more reliable, more sustainable and more competitive compared to the other land-based transportation modes.

2.4.3.1.Ship design

Many of the solutions mentioned for maritime transport can be adopted for inland waterway vectors (with, of course, a difference of scale). Increasing barges' size (where possible), optimizing the design of their hulls, using composite materials and

[32] http://www.naiades.info/

lightweight structures are indeed technical solutions potentially available also for inland navigation (Hazeldine et al., 2009).

Fluctuations in the water level can change the distribution and the nature of the motion resistances (Radojcic and Bowles, 2010). This results in a considerable increase in fuel consumption and emissions, which affect also the system competitiveness (Koetse and Rietveld, 2009). Focusing ships' design on the minimization of the dependence from the water level can provide significant benefits to the inland navigation system (Radojcic and Bowles, 2010). Hull cleaning and monitoring activities, as described for maritime transport can be considered also for inland navigation.

2.4.3.2.Propulsion

Most of the options presented for maritime transport can be considered for the inland navigation as well. Barges' propeller propulsion efficiency can be improved by, e.g., ducted propellers, contra-rotating propellers and propeller boss cap with fins (Hazeldine et al., 2009). New propeller concepts are also being tested. For example, whale-tail propellers have shown a higher efficiency (Hazeldine et al., 2009). Wind power is not an alternative for inland navigation, due to land proximity.

2.4.3.3.Machinery

For inland navigation the energy required for ships to move and for on board devices to work is more limited than that required in maritime traffic. Fuel cells and electric engines can therefore play a significant role in making inland navigation even more environmentally friendly and efficient (Hazeldine et al., 2009). Also the use of scrubbers and shore-side power can be applied also to inland navigation.

2.4.3.4.Operation, traffic management, intermodality and the role of ICT

The creation of an optimized and integrated logistic platform is at the forefront of the strategy for the promotion and the development of an effective and sustainable inland waterway transport. The previously mentioned NAIADES framework and the consequent PLATINA project strongly focus on these aspects. Example of already existing European national river information systems and infrastructures are ARGO, BICS, BIVAS, DoRIS, ELWIS, IBIS, GINA, IVS90, NIF, VNF2000, VTS's Rhine (see Mihic et al., 2011 for a more comprehensive description). Such information systems have an important role in keeping always an adequate level of service of the waterway network, allowing for a fruitful traffic management.

2.4.3.5.Fuels

Inland navigation fuelling opportunities are different from those of maritime transport. Indeed, on one hand, the shore proximity would require ships to be compliant to the pollution limits of land-based sources. On the other hand, such a proximity as well as reduced fuel consumption, would allow a faster introduction of alternative fuels in this sector (LNG might be implied without particular problems, once it would be widely available on the inland waterway LNG fuel supply network).

2.4.3.6.Infrastructure

As for maritime transport, also for inland navigation ports areas play a fundamental role for the competitiveness and the efficiency of the system by providing the necessary facilities for an efficient integration with the other transportation modes. As required in the "Motorway of the Sea" concept, the correct and efficient use of mode

interchange areas plays a fundamental role in the optimal use of the transport capacity that the whole transportation system makes available. All this requires infrastructural as well as operational investments in order for the ports to reach the required level of service. This concerns not only the inland ports, but also the accessibility of seaports for barges which require adapted infrastructure.

2.4.3.7.Safety and security

The peculiarities of river environments make safety one of the main issues for inland navigation. Actually the system is probably the safest transportation system and therefore this issue is not at the centre of the political debate. One of the reasons why the system is so safe is the lack of congestion. As the traffic will increase, also the overall safety might be reduced. This is not necessarily true, but measures need to be considered in advance. River Information Systems, which are mainly used to check and control the reliability of the logistic chains involving inland navigation, may in turn represent the principal source of information for safety and security monitoring and control. As already anticipated, one of the main issues for RIS is the integration of the several information systems implemented on a local scale. This integration would represent a considerable contribution in the creation of a single information system to be managed, hopefully, at the European level.

2.5. Fuels and energy

Author: L. Lonza

2.5.1. Current Status:

Fuels used today in the transport sector are mostly produced using non-renewable fossil sources. Despite constant improvements in energy efficiency over the past years, benefits have been systematically offset by increased fuel demand volumes and higher congestion levels.

Oil is the main energy source for transport overall, supplying about 96% of transport fuels. In view of both security of supply and environmental concerns, oil substitution is today a must and is indeed a key policy objective for the European Union[33]. Alternative, non-oil based fuels, are seen as the ultimate solution to meet EU policy objectives.

In this respect, the energy mix of primary energy sources, for instance the electricity mix, need to be carefully considered when analysing the environmental impacts of specific fuels and energy carriers.

Increased energy efficiency today cannot be considered as an alternative to oil substitution. It is yet a relevant tool to alleviate pressure on oil demand and – subsequently – on oil dependency of the transport sector: increased efficiency of the overall functioning of the transport system, including enhanced management of transport volumes and flows, equally play a very important role.

Today's available and tomorrow's prospective fuel alternatives vary substantially per transport mode: whereas jet-fuel production is today almost entirely oil-based, both fuel alternatives – such as biomass-based fuel components and the electric option – and powertrains – including various hybrid solutions – are already marketed (or close to market) alternatives for road transport. Another key aspect when analysing the different situation per transport mode is the extremely different lifetime of vehicle/ vessels and aircrafts and therefore the significantly time leads required to achieving a substantial fleet renewal per mode.

2.5.2. Vision and how to achieve it

The mix of fuels is not expected to change significantly by 2025[34]. This implies that a range of fuel options for different transport modes and even within modes will be present in Europe at research and market deployment phase for transport fuels and energy carriers. Oil substitution in transport is expected to progress with the improvement of transport efficiency and management of transport volumes, while main alternative fuel options are being fully developed and introduced in the different transport modes depending on the specific life span of vehicles/vessels in each

[33] Spring European Council, Presidency Conclusions, 7880/1/09 of 29 April 2009 re-affirming the commitment to limit global warming to below 2 °C,
Europe 2020. A strategy for smart, sustainable and inclusive growth, COM(2010)2020 of 3 March 2010

[34] http://ec.europa.eu/transport/urban/vehicles/directive/doc/2011_01_25_future_transport_fuels_report.pdf

http://www.eutransportghg2050.eu/cms/assets/EU-Transport-GHG-2050-Final-Report-22-06-10.pdf

transport mode. At the same time, despite alternatives, long-distance transport is expected to remain largely dependent on liquid fuels. Decarbonisation of transport and energy generation should be considered as complementary, yet requiring different technical approaches. The current imbalance in diesel-gasoline refining is expected to remain with increased imports to Europe not only of primary sources but also refined fossil products (diesel and jet fuel in particular). Tightening controls on sulphur emissions from the maritime sector will further increase demand for diesel as shipping reduces its reliance on heavy bunker fuels.

Main fuel alternatives are:

1. Electricity and hydrogen: can be produced from all primary energy sources, therefore both pathways can be CO_2 free depending on the primary energy sources used for electricity and hydrogen production. Propulsion uses electric motors. Energy can be supplied to vehicles via:

(a) Battery-Electric Vehicles (BEVs): with on-board electricity storage, power transfer between grid and vehicle requires new infrastructure/grid management. Application addresses short-range road transport and rail. Strategic issues: development of cost-competitive high energy density batteries and the build-up of charging infrastructure. Huge funding is being devoted to battery research, which increases the chances of a technological breakthrough within a short timeframe. Yet, issues such as range, capacity, storage and recuperation of energy are certainly key outstanding issues. Infrastructure is another determining factor to deployment.

(b) Plug-in Hybrid Electric Vehicles (PHEVs) represent the short-term solution before BEV technology reaches market maturity stage.

(c) Fuel cells powered by hydrogen, used for on-board electricity production. Hydrogen production, distribution and storage require new infrastructure. Application is unlikely for aviation and long-distance road transport. Strategic issues: development of cost-competitive fuel cells, on-board hydrogen storage, refuelling infrastructure. In particular, economies of scale need to be reached despite unit cost reductions being already substantial. The current composition of the European passenger car fleet characterised by growing dieselisation makes the replacement by hydrogen vehicles less likely than it is the case in other world regions characterised by a higher presence of gasoline vehicles such as Japan.. Also hydrogen production is a key determinant to assess whether and to what extent hydrogen represents an effective alternative to conventional fuels from a well-to-wheels perspective.

(d) Conventional biofuels (ethanol and FAME) in low-blends are technical substitutes for fossil fuels in all transport modes, with existing technologies and re-fuelling infrastructures. Both conventional and advanced biofuels supply is limited though by feedstock availability either as crop or waste and residues. Competing demand for the same feedstock by different biofuels, e.g. Hydrogenated Vegetable Oil (HVO) from different modes within the European context and from different world regions highlights the priority of tackling two strategic issues at least: development of feedstock potential and production processes. The quantification of sustainability impacts, the identification, characterisation and localisation of indirect effects are areas of techno-economic research activities for all biomass-based fuel alternatives both conventional and advanced, as well as analysed impacts of taxation and tariffs on imports and exports of biofuels or bio-components to produce biofuels.

(e) Synthetic fuels are a promising pathway despite greenhouse gas and energy balances performing quite differently depending on feedstocks used and conversion process used for manufacturing, i.e. Coal-to-Liquid (CtL), Biomass-to-Liquid (BtL), Gas-to-Liquid (GtL).

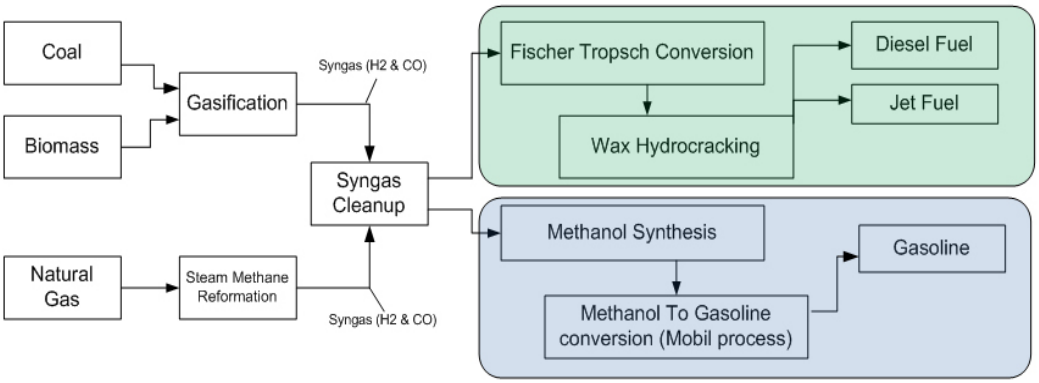

Figure 1. Pathways for synthetic fuels production

In any case, synfuels represent an alternative to diesel and therefore of interest to different modes of transport, also because of low-S and aromatics emissions. They can use the existing distribution and refuelling infrastructure and are likely to meet higher social acceptance in that they do not require a drastic change in behaviour.

(f) Synfuels can be used either blended or neat (which constitutes an advantage compared to conventional biofuels) and face sustainability concerns to a limited extent as feedstocks are residues or anyhow non-food crops, although the issue still remains open for vegetable oils in particular, as highlighted in (d). At refining, they may lower pressure to the current (and expected to grow) imbalance between gasoline and diesel production in European refineries.

(g) Liquified Natural Gas is likely to play a role as a niche alternative in high-consumptions segments of the transport sector, namely long-distance heavy duty road transport and inland waterways/maritime transport. Once more, refuelling infrastructure is the key obstacle.

(h) Bio-methane injected in the gas grid or provided at the pump is another relevant alternative to be considered which suffers from the same restrictions in terms of infrastructure as today's Natural Gas Vehicle (NGV) fleet, i.e. high development in limited areas, which makes continuity and free circulation not possible. Additionally, standardisation is required at European level for compressed biogas (CBG) injected in the grid

For a complete overview, nuclear energy is a technically suitable application for maritime transport, although its use is highly controversial for both safety and security issues and would require a strong political decision.

2.5.2.1.Infrastructure

Charging and refuelling infrastructures are certainly an outstanding issue in the introduction and uptake of alternative fuels in the European fleet for all transport modes. In fact, only conventional biofuels in low-blends and synfuels can use the existing refuelling infrastructure without modifications.

Charging and refuelling infrastructures need to comply with the requisites of interoperability, availability, reliability and continuity on the European scale at least, although certain transport modes (air and maritime transport) impose the same

requisites at the global scale. The free circulation of vehicles, vessels and aircrafts requires in fact that not only the road network but also ports and airports are upgraded to allow the uptake of alternative fuels. Further electrification of the European rail network – where economically viable and bringing environmental benefits and therefore dependent on the electricity mix per regional context – would permit a greater share of direct transmission of low-carbon electricity to rail transport (both passenger and freight).

Standardisation requisites, including safety and health specifications, per alternative fuel/energy carrier type, are a clear outstanding issue when considering the development of charging and refuelling infrastructures. Yet, the funding instruments, incentive schemes, regulatory measures (e.g. green procurement) are at the forefront as well to overcome the barrier of very high investments needs.

2.5.2.2.Other

With respect to transport policy, a level playing field for all fuel alternatives is a clear need at regulatory level and needs to be supported by timely standardisation to ensure EU-wide free circulation of goods and people. Incentives for alternative fuels and vehicles together with disincentives for conventional fuels should be put together in a coherent package and should be harmonised at the EU level, in order to prevent market distortions while fostering economies of scale and clearly indicating the future path trend to customers. The impact of fuel diversification on tax incomes for European Member States is a crucial aspect to assess the long-term sustainability of alternative options, which cannot rely on subsidies pulled from a shrinking resource basis.

2.6. Urban Mobility

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With contributions from: G. Giannopoulos

2.6.1. Current Status

Roughly three quarters of the EU population live in urban areas, and this share is expected to increase to 85% by 2050. Urban mobility is clearly the main component of short-distance transport, both for passengers and freight, since urban areas are the most important centres of consumption of goods and services. The weight of urban transport in the total transportation task is such that it is responsible for one quarter of CO_2 emissions from transport, and 69% of road accidents occur in cities[1]. Urban areas also suffer the most from congestion, poor air quality (leading to health problems) and noise exposure. They are the subject of policies that foster economic and social cohesion, especially once the needs of persons with reduced mobility, families and children are taken into account. Urban motorised mobility has significantly lower energy efficiency and higher emissions compared to interurban transport, due to lower speeds, reduced distances and frequent stops; although technological developments are producing more efficient, urban-oriented vehicles for private and public transport, the efficiency gaps still remain significant[35].

All these elements help understanding why urban transport systems have a large influence on the achievement of European-wide goals such as those related to GHG emissions, biodiversity, oil dependency and resource efficiency. The importance of urban areas with respect to the EU transport policy goals is specifically recognised in Transport White Paper[1]. The White Paper also stresses the importance of technology and mentions the need to address its full cycle, from research and development to commercial deployment. Urban areas, given their importance in the transport context, their pressing needs to solve some of the transport-related challenges (like, for instance, congestion and local pollution) and their leadership in adopting innovations, need to be central in this process.

Analysis of the existing innovation capacity in transport[36] and the specific needs of urban mobility suggest that the application of transport innovation in urban areas may be problematic. Although expected technological developments are likely to have a major positive impact on urban mobility, barriers to their implementation have proved in the past to be particularly significant, and should receive more attention. From this perspective, further research on these barriers and demonstration efforts on the ways to overcome them should be a core part of any R&I strategy.

In particular, innovation in urban mobility is hampered by:

- The variety of transport service providers, often with narrow agendas, and the difficulty of transport authorities to effectively coordinate them, while keeping public resources dedicated to urban mobility at reasonable levels.

[35] The issue of interurban mobility is dealt with in Annex VI.

[36] Mapping innovation in the European Transport Sector, T. Wiesenthal, G. Leduc, P. Cazzola, W. Schade, J. Köhler, 2011.

- The difficulties to develop sustainable transport systems, particularly in medium and small-size cities, where conventional public transport services are expensive to operate and lack attractiveness compared to private car use. The large majority of the European urban population resides in these environments.

- The commercial risks associated with the development of vehicles specialized for urban environments, particularly small vehicles (which, with the support of ITCs, could offer convenient solutions for urban mobility, but would represent a step change in consumers' behaviour).

2.6.2. Vision and how to achieve it

A large number of innovative solutions are expected to contribute to EU policy objectives relating to urban mobility. They include, amongst others, the adoption of urban planning approaches that lead to the establishment of mixed income and mixed-use communities in urban areas with relatively high population densities, the conception of public transport oriented urban developments, the contextual improvement of mass public transport systems (from buses to light rail, bus rapid transit (BRT) and underground rail systems) and the promotion of non-motorized transport.

2.6.2.1.Vehicles, fuels, infrastructure

Organisational approaches in planning, favouring higher density, mixed income and mixed-use communities developing along public transport-oriented axes tend to reverse the trend towards urban sprawl. They reduce the allocation of large portions of land to roads and parking areas, limit the incentives to use of individual transport modes contain the fragmentation of ecosystems associated to urban sprawl. Better planning practices contribute substantially to a wide number of policy objectives: reducing traffic congestion, improving road safety, reducing vehicle operating costs, reducing air pollution, improving access, reducing energy demand (and therefore increasing energy security) and fighting climate change by curbing greenhouse gas emissions.

A high density is certainly one of the main requirements behind the possibility to provide more frequent (and therefore more appealing) public transport. Denser areas are also better suited for walking and cycling, as well as new solutions for the mobility of people and goods in urban neighbourhoods (possibly powered by electricity), ultimately making a wider set of choices more widely available to passengers. Journey planners also fit well in this context because they have the potential to stimulate the use of public transport, non-motorized modes and co-modality, contributing to the integration of mobility-related services.

Transit-oriented urban mobility systems result in much less traffic congestion, lower energy use and emissions, and improved mobility for everyone. Advanced public transport systems require innovative improvements to existing vehicles and infrastructure, including the organization of the public transport network around transit-oriented corridors (involving metros – including driverless systems, tramways and BRT) and feeders, the use of dedicated lanes, the integration of non-motorized modes, and the use of well-designed specialized public transport stations (e.g. allowing pre-board ticketing on major transit axes).

The investment costs associated to sustainable urban planning practices are low, but their adoption is difficult. It requires significant efforts at the regulatory level, better cooperation of European and national authorities with local and regional authorities, and important efforts in terms of information and awareness-raising in order to gain the support of citizens. As a result, these solutions have not been implemented at a sufficiently large scale and fast pace in the past few decades.

Innovations targeting the public transport systems are complemented by advanced vehicle powertrain technologies, which are also being developed for other road modes. Cost is currently the main barrier limiting innovative urban mobility solutions involving changes in the conventional vehicle characteristics. Most of the issues stem from the "chicken-and-egg" problem, including uncertainty of supply from manufacturers and low demand associated to the limited provision of infrastructure. One important element to reducing costs and recovering investments can be the evolution from the traditional vehicle ownership paradigm towards a service-oriented concept. This would allow the recovery of value not only from vehicle users but also (in the case of electromobility) from the provision of services to the electricity distribution grid.

Conventional metros are efficient means of city transport when transport volumes are expected to be high. Technical development of metro system is possible both for the vehicles and the operation. Driverless systems are in service and have potential to reduce costs and energy consumption and delays. For metros, which are stopping very often, light trains and full regeneration of electricity, are important.

For urban transport a new technique may be available in the future through Personal Rapid Transport (PRT) also called cab track. These are electric vehicles for individual travels on a public network with stations. The wagons are allocated on demand and travel will be direct so the average speed will be approx. 40 km/h compared with approx. 20 km/h with conventional bus systems in urban transport. There are many development projects around the world but no one has yet reached the commercial market.

Other solutions incorporate the improved organisation and integration of mobility-related services, as well as the provision of new ones (such as the introduction of new vehicle concepts and new ownership schemes). Electromobility is certainly one of the options that are expected to benefit from this development. Intermodal connection platforms for passengers are also going to play a relevant role because they enlarge the choice of collective and private transport modes available for personal mobility.

A widespread move towards the stimulation of electromobility, especially in cities, is currently taking place in a number of European cities, regions and some Member States. Local initiatives tend to favour the deployment of electric vehicles with incentives like access to restricted zones or free electricity, while some Member States introduced significant tax rebates or even subsidies for electric vehicles (one example is France, with the bonus-malus system for vehicle taxation).

Costs are low also for the development of infrastructures that favour the choice of non-motorised transport options: adding bicycle lanes and pavements for pedestrians is generally cheaper than building new roads for motorized traffic. Some interesting initiatives (like, for instance, the provision of bike-sharing facilities and the strengthening of bicycle lanes) have been undertaken in recent years in a number of cities in Europe. More are needed, since incentivising non-motorised transport cannot be excluded from sustainable urban planning practices.

Intermodal connection platforms for passengers also fit well in the context of sustainable urban mobility measures, since they enlarge the choice of collective and

private transport modes available for personal mobility. They are developing around airports and railway stations, coordinating international, intercity, regional, urban and local transport options. They are best conceived when coupled with integrated payment systems that enhance modal interoperability. As in the case of other solutions involving transport planning, the costs associated with intermodal connection platforms are not necessarily higher than those characterising each piece of infrastructure taken separately. Nevertheless, intermodal connection platforms would still require very significant investments (typical for all infrastructure developments leading to the modification of the built environment).

2.6.2.1. Mobility, planning and ICT

ICT is expected to provide a wide range of opportunities for advanced traffic management systems, co-modality, improved public transport services, but also instruments capable to promote the internalisation of transport externalities (including advanced transport payment systems).

For public transport, ICT-based innovations include the use of geo-localisation instruments like GPS to monitor and manage the fleet, to provide information to bus companies, users and authorities, traffic light prioritization, as well as the diffusion of service and fare integration.

Mobility management or *mobility schemes* can be thought of as innovations promoting intelligent mobility and mobility management as well as the notion of "co-modality" (cooperation between the modes) in order to provide integration of information provision (between the modes); integration of network management systems; integration of payment and charging systems; interfaces between long distance and local (urban) networks, for freight and passenger transport.

ICT and electronic devices are going to be instrumental to allow the wireless communication of a vehicle with other vehicles and with roadside infrastructure. ICT and electronic devices also allow the collection and synthesis of information for improved traffic management, enabling the opportunity to foster the cooperation amongst travellers and service providers. Nevertheless, traffic management measures also have the potential to increase the attractiveness of the use of the most energy intensive modes and may induce more travel, energy demand and greenhouse gas emissions unless they are implemented as a part of a lager set of measures. Cooperative systems also have drawbacks, since they need to be integrated with existing systems and investments already made and may start providing benefits only once enough vehicles and infrastructures are equipped.

Some initiatives related to the use of ICT in transport have already been experimented in European cities: one example is given by automatic number plate recognition systems, used not only to enforce access restriction but is also experimented for route guidance. Short term traffic forecasting models are also starting to be tested and used in number of cities across Europe. In addition, various types of communication networks have been deployed and started to be used in transport applications (like, for instance, the provision of information on parking availability and traffic conditions): they already include WiFi, GPS and a number of other networks, and they will certainly benefit from the operational introduction of GALILEO, expected for 2014 and beyond, upon the completion of its deployment.

Web-connected smart phones also have the potential to involve individuals as sensors on the network and therefore offer an impressive potential to gather and disseminate

travel-related information, creating further opportunities for traffic and network management. In addition, ICT may have a catalysing role to play in supporting the deployment of electromobility across Europe, since ICT are going to be instrumental for the provision of information to electric vehicles on charging points, but also to provide interfaces for the payment of services and to manage the interaction between the vehicle and the grid.

The increased use of information is also expected to face organisational and privacy issues (e.g. involving the provision of information by different public and private actors, since some of the systems mentioned require the transfer of location data that can be considered as personal data, raising a security issue on one hand as well as a user acceptance one on the other). These problems will need to be properly addressed, making sure that personal data are adequately protected, as already indicated in the Directive 2010/10/EU on the framework for the deployment of ITS.

Costs are another important barrier for ICT-based intelligent transport systems, since they require additional equipment (like cameras, sensors, electronic equipment, traffic lights and variable message signs), as well as additional road works. ICT-based systems also add costs on the vehicle side, since vehicles need to be equipped with the appropriate tools for the communication and the reception of signals. They also entail software costs (e.g. for the synthesis if the information collected and the conception of the control strategies). Even if traffic management is a relatively cheap option on the infrastructure side (its costs are limited if compared to the construction of new infrastructure), vehicle costs will need to be justified by the benefits delivered (like the alleviation of bottlenecks).

Innovative urban mobility solutions can also include transportation concepts that involve changes in the conventional vehicle characteristics (e.g. leading to the use of smaller, lighter, more specialised road vehicles with a lower environmental and health-related impact).

The achievement of EU policy objectives for urban mobility will require significant efforts. These efforts, in turn, are expected to result in the generation of a demand for new technological solutions to deliver tools that assist policy needs. The Communication "A sustainable future for transport: Towards an integrated, technology-led and user friendly system"[37] suggests that the policy solutions that would be best suited to favour sustainable urban mobility must include instruments capable of promoting the internalisation of transport externalities. Such options in urban areas require the implementation of road pricing and congestion charging in order to have price differentiation for the use of the road in peak versus off-peak hours. They may even require the setup of innovative value capturing solutions (especially relevant in the case of public transport oriented development in cities). Other instruments include access restrictions and measures aimed at changing travellers' attitudes and behaviour (mobility management). ICT is likely to be best suited to address many of the needs determined by these policy options. This is particularly relevant in the case of advanced transport payment systems, especially when a single platform needs to assure the interoperability of the system across different modes. Some of these solutions already are starting to be developed, while others are likely to undergo a rapid development in the next few years.

In all, it is likely that congestion, noise, health-related constraints, energy and environmental issues will lead to more expensive motorised urban mobility in the

[37] COM(2009) 279 of 17 June 2009.

future. In order to face the challenges of social cohesion, it will be necessary to develop appropriate charging schemes and it will be necessary to better target the already significant resources dedicated to public subsidies. This is likely to include the development of technological tools that provide more detailed information on the costs (including external costs) associated to urban trips and that allow for more sophisticated charging policies.

2.7. Logistics

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2.7.1. Current Status

Logistics comprises the range of inter-related activities associated with the movement, storage and handling of products as they move from raw material source to final point of use. According to a survey undertaken A.T. Kearney (2009), European companies spent an average of 7.2% of their sales revenue on logistics in 2008. Having dropped from 12.1% in 1988 to 6.2% in 2003, logistics share of revenue appears to be rising again and is forecast to reach 7.7% by 2013. For companies located in Europe, freight transport accounts for around 45-50% of total logistics expenditure (other costs include warehousing, inventory, order processing and administrative tasks). This percentage has been increasing in recent decades and the average conceals wide variations between industrial sectors. Most companies now manage their freight transport operations as an integral part of their logistics systems, co-ordinating it closely with warehousing, materials handling, inventory management and related information processing. This was recognised by the Commission's 'Logistics Action Plan' and has been reflected in national government policies on freight transport. It is important therefore that the review of freight transport-related technologies adopts a broader logistical perspective as technology is likely to redefine the relationship between transport and other logistical activities over the next few decades.

Logistics is a key determinant of business success at the micro-level, while at the macro-level it plays a vital role in the economic development of regions, countries and continents. First, it provides essential support for industry and commerce, exerting a strong influence on domestic levels of productivity and customer service and facilitating international trade. Second, the nature of a region's logistical system is high on the list of criteria that companies take into account when assessing its attractiveness as a location for inward investment. Third, logistics represents an important sector in its own right, accounting, on average, for around 11-16% of GDP in EU countries (Rodrigues et al, 2005) with around 8% of the workforce working in the logistics sector in Germany (Invest in Germany, 2007) and the UK (Skills for Logistics, 2010). Fourth, logistics services are international and, if globally competitive, the companies providing them can earn significant amounts of foreign revenue. In line with the Commission's Communication on An Integrated Industrial Policy for the Globalisation Era logistics should be seen as a fundamental pillar for industrial competitiveness and completion of the internal market for transport.

Effective management of the internal logistics of a single company must be complemented by effective co-ordination of its operations with those of suppliers upstream and distributors / customers downstream which are linked together in a supply chain. The design and management of supply chains strongly influences the freight transport system and are also likely to be subject to major technological change over the next few decades. 'Supply chain' technologies that are likely to have a bearing on the European freight transport system are also within the scope of this review.

The European Union currently has a comparative advantage in logistics. EU countries gained high rankings in the World Bank's 'logistics performance indicator' survey in 2010 (World Bank, 2010). Germany topped the ranking, with EU member states

accounting for 4 of the top 5 positions and 11 of the top 20. Several of the world's largest and fastest growing logistics providers, most notably DPWN, DB-Schenker, Kuhne and Nagel, Maersk and TNT, are EU-based, and collectively handle a substantial proportion of global trade.

Against the huge economic benefits of logistics must set its environmental costs. Most of these costs arise from freight movement, though allowance should also be made for externalities associated with the storage and handling of products at the various nodes in the supply chain. Advances in technology will greatly improve the future environmental sustainability of logistics, while in most cases also increasing its economic efficiency. For example, in a review of the options for decarbonising supply chains, the World Economic Forum / Accenture (2009) identified 'clean vehicle technology' as the most promising.

The Commission's Communication on Freight Transport Logistics in Europe[38] issued in 2006 acknowledges that logistics is primarily a business-related activity and its development is essentially a task for industry. Nevertheless, it underlines that public authorities have a clear role to play in creating appropriate framework conditions for its development. It also identifies a number of areas of action, both for uni-modal and multimodal logistics, emphasising the need to optimise the complementarity of modes in order to provide the best possible services to freight transport users.

In response to this Communication, the Commission published a Freight Transport Logistics Action Plan[39] in 2007. The Plan proposed the development of green corridors, the freight-oriented rail network and a European maritime space without barriers. It also advocated the creation of a single transport document for intermodal transport, aiming to reduce administrative hurdles. New technological ICT frameworks were proposed, particularly the concept of e-freight, which envisaged a paper-free, electronic flow of information related to the physical flow of goods. The Communication also looked more generally at the increased use of ITS in freight transport. Finally, it argued that the rules on vehicle dimensions and standards in road transport needed to be reviewed.

Some efforts in the directions indicated by the Action Plan started before its publication. One example is the Commission Regulation 62/2006/EC, setting the technical specifications for the interoperability of telematic applications for freight, in order to facilitate the interchange of information between the different infrastructure managers, railway undertakings and other service providers involved in the commercial operation of trains, wagons and intermodal units throughout the trans-European rail network.

The Commission's specific Action Plan for the Deployment of Intelligent Transport Systems in Europe[40] in 2008 also contains several initiatives that are relevant to freight and logistics, particularly those relating to the optimal use of road, traffic and travel data, the continuity of ITS services along major corridors, ITS applications to improve road safety and security, the integration of various vehicle-based applications in one platform, data protection issues and the co-ordination of ITS deployment across the EU. The proportion of ICT-enabled trucks on the European road network is rapidly rising. Electronic truck tolling has between adopted in several EU member states and

[38] COM(2006) 336 of 28 June 2006.

[39] COM(2007) 607 of 18 October 2007.

[40] COM(2008) 886.

others are planning to introduce it. This is creating the need for an EU initiative to improve international co-ordination of freight / logistics-related ITS and establish a common basis for the distance-based charging of trucks across the continent, building on Directive 2006/38/EC, and allowing for the internalisation of costs related to pollution and congestion caused by heavy goods vehicles.

The movement of freight by rail is affected by the deployment of the European Rail Traffic Management System (ERTMS), a tool which aims to remove the technical barriers to the development of rail transport at the European level[41]. ERTMS consists of a unique signalling standard (also requiring the communication between vehicles and rail tracks) that is now recognised as the global reference. A similar system also exists for maritime transport, since the Directive 2002/59/EC established a Community vessel traffic monitoring and information system and Directive 2009/17/EC amended it, leading to the current Community vessel traffic monitoring and information system, SafeSeaNet. Directive 2005/44/EC established a framework for the deployment and use of a similar system for inland navigation, the River Information System (RIS). Other initiatives for maritime transport include the Vessel Traffic Management and Information Systems (VTMIS), the Automatic Identification System (AIS) and the Long-Range Identification and Tracking (LRIT).

GALILEO, Europe's initiative for a global navigation satellite system, also has a very prominent role for ITS, since it will provide a highly accurate, guaranteed global positioning service, making it suitable for applications where safety is crucial, such as running trains, guiding road vehicles and landing aircraft. GALILEO is fully funded by the European Union and managed by the Commission.

Classification of Innovation in Logistics

Figure 2 outlines a classification of logistics-related innovations impacting on freight transport under five headings. More detailed information about all these can be found in Annex IIIa. At the highest level are innovations relating to the management of supply chains, whose implementation will involve organisations at different levels in the chains and be technologically-enabled. Below this are the logistical systems operated by individual companies, whose restructuring over the next few decades will be partly in response to technological change. Within these systems, the way in which companies manage the freight transport operation is changing in response to a series of technological developments. Finally, at the two lower operational levels are innovations relating to loading and transhipment activities and the nature of the vehicle. Across all these levels of logistics management new technology will reinforce the application of more sustainable business processes and practices.

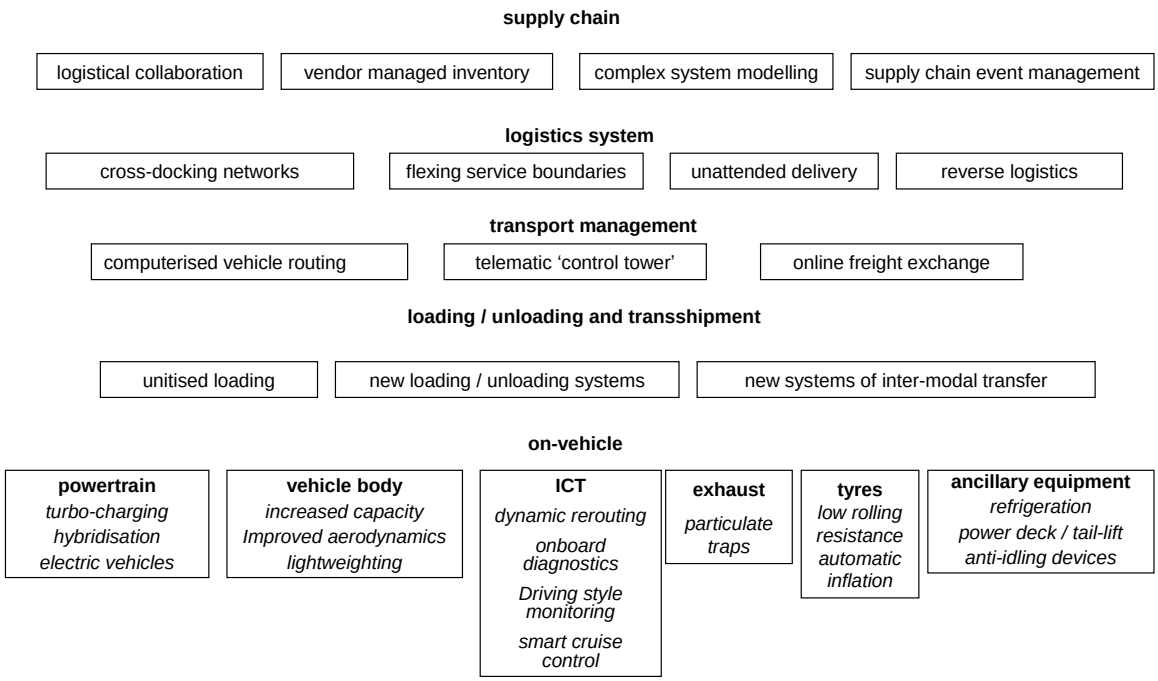
The existing innovation capacity in freight and logistics is characterised on the one hand by relatively low R&D intensity by transport service providers and, on the other, by a relatively high R&D intensity from vehicle manufacturers. Manufacturers of commercial vehicles are under strong competitive pressure to use technology to differentiate their products in terms of operating performance, fuel efficiency, maintenance routines and IT-capability. The slim margins and low rates of return which characterise much of the European road haulage market make it difficult for carriers to upgrade to higher specification vehicles. In times of recession, they also

[41] COM(2005) 298.

extend vehicle replacement cycles, further delaying the uptake of new vehicle technologies.

Much of the innovation in the logistics sector is ICT-related and some of it has a link to transport infrastructure (e.g. for electronic tolling systems and e-freight). In this field, regulations, technical specifications and, more broadly, the legal framework have a strong influence on technology and innovation deployment. As in the case of urban mobility, lock-in phenomena are significantly affecting the way innovation develops and diffuses in the logistics sector. Lock-ins can be due either to the previous investments in particular types of vehicle and equipment or to organisational issues. Choice of a particular brand of truck, for example, can restrict a carrier's subsequent ICT options. Several European truck manufacturers promote their particular telematics systems as valuable 'add-ons' at time of purchase. This can allow them to undertake vehicle diagnostics during the life of the vehicle and offer, on an ongoing basis, a value-adding range of maintenance and support services. However, the provision of proprietary telematics systems by vehicle manufacturers is making it difficult to establish an open industry standard for telematics which would undoubtedly accelerate its diffusion.

Figure 2: Classification of Logistics-related Innovations (adapted from McKinnon (2009)



2.7.2. Vision and how to achieve it

For freight transport and logistics, innovative solutions will comprise both software and hardware elements. Arguably ICT developments will have the greatest impact, though the potential for redesigning vehicles, handling and storage systems should not be under-estimated.

Priority areas for ICT development will include improved communications vehicle - infrastructure communication, the calibration of vehicle-routing software with telematics data, the application of multi-agent / complex systems modelling to

logistics systems, improved information exchange at logistical / intermodal hubs, using ICT to promote logistical collaboration, standardised road charging schemes for freight traffic and the use of ICT for tighter enforcement of regulations and greater security in the logistics sector.

For Supply Chain Management, ICT will enable multi-lateral collaboration, permitting both the exchange of transport data and the identification of back- and shared-loading opportunities. Cloud computing, in which companies gain common access to software and systems on the internet, can create new information-sharing models to support logistical collaboration.

E-freight, denoting specifically the vision of a paperless electronic flow of information associated to the physical flow of goods is another subject linking innovations in logistics with ICT. It includes the ability to track and trace freight along its journey across modes (especially including dangerous goods), the use of standardised coding in all Member States and the exchange of content-related data for regulatory or commercial purposes. E-freight relies heavily on ICT and requires the definition of standards for the characterisation of information flows both within and between transport modes. E-freight can also enable the release of the information on-line. It will benefit from several major developments, particularly the diffusion of radio frequency identification (RFID), the launch of the Galileo, Europe's initiative for a state-of-the-art global navigation satellite system, and the growth of cloud computing. The freight transport sector will not only benefit from improved ICT networking; product identification and scanning systems will transform data collection while major advances in software design will greatly improve analysis and optimisation capabilities.

Vendor managed inventory (VMI) also relies on advances in telemetry and wider use of RFID across the supply chain. It gives the supplier greater control over the replenishment process, allowing it to improve the loading of vehicles. The related transport benefits can be enhanced where the vendors have visibility of the inventory level and storage capacity at customers' premises.

Anther ICT-related innovation is the optimisation of the route that vehicles follow when delivering and/or collecting consignments to/from several locations. Numerous software packages exist to help plan routes and they are now widely applied across the European freight sector. Future improvements in this technology are likely to be incremental rather than transformational but, when combined with wider adoption, have the potential to cut the economic and environmental costs of freight transport by a significant margin.

On-board vehicle telematics are likely to be increasingly fitted as standard in new vehicles and give fleet managers real-time information about the location and operation of their vehicles. This allows them to reschedule and reroute vehicles in response to changing customer demands, traffic conditions and other random events.

Hardware innovations will both improve the internal efficiency of individual transport modes and facilitate the intermodal transfer of freight. It is possible to conceive of a hierarchy of physical innovations in this sector extending from the basic handling units in which freight is moved, through the containers in which their movement is modularised, to the vehicles, the transport networks, the logistics systems and ultimately the supply chains formed by the interaction of these systems.

At the lowest level in the hierarchy, one can envisage the development of new modular systems (requiring standardisation) to enhance the flexibility and interoperability of the transport within co-modal networks. The emergence of new forms of unattended

delivery, particularly at the 'last-mile' end of the supply chain, will rationalise the movement of freight at the local level within urban and rural areas. Where linked with the growth of online retailing, it will alter the relationship between freight and passenger movement. These two forms of transport are often analysed and planned separately overlooking opportunities for closer co-ordination. For example, by treating the replenishment of supplies to the home as a single, holistic system one can explore novel options for city logistics involving the use of collection points for online orders at public transport terminals and the widespread installation of reception boxes at shops, offices, community centres and homes. A new generation of freight terminals could combine intermodal transfer of inter-urban freight flows with consolidation of supplies for delivery to shops and the picking of online orders for local delivery to the homes. While this will involve investment in physical premises and equipment, the success of such a multi-functional logistical platform would depend just as much on its ICT capability.

In addition, the degree of inventory centralisation is a major determinant of the freight transport intensity of a logistics system. It is generally found that the higher the degree of centralisation, the greater is the amount of freight movement per unit of sales. Both software and hardware innovations are relevant to deliver improvements in this context. The economic and environmental cost penalty associated with this additional freight movement can be reduced if the centralised facility is supported by a network of transhipment points at which break-bulk / cross-docking operations can be localised and, if necessary, combined with inter-modal transfer. Advances in warehouse design, demountable vehicle systems, materials handling and ICT will facilitate these satellite operations. The deployment of more sophisticated stock management and forecasting systems should also help to reduce the need for inventory repositioning which generates additional freight movement.

Much of the discussion to date has focused on the application of ICT in the road freight sector. The movement of freight on other modes will also benefit from ICT innovation at vehicle, network and logistics system levels. This is the case, for instance, of the ERTMS (whose deployment is still slow, in Europe), as well as the SafeSeaNet (already deployed) and the RIS (whose adoption is being addressed by the NAIADES Action Programme) for waterborne transport.

The use ITS in freight transport and logistics is realized through a set of "intelligent" services, application software and technologies for gathering, storing, analyzing, and providing access to cargo data to help users make better decisions. ITS contributes to the efficiency improvement of freight transport, by developing interoperable information services at national and global levels and building on standardised data structures and exchange services. The main application areas of ITS in the freight transport and logistics domain are the following:

- Development and implementation of the next generation freight transport environment known as "*e-freight*" (inducing individual cargo item intelligence and providing interaction with the item throughout the transport chain)
- *Freight Transport Management* applications (dealing with the management of the transport operation from order capture to payment and invoice control)
- *Fleet management* applications with the objective of optimising the utilisation and scheduling of a fleet of freight vehicles (or wagons, or vessels)
- *Telemetry,* permitting the remote scanning of inventory levels and storage capacity to determine the quantities of freight to be delivery (particularly relevant in the case of vendor managed inventory (VMI) systems)
- Management of special categories of freight such as *Dangerous goods*.

- *Terminal management* including access control, loading bay and parking zone management, etc.
- *Online freight exchanges and web-enabled procurement of freight / logistics services*

Costs have been an important barrier to the application of ICT in the logistics sector, particularly within the general road haulage market, where competition is intense, profit margins slim and available resources for investment limited. Many shippers treat road haulage as a basic 'commodity' service to be purchased at minimum cost and are reluctant to pay higher rates for more technologically-enabled services, despite the fact these services benefit their logistics operations in other ways and can represent good value for money. Several surveys have suggested that the diffusion of ICT innovations in the freight and logistics sector has been inhibited by carriers' perception that their clients do not demand or value these innovations. A common view among logistics providers is that they will not be adequately recompensed for investments that they make in innovative systems. Some also argue that contracts with clients tend to be so strictly prescribed and legalistic that it is difficult to be proactive and innovative. These appear to be significant barriers to the adoption of innovation, particularly ICT-related innovation, in the logistics sector and merit attention from public policy-makers.

The vision of new networks of intermodal terminals developing across the EU, providing logistical services for a mix of urban, inter-urban and international traffic flows, may also be difficult to implement in practice. Much intermodal freight terminal capacity already exists, though often in the wrong locations and of the wrong type. Much of the new terminal development is likely to be within the new 'green corridors' for freight traffic that will traverse the continent. If fully implemented the 'green corridor' strategy will lead to some realignment of freight terminal capacity in Europe. As in the case of intermodal passenger interchanges, however, there is a 'lock-in effect' with this legacy of past investment obstructing the development of new facilities. Also, although new intermodal terminals could yield sustainability benefits, their development is likely to be resisted by local citizens concerned about their local environmental impacts. Given their significant land requirements, intermodal freight terminals invariably require the involvement of numerous stakeholders and public acceptance can be difficult to win. Care must therefore be taken to locate them away from sensitive environments and use new technology to minimise their land requirements and adverse effects on the surrounding area. The planning and approval process must also be managed effectively by public authorities and used in a way that maximises the value of intermodal terminals to the local community and economy.

As discussed earlier, much of technical innovation in freight transport will be vehicle-related and have the objectives of increasing fuel efficiency, reducing emissions, improving safety and enhancing the overall competitiveness of the European logistics sector. One of Europe's main truck manufacturers estimates that the potential exists to cut the CO_2-intensity of long haul trucks by two-thirds between 2010 and 2020 with the main savings accruing from infrastructural and regulatory changes (-30%) and the operation, repair and maintenance of trucks (-30%). Improvements in the design of new vehicles would cut CO_2-intensity by a further 15% and a switch to alternative fuels 5% (Blake, 2011). The 'Freightvision' project (AustriaTech, 2009) predicted that total CO_2 emissions from long-distance freight traffic in the EU could be reduced by 30% between 2005 and 2050 on the assumption that 'moderate improvements' would be made in the 'engine efficiency, aerodynamics and rolling resistance of heavy trucks'.

As in the case of urban mobility, electrification will be one of the most interesting options for freight movement, however its application is expected to be confined

mainly to the localised (mainly urban) distribution of goods by road and inter-urban transport by rail. Besides electrification, other alternative power options for freight transport include the use of bio and natural gas and, possibly in the longer term, hydrogen as energy carriers. This topic is discussed in greater detail in the alternative fuels section.

2.8. Intelligent transport systems across modes

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With contributions from: P. Dilara

2.8.1. Current Status

Intelligent Transport Systems - ITS is the term used to denote the use of *Information Communication Technologies (ICT)* in creating fully integrated operating environments in which the uninterrupted real-time flow of information and data enables many interrelated and interoperable transport applications in all fields. ITS has been identified as a domain of high potential in all previous sections and one capable of tackling the many challenges facing the Transport sector both within each of the modes and (most importantly) in creating interfaces and integration across the modes. Deployment of ITS systems and services has so far been largely "unimodal" in scope and extent, leaving wider "cross modal" applications a development to be sought for, in the future. The 2008 EU Communication "*Action Plan for the Deployment of Intelligent Transport Systems in Europe*"[42], and the *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[43], provide the framework for the development for interoperability, compatibility and continuity in the deployment and operational use of ITS.

The various ITS systems and services across the modes can be distinguished by reference to the following 8 *areas of application*[44]:

1. *Traffic and Travel Information*
2. *Traffic and Public Transport Management*
3. *Navigation services*
4. *Smart ticketing and fee collection*
5. *Transport safety and security*
6. *Freight Transport and Logistics* (including *Urban Logistics*)
7. *Environmental and energy efficiency* (including Electro mobility)
8. *Intelligent mobility and co-modality services*.

Some of these areas apply mostly to one sector (road, logistics, etc.) and were therefore already covered under the relevant sections in the previous chapters. However, the vision for the future ITS systems for what concerns applications across the modes, is presented below.

2.8.2. Vision and how to achieve it

[42] *Commission Communication*, of 16 December 2008, "*Action Plan for the Deployment of Intelligent Transport Systems in Europe*".

[43] See http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:207:0001:0013:EN:PDF

[44] ERTICO suggests a broader classification into 4 areas, i.e.:
- *Cooperative Mobility:* Connected vehicles and infrastructure
- *Safe Mobility :* providing safe Transport operation
- *Eco Mobility :* reduced impact on energy consumption and the environment
- *Info Mobility* :Real time information for travellers.

The most challenging task, in the foreseeable future, will be to establish a common coherent long-term strategy to support deployment of the relevant ITS services in all 8 of the above areas of application, from the current "island" solutions with limited data exchange capability between networks and general lack of interoperability, towards a comprehensive co-modal data exchange network and seamless mobility services, where people, goods and vehicles are continuously and ubiquitously connected receiving or sending useful data and information.

In the area of *Traffic and Travel Information (TTI)* technologies, there are four main issues to be considered: the legal framework for the provision of TTI, the technical standards used and the interoperability of these standards, the business models used for the provision of these data, and the extent to which the travellers themselves (i.e. the "demand") are reacting to TTI provision.

The European legislating framework for TTI services is still in the making especially at the level of the individual EU member states, where relevant provisions either pre-existed the EU Action Plan and need harmonisation, or they do not exist at all[45]. In the technical standards used for the transfer of traffic and travel information and data, the last decade has seen the development of a number of TTI standards but there must be added emphasis on the interoperability among these standards ("*Alignment*"). The business models used for the provision of TTI, are based on public – private partnership arrangements that normally provide for outsourcing the data collection and storage to commercial contractors, distribution of these data to service providers who provide high quality travel information to the public. A most notable trend is the increased availability of data through the so called "*collaborative*" model where each vehicle on the network becomes information gatherer and transmitter.

A significant challenge for the next generation of *traffic management systems* (see Annex VII for a list of modal traffic management systems) is the development of *cross-modal* traffic management, i.e. systems that optimise traffic management across two or more modes. Such cross-modal systems would: a) exchange real time information and data between the traffic management centres of two or more modes, b) analyse and compare the traffic conditions in the two (or more) networks, and c) provide optimisation of traffic flow in all networks based on the conditions at the integrated system.

The future of *Navigation Services* will see developments towards the *personalized information provision, environmental aware routing* and navigation services to *assist travellers* in understanding the implications of different travel choices especially between modes and provide advice for greener choices. Also, providing *optimal routing strategies*, as opposed to today's routing suggestions, for routes with the lowest degree of travel time uncertainty, thus highest degree of reliability. Some behavioural issues related to the users' perception and response to navigation devices, are of interest here but do not fall under the scope of this work.

In the area of ITS technologies and services for *smart ticketing* and *fee collection*, there is a long series of policy decisions, standardization and legislative steps that create the current landscape in this area. As we are moving towards the integration of payment systems for multi-sectoral transport services and charges, the challenge is to develop interoperable interfaces between payment systems that could be provided by a single

[45] An example of the multitude of legal provisions is the area of re-use of public sector information. National legislations vary as regards the provision of such data free of charge and the degree to which they ensure that their provision is fair, transparent, and non-discriminatory. For example in the UK there is free access and re-use, including traffic and public transport information, in the German model contracts the provision is for the sale of traffic data from federal traffic control centres and from local authorities to ITS service providers and manufacturers, and so on.

platform and could rely on various means such as credit cards, mobile phone payments and integrated transport ticketing solutions (emerging standards for transport smartcards are currently being developed).

Finally, ITS can be used in order to assist in providing *environmental and energy efficiency*. In the 2008 Action Plan for the Deployment of ITS in Europe, it is clearly stated that ITS applications have an essential role to play in making the domain of transport more energy efficient. The key energy-related actions of ITS, are[46] optimization of the use of the infrastructure; more efficient traffic management and better interaction of modes; reduction of congestion in freight corridors; development of European solutions for flexible demand management; enhancement of environmentally friendly & energy efficient transport solutions; improvement of the efficiency of logistic chains.

The main goal of ITS applications across the modes, which are currently in an important transition phase, is to translate the currently deployed "island" solutions - with very limited data exchange between networks and lack of interoperability - towards a comprehensive co-modal data exchange network and seamless mobility services, where people, goods and vehicles are continuously and ubiquitously connected receiving or sending useful data/information. Therefore, the most challenging task in the immediate future will be to establish a common vision, common goals, common roadmaps and a coherent long-term strategy to support deployment of the relevant services towards the above goal[47].

Lack of specific ITS strategies will hamper the further development of interoperable systems and technologies and form a potential barrier because it will increase the risk, real or perceived, to the perspective players and stakeholders.

Some priority issues as derived from the above, but also from the relevant ITS sections in the modal chapters can be summed as follows:

- Interoperable – integrated Traffic and Traveller Information systems across all modes;
- Cooperative Mobility systems and services especially in urban areas;
- Safety applications (e.g. like the pan-European application of the *e-Call*);
- Interoperability of road charging/tolling;
- ITS and electro-mobility ;
- Freight and logistics management for safe, secure, and environmentally friendly freight transport especially in urban areas (e.g. parking of trucks);
- Public transport/multimodal traveller services.

The following issues will also need particular attention in enabling an integrated ITS across the modes[48] :

- Communication bearers for ITS services,
- Data warehouses/data marketplaces,
- Location referencing methods, and
- E-Freight applications across the modes.

[46] COM (2008) 886 "Communication from the Commission: Action Plan for the Deployment of Intelligent Transport Systems in Europe", see also: European Commission DG Energy and Transport (2009) "Intelligent Transport Systems Thematic Research Summary"

[47] Based on ERTICO's contribution to the STTP stakeholders consultation.

[48] As prioritized by the ERTICO position paper, and other stakeholders' position papers (POLIS, ERRAC)

The role of the Commission is seen mainly as a facilitator for interoperability of ITS across the modes and as a promoter of reliable and efficient ITS services within and between modes for the benefit of the European citizen through assuring the availability of good quality of data at all levels, quality assurance of the systems deployed, interoperable standardisation, and promotion of research and innovation, taking care to address properly intellectual property rights and privacy issues.

3. SCORING AND PRIORITISATION OF SELECTED TECHNOLOGIES

Author: L. Lonza

3.1. Methodology description

The scoring methodology is the result of collegial work. It has been designed by the JRC and validated/refined through input of the Scientific Panel. The scoring methodology applies to the list of identified technology areas as identified in the previous sections.

Consistently with the inclusive design of the STTP, additional input has been sought and collected via outcomes of the meetings with the stakeholders and the public Internet consultation as well as information provided by the FP7 Transport Programme Committee and the Scientific Panel. All input data at succeeding steps of elaboration have been submitted to the consistency check of: all involved Commission's services, the Scientific Panel, and the FP7 Transport Programme Committee.

The selection and prioritisation methodology is designed along four axes and encompasses four sets of criteria.

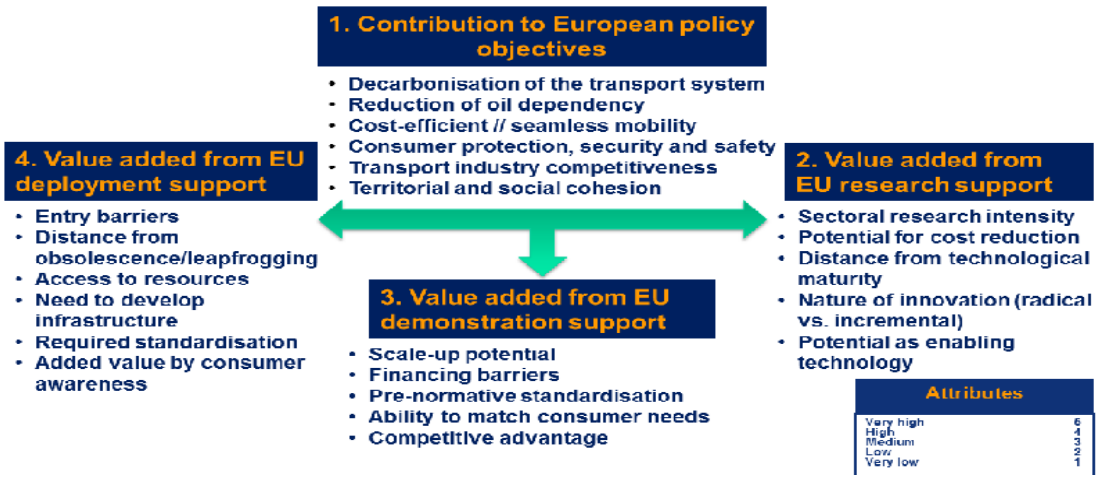

Figure 3. Selection and prioritisation methodology: schematic view.

Criteria along these four axes have been defined (see ANNEX VIII: Criteria for Prioritisation Exercise) and definitions submitted for validation to: all involved Commission's services, the Scientific Panel, and the FP7 Transport Programme Committee.

The first axis included in the selection and prioritisation methodology evaluates the contribution of identified research and innovation areas to the following European policy objectives:

- Decarbonisation of the transport system
- Reduction of oil dependency
- Cost-efficient and seamless mobility
- Consumer protection, security and safety
- Transport and industry competitiveness
- Territorial and social cohesion

The remaining three axes in the selection and prioritisation methodology are designed to position each research and innovation area along the innovation chain based on technology maturity level and closeness to market uptake. The objective is that of assessing where in the innovation chain EU intervention is expected to produce the highest added value.

The second axis considers the value added per research and innovation area of EU intervention at the level of support to research. Criteria considered are:

- Sectoral research intensity
- Potential for cost reduction
- Distance from technological maturity
- Nature of innovation (incremental vs. radical)
- Potential as enabling technology

The third axes moves on along the innovation chain and focuses on the value added per research and innovation area of EU intervention at the level of support to demonstration. Criteria considered are:

- Scale-up potential
- Financing barriers
- Pre-normative standardisation
- Ability to match/meet consumers' needs
- Competitive advantage

The fourth axis moves closer to market uptake of innovation and focuses on the value added per research and innovation area of EU intervention at the level of support to deployment. Criteria considered are:

- Entry barriers
- Distance from obsolescence/leapfrogging
- Access to resources
- Need to develop infrastructure
- Required standardisation
- Added value by consumer awareness

3.2. Scoring exercise

To perform a qualitative assessment of research and innovation areas and identify where in the innovation chain EU intervention is expected to be most efficient, a simple set of qualitative attributes has been used.

Table 2. Set of qualitative attributes.

Attributes	Values
very low	1
low	2
medium	3
high	4
very high	5

The broad list of identified technology areas consistently with the findings and data collected in the Scientific Assessment Report and the Capacity Map and the additional input collected in the preparatory phase has been submitted to a scoring exercise performed by independent experts of the Scientific Panel and European Commission's in-house JRC experts. In total 16 experts have marked the areas selected.

Each expert participating in the scoring exercise has completed a self-assessment to indicate his/her level of competence per transport sector considered: the attributes used are the same as those used to perform the qualitative assessment.

Table 3. Level of competence: self-assessment by experts participating in the scoring exercise.

level of competence	**score**
very high	5
high	4
average	3
low	2
very low	1

The self-assessment provided by experts is reproduced in Table 4. It allows understanding not only of the individual expertise, its composition and balance but most importantly the expertise available as a group per transport sector considered. The level of expertise in the group is indeed very relevant when interpreting the qualitative assessment resulting from the scoring exercise: individual different levels of expertise and their balancing in the overall results from the group must be properly normalised to avoid the risk of diluting individual expertise in the collective opinion.

Table 4. Experts' self-assessment per transport sector considered.

	Road transport	Ships and barges	Aircrafts	Trains	Enabling technologies	Safety and security	New concepts	Alternative fuels strategy	Integrated ITS	Intelligent infrastructure	Urban mobility
Expert 1	4	3	4	1	3	3	5	5	4	4	5
Expert 2	5	2	4	3	3	2	4	5	4	3	4
Expert 3	5	3	3	2	4	3	4	3	4	4	4
Expert 4	5	2	2	2	3	4	4	5	4	3	4
Expert 5	5	5	1	1	4	3	3	2	4	4	4
Expert 6	4	1	3	1	2	1	1	5	2	1	1
Expert 7	5	2	2	4	3	5 sfty / 1 scrty	3	3	4	3	5
Expert 8	5	4	3	4	2	2	3	4	4	4	3
Expert 9	3	2	2	4	2	3	4	3	5	5	5
Expert 10	4	3	2	4	2	4	3	4	3	3	5
Expert 11	5	3	1	3	3	2	2	3	3	2	2
Expert 12	5	1	3	3	3	4	4	3	4	4	5
Expert 13	5	2	2	5	3	5	4	4	4	5	5
Expert14	4	3	4	5	2	3	4	4	3	4	5
Expert 15	3	3	5	3	5	5	4	5	4	4	3
Expert 16	3	5	2	2	3	3	3	3	3	3	2

Data resulting from the scoring exercise have been collected and treated in two consequent steps:

(a) Results have been weighted on the basis of the competence level declared by each expert. This has been done in order to give a higher value to the opinions expressed by specialists in any given transport sector. ***Weighted results*** are attached in the PDF version of this Report.

(b) The analysis of the outcomes of the scoring exercise implies considering the qualitative assessment expressed by a group of experts. Due to the different levels of expertise available per transport sector, results have been normalised in order to give a higher value to the opinions expressed by specialists in any given sector on the opinions expressed by the entire group. The reasoning is that of avoiding the risk of diluting specialist opinions among opinions expressed by specialists in other transport sectors. ***Normalised results*** are attached in the PDF version of this Report.

It must be noted that the scoring exercise has not targeted the issues of socio-economic research and of the interaction between transport and other sectors, including the environment and health. The scoring exercise has also not targeted the issue of noise nuisances.

3.3. Analysis of scoring exercise results

A first general consideration of the scoring exercise is that there are no definite winners or losers of research and innovation areas identified through the analytical and inclusive screening briefly explained in the description of the methodology.

The resulting list of research and innovation areas is inclusive and provides useful indications of where clustering of activities may enhance efficiency of EU intervention. The methodology developed and the scoring exercise provide also a useful indication of the maturity of research and innovation areas initially identified and therefore of where in the innovation chain EU intervention is expected to have the highest leverage effect.

3.3.1. Transport management and information systems

[modal management and information systems; integrated management and information systems; air traffic management; solutions for crisis response]

Cross-modal interoperable Information and Communication Technologies (ICT) applications score high averages across policy objectives (3.5 average) with very strong emphasis on the potential contribution to cost-efficient seamless mobility (4.3).

Although scoring is high throughout the different phases of the innovation chain (3.4 average scoring in research phase; 3.8 average scoring in demonstration phase, and 3.5 average scoring in deployment phase), EU intervention is valued in particular:

- In support to research, to support radical vs. incremental innovation (3.6) and to better exploit the potential of ICT as enabling technology (3.6);
- In support to demonstration, to better address consumer needs (4.2) and adding to competitive advantage of developed technological solutions (4.2), in particular via pre-normative standardisation (3.9);
- These priorities of intervention are consistently mirrored in the support to deployment (3.5) with reference to consumer awareness (3.8) and the role of the EU to spur timely standardisation of technologies (3.9).

All research and innovation areas within this chapter score high throughout the innovation chain, highlighting the link with the categories "Smart systems/ infrastructure" and "Sustainable urban mobility" and some areas – namely the service-oriented mobility and transport – within the "Exploratory and strategic issues" category.

Modal management and information systems with main focus on the road transport mode, in particular with attention to monitoring and managing urban freight flows. Not surprisingly this field scores consistently across policy objectives (3.2 average) with strong emphasis on the potential contribution to cost-efficient seamless mobility (3.8)

Although scoring is slightly above the median value of 3 in the exercise in all phases of the innovation chain (3.1 average scoring in research phase; 3.4 average scoring in demonstration phase, and 3.2 average scoring in deployment phase), EU intervention is valued in particular:

- In support to research to enhance the potential (or increase the steepness of the curve) to reduce costs (3.2), as well as to support radical vs. incremental innovation (3.2). In combination, these score indicate that EU support is basically considered as a factor to lower investment risks for industry;
- In support to demonstration, to better address consumer needs (3.8) and adding to competitive advantage (3.8);
- In support to deployment, it is the role of the EU in the standardisation process which is emphasised (3.8)

With respect to intelligent transport systems (ITS) applications for seamless door-to-door mobility, the resulting assessment is quite similar to the above. This field scores consistently across policy objectives although with a negligibly lower average of 3.1 with – again and consistently – strong emphasis on the potential contribution to cost-efficient seamless mobility (3.8)

Scoring is consistent across all phases of the innovation chain (3.4 average scoring in the research phase; 3.3 average scoring in the demonstration phase, and 3.2 average scoring in the deployment phase), with EU intervention valued in particular:

- In support to research to support radical vs. incremental innovation (3.6);
- In support to demonstration, clearly to better match consumers' needs (3.8) and therefore it is suggested that EU support targets a role as multiplier for innovative solutions to a broader scale;
- Priority in the demonstration phase is consistently mirrored in the support to deployment, with reference to consumer awareness (3.8) and the role of the EU to spur timely standardisation of technologies (3.7).

It is also worth noting that in with respect to support for deployment of ITS applications for seamless door-to-door mobility, the role of the EU to develop infrastructure scores 0.5 above the median value of 3, which may possibly be read in conjunction with the expected role of the EU in timely standardisation.

Air traffic management and solutions for crisis response were not included as separate areas in this scoring exercise and therefore the former belongs logically to modal management and information system while the latter encompasses a specific set of applications within the cross-modal interoperable ICT.

3.3.2. Smart systems/ infrastructure

[low-maintenance, climate resilient infrastructure; intelligent hubs for passengers and freight; intelligent road infrastructure; demand management (E-toll, road user charging, access regulation)]

Smart infrastructure and smart transport system management score high averages on policy objectives with respect to cost-efficient and seamless mobility and consumer protection and safety. The importance of EU intervention is valued as particularly high in the research and demonstration phases where the support to accelerate the progress to market maturity and pre-normative standardisation are the most prominent aspects. In the research phase, EU intervention is mostly valued when addressing simultaneously the possibility to meet consumer needs on the one hand while lowering the investment risk of developing enabling technologies.

Intelligent transport infrastructures score high on average (3.6) across policy objectives, yet it is worth noting that the expected contribution towards achieving a

cost-efficient and seamless mobility in Europe (4.2) goes hand in hand with considerations regarding the opportunity to serve the citizen better by providing better consumer protection, security and safety (3.8) and those related to sustained industry competitiveness (3.7).

Scoring is consistent across all phases of the innovation chain (3.6 average scoring in the research phase; 3.7 average scoring in the demonstration phase, and 3.5 average scoring in the deployment phase), with EU intervention valued in particular:

- To fully exploit the potential of technological solutions as enabling technologies (3.9) while reducing costs (3.7) in the research phase;
- To better match consumer needs (4.1) (again the role of the EU as a multiplier for innovative solutions) while spurring the competitive advantage (4.1) in the demonstration phase;
- To support the development of infrastructure (3.9) in parallel to consumer awareness (3.7) in the deployment phase, to facilitate a smoother uptake of close-to-market solutions in this field.

Intelligent hubs for passengers and freight score in a very similar way as the related field of intelligent transport infrastructures, yet with lower average scoring: 3.5 across policy objectives with highest scores in the expected contribution towards achieving cost-efficient and seamless mobility (4.1) while enhancing consumer protection, security and safety (3.7).

Scoring puts emphasis on the research phase of innovation (average scoring 3.6) compared to demonstration (average scoring 3.4) and deployment phase (3.3), with EU intervention valued in particular:

- To fully exploit the potential of technological solutions as enabling technologies (3.9) while stimulating R&D intensity (3.7) by fostering radical innovation vs. incremental changes (3.7) in the research phase;
- To better match consumer needs (4.2) by putting to use the capacity of the EU level as a multiplier for innovative solutions in the demonstration phase;
- To support better consumer awareness (3.9) in the deployment phase while supporting the development of infrastructure (3.7), again to have the EU level acting as a facilitator of market uptake via lowering initial investment costs on the one hand and facing equally a lower risk in view of potential market scale (continental and even global level).

Demand management (e-toll, road user charging, access regulation) score 3.0 across policy objectives with the expected peak value as for what concerns the contribution to cost-efficient and seamless mobility. The scoring is equally unimpressive across the innovation chain (3.1 average scoring in the research phase, 3.4 average scoring in the demonstration phase, 3.4 average scoring in the deployment phase) possibly reflecting the maturity level of technologies in this domain.

Consistently, expert assessment highlights the added value of EU support to be focused in particular on a timely standardisation process (3.8) and on promoting wide-scale awareness of consumers (3.7) in the deployment phase.

3.3.3. Safety and security

[active and integrated safety and security (passengers and goods), tracking and tracing of goods]

Research and innovation areas in this category score slightly above the median value of 3 across policy objectives with the remarkable exception of improved consumer protection, security and safety.

The added value of EU intervention is considered relevant throughout the innovation chain with particular impacts expected on consumer awareness in the deployment phase and the capacity to meet consumer needs in the demonstration phase. What is also relevant is the stated role of EU intervention to support radical innovation compared to incremental solutions as well as the potential to develop technological enabling solutions for broad-range applications.

Integrated and intelligent road safety and security systems score an average 3.3 across policy objectives with an unsurprising peak of 4.5 in consumer protection, security and safety.

Scoring privileges the demonstration phase of the innovation chain (average scoring 3.8) compared to research (average scoring 3.5) and deployment (3.4) phases, with EU intervention valued in particular:

- To foster radical innovation vs incremental changes (3.7) in the research phase;
- To support the competitive advantage of innovative solutions (4.3) while exploiting the ability to match consumer needs (4.1) while actively contributing to define pre-normative standardisation (3.9) in the demonstration phase;
- To support better consumer awareness (4.0) in the deployment phase while fostering a timely definition of standards (3.7) in line with the pre-normative standardisation role identified in the demonstration phase.

Active safety technologies for navigation score an average 3.1 across policy objectives with the expected peak value in consumer protection, security and safety (3.8). The priority to this area is considerably lower on average across the innovation chain compared to others in the field of safety and security with average scoring of 3.3 in the research phase, 3.4 in the demonstration phase and 3.2 in the deployment phase.

The role of EU support is expected to be valuable for the following aspects:

- To foster radical vs. incremental change (3.6) while exploiting the potential of innovative solutions in this field as enabling technology (3.6) in the research phase;
- To better match consumer needs (4.0) in the demonstration phase while contributing to boosting competitive advantage (3.8);
- To support better consumer awareness (3.9) in the deployment phase while – once more – promoting timely standardisation (3.6).

Tracking and tracing technologies across all modes score relatively lower in terms of the capacity to meet EU policy objectives (average score 3.0). The priority to this area is close to the median value of 3 across the innovation chain: 3.1 average scoring in the research phase; 3.2 average scoring in the demonstration phase; 3.1 average scoring in the deployment phase.

The added value of EU intervention lays in the area of standardisation, which correctly indicates that these technologies are assessed as being relatively mature.

In that respect though, EU added value scores high at the research step in the innovation chain, i.e. funding fully innovative solutions capable of both reducing costs (3.6) while pursuing radical vs. incremental change (3.5).

3.3.4. Sustainable alternative fuels

*[propulsion systems, including electromobility are assessed in Section 6 "*Clean, safe and silent vehicles for all modes*" below on "Clean, safe and silent vehicles, aircrafts and vessels" ; alternative fuel infrastructure; uptake of alternative fuels]*

Production technologies for alternative fuels as well as charging and refuelling infrastructure for alternative fuels are of absolute relevance for EU policy objectives. The added value of EU intervention is high on average throughout the innovation chain but scores clearly higher in the demonstration stage in which the support to the scale-up potential of innovative solutions stands out as the most relevant.

Possibly due to current research and demonstration investment flows, alternative propulsion systems are considered relevant in terms of EU policy objectives but do not stick out as a particular priority in terms of added value provided by EU support throughout the innovation chain with an exception on pre-normative requirements, which is in line with the support to the market uptake and consumer acceptance of alternative fuels.

Alternative fuel production technologies score a mere 3 on average EU policy objectives, yet this research and innovation area is expected to contribute substantially to the decarbonisation of the transport system (4.0) and the reduction of oil dependency (4.3) as well – to a certain extent – to sustained transport industry competitiveness (3.5).

EU support is considered relevant across the innovation chain with an average scoring of 3.4 in the research phase, 3.7 in the demonstration phase, and 3.5 in the deployment phase. EU support is valued in particular:

- To exploit the potential of alternative fuels production as enabling technologies (3.6) and to explore radical vs. incremental changes in production (3.6) at the research stage;
- To add to industrial and – inherently – the European system's competitive advantage (3.8) and to facilitate the scale-up potential of new production technologies (3.8) in the demonstration phase where the clearly outstanding role of EU support is reserved to fostering pre-normative standardisation with an outstanding value of 4.2;
- To sustain investments of required infrastructure development (3.7) while playing an active and timely role in the standardisation process (3.5) and raising/broadening consumer awareness (3.5) in the deployment phase.

Charging and refuelling infrastructure for alternative fuels follows a similar trend as the "Alternative fuel production" research and innovation area. It scores an average 3.1 across policy objectives with a peak value in the reduction of oil dependency (4.0) and an above average value with respect to the decarbonisation of the transport system (3.6).

EU support is considered relevant mostly in the demonstration and deployment phases of the innovation chain, scoring on average 3.8 and 3.7 respectively while support to the research phase scores 3.1 on average with no remarkable peak values. EU support is valued in particular:

- To contribute to the (low) R&D intensity in this field (3.3) in the research phase;
- In the demonstration phase, to contribute to building the market potential for alternative transport fuels on solid grounds by matching consumers' needs (4.1) while fostering pre-normative standardisation (4.0) and supporting the scale-up potential required for alternative transport fuel infrastructure to be viable (3.9);
- To sustain investments of required infrastructure (3.9) while acting as multiplier of consumer awareness (3.8) in the deployment phase without forgetting the added values of timely standardisation (3.6) and support in overcoming entry barriers for innovative players (3.6).

Deployment and demonstration of alternative fuels score an average 3.0 across policy objectives with – expectedly so – higher values with respect to transport system decarbonisation (4.0) and oil dependency reduction (4.0).

Based on the very definition of this research and innovation areas, one would expect considerably higher average scoring of EU interventions in the demonstration and deployment phases along the innovation chain. The fact, that the averages are very similar (3.4 on average in the research phase; 3.4 on average in the demonstration phase, and 3.3 on average in the deployment phase) is most likely mirroring the variety of maturity levels of different alternative fuels.

This observation is confirmed when noting that EU support is valued in particular:

- To contribute to cost reduction (3.6) and to stimulate radical vs. incremental change (3.6) in the research phase, with the first value likely to address research aspects of close-to-mass market alternative fuels and the second value likely to address fuel alternatives which are considerably less mature;
- To foster pre-normative standardisation (3.6) while supporting the scale-up potential (3.5) required for fuel alternatives to be viable substitutes of conventional fuels in the demonstration phase;
- To sustain investments of required infrastructure (3.7) while increasing consumer awareness (3.5) in the deployment phase.

3.3.5. Sustainable urban mobility

[management of urban freight; innovative planning tools; urban-specific demand management; high quality public transport]

This Section grouping research and innovation areas specifically targeting mobility of persons and goods in urban areas clearly sticks out as being very prominent. Urban planning innovations score very high across policy objectives and phases of the innovation chain, highlighting the link – and the possibility to cluster activities – with some of the areas currently comprised in the "Exploratory and strategic issues" category. Urban-specific pricing/tolling schemes are valued as less relevant although the role of EU intervention comes out as an important one for scale-up potential in the demonstration phase and consumer awareness in the deployment phase. ICT for urban

freight flow management scores high on average, the demonstration phase coming out as the most prominent.

As already highlighted in Section 3.3.1 "Transport management and information systems" above, the **management of urban freight flows** scores 3.2 on average across policy objectives with strong emphasis on the potential contribution to cost-efficient seamless mobility (3.8).

Although scoring is slightly above the median value of 3 in the exercise in all phases of the innovation chain (3.1 average scoring in research phase; 3.4 average scoring in demonstration phase, and 3.2 average scoring in deployment phase), EU intervention is valued in particular:

- In support to research to enhance the potential (or increase the steepness of the curve) to reduce costs (3.2), as well as to support radical vs. incremental innovation (3.2). In combination, these score indicate that EU support is basically considered as a factor to lower investment risks for industry;
- In support to demonstration, to better address consumer needs (3.8) and adding to competitive advantage (3.8);
- In support to deployment, it is the role of the EU in the standardisation process which is emphasised (3.8)

Urban mobility planning innovations scores 3.4 on average across policy objectives, yet with an interesting coupling of policy objectives, uncommon to other research and innovation areas marked by high technology intensity: innovative planning tools are in fact deemed to contribute substantially to achieving cost-efficient and seamless mobility (4.0) while contributing to decarbonise the transport system (3.6). EU support across the innovation chain is far from being impressive: 3.3 on average in the research phase; 3.1 on average in the demonstration phase; 3.1 on average in the deployment phase. EU support is valued in particular:

- To increase R&D intensity in this domain (3.6) in the research phase while exploiting its potentials as enabler (3.6);
- To help better meeting consumers' needs (3.6 while adding to the competitive advantage of solutions in the demonstration phase;
- To markedly enhance consumer awareness (4.0) in the deployment phase.

Urban-specific demand management, including road pricing and access restriction schemes scores 0.1 below the median value of 3.0 on average across policy objectives with the peak value (3.5) in contributing to decarbonising the transport system. Scores are equally unimpressive across the innovation chain with 2.8 on average in the research phase; 2.8 on average in the demonstration phase and 3.0 on average in the deployment phase.

This result reflects the relative maturity of existing (and implemented) technological solutions and correspondingly identifies the highest values of EU support in the deployment phase solely; timely standardisation (3.3) and consumer awareness (3.3) are the peak values with value allocated also in the support to infrastructure development (3.2).

Partnerships for urban mobility scores 3.1 on average across policy objectives and is a low-technological research and innovation area that is expected to contribute mostly to cost efficient and seamless mobility in Europe (3.8) and towards the decarbonisation of the transport system (3.5). This area scores 3.0 on average in the research phase, 3.3 on average in the demonstration phase, and 3.2 on average in the deployment phase. EU support is valued in particular:

- To push R&D intensity (3.2) in a low-tech domain in the research phase;
- To better match consumer needs (3.9) while adding to industry and – inherently to urban areas – competitive advantage (3.5) in the demonstration phase;
- To markedly enhance consumer awareness (4.3) in the deployment phase.

It must be noted that the scoring exercise has not addressed high quality public transport.

3.3.6. Clean, safe and silent vehicles for all modes

[innovative and efficient vehicles, aircrafts and vessels, including components; underpinning technologies; new approaches to design, manufacturing, maintenance, recycling and monitoring]

In the modal sections of the scoring exercise, vehicle/aircraft and vessel design scores high on average and on average there is a high added value of EU intervention particularly in the support to enabling technologies in the research and demonstration phase of the innovation chain, slightly less so on deployment. Certainly, the scoring exercise highlights that for specific transport modes – the case of rail transport – the role of the EU is not seen as prominent in terms of supporting research activities. EU added value is a very relevant one in supporting radical innovation in the area of innovative materials.

Innovative and efficient road vehicles: design scores 3.1 on average across policy objectives with peak values of 3.9 with respect to transport industry competitiveness and 3.7 with respect to enhanced consumer protection, security and safety. This research and innovation area scores considerably the highest in the demonstration phase along the innovation chain (3.5 on average) while the research phase scores 2.8 on average and the deployment phase 3.2. EU support is valued in particular:

- To reduce costs to industry in the research phase (3.5);
- To add to the competitive advantage of developers (4.3) while at the same time matching better consumers' expectations (4.2), in the demonstration phase, which is a result fully consistent with the scoring in the field of policy objectives;
- To leverage its impacts on consumer awareness (3.7) and fostering timely standardisation (3.5) in the deployment phase.

Innovative and efficient road vehicles: propulsion technologies scores very high across policy objectives (4.5), with peak values in contributing to decarbonising the transport system (4.4) and enhancing consumer protection, security and safety (4.1). EU support scores 3.2 on average in the research phase, 3.4 on average in the demonstration phase and 3.3 on average in the deployment phase. EU support is particularly valued:

- To stimulate radical vs. incremental innovation (3.6) while exploiting potential as technological enablers (3.6) and narrowing the gap to technological maturity (3.5) in the research phase;

- To add to competitive advantage of developers (3.7) while ensuring a better matching of consumers' needs (3.7) and facilitating the scale-up potential (3.6) of new technologies in the demonstration phase;
- To increase/broaden consumers' awareness (3.7) while lowering entry barriers for innovative players (3.4) in the deployment phase.

Innovative and efficient road vehicles: manufacturing processes scores low across policy objectives on average (2.5) with the peak value in the transport industry competitiveness objective (4.0). Scoring is relatively low on average throughout the innovation chain: 2.8 in the research phase; 3.0 in the demonstration phase; 2.8 in the deployment phase, with the sole important peak value allocated to the competitive advantage of innovators (3.9) in the demonstration phase.

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Innovative and efficient ships and barges: design scores 3.1 on average across policy objectives where industry competitiveness (3.5) and transport system decarbonisation (3.5) are assessed to be the outstanding ones accompanied by a contribution to reduced oil dependency (3.4). EU support scores 3.0 on average in the research phase; 3.4 on average in the demonstration phase; 2.9 on average in the deployment phase. EU support is valued in particular:

- To reduce costs (3.5) in the research phase;
- To add to competitive advantage of the industry sector (3.8) while contributing to lowering barriers to access financial resources (3.5) in the demonstration phase;
- To mildly contribute to keep technologies up to date (3.2) and to contribute to standardisation process (3.2) in the deployment phase.

Innovative and efficient ships and barges: propulsion systems scores 3.0 on average across policy objectives with the remarkable peak values in the decarbonisation of the transport system (4.0) and – consequently – reduction of oil dependency (4.1) but also – to a lesser extent – the support to industry competitiveness (3.5). As for design EU support does not score particularly high across the innovation chain with 3.0 on average in the research phase; 3.3 on average in the demonstration phase; 3.2 on average in the deployment phase. EU support is valued in particular:

- To reduce costs (3.5) in the research phase while helping to narrow the gap to technological maturity (3.4);
- To add to competitive advantage (3.8) in the demonstration phase;
- To mildly contribute to keep technologies up to date (3.3) in the deployment phase.

Innovative and efficient ships and barges: manufacturing processes scores 2.4 on average across policy objectives with the peak value in the transport industry competitiveness objective (3.6). Scoring is relatively low on average across the innovation chain: 2.7 in the research phase; 2.8 in the demonstration phase; 2.5 in the deployment phase, with two peak values worth noting in the research phase with respect to the potential of EU support to reduce costs (3.3) and in the demonstration phase with respect to the potential of EU support to contribute to competitive advantage of developers.

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Innovative and efficient aircrafts: design and propulsion technologies scores 3.2 on average across policy objectives with the peak value (3.8) in the consumer protection, security and safety policy objective, followed closely by the objective regarding industry competitiveness (3.6). EU support scores the highest in the demonstration phase of the innovation chain with 3.4 on average compared to 2.9 on average in the research phase and 3.2 on average in the deployment phase. EU support is valued in particular:

- To contribute to reduce costs of research in the relevant phase;
- To fully exploit the competitive advantage (4.0) of innovators in the demonstration phase;
- To focus efforts and exert impacts at the appropriate scale with respect to standardisation requirements (3.8) in the deployment phase.

Innovative and efficient aircrafts: materials and structures scores 3.0 on average across policy objectives with a clear peak value in industry competitiveness (3.7). Scoring is substantially comparable between the research (3.3 on average) and demonstration (3.4 on average) phases of the innovation chain with lower importance attributed to the deployment phase (2.9). EU support is valued in particular:

- To fully exploit the potentials of this research and innovation area as enabling technology (3.8) and to privilege radical vs. incremental change (3.7) in the research phase;
- To maintain/sustain the competitive advantage of industry (4.2) via support at EU scale in the demonstration phase;
- To focus efforts and exert impacts at the appropriate scale with respect to standardisation requirements (3.3) while ensuring appropriate technology upgrading (3.3) in the deployment phase.

Innovative and efficient aircrafts: manufacturing processes scores low on average across policy objectives (2.6) with an expected peak value (3.5) in the industry competitiveness policy objective. EU support scores relatively low also throughout the innovation phases with an average 3.0 in the research phase, an average of 3.2 in the demonstration phase and an average value of 2.7 in the deployment phase. Within this setting, EU support is valued in particular:

- To contribute to reduce costs (3.5) in the research phase;
- To substantially contribute to the competitive advantage (4.0) of industry via innovative solutions in the demonstration phase;

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Innovative and efficient trains: design scores 3.2 on average across policy objectives, with a clear emphasis (3.7) on consumer protection, security and safety followed by considerations on industry competitiveness (3.6). EU support scores the highest value on average in the demonstration phase (3.3) with an average value in the research phase of 2.9 and an average value of 3.1 in the deployment phase. EU support is valued in particular:

- To mildly contribute to reduce costs (3.1) in the research phase;

- To add to the competitive advantage (3.6) while enhancing the capacity to better address consumers' needs (3.5) in the demonstration phase;
- To increase/broaden consumer awareness (3.3) while enacting timely standardisation (3.3) in the deployment phase.

Innovative and efficient trains: propulsion technologies scores 2.9 on average across policy objectives with peak values on decarbonisation f transport system (3.5) and reduction of oil dependency (3.4) policy objectives. EU support scores relatively low across the innovation chain with the following average values: 3.0 in the research phase; 3.1 in the demonstration phase, and 2.9 in the deployment phase. Within this setting of relatively low values, EU support is considered as particularly valuable:

- To mildly contribute to reduce costs (3.2) in the research phase;
- To substantially contribute to rail industry competitiveness (3.8) while fostering the development and endorsement of pre-normative standards (3.4) in the demonstration phase;
- To focus on standardisation requirements (3.2) in the deployment phase.

Innovative and efficient trains: materials and structures scores 2.5 on average across policy objectives with the only value slightly above the median of 3 in the industry competitiveness policy objective (3.1). EU support scores relatively low across the innovation chain with 3.0 on average in the research phase, 2.7 on average in the innovation phase, 2.4 on average in the deployment phase. Within this setting of relatively low values, EU support is considered relevant:

- To mildly contribute to reduce costs (3.3) in the research phase;
- To better address consumers' needs (3.1) in the demonstration phase;
- To ensure up to grade technological solutions in this research and innovation area (3.1) in the deployment phase.

Innovative and efficient trains: manufacturing processes scores 2.6 on average across policy objectives with an outstanding peak value of 3.7 in the territorial and social cohesion policy objective. EU support scores relatively low across the innovation chain with the following average values: 2.9 in the research phase; 3.1 in the demonstration phase; 2.6 in the deployment phase. There are though elements of interest for consideration within this setting, in particular EU support is valued:

- To make an important contribution to cost reduction (3.5) in the research phase;
- To considerably contribute to the competitive advantage of the industry (3.9) in the demonstration phase;
- To mildly contribute to ensure up to grade technologies (3.1) and access to resources (3.1) in the deployment phase.

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Underpinning/Enabling technologies: new materials scores 3.1 on average across policy objectives with an outstanding 3.9 value attributed to contributing to industry competitiveness while also contributing to decarbonising the transport system (3.5). EU support scores relatively high throughout the innovation chain with – unsurprisingly – the highest average value (3.7) in the research phase followed on the same level buy

the demonstration phase (3.4 on average) and the deployment phase (3.4 on average). EU support is valued in particular:

- To fully exploit the potentials as technology enabler within this research and innovation area (4.0) while fostering radical vs. incremental innovation (4.0);
- To substantially contribute to industry – and inherently the European system of innovation – competitive advantage (4.3) while also contributing to lower financing barriers (3.5) and fostering pre-normative standardisation (3.5) in the demonstration phase;
- To ease access to financial resources (3.6) while in parallel lowering entry barriers (3.4) in the deployment phase.

Underpinning/Enabling technologies: design concepts scores very low on average across policy objectives (1.2) with no single policy objective scoring above 2. Consistent results stem from the assessment of EU support across the innovation chain with low average values of 1.2 in each of the phases in which the innovation chain has been segmented.

Underpinning/Enabling technologies: advances in aerodynamics scores 2.6 on average across policy objectives with the peak value in the expected contribution to decarbonising the carbon system (3.4) while contributing to industry competitiveness (3.3). EU support scores at the highest on average in the research phase (3.2) with an average value of 3.0 in the demonstration phase and 2.7 in the deployment phase. EU support is valued in particular:

- To substantially contribute to abating costs (3.9) in the research phase;
- To add to the competitive advantage of industry (3.4) in the demonstration phase.

3.3.7. Exploratory and strategic issues

[unmanned transport; service-oriented rather than ownership-based mobility and transport; innovative transport and mobility concepts for passenger transport and goods distribution, incl. in urban areas; interaction between transport and other sectors, incl. environment and health; socio-economic research]

Unmanned transport solutions score high in terms of potential competitiveness of EU industry and the nature of change (radical vs. incremental). Yet, the same areas score considerably low in terms of EU policy objectives (and on average also along the other axes of the methodology) resulting as non-top relevant technological priorities for EU intervention in the transport innovation chain.

Very different is the case of service-oriented (vs. ownership-based) concepts of mobility and innovative systems for goods transport and distribution: both score high on average but particularly so on transport de-carbonisation and seamless and cost-efficient mobility policy objectives and the added value of EU support is valued to be high across the entire innovation chain.

It must be noted that the scoring exercise has not targeted specifically the broad field of socio-economic research, which has been considered – throughout the preparatory process – an essential element of knowledge-building and analytical capacity.

Unmanned transport: aircrafts scores 2.3 on average across all policy objectives with one single policy objective, which is contribution to industry competitiveness, hitting the median value of 3. EU support scores 3.3 on average in the research phase, 3.0 on average in the demonstration phase and 2.8 on average in the deployment phase. There are though interesting considerations when looking at sub-criteria, as EU support is valued in particular:

- To substantially contribute to fostering radical vs. incremental innovation (4.1 while narrowing the distance to technological maturity in the research phase;
- To add to competitive advantage (3.5) while fostering pre-normative standardisation (3.5) in the demonstration phase;
- To exert impacts on standardisation need (3.5) while lowering entry barriers (3.4) in the deployment phase.

Unmanned transport: public transport scores 2.7 on average across policy objectives with the peak value on industry competitiveness (3.4) followed by the expected contribution of this research and innovation area to cost-efficient and seamless mobility (3.2). EU support scores equally on average (3.2) in each of the phase in which the innovation has been segmented. EU support is valued in particular:

- To contribute to reducing costs (3.5) while fostering radical vs. incremental change (3.5) in the research phase;
- To substantially contribute to the competitive advantage of industry (3.7) in the innovation chain while fostering pre-normative standardisation (3.3);
- To exert impacts on timely standardisation processes (3.7) while supporting infrastructural development (3.4) in the deployment phase;

Unmanned transport: ships scores low on average (2.0) across policy objectives with no single policy objective reaching the median value of 3. EU support throughout the innovation chain scores relatively low with the highest average value in the research phase (3.1), followed by 2.8 average scoring in the demonstration phase and 2.5 in the deployment phase. EU support is valued in particular:

- To contribute to fostering radical vs. incremental innovation (3.5) and narrowing the distance from technological maturity (3.4) in the research phase.

Service-oriented rather than ownership based mobility and transport scores 3.3 on average across policy objectives and is characterised by the remarkable fact that all policy objectives score above the median value of 3 with the peak value (4.0) on cost-efficient and seamless mobility. EU support scores relatively high across the innovation chain with average values of 3.4 in the research phase, 3.5 in the demonstration phase, and 3.4 in the deployment phase and – again – all sub-criteria in each of the phases in which the innovation chain has been segmented score higher than the median value of 3. EU support is in particular valued:

- To foster radical vs. incremental change (3.7) while contributing to lowering costs (3.5) and exploiting the potential as technology enablers (3.5) in the research phase;
- To better match consumers' needs (3.9) while contributing to competitive advantage (3.7) in the demonstration phase;
- To substantially increase/enhance consumers' awareness (4.1) in the deployment phase.

Innovative systems for goods transport and distribution scores 3.2 on average across policy objectives with an unsurprising peak value in contributing to achieving cost-efficient and seamless mobility (3.9) while also contributing to decarbonising the transport system (3.7). EU support scores the highest on average in the demonstration phase of the innovation chain (3.6) with an average value of 3.4 attributed to EU support in the research phase and 3.0 on average in the deployment phase. EU support is in particular valued:

- To substantially contribute to lower costs (4.2) in the research phase while helping to exploit the enabling potential of technologies in this area (3.9);
- To add to the competitive advantage of developers and – inherently – of the European transport system (4.4) while providing an important contribution to better match consumers' needs (4.3) in the demonstration phase;
- To increase/ enhance consumers' awareness of close-to-market solutions in the deployment phase.

3.4. Conclusions from scoring exercise

A first general conclusion of the scoring exercise is that there are no definite winners or losers of research and innovation areas identified. The scoring exercise is a ***qualitative*** tool to support decision-making in prioritising interventions and in suggesting effective moments along the innovation chain and instruments for intervention and support at EU level rather than to perform an in/out triage of options.

The resulting list of research and innovation areas is inclusive and provides useful indications of where clustering of activities may enhance efficiency of EU intervention. Clustering of research and innovation areas is to a good extent external to the selection and prioritisation methodology and to the scoring exercise.

Yet, the way in which research and innovation areas are clustered together impacts considerably on the interpretation of outcomes. Based on this consideration, it is worth highlighting that both the methodology developed and the scoring exercise which represents its application are robust tools aimed at supporting decision-making but certainly not at replacing it.

4. CONCLUSIONS

A scientific analysis of the current status and vision was made for the various transport modes (road, rail, aviation, waterborne) and for some cross-sectoral issues (urban mobility, logistics, ITS across modes). Some innovative technological areas of particular relevance were identified.

The first analysis was followed by a scoring exercise which contributed to indicate the relevant importance of each technological area towards EU policy objectives and the reasons for that (i.e. contributing to decarbonisation of transport, or support to EU competitiveness, etc.). Although not defining clear winners or losers, the same exercise provided a qualitative indication of whether EU support should focus on the research, demonstration or deployment phases along the innovation chain.

This exercise was used as one of the inputs to the development of the final list of the Research and Innovation Areas (RIA), as defined in the STTP. While not being the only input to the definition of the RIAs, this assessment provided a strong scientific base for the whole exercise.

5. DATA AND INFORMATION SOURCES

All input received during the stakeholder consultation phase was taken into account. The following organisations have provided input during or after the stakeholder hearings. In total 48 contributions were received.

Hearing	Organisation
ITS	ASECAP (European Association with tolled motorways, bridges and tunnels) CER (Community of European Railway and Infrastructure Companies) ECTAA (Group of National Travel Agents' and Tour Operators') Association within the EU) ERTICO(Network of Intelligent Transport Systems and Services Stakeholders in Europe) POLIS (European cities and regions networking for innovative transport solutions) UITP (International Public Transport Association)
Fuels	AEGPL (European LPG Association) ASFE (Alliance for Synthetic Fuels in Europe) CLEPA (European Association of Automotive Suppliers) CONCAWE (Oil companies' European association for environment, health and safety in refining and distribution) EARPA (European Automotive Research Partners Association) EURELECTRIC (Union of the electricity industry) FCH-JTI (Fuel Cells and Hydrogen Joint Technology Initiative) EUROPIA (European Petroleum Industry Association) NGVA Europe (Natural Gas Vehicle Association)
Road	ACEA (European Automobile Manufacturers' Association) CEDR (Conference of European Directors of Roads) CLECAT (European Association for Forwarding, Transport, Logistic and Customer Service) ERTRAC (European Road Transport Research Advisory Council) EUCAR (European Council for Automotive R&D) FIA (FédérationInternationale de l'Automobile) IMPACTS IRU (International Road Transport Union) POLIS (European cities and regions networking for innovative transport solutions)
Research Coordination Structures	ECTRI (European Conference of Transport Research Institutes) EPTS (European Platform of Transport Sciences) ERA-NET Transport FEHRL (National Road Research Centres in Partnership)
Rail	CER (Community of European Railway and Infrastructure Companies) EIM (European Rail Infrastructure Managers) EURNEX (European rail Research Network of Excellence) ERRAC (European Rail Research Advisory Council)

	UIRR (International Union of Combined Road-Rail transport) UNIFE (Association of the European Rail Industry)
Logistics	CLECAT (European Association for Forwarding, Transport, Logistic and Customer Service) EIRAC – European Intermodal Research Advisory Council) EPF (European Passengers' Federation) EPOMM (European Platform on Mobility Management) EUCAR (European Council for Automotive R&D) POLIS (European cities and regions networking for innovative transport solutions)
Air	ACARE (Advisory Council for Aeronautics Research…) ASD (AeroSpace and Defence Industries Association of Europe) ECA (European Cockpit Association) EREA (European Research Establishments in Aeronautics) SESAR Joint Undertaking
Waterborne Waterborne (cont.)	EBU (European Barge Union) ECSA (European Community Shipowners' Association) EMEC (European Marine Equipment Council) ESO (European Skippers' Organisation) EuDA (European Dredging Association) INE (Inland Navigation Europe) WATERBORNE (EU technology platform)
Economic &Social issues	AGE Platform (European Network of Organisations of and for people over 50)

The following lists all extra material which was taken into account during the drafting of this document. In total more than 200 documents were consulted.

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Transport Research Knowledge Centre (http://www.transport-research.info)

ANNEX I: The STTP Scientific Panel

Name	Nationality	Function	Organisation
Angel Aparicio	Spanish	Professor	Polytecnical University of Madrid
Jens Froese	German	Professor	Jacobs University Bremen
George Giannopoulos	Greek	Director	Hellenic Institute of Transport
Stefan Hausberger	Austrian	Assistant Professor	Graz University of Technology
Alan McKinnon	British	Professor	Heriot-Watt University
Bo Lennart Nelldal	Swedish	Professor	Swedish Royal Institute of Technology
Vytautas Paulauskas	Lithuanian	Professor	Klaipeda University
Michaela Popa	Romanian	Professor	University Polytechnics of Bucharest
Dieter Schmitt	German	Professor	Technical University of Munich
Wojciech Suchorzewski	Polish	Professor	Warsaw University of Technology
Katalin Tanczos	Hungarian	Professor	Budapest University of Technology

ANNEX IIa: Tables for Maritime Transport Activities.

Table 5 .Impacts due to maritime transport activities, including illegal one and accidental events (Miola et al, 2010)

		AIR					WATER		SOIL/SEDIMENT				ECOSYSTEM		OTHER	
Activities-events/Impacts		Local Air Pollution	Noise	Vibration	Odour	Global Air pollution	Water pollution	Water turbidity	Soil / Sediment pollution	Acidif.	Erosion	Land loss	Biodiv. loss	Habitat Loss / Abasement	Congestion	Waste generation
In ports	Manoeuvring	■	■	■		■		■		■	■					
	Loading & Unloading Operations	■	■	■	■	■	■		■	■						■
	Hotelling	■	■	■		■				■						■
	Dredging	■	■			■	■	■		■			■	■		■
	Land traffic	■	■	■		■	■		■	■			■	■	■	
	Waste disposal Illegal dumping	■	■		■	■	■	■	■	■		■	■	■		■
	Infrastructures construction maintenance	■	■	■		■	■	■	■	■	■	■	■	■		■
	Fuel deposits				■		■		■			■	■	■		■
	Discharge of ballast water						■	■	■				■	■		■
	Dumping of black and gray water				■		■	■	■				■	■		■
	Bulk handling Goods movem.	■	■	■	■	■	■		■	■					■	■
	Industrial activities	■	■	■	■	■	■		■	■		■	■	■	■	■
	Spills				■		■	■	■				■	■		■
At sea	Cruise	■	■			■				■			■	■		
	Illegal dumping						■	■	■				■	■		■
	Dumping of black and gray water				■		■	■	■				■	■		■
	Spills				■		■	■	■				■	■		■
Ships building, maintenance, dismantling	Hull paintings	■			■		■		■	■			■	■		■
	Metal degreasing	■			■		■		■	■			■	■		■
	Demolition	■	■		■	■	■		■	■			■	■		■

Table 6. CO_2 abatement potential for different technological measures to abate fuel consumption and emission from the maritime traffic (Miola et al, 2011).

Category	Measure	CO2 Reduction Potential (Mt)		CO2 Reduction Potential (%)	
		DNV (2009)	IMO (2009)	DNV (2009)*	IMO (2009)**
Design	*Air cavity lubrication*	50	16	3,27	1,28
	Transverse thruster openings	--	30	--	2.55
Operation	*Alternative hull coating*	--	45	--	3.60
	Hull condition maintenance	15	35	0,98	2,80
	Propeller efficiency maintenance	5	25	0,33	2,00
	Speed reduction (fleet expansion)	130	100	8,50	8,00
	Speed reduction (Port turn around reduction)	60	--	3,92	--
	Trim/draft optimization	10	--	0,65	--
	Voyage execution (include optimum speed)	30	--	1,96	--
	Weather routing	60	3	3,92	0,24
Machinery	*Cold ironing*	10	--	0,65	--
	Common-rail upgrade	--	3.2	--	0.26
	Exhaust gas boiler on aux. engines	--	--	--	--
	Electronic engine control	20	--	1,31	--
	Engine monitoring & tuning	--	5	--	0,40
	Frequency convertor for electric motors	40	--	2,61	--
	Fuel consumption meter	--	13.5	--	1.08
	Fuel cell	20	--	1,31	--
	Gas fuelled machinery	90	--	5,88	--
	Novell light system	--	0,4	--	0,03
	Reduced auxiliary power	--	--	--	--
	Shaft power meter	--	13.5	--	1.08
	Solar panel	--	--	--	--
	Steam plant optimization	5	--	0,33	--
	Waste heat recovery	100	--	6,54	--
	Wind generator	--	--	--	--
Propulsion	*Contra-rotating propellers*	75	--	4,90	--
	Fixed sails or wings	20	--	1,31	--
	Kite	50	70	3,27	5,60
	Propeller performance monitoring	--	25	--	2,00
	Propulsion efficiency devices	25	--	1,63	--

* DNV (2009) refers to 2030 CO2 emissions, estimated by DNV to be of 1,530Mton

** IMO (2009) refers to 2020 CO2 emissions, estimated to be of 1,250Mton

Table 7. Cost-effectiveness of different technological measures to abate fuel consumption and emission from the maritime traffic (Miola et al, 2011)

Category	Measure	Cost per ton of CO2 averted ($/ton)				
		Eide et al. (2009)*		DNV (2009)**	IMO (2009)***	
		Min	Max	Average	Min	Max
Design	*Air cavity lubrication*	--	--	-30	-150	-90
	Transverse thruster openings	--	--	--	-160	-140
Operation	*Alternative hull coating*	-105	-100	--	-150	-15
	Hull condition maintenance	--	--	-20	-155	-35
	Propeller efficiency maintenance	-100	30	-45	-160	-65
	Speed reduction (fleet expansion)	--	--	90	80	135
	Speed reduction (Port turn around reduction)	-100	-50	-70	--	--
	Trim/draft optimization	-110	-100	-70	--	--
	Voyage execution (include optimum speed)	--	--	-90	--	--
	Weather routing	-110	-100	-30	-165	-100
Machinery	*Cold ironing*	--	--	205	--	--
	Common-rail upgrade	--	--	--	-125	45
	Exhaust gas boiler on aux. engines	--		190	--	--
	Electronic engine control	-80	20	25	--	--
	Engine monitoring & tuning	--	--	-75	-90	470
	Frequency convertor for electric motors	--	--	50	--	--
	Fuel cell	220	250	55	--	--
	Fuel consumption meter	--	--	--	-60	330
	Gas fuelled machinery	--	--	20	--	--
	Novell light system (LED based)	--	--	--	-95	440
	Shaft power meter	--	--	--	-105	115
	Solar panel	300	450	--	--	--
	Steam plant optimization	--	--	-90	--	--
	Waste heat recovery	0	180	150	--	--
Propulsion	*Contra-rotating propellers*	--	--	-30	--	--
	Fixed sails or wings	--	--	105	--	--
	Kite	-60	-60	0	-135	-75
	Pre-swirl stator	-100	-80	--	--	--
	Propeller performance monitoring	--	--	--	-160	-130
	Propulsion efficiency devices	--	--	-70	--	--

* Estimates from Eide et al. (2009) consider different scenarios of fuel price. Those reported here refer to the scenario with which consider a fuel price of 600$/ton. In this study the cost effectiveness is calculated for two ship categories, bulk carriers (Max estimate) and container ships (Min estimate)

** Estimates from DNV are derived from Eide et al. (2009), but consider the whole fleet

*** Estimates in IMO (2009) consider a 500$/ton fuel price, a 4% discount rate and the 2020 as base year.

ANNEX IIb: Overview of measures to make rail more efficient and reduce GHGs[49].

	System development	Technical development
To reduce GHG in the rail system		
In the rail system	Eco-driving Improved load factor	Space-efficient & compact trains Energy recovery Low drag trains
In energy supply	Electrification of diesel-operated lines Production of low GHG electricity	Dual-mode locomotives Hybrid trains Biofuels in diesel engines
To reduce GHG in the transport sector		
Passenger transport	Extension of High Speed Rail network Investments in EU 12 Market liberalization for lower prices Development of customer oriented intra-modal and inter-modal network	Technique for higher speeds Running gears for smoother ride and lower dynamic forces Space efficient trains Modular trains More efficient trains for reduced cost
Freight transport	Implementation of deregulation in practice to improve supply Rail freight corridors seamless through borders Investments in EU12 Development of dense inter-modal network	Lighter wagons with less noise Running gears for higher axle loads and speed Higher axle load and larger loading gauge Electro-pneumatic breaking Distributed radio-controlled power Automatic couplers Intelligent freight wagons and trains Terminal technology for horizontal automatic transhipment
Infrastructure	Implementation of longer freight trains Higher axle loads and wider loading gauge Faster freight trains	Cost efficient Slab track Long-life cross-ties Low-cost track
Traffic management and IT	Implementation of ERTMS	ERTMS level 3 Automatic operation
New modes		Magnetic levitation trains Vacuum tunnel trains Personal rapid transit (PRT)

[49] Taken from the TOSCA project

ANNEX IIIa: Key Logistics related technologies

Author: A. McKinnon

Supply Chain Management

Many European companies are now running their freight transport systems at levels of efficiency close to the maximum that can be achieved within the constraints of their business. To achieve a step-increase in efficiency it will be necessary for them to collaborate and share vehicle capacity to a greater extent than at present. Many companies have long experience of working with supply chain partners to minimise inventory. This spirit of co-operation is now extending into the transport arena, with companies demonstrating a new willingness to collaborate with partners at higher and lower levels in the chain (i.e. vertical collaboration) and other businesses at the same level in the chain (i.e. horizontal collaboration) and sometimes in competition. This increases opportunities to consolidate outbound loads and eliminate empty backhauls. Recent bilateral collaborations by companies such as Kellogg and Kimberly Clark (Anon, 2009), and Nestle and United Biscuits (Institute of Grocery Distribution, 2011), have yielded significant energy and emission reductions.

In the future 'multi-lateral' collaboration, which is to be promoted by a new EU-funded project called CO3 ('Collaboration Concepts for Comodality'), will reduce truck-kms, fuel consumption and related emissions by an even greater margin. New ICT platforms will have to be developed to facilitate multi-lateral collaboration, permitting both the exchange of transport data and the identification of back- and shared-loading opportunities. Cloud computing, in which companies gain common access to software and systems on the internet, can create new information-sharing models to support logistical collaboration.

Supply chains, and in particular the networks of supply chains formed by collaborative arrangements, are complex systems whose optimisation requires highly sophisticated modelling. The application of agent-based approaches to the optimisation of complex transport logistics problems is now well-established (Davidsson et al, 2005) Further work still needs to be done, however, in the development and refinement of agent-based software systems which can achieve supply chain solutions that are superior both in economic and environmental terms. This will be manifest on the ground in a reduction in the amount of freight movement (relative to what would otherwise be the case), better use of vehicle capacity, lower energy consumption and fewer emissions.

Vendor managed inventory (VMI) gives the supplier greater control over the replenishment process, allowing it to improve the loading of vehicles (Disney et al, 2003). The related transport benefits can be enhanced where the vendors have visibility of the inventory level and storage capacity at customers' premises. This will be made possible by future advances in telemetry and wider use of radio-frequency identification (RFID) across the supply chain.

Visibility is also a prerequisite for Supply Chain Event Management (SCEM), a technique which has existed since the early 2000s but as yet found limited application (Otto, 2003). It involves decomposing supply chain processes, including freight deliveries, into a series of discrete events, and monitoring them closely, using largely automated systems, to ensure that they occur at the right time and place. Where 'events' deviate from schedule, pre-arranged contingency plans are activated to correct the problem. This might involve switching a consignment to an express transport service or diverting it to another location where there is a greater need for it. SCEM is a logical extension

of the enterprise resource planning (ERP) systems that now run most medium and larger businesses, though it is still evolving and at an early stage in its diffusion. It, nevertheless, could have a significant impact on the way in which freight transport operations across Europe are managed over the next few decades.

Over the next decade 'direct digital manufacturing' (DDM) (also known as 'rapid manufacturing' or simply 'fabbing') is likely to transform supply chains and patterns of freight flow in several industrial sectors (Reeves, 2008). This involves the 3-dimensional printing of objects at the point of demand or use. Details of the product design are distributed online to the 'fabbing' machines, permitting customisation to individual specifications. These machines are currently small and can either fit on a desk or in a small workshop. A range of small products can now be produced in this way, including aircraft spare parts, dental crowns, plastic models and various toys. It is anticipated that, as DDM evolves, the size and complexity of the fabbing devices will expand, permitting the application of the technology to a broader range of products and industries. DDM represents a fundamental redefinition of manufacturing, dispersing it from factories, where goods are produced in large batches, to the locations where the products are actually required and can be made in single units. Hopkinson et al (2006) argue that it will trigger an 'industrial revolution for the digital age'. It will also have major implications for logistics. Supply chains comprising several production and storage points will be replaced by the direct delivery of the plastic and metal powders required to fabricate the products. The cubic volume of product moving through the chain will be dramatically reduced. There will also be much less wastage of product. The manufacture and distribution of the DDM machines will, of course, generate additional transport, though this should be greatly exceeded by the reduction in freight movement achieved by the dispersal of the production process.

Logistics Systems

Several trends in the design and operation of logistics systems, which have the potential to improve the sustainability of freight transport, can be reinforced by technological innovation.

A major determinant of the freight transport intensity of a logistics system is the degree of inventory centralisation. It is generally found that the higher the degree of centralisation, the greater is the amount of freight movement per unit of sales. The economic and environmental cost penalty associated with this additional freight movement can be reduced, however, where the centralised facility is supported by a network of local transhipment points, permitting break-of-bulk, cross-docking and inter-modal transfer. Advances in warehouse design, demountable vehicle systems, materials handling and ICT will facilitate the development of these satellite operations. The deployment of more sophisticated stock management and forecasting tools should also help to reduce the need for inventory repositioning within logistics systems which generates additional freight movement.

The efficiency of freight transport at all levels of the supply chain is impaired by the need to deliver within specified 'time-windows'. Greater flexibility in the scheduling of deliveries can translate into better use of vehicle assets and fewer vehicle-kms. This can be achieved through the development of unattended delivery systems, in which goods are delivered to secure reception boxes, often in the evening or during the night. By allowing deliveries to be made during off-peak periods, unattended delivery spreads the demand for transport infrastructure more evenly across the day and ensures freight vehicles can travel at more fuel-efficient speeds. Some use is currently made of locker-bank and reception box systems in particular supply chain applications (Rowlands, 2009). It is likely that unattended delivery will become much more

widespread, particularly at the bottom of the supply chain where the rapid growth of online retailing will encourage the installation of reception boxes at homes and automated collection points in neighbourhoods. Various unattended delivery systems already exist, though their uptake has been limited and largely confined to the business-to-business (B2B) market. Once the quantity of consumer purchases delivered to the home passes critical thresholds, the use of reception boxes is likely to become more extensive in residential areas.

It is not only the forward movement of goods through the supply chain which will be subject to technological change over the next decade. The return flow of products for recycling, re-use, repair and disposal will also benefit from new technology. The volume of reverse flow is steadily rising as waste directives require companies to 'bring-back' end-of-life products and all organisations to recycle an increasing proportion of their material waste. Many reverse logistics systems are currently inefficient and need to be re-engineered to make greater use of ICT and new types of handling, sorting, compaction and storage equipment (Pokharel and Mutha, 2009). This will rationalise the return movement of product, improving the economics of recycling while reducing its environmental footprint.

Transport Management

One of the most fundamental challenges of freight transport management is optimisation of the routes that vehicles follow when delivering and/or collecting consignments to/from several locations. Numerous software packages exist to help plan routes and they are now widely applied across the European freight sector. Computerised vehicle routing and scheduling (CVRS) was first developed in the 1970s and since then its functionality, performance, cost-effectiveness, flexibility and user-friendliness have greatly improved. Annex IIIb reviews the development and implementation of this technology over the past 40 years, using it to illustrate the problems and barriers that logistics innovations can encounter. Future improvements in this technology are likely to be incremental rather than transformational but, when combined with wider adoption, have the potential to cut the economic and environmental costs of freight transport by a significant margin. For example, efforts are being made to incorporate historic telematic data into CVRS systems to replace fixed average speeds for particular road classes with mean values and variances for the speed actually achieved on specific road links at particularly times of the day and week. This is likely to yield more optimal solutions particularly on congested road networks. One study has found that telematics-calibrated CVRS reduced CO_2 emission on a delivery network by 8% (Maden et al., 2010). This integration of telematics and CVRS in the planning of routes prior to the vehicle's departure is a long way, however, from the dynamic rerouting of trucks on the road, as discussed below.

On-board vehicle telematics gives fleet managers real-time information about the location and operation of their vehicles. This allows them to reschedule and reroute vehicles in response to changing customer demands, traffic conditions and other random events. It can also monitor the performance of the vehicle and the way it is driven. This technology is at a reasonably advanced stage, though much of the European truck fleet is still not telematics-enabled. The main economic and environmental benefit of telematics in the freight sector over the next 5-10 years is likely to accrue more from wider adoption than from technical advances in the functionality of the equipment. It is likely to be increasingly fitted as standard in new vehicles.

The vision of telematics being widely used to dynamically reroute vehicles during a delivery operation has so far been elusive. It has been constrained by several factors

(McKinnon, 2009). First, there has been little demand for this capability from vehicle operators, even in countries and regions with seriously congested road networks. Second, as discussed elsewhere in the report, there is currently little inter-connection between road network-based and vehicle-based telematic systems, the former operated by highway authorities and road information companies and the latter by third-party telematics providers and truck manufacturers. Third, the use of real-time traffic flow data to continuously re-optimise a vehicle's movements while on the road, and do so well enough to win the driver's confidence, is extremely complex. This presents one of the major technical ITS challenges for the next decade.

B2B e-commerce is well-established in the European freight market and takes various forms. For example, several online platforms allow shippers to tender their transport requirements over periods of several weeks or months. Other freight exchanges provide short-term load-matching or auction services on an hourly or daily basis. These e-marketplaces have greatly improved the opportunities for matching loads with available vehicle capacity, particularly on backhauls. One online freight exchange estimated that companies using its procurement services were able to cut their transport costs by an average of 8% by increasing 'carrier's asset utilization while protecting their margins' (Mansell, 2006). This market is now fairly mature, though service offerings are continuing to evolve (Wang et al., 2007). It is now possible for several companies to have their freight demands bundled prior to online bidding process and for 'optimisers' to be used to achieve a better match between shippers' freight demands and the available capacity. The functionality of this form of enhanced web-enabled tendering is likely to continue increasing. The short-term application of online load matching is constrained mainly by relatively low levels of adoption. It is difficult for these freight exchanges to generate the critical volume of vehicle movements needed to establish a profitable flow of backloading opportunities It may be possible to attain this critical mass by feeding telematics data on the positioning of empty vehicles and available loads directly into online freight exchanges. This would effectively exploit synergies between two related ICT technologies and help improve capacity utilisation across the European freight sector.

Vehicle loading and transshipment

The nature of loading and transhipment operations affects the sustainability of freight transport in many ways. The handling equipment used to facilitate the loading and loading, such as pallets, roll cages, stillages and dollies, occupies space in the vehicle and so affects the size of payload that can be carried. Redesigning this equipment and related packaging material can improve 'space efficiency' and permit greater consolidation of loads. Advances in materials handling can also accelerate vehicle turnaround times and improve the overall efficiency of reception operations at commercial and industrial premises. The growth of reverse logistics is creating the need for new types of returnable transport items (RTIs) tailored to the needs of particular waste streams and end-of-life products. The fast and efficient transfer of modular units (such as containers and swap-bodies) between transport modes is critical for the realisation of the European Commission's ambitious plans for the development of co-modal transport and freight modal shift. Over the years there has been a health flow of innovation in the field of inter-modal transfer and this is likely to continue (Woxenius, 2007).

One of the potential downsides of increased modularisation is that the modules add weight to the vehicle and thus reduce its effective carrying capacity. It is important therefore that modular containers and handling-equipment be made of materials that

are both lightweight and sturdy. Advances in material science should yield innovations applicable to the modularisation of freight consignments.

ANNEX IIIb: Past Experience of Logistics Innovation

Author: A. McKinnon

Logistics has always been a fertile area for technological innovation. Research by Mena et al (2007), identified six areas in which much of this innovation was concentrated: telematics, 'information technology infrastructures' for supply chain management, RFID, computerised vehicle routing and scheduling CVRS, 'digital administration' / electronic proofs of delivery' and transport technologies. The rates at which logistics-related innovations have been commercialised and diffused, however, have been relatively slow. This is illustrated by the adoption of a range of logistics-related technologies such as CVRS, vehicle tracking systems, RFID and devices for improving fuel economy. Annex 1 charts the evolution of CVRS over the past forty years to show how long it can take for a major transport technology to gain wide industry acceptance. There is evidence too that when new equipment and systems are installed, they are not used to their full potential. In some cases, managers and operatives are not given sufficient training in their use, while in others companies are unable or unwilling to make the necessary changes to internal processes and procedures to maximise the benefits of new technology. The reluctance within the logistics sector to adopt and fully exploit technical innovations can be attributed to several factors some of which are internal to the business, others external and more difficult to influence (Gammelgaard, 2008; McKinnon, 2009).

Internal factors

The high degree of fragmentation and intense competition in some parts of the logistics sector, most notably general road haulage, urban delivery, inland waterway transport and freight forwarding, make it difficult for companies to accumulate the necessary capital to invest in innovations. For example, in European countries, typically 80-90% of carriers have five or fewer vehicles. They operate on relatively slim average profit-margins of 2-3%, have limited financial resources, often fail to adequately depreciate their assets and tend to have a relatively long replacement cycle for vehicles and equipment. Many companies operate old IT hardware that cannot support new and upgraded logistics software packages. Competitive pressures, particularly in spot haulage markets, force managers to concentrate on 'making ends meet' and limit the time available to assess new technologies and business processes. Many also lack the education and expertise to make innovation-related investment decisions and to implement them effectively.

External factors

Many companies regard freight transport as a basic, standardised 'commodity' which should be purchased at minimum cost. They take advantage of the intensely competitive conditions that exist in many parts of the European freight transport market and secure rates that leave the carrier with little margin for innovation. The integration of freight transport within a more broadly-based package of logistics services has enabled the larger logistics service providers to add value and differentiate themselves by service quality as well as cost. However, there is a prevailing view across much of the logistics sector that the users of these services are not prepared to reward providers adequately for investments made in innovative equipment and systems. This has been reflected in industry surveys. For example the 15th Annual Third Party Logistics Survey undertaken by Capgemini and Georgia Tech (2010) of 1133 users and providers of logistics services around the world identified an 'innovation gap'. Many users of these services were dissatisfied with the extent to

which providers were innovating, while the latter complained that innovation was inhibited by their clients' reluctance to share information. Logistics service providers have also complained that contracts are sometimes so narrowly defined that they have little incentive to innovate.

Freight transport operators are also deterred from adopting vehicle-related innovation because they are uncertain about the effect that it will have on the residual value of the vehicle in future years, particularly where it might affect reliability and maintenance costs.

The healthy flow of logistics-related innovations over the past few decades suggest that the rate of technological improvement is constrained much more at the demand end than on the supply side. There is evidence, however, of two deficiencies on the 'supply' of technological innovation in this sector. The first relates to the way in which it is marketed. In the past, some new freight transport systems have been 'over-sold' with their suppliers making exaggerated claims about their impact on productivity and service quality. As discussed below, this occurred, for example, in the case of CVRS and vehicle tracking systems. Early adopters were disappointed by their experience with the new technology and reported their negative experience to other transport companies through both formal (i.e. trade organisations and press) and informal channels. This undermined industry credibility in the technology which took several years to rebuild. According to the Gartner Group (2009), it is quite common for new ICT technologies to go through this 'hype cycle', in which initial expectations are over-inflated (see Figure 4). The second deficiency relates to the amount of support freight operators are given with the implementation of new technologies. Smaller carriers are often not given enough training and guidance in their use to be able to maximise the benefits. This applies particularly to those technical innovations that require some re-engineering of internal processes.

A Retrospective Case Study

Computerised Vehicle Routing and Scheduling (CVRS)

CVRS uses software tools to optimise the routing of trucks around a series of delivery (or collection) points within various operational constraints. Optimisation can be defined with respect to a series of metrics such as distance travelled, transit time and transport cost. This technology has had a major impact on the efficiency of road freight operations over the past few decades. It provides a useful illustration of how an innovation is developed and commercialised in the freight transport / logistics sector.

Mathematical interest in the 'travelling salesman' problem dates back to the 19th century, though it was not until the 1950s that algorithms were developed for its freight transport application in the so-called 'truck despatch' problem. The use of these algorithms to solve large truck routing problems was largely confined to universities, partly because of the heavy mainframe computing requirements. This academic work on the subject was reported in the operational research literature. The first commercial CVRS packages began to emerge in the 1970s, running on company mainframes and early 'mini-computers'.

Early adoption of this technology was difficult and slow. CVRS packages were developed and marketed by new business start-ups, set up mainly by academic researchers and logistics IT staff. Initial marketing tended to exaggerate the benefits

of CVRS and, as a result, the experience of many early adopters was disappointing. The functionality and user-friendliness of the software was relatively poor. In some businesses its adoption was resisted by manual route-planners who considered it to be a threat to their jobs. This was understandable because some suppliers presented CVRS as a means of fully computerising the route-planning exercise. The costs of the software and related computing requirements were high, particularly in comparison to transport hardware like vehicles, and many transport managers very sceptical about its cost-effectiveness and return on investment. There was a bias in favour of investment in tangible assets like trucks and against intangible software solutions. One software house in the late 1970s argued that on average CVRS could save one truck in every seventeen, suggesting that it would not be cost-effective for the vast majority of small hauliers running small fleets (typically 80% have fewer than 5 vehicles). Overall, the first generation of commercial CVRS packages got a 'bad press' and its credibility as a means of improving transport efficiency was serious undermined.

During the 1980s and 90s several things happened to promote wider uptake of this technology. First, the functionality, user-friendliness and performance of the software were substantially improved. Second, advances in computing, particularly with the development of micro-computing, made it much cheaper and easier to run the CVRS packages. The decline in the real cost of the hardware and software increased its cost-effectiveness, improved the rate of return and made it financially accessible to a much wider range of transport operators. Third, these packages were also remarketed as tools to assist rather than replace manual route-planning, recognising the need to retain the traffic clerk's detailed knowledge of delivery constraints. Fourth, the nature of route planning also changed at a more fundamental level. In the early days, when computer processing was slow and expensive, the main application of CVRS was in the design of fixed routes at intervals of several weeks or months, particularly for companies whose spatial pattern of demand was fairly stable. Advances in computing and software development made it much cheaper and easier to use CVRS to replan routes on a daily basis. This extended its diffusion to a wider range of companies and increased its overall impact on the amount and pattern of road freight movement. To fully exploit this short-term tactical application of the software, companies usually need to re-engineer internal logistical processes and relax constraints traditionally imposed by marketing and sales departments. These internal organisational changes can take many years to implement and are often made as part of a broader strategic review.

Although it is now a mature technology with wide adoption across the European road haulage industry, CVRS is still evolving. This is partly in response to the development of related technology, particularly telematics. The electronic trip records generated by GPS-based vehicle tracking permits much more precise calibration of average speeds. The integration of CVRS and telematics also offers the prospect of trucks and vans being routed dynamically across the road network in response to real time variations in traffic levels and backloading opportunities.

In summary, the history of CVRS conforms quite closely to the so-called 'technology hype cycle' devised by the Gartner Group (Figure 4). Early expectations of CVRS were over-inflated by the excessive claims of software houses and a failure of the systems to deliver the quoted benefits. Many of the initial users were disillusioned and it took significant product development and the emergence of new business models to restore its credibility. The parallel upgrading and cheapening of computer hardware steadily reduced the capital cost of installing CVRS, while the redefinition of its role as a logistics planning tool made it easier to assimilate within the business. It has now ascended the 'slope of enlightenment' to reach the 'plateau of productivity' where

many companies now use it as a standard procedure. It has, nevertheless, taken around 25-30 years to reach this position. As more and more trucks are becoming 'telematics-enabled', new opportunities are arising for further upgrades to CVRS, illustrating how a well-established technology can be refreshed by the emergence of a related innovation.

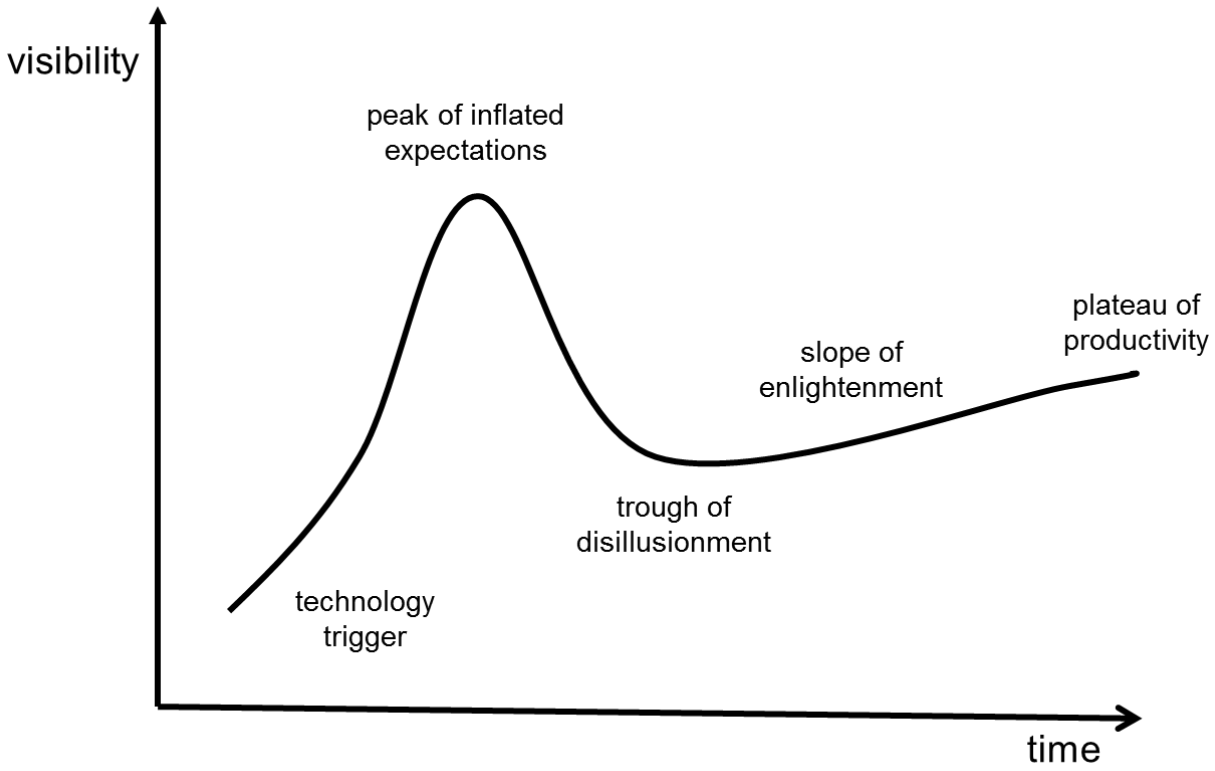

Figure 4: Typical Path Followed by ICT Innovations

ANNEX IV: Economic and social issues

Authors: P. Christidis, A. Aparicio

The current paradigm of ever cheaper, faster transport has been critical in the European project, and for territorial and social cohesion. This paradigm is currently challenged, mainly due to uncertainties/challenges regarding energy supply and environmental impacts (GHG emissions).
The transport sector has to address an increasingly fractured demand for freight and personal mobility. The traditional "one size fits all" approach is no longer valid. Niche services should probably proliferate in future; this is a major challenge for technological developments and for operators (transport service providers).
In general terms, the actual relevance of the transport system for economic and social development seems to be increasingly limited, as the European transport infrastructure and service networks have been deployed. Yet, as the result is an increasingly interconnected system, there is a need to better identify existing weaknesses (congestion, missing links, intermodal gaps…).

- **Vision and how to achieve it**

Innovation in transport -in terms of new technologies, processes or services- depends to a large extent on the socio-economic context, since the degree to which innovation meets the needs of society and the economy defines the future of any innovation. The whole history of transport technology and services is characterised by the need for faster, cheaper and safer means of moving people and goods. On the other hand though, innovation can be also a catalyst for the transformation of living or working patterns, creating new needs or freeing up resources that can be used for other activities. High speed trains and low-cost airlines have revolutionised business trip or holiday patterns; containerisation has strongly influenced industrial location and manufacturing practices. Policies aiming to stimulate innovation should take into account the economic and social context both as a driver and as recipient. This can help in identifying where R&D and innovation efforts should be concentrated in order to fulfil policy needs of high priority, but also in ensuring that technological development will lead into benefits for the largest part of the society.

The main goal of the EU transport policy is to develop a transport system that meets society's economic, social and environmental needs and is conducive to an inclusive society and a fully integrated and competitive Europe. The on-going trends and future challenges point to the need for satisfying rising demand for travel or accessibility amid growing sustainability concerns and in the context of an ageing population. The most immediate priorities appear to be the better integration of the different modes of transport as a way to improve the overall efficiency of the system and the acceleration of the development and deployment of innovative technologies within an approach that always keeps transport users (of all ages) and workers, with their needs and rights, at the centre of policymaking.

Economic development is one of the main important key drivers for transport demand and supply. This includes quantitative aspects – e.g. economic growth, increasing employment etc – as well as qualitative aspects like increasing wealth or international economic integration. Globalisation is an important economic key-driver with its international organisation of production and distribution of both goods and services. The reduction of trade barriers supported transnational economies of scale and a traffic intensive organisation of work and production processes at international level.

From the passenger side, one of the main drivers for changing mobility demand in Europe will be demographic development. Demographic ageing is a challenge for societies as well as for the mobility and the transportation system itself; decreasing individual mobility of elderly and increasing needs of safety cause a shift from active mobility of mid agers to passive mobility of the elderly. This means more demand for public transportation as well as for safe and easy accessible transportation. Mobility supply not only has to react on these changes but needs to adopt a proactive approach.

Supply and demand of mobility depends on oil price development too. Prices for transportation and mobility services remained relatively low during the last decades, while wealth and the average income were increasing. Increasing disparities of income, energy and mobility prices need to be considered. The concept of supporting decarbonisation by true cost policy for transportation imposes the problem of causing higher burdens for low income households and therefore supporting social inequality and unequal opportunities.

The discussion of key drivers shows a volatility of transportation demand due to the dynamics of the influencing factors. However, there is less volatility on the supply side. The biggest part of the transportation infrastructure is immobile, cost-intensive and has to be realised over long planning periods. Inefficient spending is endemic to the transportation system due to rapid changes in demand. More flexible transportation systems can be part of the solution.

Mobility behaviour results from actors' decisions on locations (for living, working, spending free-time, etc), frequency of travel and transportation mode. These decisions are determined by influencing social factors such as age, status and income which are relevant for lifestyle and mobility behaviour. As one main important factor, income enables actors to choose conditions and area for living as well as the transportation mode connecting them to work.

Another aspect of (mobility) disparities has to do with gender imbalance in the transport sector, reflected in travel behaviour differences between men and women. In the freight sector, the role of women as operators is still limited. Gender issues in the operation and management of transport systems has not been given sufficient attention until now.
For R&I developments the following are of particular importance:

- Better understanding of transport impacts on socio-economic developments.
- Monitoring of the socio-economic and environmental impacts of transport activity: there are statistical and research needs associated to this, which could probably be identified by the European Environment Agency (EEA).
- Mapping the expected further fragmentation of mobility demand (identification of mobility needs of particular societal groups, goods/industries, etc.).
- Spatial impacts, related to decentralisation/recentralisation trends of economic activities within the EU.

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ANNEX V: Multimodal Transport Infrastructure

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With contributions from: P. Dilara

Current status

Multimodal, yet efficient transport is one of the key aspects of the new Transport WP. Treating all modal transport infrastructures (for road, rail, inland waterway, ports, and airports) as an integrated and single Transport Infrastructure (TI) element of European transport system, represents an important step towards a Single European Transport Area.

It has been more than 15 years since the first development of the **TEN-T**, in 1996. The priority projects were extended in 2004 to take account of the accession of 10 and then 2 more New Member States to the EU. The TEN-T network comprises now of 30 priority projects which should be completed by 2020.

The sustainable use of resources is an essential aspect of policy on the TEN-T and the priority projects give privileged status to those modes which are more environmentally friendly. Of these 30 priority transport infrastructure projects, 18 are railway projects, 3 are mixed rail-road projects, 2 are inland waterways transport projects and one refers to motorways of the sea. The proposed project selection in the field of priority projects contributes to the Commission's objective in terms of sustainable development. Three quarters (74.2%) of the funding goes to railway projects and another 11.5% are reserved for inland waterways. The support for road and air transport is more limited.

Implementation of the trans-European transport networks requires substantial amounts of funding. Based on the revised information from the Member States, the overall cost of the network is 900 Billion EUR and nearly 500 Billion EUR still need to be invested until 2020. Completion of the priority projects alone requires more than EUR 250 billion by 2020 with all TEN-T project being large-scale both in terms of money invested, as well in time (some of them spanning over to 2020).

An average time per completed km is a useful indicator to reveal the long lasting works for High Speed Rail (HSR) and motorways. The figures in Table 8 and Table 9 reveal the difficult in-time progress of HSR, and respectively motorways.
The motorway's work speed is faster in EU-15 then EU-27, which indicates high interest of the EU-15 in motorway building. The EU cohesion goal has not been achieved yet. In the same time, there are poor conditions of the ordinary terrestrial networks (road and rail) in some of the NMS (e.g. Bulgaria and Romania). Similarly for other transport modes, a short review indicates the same tendencies: in EU-15 the inland waterway are growing and the most important airports (meaning hub airports with more than 10 mill. of passengers per year) are also located in EU-15 (see Table 10 and Table 11).

Table 8: HSR's work speed

Length of HSR*								km per year
km (at end of year)								
	BE	DE	ES	FR	IT	UK	EU	
1985	-	-	-	417	224	-	641	_
1990	-	90	-	699	224	-	1013	74.4
1995	-	447	471	1220	248	-	2386	274.6
2000	58	636	471	1278	248	-	2691	61
2001	58	636	471	1573	248	-	2986	295
2002	120	833	471	1573	248	-	3245	259
2003	120	875	1069	1573	248	74	3959	714
2004	120	1202	1069	1573	248	74	4286	327
2005	120	1202	1090	1573	468	74	4527	241
2006	120	1291	1272	1573	562	74	4892	365
2007	120	1300	1516	1893	562	113	5504	612
2008	120	1300	1594	1893	744	113	5764	260
23 years							5123	*222*

*Length of lines or of sections of lines on which trains can go faster than 250km/h at some point during the journey

Source: EU energy and transport in figures. Statistical pocketbook 2009

Table 9: Motorways' work speed

	km (at end of year)							Average length per year	Area, 1000 sq.km	Yearly length/ Area, km/ 1 mill. sq.km
	1990	1995	2000	2003	2004	2005	2006			
EU-27	41885	47970	54700	58850	60100	62000	63400	1345	4.323,0	311,05
km per year	-	*1217*	*1346*	*1383*	*1250*	*1900*	*1400*			
EU-15	39616	45468	51471	55292	56294	58000	59205	1224	3.236,3	378,31
km per year	-	*1170*	*1201*	*1274*	*1002*	*1706*	*1205*			
EU-12	2269	2502	3229	3558	3806	4000	4195	120	1.086,7	110,77
km per year	-	*47*	*145*	*110*	*248*	*194*	*195*			

Source: EU energy and transport in figures. Statistical pocketbook 2009

Table 10: Inland waterways - Length in use (Navigable canals, rivers and lakes regularly used for transport)

km							
	1990	1995	2000	2003	2004	2005	2006
EU-27		38963	41152	40946	42808	42870	43011
EU-15	29474	29608	32169	32021	33889	33950	34091
EU-12		9355	8983	8925	8919	8920	8920
EU-10		7103	6734	6676	6670	6671	6671

Source: EU energy and transport in figures. Statistical pocketbook 2009

Table 11: Number of European airports, by number of passengers carried per year

	more than 10 million	5 to 10 million	1 to 5 million	500,000 to 1 million	100,000 to 500,000	15,000 to 100,000
EU-27	31	29	92	43	116	81
EU-15	30	26	77	40	102	72
EU-12	1	3	15	3	14	9

Source: EU energy and transport in figures. Statistical pocketbook 2009

Urban Transport Infrastructure:

A short review of the main problems of the urban TI shows that:

- urban population is continuously growing due to the "agglomeration effect"; but, economic growth has induced the residential relocation from the dense residential city zones into the suburbs; in most of the cases new suburban settlements are mono-functional zones; without a comprehensive strategic plan of the urban development, including Rapid Transit network, most of the inhabitants are captives of the road transport (this is the case of the most capital cities from EU-12);

- restoring mobility by healing symptoms of urban road traffic congestion (e.g. trying to suppress traffic bottlenecks, increasing capacity of the main road networks, creating new parking lots or implementing techniques of traffic management), is no longer a realistic long-term strategy; experience has shown that in cities where measures were taken to increase the fluidity of traffic, the initial problems reappear some years later in an even more acute form[50];

- most of the European cities have an historical development and hence, a quasi-circular structure; the TI for passenger transportation follows city's structure: radial/ circumferential network;

- if the urban network is Rapid Transit-based: with adequate coverage throughout the central area and close suburbs; having at least one station close to each major activity zone; with good connectivity among lines requiring no more than one transfer and convenient transfer between lines, then the urban network is called "ubiquitous" and most of the travellers needs may be fulfilled in a sustainable manner. The Paris Metro

[50]Duchateau, H. (1997) Mobility and Accessibility – The Case of Brussels.In Operation Research and Decision Aid Methodologies in Traffic and Transport Management.Springer, NATO ASI Series, Series F, vol.166, pp.84-103.

network is an example for this (Vuchic, 2005)[51]. It covers the entire urban area well: no point within the central city is more than 500 m from a metro station. Munich, Madrid and some other capital cities also have many elements of the ubiquitous network pattern, but there is a large variation of the ubiquitous levels among cities, especially in Eastern part of Europe;

- despite the recognised potential benefits of rail-based services at airports, the degree of air-rail intermodality still varies widely among Europe's largest airports.

Vision and how to achieve it

1. Research on the engineering, environmental and economic performance of **track (links) systems:**

- improving the road and railway track behaviour governing stiffness, robustness, longevity, and noise and vibration performance;
- reducing deterioration rates and maintenance frequencies, mitigating the environmental effects of noise, vibration and materials use for TI links;
- improving the road and rail track monitoring systems performances; including the ITS/ICT-based monitoring systems;
- increasing the time between maintenance cycles will reduce whole-life costs and improving timetable reliability, giving financial, environmental and customer service benefits;

2. Research on rail-based **intermodal terminals'** infrastructure:

- research on hub and spokes structure of intermodal terminals (e.g. marshalling yard network, inland waterway ports, maritime ports, etc.) at different covering levels: continental, regional or/and national levels, in a coordinated manner across Europe;
- research on minimum requirements considering quality performances, in terms of equipment and interchange technological/operational processes in terminals, in order to select a given hub and spoke structure (quality standardisation);
- energy recovering/saving and decarbonisation equipment and/or technologies for the handling operations in inter-modal terminals and storage;

3. **Innovation to build rail** for a seamless and energy & environmental efficient European transport sector (rail-based and IWW-based as cross-modal innovations/ policies):

- commercial and operational regulation frame related to the strategic alliances among rail, road and inland water-way operators, on one hand, and among operators and terminals/infrastructure authorities and wagons owner/locomotives or railcars owner, on the other hand;

- innovative business tool for maintenance of track systems: the rail track maintenance market;

- developing the institutional structure for the TI development, gradually improved using the most "productive" and successful institutional structures example in Europe;

[51]Vuchic, V.R. (2005) Urban Transit: Operation, Planning and Economics. John Willey &Sons, New Jersey.

- innovative normative/regulation framework for infrastructure building and maintaining resources spent, in terms of costs and time, including environmental external costs during works times;

- innovative normative/regulation framework for the *ex-ante* evaluation of the transport infrastructure costs (for both monetary costs and shadow prices) and benefits, depending only on the transport infrastructure project scale (EU, regional or local scale), irrespective of the countries conditions and mode of transport; iterative improving process of the norms and standards in a strict *ex-post* monitoring frame, has to be considered;

- innovative, comprehensive and hierarchical frame of the priority weights for the decision-making process in case of TI projects: the upgrading TI projects must have the highest priority; inside the upgrading projects the intermodal terminals projects have higher priority against the other mode TI upgrading; the set of the new TI are a lower priority than upgrading projects and inside this set of projects again, the intermodal rail-based terminal have higher priority against the other new TI; this approach will coordinate financial flows in a efficient way;

- encouraging or pushing the Public-Private-Partnership scheme for TI development, by imposing a certain percentage of the total TI projects which has to be completed in a PPP scheme in total planned TI projects, during a certain period of time (e.g. four or five years);

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ANNEX VI: Multimodal solutions for interurban mobility

Author: A. Aparicio

- **Current Status**

Flows of passengers among EU cities have dramatically increased in the last two decades, following the integration of the E.U. economy. Furthermore, the free movement of people within the E.U. constitutes a key element of the European project, and one of those closest to the citizens' personal experience.

In 2008, total passenger transport activities in the EU27 by any motorized means of transport are estimated to have amounted to 6 527 billion pkm or on average 13.138 km per person. This figure includes intra-EU air and sea transport but not transport activities between the EU and the rest of the world. Passenger cars accounted for 72.4 % of this total, powered two-wheelers for 2.4 %, buses & coaches for 8.4 %, railways for 6.3 % and tram and metro for 1.4 %. Intra-EU air and intra-EU maritime transport contributed 8.6 % and 0.6 % respectively [EU Energy and Transport in Figures, 2010].

The dominance of the more pollutant transport modes in interurban travel has received particular attention from EU transport policy makers since 1992 White Paper. The combined used of transport modes (multimodality), carefully addressed in the document for freight, is shyly considered also for passengers, making some considerations on the prospects of improved cooperation between rail and air transport services for passengers. Furthermore, the White Paper announces the preparation of guidelines for setting up a so-called "citizens' network" of intermodal passenger services- focusing on urban and metropolitan public transport services-, and their co-ordination with intercity services.

The revision of the EU transport policy in 2001 opens the discussion on the topic of "interoperability for people" from an intercity perspective. Three major barriers are identified to materialize this concept in practice: the development of a unified, single ticketing system, provision of luggage assistance services, and guarantee of transfer among modes. In fact, 10 years later, these questions remain largely unsolved.

The 2011 White Paper states (see paragraph #23) that, although multimodal mobility services are far less developed in the case of intercity travel, compared to urban and metropolitan travel, their deployment would potentially result in substantial efficiency gains in terms of CO2 emission reduction, time savings and accessibility improvements. Accordingly, the 2011 White Paper supports the consolidation of such a multimodal mobility system through three main strategies:

- Integration of the modal networks, mainly through the improvement of their interchange nodes.

- Using ITCs for the implementation of multimodal travel planners providing information, booking and ticketing services to the user (one-stop-shop concept).

- Further developing and aligning the legal framework on passenger rights, thus protecting the expected increasing number of users of collective transport services.

- **Vision and how to achieve it**

The concept of a seamless multimodal transport system, providing EU citizens with convenient door-to-door mobility services, has been implemented, thus far, on a limited, modest scale. Congestion at major European airport hubs raised the interest on rail-air integration, particularly with the introduction of high speed rail services. In some EU regions and countries, integrated information systems are available, including long-distance and local schedules and, in some cases, long distance operators cooperate with local transport operators to offer combined or integrated tickets.

The challenge is to progressively expand these experiences so that multimodal information, booking and ticketing services could progressively cover the EU territory. Extensive research efforts have been dedicated within the EU framework programmes to the implementation of this concept since the mid- 1990s. The research project EU-Spirit, closed in 2001, developed a door-to-door transport information system accessible through Internet, but limited to some areas of Europe. In fact, the service remains active today (http://www.eu-spirit.com), covering Sweden, Denmark and some German regions. This was followed by the EUPI study (Towards Passenger Intermodality in the EU), launched by the Transport Directorate of the European Commission in 2003, focusing on long-distance, international trips (although the last mile or urban/metropolitan link was included). Within the 6th Framework Programme, two new research projects were funded: KITE and LINK. KITE (A Knowledge base on Intermodal Passenger Travel in Europe) is focused on gathering technical information on intermodality, and establishing an information platform (clearing house), accessible through Internet (http://www.kite-project.eu/). The recently closed (Mars 2010) LINK Project (European Forum on Intermodal Passenger Travel), has allowed in-depth identification and analysis of the main barriers, which prevent the development of intermodality. Last but not least, the DATELINE research project, running also from 2000 to 2003, developed proposals for harmonized data collection on long-distance personal travel within the EU, an essential tool to know the market demand and to provide stakeholders with the information needed to assess the risks and potential associated to the provision of multimodal services.

As a follow up to the former research, in 2009 three new research projects were launched within the 7 FPRD: HERMES (exploring new business models associated to intermodality), CLOSER (focused on the interfaces between long and short-distance services) and INTERCONNECT (innovative tools for operators and decision-makers, to develop attractive intermodal solutions).

The three major challenges for the implementation of the "seamless mobility" concept to intercity passenger travel, as identified in the research, include:

- The implementation of adequate design concepts to facilitate the interchanging between transport modes. Transport terminals are frequently designed and managed from a uni-modal perspective, so that designers and managers give priority to one single transport mode, and favour the concept of the terminal as a "shopping centre" (particularly in the case of airports, but increasingly expanding to rail stations), thus giving little consideration to the key aspect of smooth and quick transfer with other modes. Research has been made on how these diverging objectives can be harmonized, but the implementation of research results is proving to be difficult to make.

- The use of technological solutions for setting up integrated information, booking and ticketing systems, as well as to provide users with assistance during their trip

chain, and particularly at transfer points. This includes the development of convenient solutions for luggage checking or carrying (avoiding where possible multiple checking and providing door-to-door services), transfer assistance, provision of the best available door-to-door ticketing solution in terms of time or fares, mobile and smart phones ticketing, etc. From the operators' perspective, technological solutions are critical for better knowing the demand (and thus adjusting individual marketing strategies to the new framework), and for the fair distribution of integrated ticketing revenue.

- Setting up an adequate institutional and legal framework. Directive 2010/40 has set up a first landmark in this direction, and it has been followed by a consultation launched by the Commission in April 2011 on the feasibility of setting up a European travel planner and information system. The integrated, "seamless" transport concept has still to overcome the indifference- if not the opposition- of some operators and transport authorities: the former, still seeing each other as competitors, the later, still too much focused on their respective "territories" and competencies.

While extensive research results are available in the three areas, and "best practices" have been identified throughout Europe (see in particular the results of the INTERCONNECT project), a significant demonstration and regulatory effort has to be made in the next years at the EU level, in cooperation with national and regional/local transport authorities, if the objectives of the 2011 White Paper in the area of intercity passenger transport are to be attained.

ANNEX VII: Traffic Management ITS systems in the various transport modes

A concise list of ITS technological systems and technologies for traffic management in each of the modal domains is the following:

- Road traffic management and control
  - Cooperative systems and technologies (V2V, V2I);
  - Real Time Traffic and Travel Information services supporting traffic management (RTTI)[52];
  - Various efficient traffic management systems and algorithms;
  - Implementation and use of RDS-TMC/GSM broadcast technology;
  - TMC and TPEG[53]-TISA[54] real-time navigation and Floating Vehicle Data collection[55].
- Air traffic management and control
  - Unified Air Traffic Management for Europe (SESAR)
  - Airborne Separation Assistance System (ASAS)
  - Automatic Dependent Surveillance – Broadcast (ADS-B) and applications on ground and airborne surveillance (GS-AS)[56].
- Waterborne traffic management and control
  - Maritime Operational Systems (MOS)[57]
  - Vessel Traffic Management and Information Systems (VTIMS)[58]
  - Integrated Ship Control (ISC)
  - Electronic Chart Display & Information System (ECDIS)
  - River Information Systems (RIS).
- Rail network management
  - ERTMS (European Rail Traffic Management System)
  - European Train Control Systems (ECTS)
  - Global System for Mobile communications Railway (GSM-R).

[52] Several recent European projects support the actions proposed by the RTTI recommendations (CONNECT Euro-Regional (TMC), Mobile Info (TPEG), TISA (TMC and TPEG)).

[53] The first service trials using TPEG-based technology started in 2006. The first commercial services began to broadcast in the UK in 2008.

[54] The Traveler Information Services Association (TISA), a non profit organization hosted by ERTICO founded in the basis of the TPEG project, aims to develop a new and open international standards for broadcasting language and multimodal traffic and travel information, covering all modes and offering:

- Advice on all aspects of setting up TMC services
- Harmonisation, standardization and quality assurance
- Development work to implement new features to improve services
- Development work on advanced TPEG services for digital bearers

[55] Public/private partnerships must be established for increasing the use of these techniques.

[56] GS applications consist in:

- ATC surveillance for en-route airspace, in terminal areas and in non-radar areas
- Airport surface surveillance
- Aircraft derived data for ground tools

AS applications include:

- Airborne traffic situational awareness for improving safety and efficiency
- Airborne spacing and airborne separation for improving capacity and flexibility

[57] Developed in the MarNIs project, implementation planned between 2012 and 2020). The MOS concept integrates Vessel Traffic Management (VTM), Search and Rescue (SAR) and Pollution Preparedness Response and Co-operation (OPRC), coordinating these services virtually and sharing information for overlaying real-time web-mapped (geo-spatial) information to help mitigate risks.

[58] Including Vessel Traffic Services (VTS) and coastal Automatic Identification Systems (AIS)

ANNEX VIII: Criteria for Prioritisation Exercise

EU policy objectives	*Definitions*
Decarbonisation	The EU has accepted, and the international community agreed, on the need to drastically reduce world greenhouse gas emissions, with the goal of limiting climate change below 2ºC. Overall, the EU needs to reduce emissions by 80-95% below 1990 levels by 2050, in the context of the necessary reductions of the developed countries as a group, in order to reach this goal. Commission analysis shows that while it is economically more efficient to have deeper cuts in other sectors of the economy, a reduction of at least 60% of GHGs by 2050 with respect to 1990 is required from the transport sector, which is a significant and still growing source of GHGs. By 2030, the goal for transport will be to reduce GHG emissions to around 20% below their 2008 level. Given the substantial increase in transport emissions over the past two decades, this would still put them 8% above the 1990 level. [White Paper, #7, p. 3]
Reduction of oil dependency	Oil will become scarcer in future decades, sourced increasingly from uncertain supplies. As the IEA has recently pointed out, the less successful the world is in decarbonising, the greater will be the oil price increase. In 2010, the oil import bill was around € 210 billion for the EU. If we do not address this oil dependence, people's ability to travel – and our economic security – could be severely impacted with dire consequences on inflation, trade balance and the overall competitiveness of the EU economy. [White Paper, #6, p. 3] The challenge is to break the transport system's dependence on oil without sacrificing its efficiency and compromising mobility. [White Paper, #19, p. 6]
Cost-efficient seamless mobility (modern infrastructure, modal integration, seamless mobility, promotion of the internalisation of externalities, smart pricing)	Curbing mobility is not an option....Optimising the performance of multimodal logistic chains, including by making greater use of inherently more energy-efficient modes, where other technological innovations are insufficient. [White Paper, #17, p. 5] Better modal choices will result from greater integration of the modal networks: airports, ports, railway, metro and bus stations, should increasingly be linked and transformed into multimodal connection platforms for passengers. Online information and electronic booking and payment systems integrating all means of transport should facilitate multimodal travel. [White Paper, #22, p. 6] Freight shipments over short and medium distances (below some 300 km) will to a considerable extent remain on trucks. [White Paper, #23, p.6]

	Above 300 km, options for road decarbonisation are more limited, and freight multimodality has to become economically attractive for shippers. [White Paper, #24, p. 6] The challenge is to ensure structural change to enable rail to compete effectively and take a significantly greater proportion of medium and long distance freight. [White Paper, #25, p. 7] Seaports have a major role as logistics centres and require efficient hinterland connections. [White Paper, #26, p. 7] Goal for a competitive and resource efficient transport system: optimising the performance of multimodal logistic chains, including by making greater use of more energy-efficient modes [White Paper goals (3) to (6), p. 9] No major change in transport will be possible without the support of an adequate network and more intelligence in using it. [White Paper, #11, p. 4] Congestion is a major concern, in particular on the roads and in the sky, and compromises accessibility. In addition, transport infrastructure is unequally developed in the eastern and western parts of the EU which need to be brought together. [White Paper, #12, p.4] Goals for a competitive and resource efficient transport system: increasing the efficiency of transport and of infrastructure use with information systems and market-based incentives, including a move towards full application of "user pays" and "polluter pays" principles. [White Paper goals (6) to (9), p. 9]
Safety and security	Setting the framework for safe transport is essential for the European citizen. A European Strategy for civil aviation safety will be developed, which includes adaptation to new technologies and, obviously, international cooperation with main partners. In maritime transport, passenger ship safety needs to be proactively addressed. For rail transport, the harmonisation and supervision of safety certification are essential in a Single European Railway Area. [White Paper, #38, p. 10] Even though the number of road fatalities in the EU was almost halved in the past decade, 34,500 people were killed on EU roads in 2009. [White Paper, #39, p. 10] By 2050, move close to zero fatalities in road transport. In line with this goal, the EU aims at halving road casualties by 2020. Make sure that the EU is a world leader in safety and security of transport in all modes of transport. [White Paper goal (10), p. 9] Transport security is high on the EU's agenda. For passenger security, screening methods need to be improved in order to ensure high security levels with minimum hassle. A risk based approach to the security of cargo originating outside the EU should be considered. [White Paper, #37, p. 10] The quality, accessibility and reliability of transport services will gain increasing importance in the coming years, inter alia due to the ageing of the population and the need to promote public transport. Attractive frequencies, comfort, easy access, reliability of services, and intermodal integration are the

	main characteristics of service quality. [White Paper, #40, p. 10]
Transport industry competitiveness	Many European companies are world leaders in infrastructure, logistics, traffic management systems and manufacturing of transport equipment – but as other world regions are launching huge, ambitious transport modernisation and infrastructure investment programmes, it is crucial that European transport continues to develop and invest to maintain its competitive position. [White Paper, #10, p. 4] New technologies for vehicles and traffic management will be key to lower transport emissions in the EU as in the rest of the world. The race for sustainable mobility is a global one. Delayed action and timid introduction of new technologies could condemn the EU transport industry to irreversible decline. [White Paper, #9, p. 4]
Territorial and social cohesion	Transport is fundamental to our economy and society. Mobility is vital for the internal market and for the quality of life of citizens as they enjoy their freedom to travel. Transport enables economic growth and job creation: it must be sustainable in the light of the new challenges we face. Transport is global, so effective action requires strong international cooperation. [White Paper, #1, p. 3] The future prosperity of our continent will depend on the ability of all of its regions to remain fully and competitively integrated in the world economy. [White Paper, #2, p. 3] A lot needs to be done to complete the internal market for transport, where considerable bottlenecks and other barriers remain. The transport systems of the eastern and western parts of Europe must be united to fully reflect the transport needs of almost the whole continent and our 500 million citizens. [White Paper, #4, p. 3] Overall, transport infrastructure investments have a positive impact on economic growth, create wealth and jobs, and enhance trade, geographical accessibility and the mobility of people. [White Paper, #11, p. 4] Market opening needs to go hand in hand with quality jobs and working conditions, as human resources are a crucial component of any high quality transport system. It is also widely known that labour and skill shortages will become a serious concern for transport in the future. It will be important to align the competitiveness and the social agenda, building on social dialogue, in order to prevent social conflicts, which have proved to cause significant economic losses in a number of sectors, most importantly aviation. [White Paper, #36, p. 10]

Low sectoral R&D intensity	The transport sector comprises highly heterogeneous subsectors (modes, markets, service providers, vehicle manufacturers, cross-modal actors, construction companies building and maintaining infrastructure), all of which are exposed to a different market environment and innovation system. Hence, they vary considerably in terms of drivers, needs and boundary conditions for innovation. This is reflected in diverse R&D intensities across modes, but also in the fact that some sectors significantly invest in own research and development activities, while others prefer to buy in innovation through external knowledge. Sectors where R&D intensity is lower are those where public support has the largest potential to be a game changer for the introduction of innovations.
Potential for cost reduction	From the business perspective cost competitiveness is crucial for large scale technology adoptions. Public support may be instrumental for the achievement of technological developments necessary to deliver cost reductions. This is especially effective in those cases where the technology readiness level is still low and should concern primarily solutions for which cost competitiveness has not yet been achieved.
Distance from technological maturity	Technologies and innovations that are still far from maturity are those characterised by larger opportunities for the effective achievement of targets consistent with those required by market conditions and the transport policy objectives. Support for these solutions would be instrumental for the commercial application of these technologies and innovative solutions.
Nature of innovation (radical vs. incremental)	Incremental changes enhance or correct existing aspects of a technology, for instance focusing on the improvement of a skill or process. Radical changes require a shift that can result in significant differences in terms of structure, processes, organisation and strategy. Incremental innovations are in line with the currently predominant design and they can therefore benefit from existing production technologies, infrastructures, and build on a high accumulation of knowledge within established groups collaborating on innovation. Radical innovations require high upfront investments and face elevated risk levels that act as a disincentive to industrial research and development. As a result, they are the ones that are likely to require more public support.
Potential as enabling technology	The transport sector comprises highly heterogeneous types of technologies and innovations. Some have the potential to be relevant for a wide range of applications, while others have a narrower scope because they target specific applications and cannot find applications in a broad range of conditions and product. Technologies and innovations with a broader scope are likely to deliver larger returns than technologies with a narrower scope of application.

Scale-up potential	The ability to move from laboratory scale, typically characterising research activities, to mass production, and the capacity to function with different load and production demands (or the ability to adjust rapidly to these variations). Public support is suited to demonstrate scaling up potential in pilot applications and the learning opportunities associated to them.
Financing barriers	Demonstration is a crucial step required for the transition from the research to the deployment phase for innovations. Financial resources are instrumental for this purpose. Barriers limiting the access to these funds include the difficult access to financial resources for smaller actors, as well as a lack of structure, resources and expertise between the companies/institutions on the research side of innovation and those on the commercialization side. This gap is often affecting small innovative companies, in the pre-commercial stage, where they are no longer eligible for public start-up assistance, but the product development process is still too risky to receive sufficient private investments. The market risks comprise uncertainties of the prices of inputs (e.g. capital costs; labour) and the performance of an innovative technology. Public intervention is best suited for applications that are facing higher financing barriers.
Pre-normative standardisation	Standardisation is geared towards achieving economic benefits from harmonisation and economies of scale. Providing a framework allowing the deployment, standards are crucial in facilitating market penetration of innovative goods and reducing production costs thus supporting industrial policy by ensuring that technology providers compete on merits. Demonstration is a critical phase with respect to standardisation, since it can provide important insight on the most relevant characteristics of products both with respect to manufacturing processes and use. In the demonstration phase, public intervention is best in those cases where standardisation would help the diffusion of innovation and has not yet been finalised.
Ability to match consumer needs	Consumer awareness, absorptive capacities and acceptance of new technologies/products/processes is key to innovation diffusion. Demonstration support geared towards having innovation match consumer needs is expected to be part of funding support at EU level.

Competitive advantage	Competitive advantage theory suggests that states and businesses should pursue policies that create high-quality goods to sell at high prices in the market. Competitive advantage occurs when an organization acquires or develops an attribute or combination of attributes that allows it to outperform its competitors. These attributes include at demonstration stage: material and manufacturing costs. Material cost reduction encompasses the attempts to reduce cost of components/raw materials through activities like competitive benchmarking, part rationalisation, product design change, etc. Productivity improvements deliver lower manufacturing costs and include those modifications of any process - be it a core manufacturing process or be it a support process such as material handling - that is part of the production phase. This is particularly linked to scale up and integration opportunities: new technologies therefore either to be included as a part of the product, or to assist making it. Competitive advantage therefore implies two variables: prospect of cost reductions and unique selling point of emerging innovative solutions.
Entry barriers	Technological and institutional lock-in hampers innovations that lie outside of the currently dominant design; this is particularly relevant in the transport sector due to high costs of production equipment and infrastructure. It affects both modal shares (e.g. leading to a dominant role of cars where favourable taxation has been enforced over time, together with significant infrastructure developments) and specific technological choices within modes (e.g. petroleum-based vehicles vs. vehicles using alternative fuels, like natural gas or electricity). It is further strengthened by the capital intensiveness of many of the industrial sectors related to transportation and the high infrastructure costs, the high concentration of R&D investments into a limited number of dominant players, and the orientation of private and public research along the lines of existing modes. Public intervention to promote the deployment of innovation is best suited in those cases where lock-in effects are stronger, in order to limit their influence.
Distance from obsolescence and leapfrogging risk	Technology risk provides a representation of the negative factors associated with technologies like obsolescence and leapfrogging. Obsolescence typically has to do with the ability of a given technology to remain supportable and cost effective for the functionality it provides. Leapfrogging is related to the emergence of a new but even better technology that provides nearly equivalent capabilities. Since the higher is the technology risk, the more likely are the difficulties to recover investment costs for a given technological solution, public support should focus on the deployment of innovative solutions that do not risk becoming obsolete quickly.

Access to resources	Resource availability risks are a representation of the negative factors associated with technologies that rely heavily on materials whose availability is limited. The higher is the resource availability risk, the more likely are the risks to loose cost competitiveness because of increases of resource costs. Public support should focus primarily on the deployment of innovative solutions that rely on available resources and possibly reduce resource availability risks. If resource availability risks exist for some primary materials for conventional technologies and other primary materials for innovative solutions, the assessment should balance the benefits and the drawbacks that are associated to the introduction of new technologies.
Need to develop infrastructure	Infrastructure is made of assets that serve the function of transporting, moving or managing vehicles, vessels and aircraft or transport-related information in the form of a network composed of links and nodes. Infrastructure also includes soft equipment, like control systems, software, communication interfaces, and even procedures and processes for planning, coordination and monitoring. transport infrastructures are often characterised by a long lifetime and high investment costs. For these reasons, they are one of those elements leading to lock-in phenomena in transportation. Public interventions to promote the deployment of innovations are best suited in those cases where infrastructure development needs are stronger (notwithstanding the need for large potential benefits provided by the innovative solution supported) because they can be instrumental to overcome infrastructure-related lock-in effects.
Required standardisation	The availability of standards (when standardisation is needed) is a firm requirement for public interventions aimed to favour the deployment of innovations.
Added value by consumer awareness	Consumer awareness, absorptive capacities and acceptance of new technologies/products/processes is key to innovation deployment. Deployment support geared towards having innovation match consumer needs is expected to be part of funding support at EU level.
1. Basic principles observed and reported	Transition from scientific research to applied research. Essential characteristics and behaviours of systems and architectures. Descriptive tools are mathematical formulations or algorithms.
2. Technology concept and/or application formulated	Applied research. Theory and scientific principles are focussed on specific application area to define the concept. Characteristics of the application are described. Analytical tools are developed for simulation or analysis of the application.
3. Analytical and experimental critical function and/or characteristic proof-	Proof of concept validation. Active Research and Development (R&D) is initiated with analytical and laboratory studies. Demonstration of technical feasibility using laboratory or out-of-laboratory implementations that are

of-concept	exercised with representative data.
4. Component/subsystem validation in laboratory environment	Standalone prototyping implementation and test. Integration of technology elements. Experiments with full-scale problems or data sets.
5. System/sub-system/component validation in relevant environment	Thorough testing of prototyping in representative environment. Basic technology elements integrated with reasonably realistic supporting elements. Prototyping implementations conform to target environment and interfaces.
6. System/sub-system model or prototyping demonstration in a relevant environment	Prototyping implementations on full-scale realistic problems. Partially integrated with existing systems. Limited documentation available. Engineering feasibility fully demonstrated in actual system application.
7. System prototyping demonstration in an operational environment	System is at or near scale of the operational system, with most functions available for demonstration and test. Well integrated with collateral and ancillary systems. Limited documentation available.
8. Actual system completed and "mission qualified" through test and demonstration in an operational environment	End of system development. Fully integrated with operational hardware and software systems. Most user documentation, training documentation, and maintenance documentation completed. All functionality tested in simulated and operational scenarios. Verification and Validation (V&V) completed.
9. Actual system "mission proven" through successful mission operations	Fully integrated with operational hardware/software systems. Actual system has been thoroughly demonstrated and tested in its operational environment. All documentation completed. Successful operational experience. Sustaining engineering support in place.

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Abstract

The Strategic Transport Technology Plan (STTP) is an initiative of DG-MOVE with the collaboration of the JRC, DG RTD and INFSO, which address the technology pillar of the Transport White Paper. The JRC undertook the responsibility to produce this scientific assessment, as a contribution to the STTP preparation. The assessment took place from November 2010 to August 2011 and covered all transport sectors and issues.

The Scientific Assessment took into account the answers received to questions prepared by the JRC for the stakeholder hearings held during the preparation of the STTP as well the Visions and Roadmaps already created by the technology platforms and partnerships in the transport field. The assessment was also extensively reviewed by the STTP Scientific Panel and by several Commission experts in DG MOVE, INFSO and DG RTD.

On the basis of the description of the status and vision for all transport modes and cross-modal aspects, a prioritisation exercise also took place by the JRC and with the participation of the members of the Scientific Panel. The analysis of the results of the prioritisation was a valuable (but not the sole) input in the final selection of the Research and Innovation Areas for the STTP.

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Key policy areas include: environment and climate change; energy and transport; agriculture and food security; health and consumer protection; information society and digital agenda; safety and security including nuclear; all supported through a cross-cutting and multi-disciplinary approach.

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