Towards a 50% more efficient road transport system by 2030

Technical document

October 2010

INTRODUCTION

Guiding Objectives in view of the societal needs

A European road transport system that is 50% more efficient than today could be achieved, by 2030, by adopting the range of research and innovation priorities defined in this Strategic Research Agenda. This ambitious headline objective guides ERTRAC's contribution to Europe's efforts to address the 'grand challenges of our time', and to bring sustainability to the European community (Lund, 2009). This contribution involves bringing significant improvements to the European road transport system. The research and innovation proposed in this SRA will enable such improvements by addressing the broad range of challenges related to the road transport system, including: the supply of energy and resources; global climate change and the environment; health and safety; and increased global competitiveness of the road transport industry leading to economic growth and high quality employment in Europe.

The approach taken by the SRA recognizes, in particular, the societal demand for decarbonization, reliability and safety of the road transport system from a user's perspective. For each of these societal needs, clear indicators have been selected, each with specific guiding objectives towards 2030 (see Table 1). reference to the headline objective of a 50% more efficient road transport system.

In addition to the end-user's need for a more efficient road transport system, it also recognizes the urgent need to ensure global competitiveness of the road transport-related industry in general, and the automotive industry in particular. Aside from its domestic importance to the European economy and society, the European automotive industry is one of the most 'globalized' production sectors, and faces significant competition on the global market.

Table 1 Guiding objectives for 2030

	Indicator	Guiding objective
Decarbonization	Energy efficiency: urban passenger transport	+80% *
	Energy efficiency: long-distance freight transport	+40% *
	Renewables in the energy pool	Biofuels: 25% Electricity: 5%
Reliability	Reliability of transport schedules	+50% *
	Urban accessibility	Preserve Improve where possible
Safety	Fatalities and severe injuries	-60% *
	Cargo lost to theft and damage	-70% *

* Versus 2010 baseline

With regard to the societal need for decarbonization in road transport, the SRA focuses both on increasing the energy efficiency of road transport activities and on decarbonizing the energy they consume. This approach will make a considerable contribution towards the requirements of European policy on energy and climate change.

To address the societal need for reliability of the road transport system, the SRA focuses on improving those aspects of the system that contribute to the reliability of transport schedules and urban accessibility. Both of these indicators, which involve all modes, are strongly linked to economic growth and employment, and aim at reducing congestion and the significant related societal costs. Recognizing the extent to which today's society depends on mobility, the guiding objectives for 2030 imply a significant improvement in mobility that will not only benefit Europe's competitiveness in the global market, but also aims to enhance societal integration throughout Europe, e.g. by making the peripheral regions more accessible and allowing much greater occupational mobility.

With regard to the societal need for safety and security in road transport, the focus of the SRA is on reducing fatalities and severe injuries, as well as reducing the amount of freight cargo lost due to theft and damage. The policy of reducing fatalities is a long-standing objective which reflects the ongoing efforts of the European Commission, the Member States and industry in reducing fatalities on the roads towards zero in the long term. However, ERTRAC has extended the reach of this indicator so that it now also includes the reduction of severe injuries. The indicator on cargo lost to theft and damage calls for action on international trade, where security is a clear priority. A lack of security has a negative impact on trade and, hence, also on competitiveness; improving cargo security will therefore enhance the notion of free trade. Efforts to protect against theft would focus particularly on the entry points into Europe, and would involve enhancing EU policies concerned with the development of neighbouring regions.

Finally, efforts to address the urgent societal need for global competitiveness of the automotive industry aim at producing vehicles that are affordable and which meet (domestic and global) consumer's demands (see Figure 1), as well as producing them in a sustainable way. The indicators selected to measure the required changes in the production systems are: total cost of ownership (TCO); earnings before interest and taxes (EBIT); energy footprint of the supply chain; and the human development index (HDI). To achieve these ambitious guiding objectives for 2030 will require a comprehensive and consistent 'systems approach'. Two such approaches are presented in this SRA, one involving the road transport system as it is used and experienced by the consumer, end-user and citizen (see Figure 2), and the second involving the global competitiveness of the European automotive industry's production system.

Figure 1 The need for a sustainable road transport system will shape the development of future vehicle concepts

The systems approach to address innovation in the use of the road transport system

The systems approach to address innovation in the use of the road transport system focuses on the following three key elements in the respective transport system:

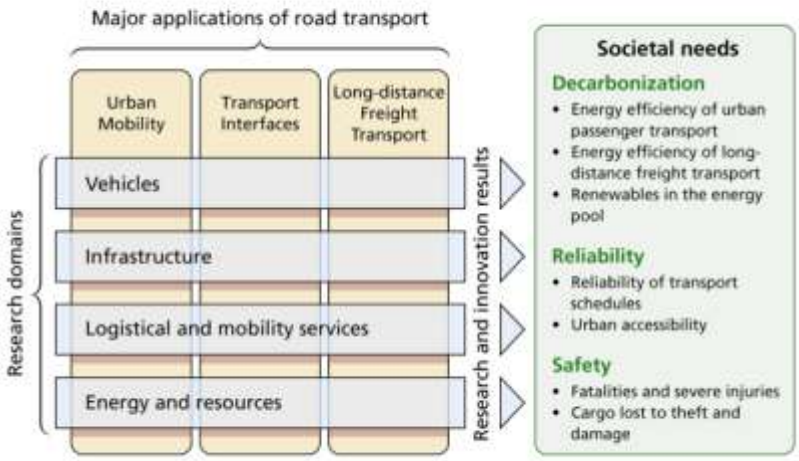
1. urban mobility;
2. long-distance freight transport; and
3. transport interfaces.

The transport interfaces will provide a seamless link between modes and networks, and between urban mobility and long-distance freight transport systems.

Together, these elements provide an integrated core transport system that serves the road transport demand of more than 80% of the population (ERTRAC, 2009a), hence they are of the greatest strategic significance to European societal needs.

Although this SRA places a focus on the three major road transport applications mentioned above, ERTRAC acknowledges the importance of the social interaction between urban and rural territories. Therefore, where needed, the guidelines contained in this research portfolio should also consider specific scenarios for the rural sections of the road network, in particular with regard to energy and safety.

Figure 2 A systems approach to achieving a 50% more efficient road transport system



As a part of the process of identifying and prioritizing the areas of research and innovation for discussion in this SRA, ERTRAC has drawn on its vision for 2030 and the decades beyond (ERTRAC, 2009a). The key points outlined in ERTRAC's vision document are encompassed in each of the four enabling research and innovation domains indicated in Figure 2 (i.e. for vehicles, infrastructure, logistical and mobility services, and energy and resources). These are described below.

Vehicles

In the decades leading to 2050, the challenge will be the need for a wide range of complementary propulsion systems and fuel/energy types to be developed simultaneously (see Figure 3). Although the electrification of road transport will be a strong and inevitable trend (for which ERTRAC, in alliance with EPoSS and SmartGrids, has established a clear roadmap) the fact is that, by 2030, the internal combustion engine (ICE) will remain the dominant propulsion technology.

Advances in vehicle technology will see a leap in intelligence through the progressive introduction of ICT. This will not only bring advances in vehicle performance and driver support systems, but will also enable the exchange of information with

intelligent infrastructure and a variety of system services. For example, in the case of the electrification of road transport, this would include communications with other sectors, such as electricity generation and distribution.

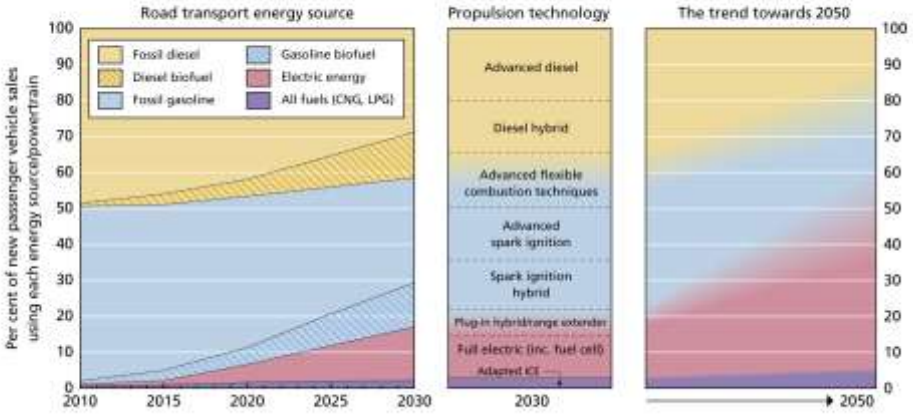
A further trend will be the increasing variety of vehicle concepts that are able to adapt to the diversifying mobility demands of passengers and the freight transport sector whilst providing at least the same level of safety as today's vehicles.

This trend will be further encouraged through urban development and environmental policies (e.g. on noise abatement, and air quality).

The cost-effective development of such a wide array of energy sources and associated propulsion technologies and vehicle concepts will depend on economies of scale. In this respect, the forthcoming decades will see a strong trend towards extended standardization in terms of weight, dimensions and modularization.

Figure 4 Energy sourcing in 2030 will involve a wider range of sources, carriers and powertrains

Figure 3 The evolution of passenger road transport energy source and propulsion technology, towards 2050



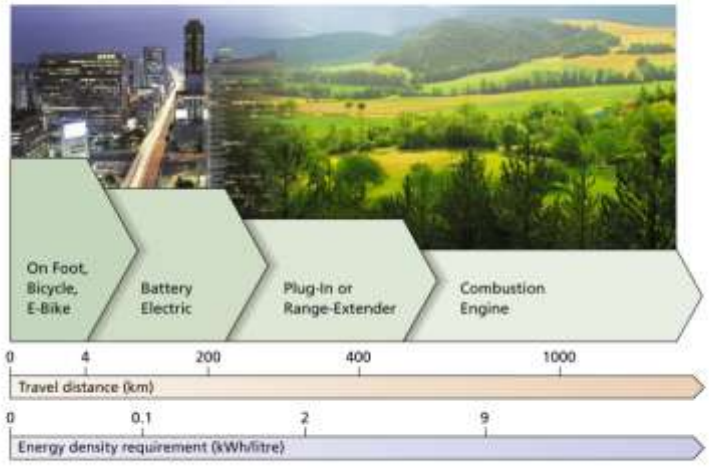
Infrastructure

The rate of expansion of the road transport infrastructure will not keep pace with the increase in demand for road transport services. The critical challenge will therefore be to make the best possible use of the available infrastructure in order to accommodate the growing transport demand (an estimated 50% increase over the coming two decades) through measures that increase its intrinsic capacity (e.g. the number of vehicles and travellers per area, and infrastructure uptime) as well as through advanced demand management measures.

The trend will be towards the swift development and deployment of next-generation infrastructure technology, and network management concepts, procedures and practices, to ensure that traffic density and infrastructural uptime remain at optimal levels, and that the road network is adaptable, automated and resilient.

As in-vehicle ICT systems are introduced, together with ICT-based logistics and mobility services, ICT-driven intelligence will also be progressively introduced into the road infrastructure.

Figure 5 Mobility solutions for both urban and long-distance travel



The use of 'multi-modal hubs' (i.e. transport interfaces) and dedicated road capacity will enable the optimal integration of transport modes and services to relieve bottlenecks in specific areas of high congestion.

Logistics and mobility services

Increasing levels of congestion will place mounting pressure on the mobility services, particularly in the larger urban areas. This will give rise to comprehensive, integrated service concepts and business models that complement existing modes, and for which the dominant factor will be extensive cooperation between the various actors in the chain. In turn, this will serve to optimize the movement of goods and people to better reflect the actual demand for mobility services (including public transport). Models and service solutions will be introduced to support innovative business practices, route planning regimes and efficient trans-shipment of goods (in particular, over the 'last mile') and people, between modes and networks. Again, ICT and a better knowledge of transport demand will play a major role in these developments, as will the trend towards extended standardization for freight carriers in terms of dimensions and modularization.

Energy and resources

Although the energy basis for road transport will diversify considerably over the coming decades, the expectation is that fossil-based fuels will still dominate the energy pool for road transport in 2030. However, the supply of crudes and distillates will not be able to keep pace with the increase in global demand, and hence, the future energy market will become volatile and competitive. Efforts will therefore aim at taking a 'greening' approach to diversifying the fuel pool through the

development of new combustion-based propulsion technologies (see Figure 4) in order to achieve optimal performance on a well-to-wheels basis.
Additional decarbonization will occur through the increased uptake of electrically-powered drivetrains, for which the electricity supplied by the power sector would need to be generated from renewable energy sources. However, the challenge will be how to store the electricity onboard the vehicle in such way that it can compete with hydrocarbon fuels in terms of the required energy density (see Figure 5). In addition, the minerals used in the production of electric vehicles (e.g. neodynium, dysprosium and copper) are scarce and unevenly distributed throughout the world. Hence, to rely on such minerals would limit the security of supply and lead to fluctuations in pricing.
There is, therefore, a strong drive towards minimizing the use of, and recycling, such precious materials and, potentially, replacing them with more abundant alternatives in order to achieve optimal performance in a life cycle analysis.

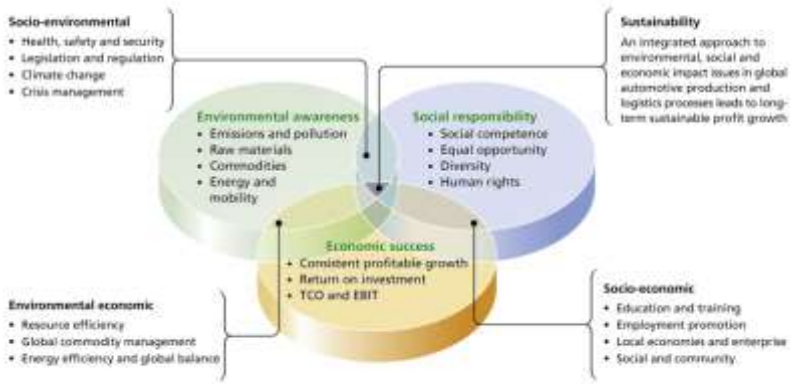
The four research and innovation domains described in this SRA will address the needs of the (end) user of the road transport system in terms of the human factors (needs, abilities, acceptance) involved in the correct and optimal functioning of the respective technologies to be researched and developed. It should be noted, however, that such consideration is restricted to advances in the respective technologies, and excludes the realm of public policies on mobility, e.g. behaviour and demand management.

The systems approach to address innovation in achieving global competitiveness

Currently, Europe is at the leading edge of vehicle development, with advances in energy-efficient ICEs, safety, light-weight design, and more. Achieving the economic, environmental and social aspirations for Europe's future will require European industry to remain successful in the global marketplace (see Figure 6).
With regard to energy-efficient propulsion, the strategy proposed for the European motor industry is based on a two-fold approach which involves:
- improving the efficiency of conventional engines; and
- making electrically-powered mobility a reality for the European consumer.

During the next decades, the global market balance for the automotive industry will shift significantly in favour of the currently emerging markets in the BRIC nations (Brazil, Russia, India, China), as the rate of motorization in these countries begins to outpace that in Europe. The capacity for innovation in these countries will also grow as they benefit from their increasing share of the global mass markets, and this will place Europe in a critical position as it struggles to maintain its competitiveness. Furthermore, the ICE— originally developed to meet the high levels of demand for mobility—will become less popular due to the increasing demand for clean mobility which, in turn, will lead to the emergence of the electric vehicle concept. The European automotive industry will need to adapt to this transition in technology and markets on a global scale by investing in, among others, new production systems designed to achieve the two toplevel objectives of:

Figure 6 The importance of social, environmental and economic factors in sustainable production systems



a) meeting society's needs for a sustainable transport system; and
b) maintaining Europe's leading position in the global marketplace.

The industry will face significant levels of competition in two important areas. In the research and innovation arena, there will be competition over the available levels of skill and funding required to support the development of future technologies. By 2030, skill levels in the emerging markets will have will enable the industry in those countries to maintain a strong advantage. Competition will also exist in relation to the emerging technologies and products themselves, as manufacturers aim to produce the most affordable or reliable products, or compete to protect their intellectual property rights. Success in these areas will have a fundamental impact on the industry's level of success in the marketplace.
At the domestic level, the European automotive industry will need to face the challenge of ensuring that new technologies are able to compete with complementary solutions already available on the home market (i.e. existing ICEs and the respective infrastructure). On the global scale they will also need to compete with solutions developed by the much larger emerging markets which, by contrast, will already be enjoying the advantage of a 'green field' domestic market. It is clear that a more comprehensive and holistic approach to meeting these challenges will be required, which takes into account the views of manufacturers, service providers, equipment and commodity suppliers, as well as accountants, and which builds on the strong innovation potential of the European automotive industry in cooperation with its research partners.

Key to success will be a good balance of investments in product, process and service innovations as well as in integrated production systems (Figure 6). This can only be justified if a sustainable return on investment from the entire production network can be ensured. Thus, the systems approach to achieving global competitiveness considers the entire supply chain, from the demands of the consumer, end user and citizen to the basic commodities and raw materials used in the final process.

Process Followed

The first step in the process was to consult with experts from within the ERTRAC community as well as from outside the ERTRAC community on important themes and topics for research and innovation for each research domain in the systems approach. With respect to the major applications for road transport (urban transport, long-distance transport, and the transport interfaces) These were: Vehicles, Infrastructure, Logistical and mobility serves, and Energy and resources.
With respect to global competitiveness the research domains were selected according to the three sustainability indicators: Economic success, Environmental awareness, and Social responsibility. Within these domains the topics were distinguished between Production Processes, Logistics Processes and Business Processes.
All input was categorised and descriptions were provided as specific as possible. This technical document provides the full overview of the result.
The next step was to determine the priority research and innovation topics. These are presented in the Executive Summary. Again the experts were consulted on their opinion about the impact the topics would have on the guiding objectives to each of the societal needs as well as on the time it would take to have the research and innovation to reach the point where its feasibility will be demonstrated e.g. by Field Operational Tests, that perform testing on a sufficient scale as to allow reliable extrapolation on to the real practice.
The impact on innovative systems and solution need to be evaluated in detail to decide to promote their wide diffusion through incentives and campaigns. Field operational tests (FOTs) are the instrument to evaluate such impacts (in safety, efficiency, security, etc.). Without a clear indication of the benefits the market penetration will be left to the user awareness and willingness to pay, that in some cases (safety belt is a clear example) never happens. FOTs will be very important in the future to accelerate the user acceptance and market penetration of new solutions, like cooperative systems, (semi) autonomous driver assistance systems, self-explaining and forgiving roads.

It should be noted, however, that innovation and research, by nature, holds a degree of uncertainty that will increase with the time it takes to reach a decision on commercialization. The respective deliveries will be prototypes, pilots, etc. that will demonstrate the feasibility of the proposed solutions. Typically, this research will continue towards the development of subsequent generations of the technologies concerned; these stages will be addressed in later SRAs.
Following chapters present the full glossary of research and innovation topics that have been identified and described by the experts.

Research Domain**: VEHICLE**

Scope & Setting

This research perspective is concerned with all research on the vehicle, to ensure that it fulfils the future demands of consumers for transport and mobility. By 2030, under the influence of a variety of trends, the consumer will value the car as one of the key enablers of his or her mobility. The primary consumer factors are convenience, affordability, environmental friendliness and safety. Total cost of ownership is another key factor for owners of commercial vehicles.

By 2030 new vehicles will be smart enough to 'sense' their surroundings and navigate through traffic safely and efficiently, while providing their occupants with personalized comfort and convenience. The vehicle will be a 'node on the internet', and will be 'on-line' with other vehicles (V2V), with the transport infrastructure (V2I), and with homes, businesses and other sources (V2X). The vast majority of the fleet will be equipped with several advanced systems that provide user-friendly assistance to the driver in assessing the safety aspects of any traffic situation. However, the sophistication of the individual systems will depend on the class and age of the vehicle. Systems will be ' self learning' in the sense that they will tailor their performance to the specific driver. Nevertheless, the driver will always remains in control. Intelligent roads and intelligent vehicle systems interact and communicate with the driver to increase safety, reduce fuel consumptiona and to improve efficiency.

Respecting the right of privacy for citizens, vehicles will be equipped with theft deterrent systems, vehicle tracking technology and personal safety systems such as those based on biometrics.

There will be a wide array of fully optimised power train systems, including conventional ICE, Plug-in HEV and full EV. The trend towards full electrification in the years up to 2030 will mainly effect private cars and freight delivery vehicles in urban areas. For heavy duty, long distance freight transport, the extent of electrification will be limited because problems related to standardisation, energy storage and charging will mean unrealistic costs for the foreseeable future. Electrification of the collective transport system will be progressive and contribute to a better energy management within the network, due to the patterns of use of these vehicles. Beyond this, vehicles for public transport should be developed to contribute to the European bus system of the future. Their design and technology will be more modular to allow their efficient integration in the urban mobility system.

Significant improvements in road safety will strongly depend upon the implementation of an Integrated Safety approach. Accidents involve vehicles, road infrastructure and people, whether they be drivers, passengers, pedestrians or other road users. A focus on one of these alone can only be partially successful, and true progress will only come when interactions between the driver, vehicle and road infrastructure are effectively employed. Overcoming classical boundaries will serve as an enabler for a systems approach for accident prevention and mitigation and a completely new approach to vehicle and infrastructure design will be aimed at maximising both the passive and active safety of vehicle occupants and other (vulnerable) road users, especially in areas with a high density of road users. This will be achieved using lightweight, low carbon materials, components and systems.

The competitiveness of the vehicles will be enhanced by highly standardized components, that ensure a high level of portability between the different vehicle types and interoperability with surrounding ICT systems, throughout the EU. However,, although vehicles will be highly standardized, the consumer in the last stages is still able to customize its private vehicle to its own specific needs and desires.

Similar new approaches will be applied to goods vehicles, whose size and performance will be much more closely matched to the transport task and operation undertaken, based on standardised loading units that enable rapid and efficient loading and unloading but are sufficiently flexible for a wide variety of commodities and distribution tasks.

Research and innovation Themes & Topics

Theme: Next Generation Propulsion & Power Platforms

All research on the complete system that makes the vehicle move (power supply & demand within the vehicle), in order to reduce energy consumption and reduce GHG emissions. Among the key factors in improving the efficiency of the transport and mobility sector will be the development of future (low emission) propulsion/drive train systems which provide sufficient performance for all future transport needs, together with the development of new vehicle concepts.

- **ICE-based drivetrains for light duty vehicles:** Light duty vehicles will continue to be dominated by the use of the ICE, both spark ignition and compression ignition. Both petrol and diesel fuels will be used, but the distinction between compression and spark ignition may become less clear-cut with new combustion techniques. Continued improvement of the combustion system, for example through variable valve and piston operation and enhanced injection techniques, holds large potential for efficiency gains. Advanced control strategies for engines will improve emission control and fuel consumption. Efficiency gains will also be possible through additional engine downsizing and turbo charging, which in turn will increase the oil stress, requiring more

robust lubricants. Recovery of exhaust energy through Rankine cycles and thermoelectricity is expected.. The proportion of vehicles with an electric hybrid power train will increase in passenger cars, with different levels of electric power for different applications, from start-stop- to full hybrid. This will mainly be governed by performance and cost of the electric energy storage technologies available. The hybridisation will therefore require further advancements in electric/ICE systems integration. The trend towards small city vehicles will strengthen the need for small internal combustion engines. This is also valid for the development of plug-in hybrid vehicles with a range extender, downsized ICE integrated into the main electric power train . These engines will most likely be used to charge the battery, not power the wheels directly. Optimisation of small, low power ICE for both driving and charging duty will, therefore, be necessary.

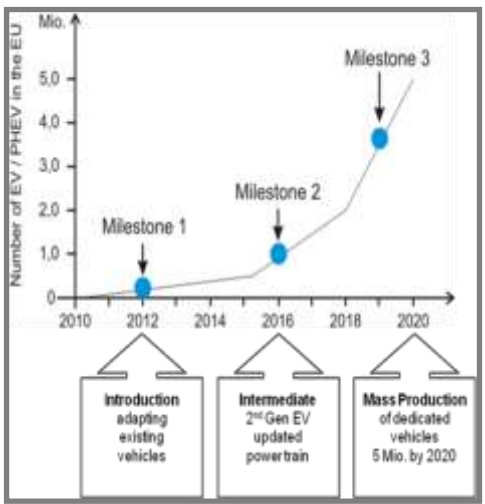
- **ICE-based drivetrains for heavy duty vehicles:** Today, transportation of freight is responsible for the major part of the increase in oil consumption for road transport. New technology from the vehicle industry that can fundamentally disrupt or mitigate this trend will, therefore, have a great effect in the long run.
  Powertrains for heavy-duty and long-haul trucks are expected to be based primarily on internal combustion engines (ICEs) for the foreseeable future because of the limited storage/range and long charging times of electric alternatives. The majority will be compression ignition, although this distinction may be blurred with the advent of new combustion systems. . Development of advanced combustion and exhaust aftertreatment systems improving the thermal efficiency of the engine while keeping NOx and particulate emissions on a low level is a prioritised research topic. Variable valve timing, flexible high pressure injections systems, highly efficient turbo charging systems combined with advanced control and highly efficient NOx aftertreatment systems are key elements in such a development. Technology development that enables recovery of both brake and heat energy will be needed. Recovery of exhaust energy through rankine cycles and thermoelectricity is expected . Hybridisation, including brake recovery, is anticipated to play an important role also for heavy-duty engines with the degree of hybridisation depending on the development of the battery technology and the urban nature of the driving cycle.
  In order to further reduce the fuel consumption of heavy duty trucks, it is also necessary to investigate the engine downsizing potentials mainly for city distribution applications, along with the integration of hybrid systems for boosting the power for acceleration and starting of heavy duty trucks on a hill. This approach also opens for a reduced emission potential, due to reduced transient behaviour period of the truck engine. However, with smaller capacity engines, oil stress will increase considerably, again requiring a new generation of lubricants.
  To increase transport efficiency the maximum vehicle size and weight might be increased, which would then increase the torque and power needed from the powertrain. The powertrain systems therefore needs to be right sized and optimized according to the many different applications that will exist. Both downsizing and upsizing may be required depending on application. The overall potential for fuel consumption reduction in the driveline is exceeding 10% for long haul and 35% for city bus applications illustrating the importance of the brake recovery potential in the driving cycle.
  The amount of bio-fuel blendings effect on combustion and after treatment system is important, as is other fuels such as natural gas or bio-gas indicating need for development of efficient dual fuel engines. These new fuel alternatives will show a better environmental performance compared to conventional fuels.
  Clean diesel technology for buses, including innovative gear control systems should be considered.

- **Electric drivetrains** - The path towards the introduction of electric vehicles in Europe has been described in much detail in the European Roadmap *["Electrification of Road Transport" which had been jointly drafted by a task force of ERTRAC, EPoSS and SmartGrid members European Roadmap Electrification of Road Transport;Version 3.5; 30 October 2009; ERTRAC (European Road Transport Research Advisory Council), EPoSS (European Technology Platform on Smart Systems Integration), and SmartGrids]*

- The involved industries have combined their knowledge and experience in order to assess what benefits of the electric vehicle can be achieved by when, and what actions will be required to master the challenges of electrified mobility at large scale over the next ten years.

The setting of milestones refers to different scenarios (passenger cars, vans and buses) and considers six major technology fields being:

- Energy Storage Systems
- Drive Train Technologies
- System Integration
- Grid Integration
- Integration into the Transport System
- Safety



In many cases, further research and development is needed before the phase of market introduction. This is particularly true for the energy storage systems where substantial

improvements in performance and life cycle cost are required for a successful market introduction.

Dedicated roadmaps were drafted for each of these milestones indicating what has to be done when for a well-timed move of Europe towards the electrification of road transport (see following figure). The further development of the European EV market beyond 2020 .

Fuel cell powered drivetrains-There are great similarities between battery and fuel cell powered electric drivetrains.The balance between preferred technology depends on increased battery performance for the battery powered drivetrain and on a breakthrough in hydrogen storage as well as in performance and cost for fuel cell technology.

Integrated Drivelines

Research is needed on advanced combustion and exhaust aftertreatment systems improving the engine thermal efficiency , optimised in size as well as according to the specific application. Efficiency development of driveline key components are important as is system multi-fuel capability.

The ICE PT system needs to be optimised in size as well as according to the application. To meet this demand, further efficiency development of key components such as e.g. the turbo charging system, thermal management for the aftertreatment system and the system efficiency of the SCR (HD engines) system will be very important enablers for this adaptation.

The ICE powertrain needs to be made tolerant to alternative fuels and multi-fuel blends, and the use of fuel-efficient, multi-fuel compatible lubricants. The increase of other fuels such as natural gas or bio-gas will make it necessary to improve dual fuel engine technologies.

Specific items in the research on integrated powertrains (LD&HD) are: Advanced combustion systems (CHHC, DI-gasoline, CAI); Flexible high pressure injection systems; Advanced air charging systems incl fully flexible valvetrains; Advanced exhaust aftertreatment technologies such as highly efficient NOx aftertreatment systems (CI-engines); Alternative fuel and Multi-fuel Capabilities (e.g. 2nd gen biobased diesel, dual fuel: gas/diesel); Waste Heat Recovery systems for recovering of energy from the exhaust (rankine cycles and thermoelectricity); Advanced engine and driveline control systems incl multi fuel and different energy sources; Advanced mechanical concepts including cylinder shut-down; Friction Reduction e.g. advanced coatings and new piston/cylinder liner concepts; Engine design for higher cylinder peak pressures; Engine Down/optimal Sizing; New energy conversion technologies (e.g. free-piston engines); Distributed power systems (e.g. commercial vehicles); Power Train for Hybridisation; Advanced transmissions; Brake recovery (electric, hydraulic, compressed air, flywheels other non-electric); Light weight powertrains (Advanced light weight materials & optimised structure); Fuel cell based drivelines (fuel cell performance and cost, hydrogen storage); Complete powertrain-System integration; Driveline energy management

Energy Management

Research is needed on the complete vehicle energy management system taking into account the actual transport situation, i.e. type of mission, route, traffic situation, possible charging possibilities, optimising all configurable vehicle parameters while balancing energy efficiency.

- Brake recovery (electric, hydraulic, compressed air, flywheels other non-electric)
- Waste Heat Recovery systems from the exhaust or brake (rankine cycles and thermoelectricity)
- Thermal management
- Air conditioning
- Auxiliary Systems: Auxiliary Power Units (APUs) can provide a secondary (backup) source of electrical generation for emergency and safety reasons, auxiliary load powering (hotel loads), and generally as an additional source of electrical generation and efficiency to reduce idling.
  Research is needed on how to best electrify/power existing auxiliaries while increasing energy efficiency as well as the level of centralised management as well as on how to design and develop (and power) auxiliaries. Specific topics include: Energy optimised auxiliaries; Enhanced efficiency; Fuel cell applications, e.g. as range-extender for passenger cars or APU on trucks; System Integration with focus on efficiency; Distributed drive systems

Electric Vehicles

Research is needed on the development of the electric vehicle concept for usage in urban areas, including LD applications. Such in line with the Industrial Roadmap on Electric Vehicles that was adopted by ERTRAC in alliance with EpoSS and Smartgrid ETP's *["Electrification of Road Transport" which had been jointly drafted by a task force of ERTRAC, EPoSS and SmartGrid members European Roadmap Electrification of Road Transport;Version 3.5; 30 October 2009; ERTRAC (European Road Transport Research Advisory Council), EPoSS (European Technology Platform on Smart Systems Integration), and SmartGrids].*

Reduced resistance to motion

Research is needed on reducing and optimising the vehicle resistance to motion resulting in increased fuel efficiency e.g. weight (inertia), aerodynamic drag and rolling resistance. Of particular interest are the development and implementation of low cost lightweight structures and components, Optimised transmission, Low rolling resistance tyres (and road surfaces with link to infrastructure), Adaptive tyre pressure, Optimised wheel units, Monitoring and control of all parasitic rolling losses, Aerodynamic styling and matching of the vehicles and trailers), and (for buses and trucks) the development and application of new light weight materials for the production of vehicle bodies and interior compartments components (lighter body shell structure/honeycomb structures, composite materials, or any material derived from technology transfer).

Safety of low carbon vehicles

Research is needed on an integrated safety concept behind the emerging Electric Vehicles. More specific the research is focussed on maintaining or even improving on existing (vehicle) safety levels, e.g. where it concerns the crash worthiness of lightweight vehicle designs, the co-existence of (alternative) fuels and (high voltage) electric powertrains, the Acoustic Perception of Electric Vehicles and the subsequent Standards for Safety, EMI, Health.

- Improve Crashworthiness of Lightweight Cars. To increase the range electric vehicles will be lighter and smaller, but they have also more degree of freedom (component distribution and their position). Research has to exploit the opportunities to reach good levels of crashworthiness without requiring extra weight on the vehicle. This work will include research on novel materials and structures as well as more advanced protective systems including advanced sensor systems. Ultimately this development will depend on the availability of new refined models of the human body requiring new knowledge about the human body properties and tolerance to loading.

Develop Acoustic Perception. Electric road vehicles have very low noise emissions especially in low-speed and urban driving situations due to the absence of engine noise. The remaining noise output is dominated by tyre/road noise down to very low speeds. For this reason the acoustic perception of electric vehicles travelling at low speeds is very difficult, especially if those vehicles share the road with conventional vehicles which dominate the soundscape. Approaching electric vehicles are not easily recognized by other road users. Especially vulnerable pedestrians (elderly people, children, etc.) and cyclists are affected. This results in new types of road safety hazards that need to be analysed and countered appropriately. A proper solution aids the perception of electric vehicles in traffic scenarios by intelligent systems. The implications and required technologies should be subject of future research.

- Compatibility in crashes (regarding vehicle difference in size and weight of electrified vehicles). Research has to increase the compatibility between very different vehicles, working on both sides, with requirements/solutions also for heavy/large vehicles and innovative integrated solutions. Also the relations with Roadside Restraint Systems have to be analysed.
- Advanced passenger protection systems. The availability of high electric power could be an opportunity to improve the passenger protection with innovative restrain solutions.
- Develop representative test and evaluation methods and performance criteria for the crash safety of electric energy storage systems
-
- Develop Integrated Safety Concept (HV, Fire, …) and setup Standards for Emergency Handling, Including Roadside and Tunnel Safety
- Create & Review Standards for Safety, EMI, Health for Electric or alternative fuel vehicles.

Theme: Noise, Vibration & Harshness

This theme is about how to design and develop vehicles and vehicle concepts that can perform transport and mobility assignments resulting in as little noise and disturbance to the environment as possible.

Exterior noise from road vehicles is the most important noise annoyance source in EU countries. Due to the high mobility requirements and the resulting high volume of road transport every reduction in effective noise levels will provide great benefits to the resident population. Road transport noise is generated in an interactive process by the vehicle, its tyres and their interaction with the road infrastructure. Research should focus on all three components and their interaction to achieve noise abatement at the source or as close to the source as possible (both interior comfort aspects, as exterior emissions and safety aspects).

Tire-pavement noise is now a dominant component of overall road traffic noise emission at speeds above 30-50 km/h. With the introduction of hybrid or fully electric vehicles it will also become the most important noise source at lower speeds. For this reason further research into the tire-road noise generation emissions will be necessary to design new generations of low-noise road pavements and tires without reducing other performance indicators (eg. skid resistance, energy-efficiency).

- Low noise cargo handling (on, off and reloading) and distribution concepts
- Low noise technologies for light-weight design

- Development/adaptation of novel acoustic materials
- Development of smart systems for improved NVH behaviour
- Tyre-road noise (will become dominant) -> new strategies need to be defined
- Dedicated NVH aspects of electrified vehicles:
- Investigation of NVH properties of electrified drives (currently unknown)
- Noise reduction technologies for critical elements (?)
- NVH of aggregates (incl. heating)
- Reducing vibrations and noise for increased vehicle interior comfort.
- further advancing of numerical and experimental analysis techniques (including CAE tools)
- Improved source and damping characterization (incl. non-linear)
- Extending NVH simulation capabilities to mid-frequency range
- Enhancing CFD – aero-acoustic modeling to make it practically applicable in design
- Accurate modeling of vehicle sound packaging
- Effects of variability and uncertainty on NVH
- Development of new modeling paradigms for sound engineering (Sound Quality design)

Tyre-Pavement Interaction and friction force estimation

Research is needed on the design and development of advanced tires and pavements with extreme low rolling resistance without reducing other performance indicators, in particular related to the safety aspects. Technology prototype are needed to optimise tyre-pavement interaction with regard to e.g rolling resistance, durability, cost, winter and wet weather, robustness, noise. The estimation of friction force will enable new solutions of vehicle dynamics control, including low adherence scenarios.

Estimation of road-tyre friction by modelling in order to develop friction estimation systems used in information and active safety systems New friction estimation methods enable novel dynamic stability control algorithms. Models to estimate current friction force at each tyre have to be developed. Furthermore, the maximum available friction considering pavement and tyre characteristics, vehicle speed, weather conditions, etc. requires modeling. A dynamic real-time application is thought of; therefore appropriate methods for implementation (databases, communication, etc.) have to be considered.

- Development of Intelligent tyres able to measure friction in real time, together with the force applied to the tyre, to allow an improved stability control of the vehicle

Theme: On-board Intelligence

All research on ICT based systems on board of the vehicle that make it perform better on its own and optimising its performance and transport operation in interaction with user, infrastructure and traffic operators. That includes:

- Driver support systems to reduce the risk of accidents as well as provide reliable traffic information and vehicle positioning data. This will enable the driver to operate the vehicle in a safe and energy-efficient way, i.e. by adapting vehicle speed at high risk road sections, avoiding heavy traffic, congestion and consequent 'stop-start' driving and also by coaching the driver to operate the vehicle in the most energy efficient way, thus contributing to reduced fuel consumption.
- Adapted integrated Human-Machine-Interfaces for a safe and efficient information management
- In combination with systems to support safer driver operation, develop technology to monitor performance more directly in order to support increased flexibility in the use of drivers hours.
- Use of on-board intelligence to optimize power platform (see topic Energy management)
- Driver status Monitoring & support for impairment (How to measure and interpret the physical and mental state of the USER in relation to his driving performance? How to over come a USER's condition of being unable to perform as a consequence of physical or mental unfitness?
- Collision mitigation/warning/avoidance, (intelligent integrated sensing systems incl. GNSS; simulation tools for intelligent safety systems; test and assessment methods for advanced pedestrian and cyclist protection systems; Field Operational Tests; …)
- Automatic Vehicle Guidance (AVG), and (Supervised) autonomous driving (platooning, co-piloting, …) or semi-autonomous vehicle operations to support safe and efficent(energy consumption) handling of vehicles
- Evolution towards automated driving, solution for active co-piloting
- Intelligent, performance based, access programmes – the use of on-board telematics to enforce restricted access of goods vehicles to the road network can be used to grant access for larger vehicles to more of the road network where operators have excellent compliance and safety records and vehicles that perform to improved standards, thus allowing increased productivity without safety or infrastructure risks.

Management of Driver Behaviour

Research is needed on bridging the gap between the driver's awareness e.g. of a safety risk or ecological impact and the actual behaviour. The objective is to deploy such research on a short time scale. This research should address the causal

chain that leads to the actual driver behaviour, such as to be able to ultimately predict and manage real time as well as longer term behaviour from a limited set of parameters. This shall include the development of measuring and simulation tools, in particular concerning safety and fuel consumption. Also, the research should target continuous monitoring of the driver/vehicle/road condition and the acquisition of the best practise as to allow the development of systems for on-board, real time driver training/coaching such as eco and safe driving.

In practice there can be a wide, if not conflicting, gap between the awareness of people of a certain cause and the actual behaviour. Often measures to change behaviour show gradual effect over long terms. The objective is to manage USER's behaviour on a shorter time scale, both on a structural level e.g. by targeted and tailored education raising general awareness and attitude and on a situational level e.g. by encouraging specific modes of transport at peak hours. Obviously the basis for this topic is the models and tools that can predict Road User Behaviour.

This research theme addresses the causal chain that leads to the actual behaviour of the driver. The objective is to obtain a thorough understanding of what composes the driver's awareness, motivation, attitude and behaviour towards sustainable mobility options, such as to be able to ultimately predict and manage real time as well as longer term behaviour from a limited set of parameters.

The output is a standardised set of predictive methods, models and tools to replace current empirical practices. These must be harmonised and interrelated / aggregated at the EU level.

Research should also adress the effectiveness of the different USER incentives as well asa

effective enforcement measures (e.g. mandatory 'rehab' courses, fining, community service)

V2V & V2I communications and cooperative systems

Research is needed on standard, interoperable systems that allow vehicles to communicate safely, continuously and efficient with each other and the transport infrastructure. This enables sophisticated applications to assist driving support vehicle control strategies and aid traffic management and logistics operations. Of specific importance is the large scale testing of cooperative systems solutions under representative and real conditions. Handling and processing of data and information will continue to be an important legal and organisational issue. Information must be stored and disclosed in a safe, secure and appropriate manner, and in accordance with legal requirements, so that there is confidence in systems which rely on information exchange.

- Communication design
- Platform independence, standardisation
- Cooperative applications for safety, security and improved efficiency

New V2X communication enables innovative vehicle safety applications and assistant systems. Through permanent position awareness and connection to databases (road, weather, etc.) safety applications considering vehicle dynamics, driving and traffic state and surrounding environment are possible.

- Cooperative systems, how to support driver in a "all vehicle connected" traffic

Advanced Driver Support Systems

Research is needed on ergonomically and sociologically/physiologically justified information & supporting HMI, that allows the driver to optimally use the (increasing level of) intelligence in the vehicle. Emphasis is on supporting the driver on a real time basis in properly managing the extended level of information available as to improve driving behaviour in order to reduce fuel consumption and increase safety. Although this research on the long term supports the development of (semi) automated driving , the focus should be on deployment of technology on the short term.

- Driver support for collision mitigation/warning/avoidance
    - Systems that support the driver to avoid or mitigate accidents
    - Driver behaviour modeling in critical situations to improve systems HMI and effectiveness of the systems
    - Sensor systems
    - Modeling of driver behaviour in the driving task
- Driver Impairment monitoring and support
    - Solution to support the driver in case of failure (due to distraction, drowsiness, illness, etc.). Specific aspect in this research would be the development of reliable yet non-intrusive on-board enforcement systems, such as alcohol-lock.
    - Advanced driver interfaces to simplify perception of complex physical environment easily (distracters, tensors, etc.).
    - Systems to monitor driver status and alertness
    - Cab interior comfort to improve driver alertness
- Driver Coaching
    - Real time and ergonomically (= accepted by the user) designed information & supporting interfaces to the driver e.g. coaching on driving and alertness; including sociological psychological aspects; detailing

of safety aspects e.g. alertness). This includes: real time performance diagnostics & management e.g. on energy consumption, Misuse prevention (alcohol/drugs, speeding, overloading)
    - On board information & coaching, including the issue of user's acceptance: will user still experience 'being in control'?
    - Driver coaching, towards more safe and environmental friendly behaviour; Eco driving, real time support
- HMI research
    - Advanced human machine interfaces: all research that makes the user to perceive the vehicle and physical environment as 'easy to use/understand' and comfortable to undergo.
    - Identify and analyse technologies that better exploit HMI at the various levels in terms of information access, mobility services, etc
    - User-adaptive HMI: Research should analyse the needs of various user groups such as elderly drivers and Advanced driver interfaces to simplify perception of complex physical environment easily (distracters, tensors, etc.)
    - New methods for the evaluation and assessment of HMI concepts (incl. driver monitoring functions)
- Information System and Management (in the context of the driver)
    - Information on situational traffic safety assessment, carbon footprint (shifting gear, speeding etc.), cost, nearby services, preferred routing, etc.)
    - Information system for road conditions, weather, traffic, etc. New V2X communication and permanent position awareness enable assistant systems to inform the driver on safety relevant road conditions, weather information etc.. The connection to databases (road, weather, etc.) is essential in this context. Furthermore, models and methods to dynamically update the databases are necessary.
    - Identify and analyse technologies that better exploit HMI at the various levels in terms of information access,
    - Mobility services

Safety of vulnerable road users

The protection of vulnerable road users (VRUs) has for a long time been focussing on mitigating the consequences of collisions between pedestrians and cars. This has been limited to guidelines to folow in the design of the vehicle shape. A broader approach is necessary taking into account other types of vulnerable road users, other types of vehicles and all accident phases. This includes amongst others:

- Safety systems for the protection of (moto)cyclists in collisions with motor vehicles
- Technologies to mitigate the consequences of secondary impacts on the road after a VRU to vehicle collision
- Technical solutions for the protection of VRUs in collisions with trucks, based on adapted length regulations
- Improved pedestrian and 2-wheeler detection systems for accident avoidance

Adapted test and evaluation methods for the scenarios / systems mentioned above taking into account virtual testing methods and mathematical modelling

Safeguarding systems against Theft and Damage

Security and supply chain efficiency relate closely to each other. On one end improving security will reduce the risk of economic losses but in the other end it could reduce freight delivery efficiency introducing operations not needed or risk of delays due to the security operations. The challenge of research is then to improve the security level without any negative impact on efficiency. Another important point is that the driver has to be minimally involved in the system, avoiding an increase of the risk for his/her. Research is needed in the development of solutions that will protect freight independently from the local operator actions:

- Tamper-proof identification systems, for vehicle, containers and goods;
- Advanced tracking systems, for vehicle and goods; research has to focus on solutions tamper-proof, that cannot be disabled and work also in degradated mode (without GPS signal for example)
- System for safe stopping and blocking of stolen vehicles and goods;
- Cooperative systems to increase security levels in the freight transportation, allowing alternative ways to track vehicles and freights.

Automated systems

Research is needed on automation in key operations in road transport such to allow for further improvement in energy efficiency and safety. Emphasis to be put on supervised autonomous driving (platooning) and the conveyance of goods from Heavy Duty (long distance) to light duty (urban) transport e.g. by standardised modular loading units in combination with automatic cranes, which would link in to the advancements in logistical services (information

management). Research is needed on technical as well as on socio-economic and legal issues in order to enable the extensive implementation of autonomous safety systems into the fleet, which actively intervene in driving dynamics control and will probably require not only a braking, but also a steering function for optimum effectiveness. Such research should be targeted to applications in different kinds of motor-vehicles including heavy trucks and vehicle combinations.

-
- (Supervised) autonomous driving. For safety reasons the first autonomous driving solutions will be limited to specific areas (dedicated lane on highway or in the city) with the driver still in place to intervene in case of anomalities. This will allow however to improve traffic safety and efficiency in different applications: platooning of commercial vehicles along highways; automated lane through cities,
- Development of electronic-electric architectures (HW and SW) with proper level of fault tolerance and functional safety to be adopted in autonomous driving.
- Studies on driver – vehicle interaction in semi-autonomous driving, shift between modes (automatic system - driver control)
- New regulations and standards to allow the introduction of autonomous systems, with less constrains on the infrastructure.

- Automated Urban Goods Delivery: Automated transport will start by extending goods delivery from the major transport hubs deep into the urban areas', delivering goods to local or neighbourhood distribution centers, from which the 'last mile' to the consumer's door is serviced. Such systems will be mostly separated from other non-automated traffic.
- Automated passenger transport: On a much longer term the automation will also extend to passenger travel, starting predominantly in the very centers of the city, as the mobility system in dense populated areas where normal traffic will be banned, and spreading out gradually as cost-effective business models develop.
- Heavy Duty (HD) to Light Duty (LD) Conveyance: The interface between Long Distance freight Transport and Urban goods delivery will be automated first as both heavy duty and light duty vehicles will share the same modular loading units. This allows for automated loading cranes efficiently heaving the loads form one vehicle to the other, guided by advanced (ICT-driven) logistical schemes.

Theme: Next Generation Vehicle Concepts

All research that concerns the conceptual design of the vehicle as a whole to allow for more efficient execution of task & mission of the vehicle still not compromizing safety of passengers or vulnerable road users.

The research topics are closely linked to other research concerning the vehicle efficiency and enery demand as well as logistics efficiency and vehicle owernship / usage patterns.

- New vehicle concepts for personal mobility in urban areas, adaptable to occasional use on longer distances
- New concepts for cleaner and quieter vehicles for urban delivery and night-time operation.
- New multifunctional / multi-purpose vehicles (such as post-buses) to integrate different types of passenger and freight transport.
- Continued research in the design of buses, vans, guided vehicles, two-wheelers, and new 'driver-less' conveyance systems
- Vehicle concepts that will allow for co-modality (the use of different modes, on their own and in combination), inter-modality (the use of two or more different modes in an integrated manner). Emphasis to be put on modular & standard load carriers (goods and passengers) and mass & dimension (giga-liners, eco-liners, road trains, etc). Possible interfaces to new solutions for underground, automated freight transport should be considered.
- Intelligent Inter-modal Transport Units (ITU) for modular goods movement on a European level.
- Dual-mode vehicles able to run on road and rail which may improve the efficiency of onward distribution in urban areas and of co-modal operation.
- Modularisation: use of common freight modules (goods containers) by all freight transport modes, combination of small freight modules that will typically be used for urban transport into bigger ones for long-distance transport and vice-versa, modular safe public transport vehicles, including modularity inside the vehicles with flexible interiors for the rapid conversion from maximum capacity to maximum seating, and flexibility of vehicles with multiple modules
- Research on the benefits and possible drawbacks of new standards on weights and dimensions of heavy duty vehicles to increase freight capacity in terms of volume and mass Suitable changes can also allow a greater scope for vehicle design, leading to significantly improved aerodynamics, fuel consumption, safety performance and driver comfort.
- Use of light weight materials in vehicle design and production to reduce weight and to increase efficiency

- Optimisation of mechanical structures to minimise vehicle weight with maintained mechanical characteristics (stiffness, NVH, crashworthiness etc.)
- Crash compatibility: With a higher number of downsized, lightweight cars expected, the probability of crashes between vehicles with very unequal masses might increase resulting in high risks for the occupants of the lighter vehicle. Research should therefore be targeted towards the amendment of safety requirements for the different types of vehicles available, based on in-depth research on what are the optimal features a small car should provide compared to those of a larger vehicle. Also vehicle-vulnerable road user compatibility should be considered in this context.

Matching vehicles to tasks

Single vehicles are often used for many different tasks, often inefficiently. For example., passenger cars used in commuting with only the driver on board may be large with much seating capacity because of a requirement for occasional family travel on long distances. Trucks built to carry 40 tonnes will often only carry 20 tonnes because they are carrying low density goods and are full on volume not mass. In these cases a large quantity of "dead" weight is transported. This topic concerns any research related to how to better match vehicles to their tasks to improve the efficiency of transport.

- Vehicles optimised for their transport tasks and operation, , in particular:
- New urban vehicle concepts for safer and efficient private, collective and public transport
- New vehicle concepts filling the gap between powered two-wheelers and conventional passenger cars without compromising road safety
- New concepts for quiet and clean vehicles for urban and night-time distribution
- Vehicle concepts designed and adapted to specific infrastructure, e.g green corridors
- Solutions to the conflict of economies of scale / modular architectures and optimised lightweight designs fully adapted to the specific vehicle's tasks
- Applicationof new generation of materials (bio-, nano-, high performance) and production processes
- Coordination with research on new mobility concepts for people and goods incl. logistics and new personal mobility services, new forms of vehicle ownership and usage patterns.

Manufacturing & standardisation practices

Research Question: How to reduce the environmental and economical cost of manufacturing the vehicles by using new concepts in manufacturing methods and processes tested by modeling

- standard platforms etc.; Standardisation, for example crash standards, parts, plugs (a big issue for e-mobility); Modeling: manufacturing, development implementation, predictivity (reliability and robustness) of modeling, database development
- Driver Support Systems Topic: Manufacturing & standardisation practices
- Production chain modelling
- Mass customisation and new production concepts
- Tracking and tracing of parts and final products.
- Packing and packaging optimisation
- (standard platforms etc.; Standardisation, for example crash standards, parts, plugs (a big issue for e-mobility);

Maintenance & service practices (…)

Research Question: How to best support the vehicle in order for optimised usage (no breakdowns, always "on the run")?

- Benefit from new communication strategies (V2V, V2I, …) also for the setup of maintenance schemes (i.e. vehicle indicating/signalling whenever maintenance is needed, …) to optimize the vehicle operation
- Maintenance & service practices, uptime (…)
- Tracking and tracing of vehicle and spare parts.

Diagnostics

Business and regulatory models

Research is needed to develop new technologies/solutions/systems enabling innovative regulation schemes, with the aim to improve road user behaviour and encouraging a faster market penetration of new solutions, without negative impacts on industries (extra costs) and users. Together with the development of cost effective solutions also their standardisation (equipment, interfaces, data protocols) is needed to enable a wider dissemination.

- Use of third party equipment/data analysts
- Standardisation of equipment/data format/interface
- Business and incentive models for deployment of intelligent systems and increase the use

Theme: Generic Research Topics

All research on issues that are generic to the other topics in this research domain e.g on Data, Methods, Models and Tools; Standards and regulations; test facilities and environments.

Accidentology

Research is needed in the field of accidentology as to obtain consistent and in-depth knowledge on the root causes of accidents in road transport **including analysis of existing and new naturalistic driving data**.. This knowledge would allow for better methods, tools and procedures that support the prevention of accidents and their negative consequences as well as the assessment of safety measures and concepts. The objective is to establish an standard methodology that is accepted throughout the European Union.

- The science of accidentology aims to provide a consistent and in-depth knowledge on the root causes of accidents in road transport. This provides the foundation for avoiding accidents and their negative consequences as well as for the assessment of effectiveness of any measure taken. Another important research target is to develop an accepted methodology for investigating the potential and real-world impact of any measure or technology, thus providing knowledge on the effectiveness of these measures. This topic also includes research and methodology regarding incidents for instance naturalistic driving studies.
- Consistent data sources with improved detail across Europe
- Naturalistic driving studies all over Europe, under common methodologies
- Improved crash reconstruction methods including the internal collision between the occupant(s) and the vehicle interior.
- Improved analytical tools and more robust predictive methods. Research comprises improved accident simulation tools and proper models including all aspects of road safety (vehicle, driver, infrastructure). This allows for accurate prediction in a virtual environment on how these different aspects influence accident risks
- Methodology for effect analysis: Accident Prediction Models (APM) aid in analysing accident risk and effectiveness of certain road safety measures. Including APM and similar innovative approaches in network safety management will reduce accident risks and associated costs. This step supports the assessment of effectiveness and cost/benefit of selective road safety measures. The fact of higher accident risks in rural area and secondary road network needs consideration. With the decrease of fatalaties, collection and analysis of incidents will become useful. The trigger of ABS, ESP, Airbag could be significant of infrastructure defaults or incomprehension of users. So a new domain has to be investigate incident science.

Emissions data and carbon footprinting

Sources of data, analytical tools and system wide models to enable a more robust understanding of the true emissions and carbon footprint of alternative vehicle designs.

Kinematic and biomechanic models

Research is needed on establishing and modelling of the key physical and psychological factors that determine the driver's acceptance, tolerance, capabilities and behaviour in incidents and accidents

With the convergence of primary and secondary safety, human-like reactions, as they occur in the pre-crash respectively low-g phase, will play a more and more important role in the development and fine-tuning of safety systems. Research is necessary on:

- Active human models for all kinds of road users
- Improvement of the biofidelity and injury prediction capability of these numerical representations of the human body including the reproduction of muscular activity
- Biomechanical research as a basis to get a better understanding not only about so-called structural effects of impacts to the human body, but also about functional effects, e.g. injuries to the nervous system frequently causing long lasting or disabling injuries.
- Advanced dummies introducing human-like reactions also in physical testing and covering a broad spectrum of human diversities
- Tolerance levels for different body parts and organs as a function of different impact directions and acceleration pulses (from new born up to the elderly, focus on functional effects i.e. to the nervous system, disabling and long lasting injuries)
- Effects of morphological changes spec. the elderly
- Sex differences
- Effects of different diseases eg. Scoliosis
- Different handicaps including obese persons
- Human modelling

Modelling and Simulation

The vehicle integration should be kept in mind from the very start of the vehicle concept design, and guaranteed throughout the development cycle. Currently, this 'vehicle integration focus' is typically not implemented from the very start, but instead sub-optimally synchronized during the development cycle. This brings along the risk that developed solutions and physical prototypes will remain at the level of fancy add-ons, rather than becoming integrated solutions to improve the overall vehicle performance. In future R&D, the 'integrated vehicle design' focus should be implemented from the very start. Modeling & simulation can play a key role in this, and novel R&D actions are needed to develop the necessary methodologies to achieve this.

Therefore, research is needed on design and development simulation environments that allow to predict the impact of new vehicle power platforms, vehicle concepts (even extended to their contribution to transport solutions at various system levels).

New strategies and methodologies need to be developed to optimize vehicle design with respect to new design attributes such as "energy efficiency".

- this requires a multi-physical modeling approach in which all worlds meet: combustion, electrical, mechanical, software, control, …
- holistic modeling approaches, 1D-nD schemes
- Enhanced concept modeling tools (crucial for evaluation of new vehicle concepts in an early stage
- Further advancing of probabilistic methods to include inherent variability and uncertainty in the virtual design
- Modeling: manufacturing, development implementation, predictivity (reliability and robustness) of modeling, database development
- Modeling: manufacturing, development implementation, predictability (reliability and robustness) of modeling, database development
- Traffic and transport solution modelling and simulation on different levels (Macro and Micro levels) to study effects of different transport solution concept and their impact on environment, efficiency and energy consumption
- Reliable modelling of the crash behaviour of electric energy storage systems
- Predictive numerical simulation of the mechanical performances of new materials (metal and polymer foams, composites and sandwich materials) under impact loading including their failure and post-failure behaviour, numerical modelling of applicable joining techniques
- Taking into account the characteristics of the vehicle, the user and the environment, simulation tools might enable a more exhaustive evaluation of integrated safety systems than physical tests. Research should be done on appropriate tools and on the specification of an extensive catalogue of use case scenarios, on the basis of which integrated safety systems could be evaluated virtually.
- Research should also be done on model validation procedures and tools for virtual testing, a standardised range of biofidelic human occupant models as well as on statistical modelling strategies in virtual testing. As an outcome of such research, recommendations should be given regarding the implementation of virtual testing in regulation.

Grid Integration

- Develop Simulation, Monitoring, Management Tools
- Develop Protocols/Devices for V2G Communication
- Standardise Billing Concept (ENERGY & RESOURCES)

Integration into the Transport System

- Explore Potential of ITS for Energy Efficiency

Europe-wide standards & regulations

- to ensure interoperability
- to achieve economy of scale
- (electric vehicles) Furthermore, there is a need for at least Europe-wide standards to ensure interoperability. The timing of respective measures requires horizontal coordination across the various technology fields.,

Energy Storage Systems

- Set European guidelines for Lifetime & Range
- Establish Battery Testing Facility
- Establish facilities for Prototyping

Research Domain: INFRASTRUCTURE

Scope & Setting

This perspective considers the actual physical constructions that make up the Road Infrastructure as well as it's integration with the Physical Environment i.e. with the various aspects of land use and territorial development in relation to their contribution to economic growth, quality of life, environmental impact and mobility demand.

Where it comes to the Road Infrastructure itself the research perspective is concerned with all design, construction, maintenance and network management activities concerning roads and its supporting infrastructure. This includes all functional elements in a road (e.g. pavement, structures, road equipment, communications systems, terminals and hubs) as well as the production chains related to the road infrastructure.

Where it comes to Land Use Planning this perspective is concerned with the functional dimension of land for different human purposes or economic activities. Typical categories for land use are dwellings, industrial use, transport, recreational use or nature protection areas. Land use planning consists in assigning land to the use of one of these activities. Land use planning by determining the location of human activities also determines the level of mobility which will be required for the interactions between these activities. For a, more sustainable mobility, optimized land use would require a minimum of mobility to perform efficient social and economic activities.

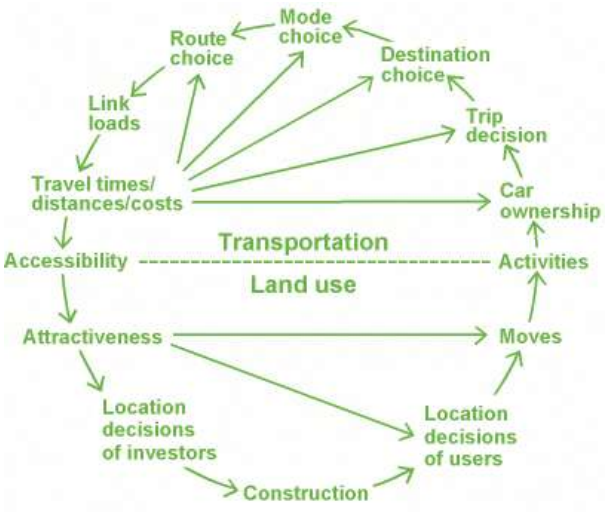


Figure 1: The land use – transport feedback cycle (Source: Wegener and Fürst (1999))

Space is one of the key resources and especially in the highly urbanized European context it is limited if not scarse. As a consequence the competition for space is fierce. In most of the densely populated areas, large developments of the road infrastructure,are no longer possible for environmental reasons and the sheer lack of space.

Maximising Capacity Usage: By 2030 European road infrastructure capacity will be stretched to its absolute limit. This has caused the system to a high susceptibility to instabilities from incidents and severe conditions. To uphold the reliability and safety of the transport system advanced, full-scale and comprehensive traffic and incident management schemes have been deployed on the congested sections of the Road Network (RN). In addition the introduction of new, more durable materials, construction and management concepts have helped to extend the intervals between maintenance measures and to reduce maintenance 'down time' of the capacity. The combined effect is an unprecedented effective road capacity level.

The importance of using existing infrastructure in an optimal way needs to be further stressed.

The infrastructure is provided with highly standardized communication technology based on open software platforms, allowing for real time, uniform interfaces to vehicle and user.

Debottlenecking Capacity: Short-term relief to the growing transport demand will be provided by full-scale and comprehensive traffic management of the congested corridors interconnecting the economic/metropolitan regions as well as those connecting these regions to the important intracontinental corridors. Additional long-term relief will be provided by 'debottlenecking' of the congested sections of the road infrastructure (e.g. short cuts, bridges and viaducts, the use of ICT based systems). However, as space in the highly urbanized European context is scarce, any expansion will be subject to the overarching objective to develop a sustainable physical environment in which it is balanced with the other functional claims e.g. agricultural and industrial. As a consequence the competition for space is fierce and often only part of the claims can be honoured. Increasingly legislation is required to streamline the procedures for civil participation and ensure that such projects are completed in the least possible time. The decrease of public funds for transport and urban mobility further limit the possibility of expanding the road infrastructures.

In 2030:

- The 'green corridor' concept will have been introduced and will be used for highly populated highways throughout Europe. The criteria for access to these corridors will be related to new vehicle concepts and transport and energy efficiency. In these corridors, longer and heavier vehicles will be the majority, and 'platooning' (electronic coupling of trucks) will be widely used. Transport modes complementing each other will be used on the basis of optimal resource utilisation.
- Multi-modal land hubs will provide fast (i.e. efficient) transhipment of people and goods between rail, inland waterways and road services as well as between long-distance transport and urban centers. Especially in and around urban areas, these hubs will attract other commercial activities such as shopping, finance and office facilities. Conventional inland terminals, as exist today, will still be operating, serving regional traffic and local distribution.
- Network management techniques and technology allows dynamic optimisation of the efficiency of infrastructure use taking into account the impact on the surrounding environment. For this purpose they can rely on flexible and dedicated infrastructures (where the space is adapted to the real time need), modular tools for demand management and accurate traffic and environmental information on personnel and goods movements. Efficient management of the infrastructure should allow to contain congestion and therefore local and global emissions accordingly.
- In the new member states, the European road network will have to be improved and upgraded in consideration of safety, environmental impact and economy.
- The road transport infrastructure is easily understood by all road users and its selfexplaining design helps to minimize road user mistakes. The built road infrastructure is constructed in a way that it forgives human errors and mitigates consequences.
- Roads and infrastructures, including road markings and road sign (including dynamic road signs), are built, upgraded, maintained and inspected according to high safety standards and procedures.
- The rising number of vulnerable road users, together with the introduction of more small, light, silent vehicles will increase vehicle incompatibility in relation to accidents, and therefore will also increase the need to better understand safety risks.
- The future transport infrastructures design requires cost-efficient and sustainable solutions for maintaining, redesigning and adapting the existing physical infrastructure including pavements, bridges, road equipment, parking, access to stations, platforms as well as new concepts for new construction.

Research and innovation Themes & Topics

Theme: An integrated transport network.

This research theme addresses the challenge to provide for a fully integrated road infrastructure, allowing the transport system be safely executed with optimal efficiency and minimal environmental footprint .

Intelligent, integrated network management principles allow for dense, but free flowing and safe traffic in such a way that network usage is optimal at any time of the day and under any condition. It relies on active communication between the users of the networks, efficient data collection, and decision support systems for intelligent network management and includes maintenance strategies as well as optimized and integrated network design & construction.

In the road transport system, shortage of capacity is a challenge with the current level of equipment of the infrastructure and mainstream models and techniques for network management, in particular in the bigger cities. Improved and integrated network management, including transport interfaces, the use of demand management, and the targeted development and deployment of intelligent transport systems could free some capacity on the existing infrastructure, providing an alternative to unlikely expensive investments in new infrastructure.

Integrated Infrastructure Network Management

Research is needed on intelligent, integrated network management principles to allow for dense, but free flowing and safe traffic in such a way that usage of the (existing) road network is optimal at any time of the day and under any (weather) condition. Emphasis should be on information systems such as cooperative systems that allow real time communication between the network operator and all the users of the road network.

- Methods are needed for intelligent, dynamic lane allocation considering the effects of variable lanes and speed limits for different traffic flows, taking into consideration all types of vehicles (trucks, cars, busses, two-wheelers) private or public.
- Market-based approaches for infrastructure use and entry into traffic streams (demand for slot entry) under saturated conditions should be evaluated.
- Design and operation of the next generation of dynamic network management centers integrating cooperative systems and integrating new decision strategies, supported by and including:
- Dynamic & intelligent traffic regulation & enforcement;
- Dynamic, information led traffic management and control models, to be created utilising embedded information, real-time data transmitted from the vehicles (position, speed, origin, and destination), individual

route planning, logistics regimes, access control to routes, lanes, and parking. More automation in traffic flow control should be developed.

- Measurement and assessment tools which are required for traffic management strategies, based on dynamic capacity optimization models, taking into account dynamic lane allocation, tidal flows, two-way communication with the users, ITS, and electronic parking management services.
- Decision support systems which should be developed, base on new models taking into account the density of vehicles and persons on the transport network, environmental situations (air quality and noise), events (weather conditions, social events) for a dynamic management of the network. They should include prioritisation techniques between possible conflicting objectives.
- Coordinated /integrated public transport and traffic management
- Links between traffic control centres across Europe should be improved in order to enable traffic management on long stretches including alternative routes, incident management and congestion management.
- Harmonised indicators and standards for assessing the level of service of the road infrastructure for all road users have to be established.

Multimodal Infrastructure and interfaces

Research is needed on new and/or improved infrastructural systems that allow equitable sharing of the road space by the different modes and vehicles (personnel and freight), including the design, construction, maintenance and management challenges involved. Emphasis should be given on upgrading the existing infrastructure, especially with respect to electrification as well as on providing intelligent multi-modal interfaces (hubs, terminal etc.) that allow for seamless connection between the modes and vehicles.

New and/or improved systems should be developed for equitable sharing road space (passenger and freight), including the design, construction and maintenance challenges.

Intelligent multi-modal interfaces allow seamless connection between modes of transport, accommodate various types of vehicles, goods and travellers and support the efficient management of the network. Key to their success is the high consideration for the needs and behaviours of the respective private and business users..

- Integration of soft modes on non-segregated infrastructure and shared spaces in urban areas: While dedicated lanes, possibly flexibly dedicated lanes, to several modes of transport, are desirable on some corridors and routes, it is necessary to consider whether shared spaces can contribute to the efficient use of road space and mobility management and to the functional allocation of some infrastructure. New infrastructure concepts need to be developed to improve the mobility and safety of pedestrians, bicycles, and disabled persons. A wide range of choices must be made available such as pedestrian pathways, cycle routes, user-friendly (e.g. bicycle lifts on slopes, pedestrian conveyors).
- Integration of automated transport: At the moment, automated transport systems are mostly confined to segregated environment such as airports or fairs. Some first trials of automated transport systems in real traffic conditions are starting. This should be further studied and the impact and feasibility of the insertion of automated vehicles on the main road network must be assessed.
- (Central) Management of automated transport systems and vehicles, including guidance systems for private and public transport vehicles
- Hubs and terminals connecting long-distance transport and urban areas: There is a need for hubs (or terminals) that efficiently transfers goods and people from different modes of long distance transport to urban delivery or transport and vice verse. The hubs can also carry a potential to integrate different commercial activities to form multi-service spots – “City Portals”. Efficient logistics requires efficient multi-modal hubs that also provide secure and efficient goods storage, transfer and movement. Other issues to consider are: Models for sustainable operation of roads and hubs; the ability to support a high diversity of vehicles (size, propulsion, in particular hybrid/electric, etc.); the design, planning, location and architecture of future bus stations, including their energy management (via photovoltaic decentralised energy supply), integrating requirements for electric vehicles such as “plug in “/docking solutions allowing fast charging, at the terminus or at bus stops during a normal stop. This should be supported by rapid charging concepts and technologies; the infrastructure to support/facilitate the maintenance and up time of vehicle road users; The upgrade of existing infrastructure, including design and maintenance, to integrate electricity charging facilities at depots and major bus stops and terminals, made possible by high performance batteries or supercapacitors. Research on all these components is required.
- Location and integrations in the transport network as well as design of these hubs needs to be studied, and one challenge is to finance pilots for logistics distribution hubs where these vehicles and distribution systems can be tested.
- Efficient design taking into account the specificities of the various modes;

Dynamic Demand Management

Research is needed on the design and operation of a dynamic system of measures to manage the (road) transport demand for a more sustainable transport system. It includes various forms of access incentives and restrictions such as charging, reimbursing, compensating, or low environmental zones, Intelligent surveillance & enforcement systems and transparent assessment tools for the impact of the various demand management strategies

- Dynamic access management to the transport networks, including various forms of access incentives and restrictions such as charging, reimbursing, compensating, or low environmental zones
- Intelligent surveillance & enforcement systems
- evaluation methods and tools to assess the impact of various demand management strategies, including road pricing, on air pollution, noise, congestion, CO2 emissions and accessibility;
- Intelligent Parking: An intelligent road based system should enable the driver to be informed about available and secure parking and resting spaces, including with dynamic navigation services, and to book them. This is of particular relevance for the allocation of parking space equipped with charging points to electric vehicles. Intelligent parking allows dynamic parking management, which is one tool to manage the demand.

Climate resilient networks and infrastructures.

Research Question: How to provide systems and technologies to keep networks operating under severe climatic conditions, taking into account vulnerable sections (potential bottlenecks)?

- This topic aims especially at developing technologies to keep European Road Infrastructure operational even under adverse climatic conditions.
- Monitoring of bridges and tunnels is required to guarantee safety and reliability
- New innovative designs and materials (drainage, pavement, substructure,…) increase safety and durability of the road transport infrastructure in thunderstorm and flood exposed regions.Real-time and seasonal effects will need to be examined to maximise the effectiveness of the system in all weather conditions.
- Develop and apply simulation methods to localize sections with specific problems due to climatic influences (e.g. storm water) and develop respective adapted design procedures

Incident management

Research Question: Especially on congested sections of the network: How to design and implement a response system on incidents that influence road safety and the traffic flow over the network in a cost-efficient, timely and legally correct way?

- In order to reduce road closures more effective traffic incident and emergency management methods need to be developed, based on full chain cooperation (transport authorities, road-side assistance, emergency services, insurance).
- Response scenarios for emergency rescues and evacuations, post-accident treatment are enhanced, as are countermeasures against illegal operations such as theft, hijackings and vandalism. Optimised cooperation and performance between the police, authorities, fire brigades and rescue teams supports this task.

Dedicated Infrastructure

Research is needed on dedicated, variable use of the infrastructure (lanes and interfaces) as to allow roads, bridges and tunnels to be optimised for particular types of vehicles and services in particular situations (time of the day, etc.) reducing maintenance and environmental impact and increasing efficiency and safety of the road transport system as a whole. In addition to efficiency effects, separating traffic types (short/long distance, trucks/cars) can be beneficial for the robustness of the transport system.

- The introduction of dedicated, variable use of the infrastructure (lanes and interfaces) allow roads, bridges and tunnels to be optimised for particular types of vehicles reducing maintenance and environmental impact and increasing efficiency and safety of the road transport system as a whole.
- Therefore the overall effectiveness of separate lanes for road operations should be evaluated, as well as the need for upgrading the secondary road network (safe alternative and escape routes).
- Ways and means to implement dedicated lanes and networks for goods and persons during certain times of the day needs to be tested. This should include light weight and reconfigurable passenger car infrastructures and reconfigurable and dedicated lanes for freight and ‘e-Safety’ and AVG enabled vehicles.
- Research should aim at dedicated systems for:
    - high-speed bus and taxi corridors
    - platooned trucks
    - electric vehicles
    - automated transport
- Simulation to assess a priori a new concept of dedicated infrastructure

Invisible roads that are 'Good and Generous neighbours'.

Research is needed on how to integrate Roads to such extend that they become virtually invisible to the surrounding living environment (Good Neighbourship) in terms of all aspects of pollution, nuisance (eg noise), community severance and natural habitat fragmentation. Also research is needed on how to integrate all the aspects of energy production from road pavements, tunnels and other structures, with the surrounding living environment.

For major roads, this would include the Green Corridors concept.

Communications infrastructure in an integrated transport network.

This research theme addresses the challenge to provide for a fully integrated communications infrastructure for the transport system, allowing optimal efficiency and minimal environmental footprint. The research should consider how to build and manage a safe, secure, robust and efficient communications infrastructure, where several modes of transport coexist and share information in the future as well as how to best design and operate the communication system from infrastructure to the vehicle, the user and the traffic operator (I2X communications). This relates also to the issue of achieving a seamless reception: The communications should provide full service to the road user in any location on the road network i.e. also in underground facilities such as tunnels, parking lots and in Public Transport services. Furthermore, the network as such should have sufficient robustness and resilience in emergency incidents and situations. This issue concerns all network components: hardware, such as electronics, sensors, actuators as well as procedures on data transfer, handling and storage; speed, volume, security, legal and integrity issues as well as models and tools for sustainable operation of the communication network.

Key to this research and innovation is the precondition that all solutions should be platform independent and highly standardised.

Intelligent and adaptive Infrastructure

Road-based systems providing intelligence to the transport system as a whole in order to enable communication between road users, infrastructure operators and managers and with public and private service providers. Spatial distributed sensor system to monitor traffic and structural conditions, provide accurate localisation and provide input to *collective intelligence*. As common lifecycles in road transport engineering exceeds short or midterm planning future road infrastructure need to adapt to changing environments. An adaptive design supports the process of innovation implementation and allows for "retrofitting" of newly developed intelligent transport solutions.

- Ubiquitous sensor networks allow for a seamless data exchange between vehicle and infrastructure. Research and development focus on sensor types, communication, data processing and handling as well as distributed intelligence in a systems approach.
- Traffic situation monitoring and communication
- Road-based systems interact and communicate its condition (road surface, structural, traffic,…) with vehicle-based systems and road user (vehicle driver and other road users). The systems provide input to novel ADAS and vehicle safety systems, warn road users of accident risks and enable safe and economic driving behaviour. This includes research on vehicle infrastructure interaction and accurate vehicle (tyre) positioning and (lateral) localisation. A connection to weather information systems and other data sources should be considered.
- The systems will also interact with and will provide information to the infrastructure operator and manager about the current structural conditions and deliver input to modern asset management systems.
- The system will enable active security management e.g. secure parking guideance, by the detection of stolen vehicles and abnormal behaviour.
- Develop Best Practice for Implementation of Road Infrastructure Measures Supporting Rapid Uptake[
- Review Effects of Large Scale Deployment on Future Infrastructure Developments
- EU Wide Signage of Roads and Vehicles

Road status monitoring

The next generation of road transport infrastructure is well monitored and large-scale data is used in innovative cross-asset management systems. The monitoring process will either take place as built-in system or in regular campaigns under traffic flow speed conditions without traffic hindrance. This will provide a sound data basis for optimising maintenance planning and reduce transport infrastructure downtimes due to maintenance or repair works.

Research Question: How to intelligently monitor and communicate road condition such as to minimize the need for disruptive maintenance and repair interventions?

- Research on long-term development of structural pavement conditions is needed (texture, skid resistance) to optimise maintenance planning and support development for new materials and designs in road pavement construction.
- Real-time monitoring of weather-dependent surface conditions (wet, icy dry) and appropriate sensor systems or models are needed.

- Monitoring of structural conditions (specifically bridges) to guarantee safe and reliable infrastructures and reduce overall lifecycle costs.
- Monitoring of road characteristics and structural conditions under traffic speed conditions
- Sensors within pavement
- Condition monitoring of structures
- Condition survey of road equipment (safety barriers, noise barriers etc.
- Bridge Condition
- Location and condition of traffic signs & systems
- Location of dangers and difficulties for users
- Dangers and difficulties diagnosis tools
- Speed management
- Real-time detection of road surface condition (friction) and communication to road users.

Vehicle status monitoring

In a cooperative transport system the communication between vehicles and infrastructure supports vehicles status monitoring (specifically for heavy goods vehicles). This is an important development in road transport safety as vehicle weights, especially overweighted HGV, and the vehicle conditions like brakes, tyres, etc. are crucial to reduce accident risks and accident severity. With novel ICT techniques monitoring and tracing of goods and HGVs is possible. Sensors in the vehicle monitor loads and the condition of tyres or brakes. Research will focus on the whole system including the vehicle and the infrastructure as well as sensor manufacturers. This allows for:

- Monitoring cargo/goods content and condition
- Driver awareness and alertness monitoring
- Vehicle (tyres, brakes, etc.) conditions
- Transport data declarations, eg, carbon footprint
- Vehicle bound axle load control

Impact of connectivity on land use, spatial distribution of activities and mobility demand

Research is needed on the key impact factors that increased level of connectivity has on location and travel patterns of people as well as industries and its operations in view of their demand for mobility and transport. Of particular interest is the assessment of the impact of e-services e.g. on the issue of optimising the location of firms and distribution centers, and the the number of (urban) delivery movements required. Another issue concerns the security of data exchange between the various actors, modes and networks in the road transport system..

Theme: Design, Construction & Maintenance of infrastructure

This theme consists of the research and innovation concerning all activities that are concerned with newly built or reconstructed road infrastructure, and the activities that are aimed on achieving and consolidating a certain maintenance level. The backdrop of this theme is that by 2030 dedicated road infrastructure should be able to support new transport concepts such as road-trains, electrification of freight transport and the first stages of automated transport.

In line with the objectives for decarbonisation, the design of new infrastructure and the upgrades of the existing, should aim for minimal carbon footprint, taken from a life cycle approach. In addition the design, construction and maintenance of the road infrastructure should consider on cost-effective measures to reduce down-time due to maintenance and repair.

Ways to electrify roads and road transports must be explored allowing for electrification of freight transport e.g. by means of wires, tracks or contactless recharging/energy supply. Systems need to be tested in full scale on suitable parts of the network.

Methods, models and tools should be upgraded as to allow cost-effective dimensioning for dedicated purpose e.g. for light duty vehicle traffic only (i.e. cheap, minimum resources etc) versus for to heavy vehicle traffic (e.g. platooning, HLV) requiring robustness.

Advanced bridge and pavement materials

Research is required to develop new materials that prolong infrastructure life, reduce the disruption caused by maintenance and replacement, to reduce the reliance of bridge construction on carbon intensive materials such as concrete and steel and to produce new pavements constructed solely from carbon neutral materials.

- Optimisation existing (through better understanding of manufacturing processes.true safety)…)
- Investigate methods and designs for prefabricated infrastructure construction for rapid renewal.
- Study on lifecyle cost optimisation through highly durable materials.

- Investigate carbon balance in road construction and deliver harmonized assessment methods.
- (reuse, prefab, …)
- New manufacturing processes for new durable materials.
- Manufacturing of recycling materials.
- Options of reuseness for reusable items
- Wear-resistant material for bus lanes, in particular for lanes used by guided vehicles, which increases the risks of rutting

Efficient infrastructure maintenance and reconstruction

Research is needed on time- and cost-effective maintenance and reconstruction technologies and regimes that maximise the uptime of the integrated road transport network by minimising the need for disruptive maintenance and repair interventions, especially in the urban areas (cables, pipes for water, gas, electricity and communication technologies) and congested corridors. Emphasis should be on durability and sustainability of maintenance measures and materials e.g by recycling surface layers on site and systems for night-time operations. In addition, systems for intelligent and dynamic road status monitoring of the road condition (e.g pavement condition).

Research is needed on the development of Best Practices for Implementation of Road Infrastructure Measures Supporting Rapid Uptake thereof. Also the effects of Large Scale Deployment on Future Infrstructure Developments should be reviewed.

Research is needed on how to best develop systems to optimize road and information network up time in the integrated transport system.

- Maintenance should be executed by quick, cost effective, durable, sustainable, … measures as to allow for minimum down time of road and information accessibility
- Quicker, more effective and durable road maintenance techniques have to be introduced. Improve the quality of recycling surface layers on site and systems for night-time operations. Materials use should be optimised minimising environmental impact
- New technologies have to be developed for maintaining underground utilities (cables, pipes for water, gas, electricity and communication technologies) with a minimum of traffic disturbance in particular in urban areas.
- Long life pavement concepts
- Condition Monitoring should be automatic and accurate to extend infrastructure life and minimise the replacement of existing infrastructure which requires non-renewable materials.

Self-explaining and forgiving infrastructure

Research is needed to develop design concepts to the paradigm of ‘self-explaining’ and ‘ forgiving roads’ as to develop a comprehensive safety standard accommodating the targets set by European and national policies. Emphasis should be on the interface between the infrastructure and the advanced on-board systems supporting the driver with real time and reliable information, such as on road conditions, local weather conditions, traffic situation, etc. In particular such systems should allow for intelligent traffic regulation & enforcement as achieving a truly integrated safety concept.

The focus in the research is on the development of accepted methodical standards for the assessment of the actual road safety level, for the design of the “self-explaining” and “forgiving” road concept and for the road side component of driver support systems.

To improve road safety reducing accidents and their consequences the road infrastructure has an important role. How to reduce the driver errors that are the main accident cause? How to reduce the consequences of these errors to the minimum (forgiving roads)?

- The infrastructure should be designed under the paradigm of ‘self-explaining’-‘ forgiving roads’ and thus has a safety standard that reflects the safety targets set by European and national policies. In addition the infrastructure feeds the advanced on board systems interfacing to the Road user with online and reliable information on relevant in situ safety aspects , such as road conditions, weather, traffic, etc. Furthermore the road infrastructure should allow for intelligent traffic regulation & enforcement, i.e. Integrated vehicle to infrastructure safety.
- Standard and accepted methods for the assessment of road safety level, enabling a better use of the resources dedicated to improve road network safety level
- Design solutions for future roads segments based on the ‘self-explaining’ “forgiving” road concept, sustainable on the (road) cost and (vehicle and road) energy aspects,
- Enhancement of performance standards & installation guidelines of road equipment (road restraints systems, road signs, road marking) in relation to users ‘acceptability or comprehension.
- Adapting urban and interurban infrastructure to the needs of vulnerable and unprotected road users (e.g. cyclists, motorcyclists, pedestrians)
- Driver support systems (road side component), road status warning, intersection support

Service level of Road Infrastructure

Research Question: HOLD

- A better understanding of removing bottlenecks is needed to provide the required capacity. Harmonised decision indicators and standards for the level of service of the road infrastructure for all road users have to be established.
- In order to meet the new demands for mobility and transport and address the shortcomings of Today's systems, an integrated, systemic and comprehensive approach not previously seen is required. This approach should contribute to the ultimate goal of a sustainable transport system, considering the social, economic and environmental aspects.
- Develop appropriate road classifications for the efficient operation of modular vehicles and road-train combinations.

Integral Asset Management

Research Question: How to develop a best practice on balancing the risk of failure to the cost of failure. How to develop e generic set of methods, models and tools that allow tailoring to the need of the different Member states and still have aggregation up to EU-level.

- Research and development is needed on decision models based on condition monitoring data
- Topic: Financing schemes on private-public partnerships (Methods/methodology on cost & revenues of investments e.g. Payment/pricing/tolling of usage of infrastructure)
- Topic: Integrated Life-time assessment and Condition monitoring/modelling including databases. Systems and models for providing optimum prioritisation of urban road space are needed. Advanced maintenance strategies, including materials and buildings concepts
- Quicker, more effective and durable road maintenance techniques have to be introduced. Improve the quality of recycling surface layers on site and systems for night-time operations.
- Innovative road surface with longer lifetime to expand intervention intervals
- Infrastructure monitoring and maintenance management systems should be upgraded using advanced software, sensors and data transmission, responding to real-time local needs and reducing the impact of road works on travel time. Low cost, autonomous sensors for road condition monitoring have to be further developed. Advanced condition measurement (e.g. pavements, bridges, tunnels) without traffic disturbance is needed.
- Durable & safe infrastructure (road, bridge, tunnel)
- Availability of road space will be maximised with quicker return to operation after maintenance and incidents.
- New technologies have to be developed for maintaining underground utilities (cables, pipes for water, gas, electricity and communication technologies) with a minimum of traffic disturbance in particular in urban areas.
- Financing schemes: Intelligent billing; Development of automatic ticketing and fee collection for seamless mobility and goods transport within Europe. This should aim to stimulate an optimal distribution over all modes.
- Uniform costbase principles throughout Europe
- Develop new tools and models for the efficient asset management of both overall network and individual sections to improve the overall life cycle costs.
- Marketing-based approaches for infrastructure use and entry into traffic streams (demand for slot entry, ramp metering) under saturated conditions should be evaluated together with the assessment of the effect to the secondary network.
- Sustainable operating schemes.

Secure Road Transport Facilities

Research is needed to enable the development of (infrastrucural) facilities that enhance the security of Road Transport. Emphasis should be on provision of cost-effective measures concerning secure resting/parking areas for freight transport and Park&Ride for Passenger Transport. The research should include intelligent and integrated monitoring (e.g. tracking & tracing) and surveillance concepts for both passengers and freight, that acknowledges requirements for data security and privacy.

- Safe parking areas, for freight transport and Park&RideSafe Public Transports, through intelligent monitoring of the passengers either in the vehicles or at the bus/metro/train stop.
- Intelligent surveillance systems for freight transport
- Integration of all monitoring systems for stolen vehicles detection and tracing
- Consideration of data security / privacy aspects
- Monitoring of pavement condition (low adherence, damages)
- Monitoring location and condition of traffic signs & systems

Theme: Land Use Planning

Research on Land use and planning is concerned with the spatial interactions i.e. the nature, extent, origins and destinations of the movements of passengers and freight as well as the transport system, that is supporting the movements of passengers and freight.

It takes into consideration the attributes of the transport system as well as the land use factors that are generating and attracting movements.

The globalisation and regionalisation of industries has a great impact on planning the locations for operation and of production sites.

Progress towards a more efficient mobility system requires that more and better consideration be given to land use planning. There is therefore a strong need for greater integration between land use and mobility planning. This is true everywhere, but is particularly important for the efficient provision of transport infrastructures in the New Member States, where the requirements for its upgrading and development are sometime particularly acute. In order to meet the new demands for mobility and transport and address the shortcomings of today's systems, an integrated, systemic and comprehensive approach not previously seen is required.

Tools and models must be developed to improve the understanding and the planning of the complex multiple interactions between land use and mobility. On one hand, a high degree of spatial separation of function results in unsustainable use of resources to ensure the mobility of people and freight. On the other hand, in very dense urban structures with overlapping uses, there is a greater potential for conflicts between the various functions of space.

The capacity and the location of services and infrastructures, including roads are key elements assessing the accessibility of these services on a given territory. As it is an important component of the competitiveness of a territory and a key indicator to measure the efficiency of a system, further knowledge about accessibility is required.

Assessment of (Urban) Accessibility

Research is needed on a common, European standard for assessing Urban accessibility in order to provide a basis for cost-benefit evaluation of possible measures to improve on the accessibility in specific urban settings. Emphasis is on determining which key functions should be taken into account in relation to the road transport consumer (passeger and freight consignments) as well as on establishing a common set of European indicators/criteria (including cost) that consider the time and distance required by citizens to access the persued goods and services. For industries, accessibility considers time and travel necessary to access services, goods and persons necessary to perform their economic activity.

- Definition of common European indicators to measure the efficiency of the mobility system including the criteria of accessibility, understood as the accessibility to services and goods by industries and citizens, considering the time and distance required to access these services. For firms and goods, accessibility considers time and travel necessary to access services, goods and persons necessary to perform their economic activity.
- Methods to evaluate with these indicators the levels of access to key services, including the cost of mobility

Spatial Interaction

Research Question: How do people and industries chose their locations and how does this affects transport and mobility ?

- Influences which determines peoples and industries choices of location, e.g regionalisation, globalisation;
- Impact of travel modes on space consumption;
- interaction between hubs, economic/human activity and traffic
- An understanding of the relationship between land use, mobility, accessibility and transport demand at both the local and regional level must be established. Segregation between living and working areas as well as relocation of production has to be reconsidered in the context of sustainability.

Integrated mobility planning

Research is needed on best practices to integrate land use and transport and mobility planning, considering in particular the location and opportunity of new transport infrastructure such as roads and interchanges for the movements of persons and goods. Emphasis should be on determining the major spatial interaction factors that determine the people and industries chosing their locations the resulting transport and mobility demand and their imbedding in decision support tools for public authorities to assess the possible impact of integrated policy packages on mobility. It should also considers socio-economic interactions between territories, in particular urban areas and their hinterland, and how this influences mobility patterns.,

- methodologies for integrating land use and transport planning
- Appropriate Geographic Information Systems (GIS) technologies need to be developed bringing together all relevant data sources (transport, land use, relevant socio-economic data such as housing, etc.)
- Benefits and costs of 'agglomeration' structure as an urban structure

- Decision support tools for public authorities to assess the possible impact of integrated policy packages on mobility;
- Specific tools to assess opportunities to locate new housing projects in a consistent way with the objective of efficient mobility;
- Comparative research on the impact of the different institutional settings methods of horizontal and vertical coordination to determinate the most appropriate organisational structures from the point of view of mobility efficiency;
- Analyses of the relation between activity which meets local, internal demand and activity which meets non-local demand. The former is non-basic ; it serves the city but does not cause it to grow. The latter is basic and city forming because it is the demand from beyond the city which causes the city to grow.
- The impact of new infrastructure on land and housing prices has to be studied and the relation between land price and suburban expansion
- An understanding of socially acceptable uses of land must to be developed.
- integration of local environmental parameters (Noise & Air Quality, natural habitat) in planning land use and mobility
- methodology to identify the best location for logistics hubs on the long distance and local transport networks;
- methodology for assessing the effects of newly planned commercial/trading centers on resulting traffic demand including calculation of resulting costs for the community
- methodology to identify the best location for interchanges for travellers, on the long distance and local transport network;
- methodology for the design of the network of EVs public charging infrastructure, considering as parameters the mobility network, the electricity grid, the location of possible renewable energy sources, and energy storage opportunities.
- methodology for the design and location of alternative and renewable fuel infrastructure supporting a high level of alternative vehicle power platforms

Service level of Road Infrastructure

Research Question: HOLD

- A better understanding of removing bottlenecks is needed to provide the required capacity. Harmonised decision indicators and standards for the level of service of the road infrastructure for all road users have to be established.
- In order to meet the new demands for mobility and transport and address the shortcomings of Today's systems, an integrated, systemic and comprehensive approach not previously seen is required. This approach should contribute to the ultimate goal of a sustainable transport system, considering the social, economic and environmental aspects.
- Develop appropriate road classifications for the efficient operation of modular vehicles and road-train combinations.

Theme: Testing Facilities & Environments

Full scale demonstrators

They are essential for demonstrating the feasibility, efficiency and cost effectiveness of the global technical solutions, proving the positive interaction between them. The new challenge is to prove the real **integration** of the different projects, each demonstrator incorporating two or three of the below listed items:

- New methods and technologies for planning, design, construction, repair, maintenance, assessment and replacement of road infrastructure which optimize road infrastructure for improving mobility especially in urban areas, serviceability and for reducing the impact on the environment.
- New construction materials, monitoring tools and implementation systems aiming at reducing environmental impacts of roads such as recycled or low energy materials, smart materials and sensors able to prevent the effect of climatic hazard conditions, low CO2 emission materials or materials helping to store CO2, smart materials reducing the pollution releases of roads (air and water).
- New methods, tools and technologies for multi-functional smart and safe infrastructure monitoring, generating real-time data for road user support and enabling a high-quality process over the life span of the road without data loss and errors, to enhance efficiency and road safety. In particular, new development of information systems attached to the road infrastructure linking the vehicles, the roadside and the different centres are needed.
- Innovative road user guidance systems enabling speed and headway control, dynamic routing, lane allocation or closure, which allow the road operator to optimize the traffic flow, in particular the heavy traffic, and during maintenance operations.
- New technical solutions, methods and models, to capture energy, supply energy to electric vehicles, lower the CO_2 emissions associated with the road construction, maintenance, operation and use, such as fuel consumption but also energy use for its own operation.

- Innovative systems, models and tools to ensure prior to the real implementation, the integration of innovations in all fields (construction, maintenance, operation) and synergism among them.

Field Operational Tests

FOTs are a powerful tool for gaining insight into the way new functions and systems suit the user when operated in the real context and for a sufficient long time to reach the daily operational and behavioural level.

- One of the challenges is to develop distribution vehicles and finance pilots for distribution hubs where these vehicles and distribution systems can be tested.
- The concept of dedicated lanes and networks has to be further developed and tested. This should include light weight and reconfigurable passenger car infrastructures and reconfigurable and dedicated lanes for freight and 'e-Safety' and AVG enabled vehicles. Ways and means to implement dedicated lanes for goods during certain times of the day needs to be tested, as well.
- Additional FOTs should be conducted to validate the effectiveness of new ICT-based systems and functions for a safer, cleaner and more efficient transport. The aims are to analyse driver behaviour and acceptability, to analyse and assess the impacts using real-life data and to improve awareness about the potential of intelligent transport systems.
- As a preliminary result of running FOTs, it becomes apparent that the derivation of impacts from recorded surrogate measures from the field needs more extensive research. So far no valid methodology exists to translate changes in driver behaviour and traffic situations in impacts on safety and efficiency.

Research Domain: LOGISTICS & MOBILITY SERVICES

Scope & Setting

This research perspective considers the research on solutions that provide efficient and high quality services in response to the demand for transport of passengers (Mobility services) and freight (Logistical services). In both cases, a sound and improved understanding of mobility and transport patterns is required for the provision of services.

Current logistics still harbour sub optimal aspects such as empty return runs and route planning. Better integration of the actors over the chain into a robust but flexible logistics network can further optimise the overall management of the logistical system and deliver significant contributions to the decarbonisation, reliability and safety of the road transport system. This requires new business and organization concepts and comprehensive support tools.

Logistical services enable efficient freight transports, providing tools for the efficient management of goods and vehicles.. ICT is an important enabler for ITS and logistical service systems.

On the mobility side the road user's predominant choice for the private car on many networks partly finds its basis in the perceived sub optimality's of other modes of transport, which lack integration. Better integration of the existing mobility provisions into a comprehensive services package, which offers the passenger seamless transport options under transparent conditions, will help to optimise the use of the network.

Mobility services will support the efficient management of persons on an integrated network. For this purpose, they enable intelligent network management, in particular with integrated information and charging services.

The evolution of the transport sector and infrastructure, with the progressive electrification of part of the network, creates the need for tailored services, for instance supporting the seamless transition of persons and goods between vehicles, modes and networks, at transport interfaces.

ICT will contribute to bring to the market innovative services, allowing to serve more individual needs and to provide more tailored mobility solutions.

These new business and organisational models must be created, simulated, tested, and implemented to increase consumer choice, enable informed decisions and to improve operator and network efficiencies.

All stakeholders are to be involved to evaluate priorities for market introduction and to consider funding schemes including public-private partnership.

By 2030 under the influence of major policy, economics, society, technology and organisation trends, the logistical and mobility services will have revolved into greater efficiency and comfort. The bases for this is the information and communication services that are omnipresent and have become an integral part of every day life both to the consumer as to the enterprises involved with logistic, mobility and infrastructure management and operation. They support an integrated transport network which allows for the efficient management of persons, vehicles and goods, relying on tools influencing demand while preserving accessibility. Network management is highly integrated with supporting information services

On the logistical services:

The logistical system is fully integrated over the entire logistics chain involving all actors and based on highly standardised concepts. It combines all modes in an intelligent way as to guarantee the optimal transport service for any consignment. The multi-modal standardised interfaces in the network offer seamless transfer of goods and passengers. Where feasible these nodes will provide expanded services to the vehicle drivers and freight shippers'/forwardes.

Inherently the system is managed cross regionally on its overall efficiency. Planning for freight transport aims at optimising the circulation of vehicles, load units and drivers in response to the shippers' demand for transport. Advanced data and information services provide cooperation between the different organisations , advanced logistics planning regimes, seamless tracking and tracing of the goods and vehicles, ensure freight consolidation and cut out the cumbersome paper work (e-freight) over the entire chain from 'door to door' and business to business. Together, the advancements allow for real time route management within the constraints of economy, environment and society. As a result journey time reliability for any consignment is higher than ever, even for the congested areas and corridors.

On the Mobility services:

A wide array of new services concepts is implemented especially aimed at the mobility demand in the Urban Areas, where the population density offers sufficient economy of scale to provide services specifically tailored to the needs of different sub populations, such as elderly and disabled. These new transport services fill the current gap between private and public transport (car pooling, collective taxis, personnel rapid transit, bus on demand, e-bikes, etc.). The services are offered with all relevant information on e.g. price, travel time, number of transits, environmental

footprint, such to provide the traveller comprehensive choice. The safety and security of the different modes is comparable. Any privacy issues are well settled in the policy framework.

Research and innovation Themes & Topics

Theme: (multi-modal)Transport Interfaces

Services at transport interfaces

Research is needed on services that allow for optimal integration of transport Interfaces in the transport network. Smooth transition between modes for goods and passengers and between long distance and local networks enabled by services for transfer and handling of goods and people at interfaces, hubs and terminals, frameworks for actors cooperation enabling business models and coordination of information between services and modes. Architectures of interfaces at include international, regional and urban scale should be aligned where needed. Driver and personnel services need to be accomodated next to primary facilities such as parking and resting services at interchanges.

Theme: Services for integrated and optimized freight transport

Research is needed on integrated logistics services to optimise the movement of goods and people in response to (flexible) transport demand. Areas to study are e.g. Integrated and optimised logistic services , systems and models enhancing collaboration between the organizations within the logistics chain to support innovative business practices , route planning regimes, efficient transhipment of goods and people between modes and networks. Other important areas to study are: Open, and platform independent, ITS solutions; information management and secure data sharing; optimisation with regard to environmental impact, cost and reliability; legal aspects related to the liability of the various actors

This theme considers the research on services supporting freight transport stretching over the entire delivery chain including long distance freight transport, interfaces between modes and networks, and urban freight delivery to the final destination of the goods. It covers topics on which research is required for the provision of services adapted to future transport demand, including interchanges, network management strategies and vehicles and terminals.

Urban Logistics

Research should enable services to optimise urban freight delivery over the network, optimizing freight movements in the urban environment. These services would increase the efficiency of delivery services and of the network, support businesses, involve the key actors and accommodate new behaviours and consuming patterns. The aim is to optimize the number of trips, the deviation of distance and time travelled, on the urban network, for the delivery of goods. This should be done while progressively using efficient route planning regimes as well as energy efficient vehicles such as electric powered delivery trucks.

- Understanding and managing urban freight delivery with the increase of e-commerce
- impact of e-commerce, and related home deliveries, on volume of traffic, including in residential areas;
- business models for eCommerce related deliveries;
- Innovative services responding to e-commerce induced transport patterns
- Investigate the possibilities to use PT vehicles/network for urban freight delivery
- Innovative service for urban delivery, including services relying on new infrastructures and vehicles (conveyors, tubes, etc.)
- innovative loading/unloading services ;
- (micro) Terminals and loading facilities integrated in the urban setting
- ITS and information based services
- Methodologies and systems for the designation of specific urban truck routes, which may be variable in time;
- Dynamic route guidance for urban freight delivery, for optimizing delivery routes, increasing the average load factor, and optimizing fleet management
- information for optimising the use of loading/unloading areas and parking for urban freight vehicles, including;
- use of cooperative systems for the above services;
- Extension of efreight to urban logistics;
- Public-private partnerships for data exchange on urban freight movements and network management;
- Specific applications of ITS for electric freight delivery vehicles, such as vehicle recognition at loading bays

Long Distance Logistics

Research Question: How to support the optimization of long distance logistics with reliable services supporting innovative business practices and efficient transhipment of goods between modes and networks in a secure way?

The provision of services to further improve long distance logistics, making it more efficient requires to further research practices and opportunities in the sector. It can benefit from the deployment of various ITS services and innovative approaches.

- Efficent logistics regimes using the most efficient transport mode when suitable and modes complementing each other,
- provision of real-time, multi-modal information including possible routes and considering all modes
- Study cooperation/collaboration models between the different organisations involved in the transportation of goods . Joint operation between logistics operators relying on standards, shared cost; sharing of freight terminals. Develop business processes to support multi-functional operation. transport capacity being offered on demand ("spot market"). Improved data collection, handling, process and security enabling business collaboration models
- Research on legal aspects related to the provision of information exchange between the actors in the logistics chain.
- Assess opportunities with the Green Corridor concept on road transport
- Study impact on the transport system for an increase in diversity in transport pattern and demand i.e. high urgency or 'must go' consignments (e.g. flowers) and lower urgency or 'can go' consignments (e.g. building and construction materials, such as sand).
- Develop standardised concepts for effective goods handling and movement throughout the entire logistics chain, not just the transport portions; new optimised and standardised load carrier concepts (see also Vehicle chapter);
- Freight flow data collection, analysis, simulation and integration with traffic and vehicle simulation platform. Simulation of the entire mobility chain to identify the impact of transport solutions and systems on the transport system, and on businesses and customers. Data acquisition, processing and decision-making (MN)
- harmonised pan-European goods transport database of performance, origin-destination, costs and prices, to be coupled to national systems in order to provide inputs to modelling and decision-making processes.
- Automated freight delivery systems.
- goods consolidation services
- Goods handling, Goods loading/unloading
- the impacts of information on distribution practices and the effect on improved journey time reliability.
- Fleet management, including alternative delivery scheduling e.g. by assigned time slots and routing in order to reduce congestion, reduce empty runs and increase average load factor;
- Study the benefits of 'Extended chain of responsibility' for more efficient logistical services, possibly considering consumer power; and the changing patterns of consumer expectations and behaviour
- In-depth study of the impacts of e-commerce on future freight transport;
- develop robust indicators on freight transport efficiency, journey time reliability, and network efficiency, allowing sound cost benefit analysis.
- Intelligent Transport Systems (ITS), including Advanced Driver support systems, e.g safety operation and driver coaching (see also Vehicle chapter)
- Secure Sharing/exchange of information Information system for traffic situation, road conditions, weather, traffic, etc (HL): important for the maintenance management of roads and bridges as well.
- Universal digital maps with integrated real time update

Safeguarding systems against theft and damage

Research Question: how to improve security for freight transport and reduce the amount of stolen goods ?

- Road transport system security (Load carriers, sealing & auto ID, …)
- Intelligent surveillance systems for freight transport
- Goods security

Collaboration models for the organizations within the logistics chain

Research Question: what are the models of collaboration between the actors of the logistic chain to allow for a greater efficiency of transport ?

- Models for increased collaboration aiming at increased transport efficiency
- Business incentives
- How to minimize unbalances in the transport system?
- How to consilidate/bundle the goods and thereby avoid empty runs?
- How to improve co-modality
- How to improve multi modality

Seamless Tracking & Tracing of freight

Research Question: How to provide seamless tracking and tracing of goods to increase efficiency within the logistics chain ?

- Develop tracking technologies in order to establish a seamless information chain to increase planning efficiency, achieve productivity gains and foster security.
- Business Processes can be made more efficient through optimised logistics and improved tracking and information. Research into on-line tracking and maximising the use of load space will reduce costs and improve security.
- Monitoring & tracking of dangerous / sensitive goods
- Automatic locking on container castings and tray castings, in combination with the automatic positioning, enable cargo and pallets to remotely communicate their status, and 'smart dust' providing physical security for loading units.
- Security of data
- Harmonise common electronic letters and tags for seamless freight tracking and tracing across Europe.

Connecting LDT and urban areas, services at transport Interfaces

Research Question: How to support efficiently the use of interfaces with services to ensure that they provide for a smooth and efficient transition between modes and networks for goods, persons and vehicles?

Transport Interfaces between modes and networks form nodes in the transport network system where goods and passengers are transferred from mode to mode and between long distance and local networks. The transfer must happen whenever this contributes to the efficiency of the functioning of the whole network and it should be as quick and smooth as possible. For this, transport interfaces infrastructures must be better integrated in the networks to serve their multiple purposes. They must be supported by a range of services, in particular though not only, information services. The increasing functional specialization of some types of vehicles and infrastructures to specific mobility services, will contribute to increase their importance as they will become even more necessary. The increasing and more rapid electrification of urban freight delivery for instance will contribute to this trend.

- Interfaces for the transport of goods
- Services for the transfer and handling of goods at interfaces, hubs and terminals
- business models for interface information provision;
- coordination of information between services and modes;
- frameworks for actors cooperation;
- drivers and personnel services at interchanges, including truck drivers rest areas;
- Standard interfaces for the exchange of information between infrastructure and traffic managers, terminals managers, fleet operators, producers, retailers ;
- Interfaces for the transport of persons
- Services for the transfer of persons at interfaces
- coordination of information and services (schedules, etc.) between transport modes and between and with other services;
- platforms for data exchange between actors, in particular infrastructure and traffic managers, fleet operators, producers, retailers;
- data interfaces for information provision;
- inclusion of innovative mobility services with interchanges;

Vehicle status monitoring

Research is needed on how to intelligently monitor and communicate vehicle loads and condition such as to minimize the need for unplanned stops and break downs.

- Cargo/goods content and condition
- Vehicle conditions, standard and performance
- Transport data declarations, eg, carbon footprint

Theme: Sustainable mobility services

Research is needed on the deployment of new and upgraded of mobility services in the urban environment as to preserve and if possible improve accessibility in a complementary way to demand management strategies.. The successful deployment of such mobility services in particular require a comprehensive knowledge of mobility behaviours on the network. Also the models need to incorporate the possibility for progressive deployment of electro mobility in the urban environment. Emphasis to be put on public Transport and the Bus System of the Future that would provide high quality public bussing services (i.e. in comfort, reliability and cost-effeciveness). In addition particular focus should be put to innovative Mobility Service Models , that may complement that current spectrum of mobility solutions (private car and public transport) in the urban area.

Mobility services must better respond to the need to contain the environmental impact of transport while preserving accessibility on the urban mobility network. They must therefore be designed to contribute to the efficiency of the urban mobility network. New innovative mobility services must complete traditional upgraded services such as public transport to further improve the network efficiency and answer the mobility needs of persons. These services are required to support an efficient network management and to provide alternatives for travels within the urban area. They would offer solutions to preserve accessibility in a complementary way to demand management strategies.

The progressive deployment of electromobility will require some specific services for the integration of the electric vehicle in the urban environment.

New business models must be explored for the deployment and upgrade of mobility services in the urban environment. These business models need to involve all stakeholders and include public-private partnerships. The successful deployment of innovative and upgraded mobility services will be made possible by a much better knowledge of mobility behaviours on the network.

Propagating Mobility Options:

city center preference for public/collective or non motorized transport modes.

New business models for pan-European mobility services and capabilities must be created, simulated, tested, and implemented to increase consumer choice, enable informed decisions and to improve operator and network efficiencies. These business models need to involve all stakeholders to evaluate priorities for market introduction and to consider funding schemes including public-private partnership. Both bottom- up (customer requirements) and top-down (policy requirements) approaches have to be used. Service quality, human-centred design, affordability, increased accessibility and equity are prerequisites.

Public Transport and the Bus System of the Future

Research Question: How to design future bus system to improve the efficiency and management of public transport and provide high quality services to passengers?

There will be an increasing pressure on public transport system, which are likely in most urban areas to face an increasing demand while the availability of public funds will decrease. Their will therefore be strong needs to gain efficiency in the provision of services. This will require to progressively implement the new bus system of the future, and its associated infrastructures and vehicles.

- integration of the system, development and test of ICT applications, based on the platform for communication between vehicles, stations/stops and back office, supported by cooperative systems and positioning technologies (Galileo), and targeted to the specific needs of the stakeholders (i.e. fleet management for PT operators, multimodal travel information for passenger/infotainment, traffic data for public authorities, system performance for industry and remote maintenance)
- Cost effective real time data transmission between vehicles and operating centres;
- energy management within the whole bus system taking into account the vehicles, the infrastructure and PT operations.
- Innovative business models and funding mechanism for collective transport services
- Methodologies and indicators to support PT operations ;

Innovative Mobility Services

Research Question: How to facilitate the emergence of innovative mobility services completing the traditional spectrum of mobility solutions (private car and public transport), relying on new business models, possibly triggered by the progressive deployment of electromobility ?

Research is needed to identify and stimulate services which will appear with the progressive deployment of electro mobility.

The need to increase the efficiency of the urban mobility network will require to offer more tailored solutions to the various mobility needs. Innovative mobility services will provide alternative or complementary solutions to the privately owned vehicle and traditional public transport. The exploration of various possible business models, based on a better knowledge of mobility behaviours and expectation will be essential for this.

- Innovative mobility services and soft modes
- Innovative mobility services and business models for the shared use of vehicles
- Innovative mobility services and business models for electromobility
- Innovative mobility services and business models for the management of transport interfaces
- new generation of urban people transit, including personal rapid transit

Mobility Services to support Social inclusion

Research Question: How to preserve or reinforce social inclusion with mobility services while the population at risk of exclusion increases and while disparities between territories is likely to be greater in the future ?

There will be an increasing challenge in the future to provide mobility services and infrastructures to deprived areas, scarcely populated areas, and mobility impaired population. Research should focus on how the organisation of services and the use of technologies can soften this difficulty and what are the business models that can support it. The ageing of the population increases the risk of exclusion of some segments of the population. The continuous urbanisation will create greater disparities between territories, this further increasing the exclusion of population living in less accessible areas.

- Collective mobility services, including demand responsive transport, for remote areas
- Concept and business models to provide services for mobility impaired persons, including demand responsive systems designed for elderly or disabled, supported by individualised and geolocalised mobility information;

Integrated ticketing & charging services

Research is needed on how to move towards the full integration of the payment of all mobility services on the same platform.

More and more mobility services will be charged to users, including the use of infrastructure in some cases. To ensure a smooth transition between modes and services increase the efficiency of the mobility system, the payment for these various services could be integrated on one common platform or with one universal payment mechanism.

- single ticket for multimodal journeys;
- interoperability of charging and ticketing systems;
- integrating road charging, parking payment, public transport ticketing, car sharing, public vehicles (cars, bikes, etc), mobility information payment, etc.
- integration of tariffs and fees for all mobility services at the local level;

Integrated information services

Research is needed on secure and efficient exchange and sharing of information involving actors in the transport logistics chain to enable comprehensive multimodal mobility information services. These include globally visible transport management systems, freight matching, multi-carrier parcel manifesting and ITS systems. Research is also needed to realize integration of transport management with supply chain management information. This systems integration challenge goes beyond transport and logistics and includes the sphere of production systems management (ERP/WMS), security systems, RFID, carbon sensitive planning and ICT for global trade compliance.

Key to the new generation of Logistical and Mobility Services is the provision of good Data and Information services, that are easy to integrate in the enterprise management of logistics supply chain and the daily (transportation) considerations of the mobility consumer. The services require efficient exchange of information, and therefore interfaces, involving the road operators and administrators (traffic information) and other mobility services operators to enable comprehensive multimodal mobility information services.

- Research on Interfaces for the integration of collective transport information service and traffic information
- Standards and guidelines for systems and data storage supporting applications for the coherent presentation of real time travel and accessibility (for mobility impaire persons) information regardless of modes or operators.
- Applications of navigation and positioning systems need to be developed for tracking the position of vehicles and for collecting real-time traffic information. Investigate potential for improved and more accurate localisation to enable new functions such as parking slot identification, lane keeping, distance relative to other vehicles (platooning) based on vehicle-vehicle and vehicle-infrastructure communications combined with the GALILEO satellite system.
- Real time traffic information for route guidance
- Individual multimodal travel & traffic information accessible to all services
- Business model on the provision of information on mobility
- More studies are needed to identify the strategic value and the use of information for infrastructure managers and for agents competing on the market in order to understand the balance between transparency and competition.
- Universal digital maps with integrated real time update

Understanding users mobility behaviour

Research is needed on on the causal chain that leads to the actual behaviour of the transport network user. The objective is to obtain a thorough understanding of what composes the user's awareness, motivation, attitude and behaviour towards sustainable mobility options, such as to be able to ultimately predict and influence behaviours and mobility patterns. Challenges include the monitoring of the behavioural impact and and adoption into new business

models of trend breaking developments: globalisation, e-commerce, pre-trip and planning information, global security, cost internalization and sustainability.

This research topic addresses all research on the causal chain that leads to the actual behaviour of the road network USER. The objective is to obtain a thorough understanding of what composes the user's awareness, motivation, attitude and behaviour towards sustainable mobility options, such as to be able to ultimately predict and influence behaviours and mobility patterns.

- impacts of expected demographic, economic and social trends on user attitude and personnel behaviour.
- Better understanding of social determinants of mobility behaviour, including
- socio-psychological aspects like life-styles, norms, social perception, emotions, status-thinking, personal security, comfort, which need to be more strongly considered. This should help to understand the development in social values and how they influence the choices people make relative to housing, schools, work, family and friends, and leisure activities and how they are related to mobility;
- "activity-based modelling" of passenger transport and users behaviours;
- the influence of flexible working hours and holiday periods, and the impact of greater mobility and freedom of movement between member states
- the evolution of demand in relation to the deployment of ICT technology in society;
- the relationship between 'home' delivery and car and public transport usage.
- the relationship between quality and price elasticity of public transport and their effect on mobility choices;
- Effectiveness of the different USER incentives e.g. (e.g. pricing of favourable, sustainable modes, provision of information, positive incentives, demand management policies.)
- Relation between energy and transport related fiscal policies and users behaviour
- The design, impact and opportunity of users education, for instance to supporting eco-driving or a better knowledge of weight and load for instance.
- The acceptation of traffic rules and the related enforcement measures (e.g. speed management, mandatory courses, fining, community service)
- Impact of new information and payment services and media on mobility behaviour.
- adjustment costs related to behavioural changes.
- the behaviour of shippers and freight transport service providers in the context of their business activities.
- how the behaviour of personnel like truck drivers influences delivery routing and schedules)
- improvement of techniques for reliable data collection, provision and use for mobility allowing to collect automatically spatial and temporal movement data , and allowing to reduce the cost for data collection on mobility
- standardisation of urban mobility indicators across Europe, including indicators to measure accessibility and mobility patterns;

Research Domain: ENERGY AND RESOURCES

Scope & Setting

This research perspective considers all features of the supply services delivering energy and resources to the road transport sector as a whole. It does not only comprise the fuel supply systems to the vehicle on the road infrastructure, it is also concerned with supplying energy and (mineral) resources & utilities to businesses, such as the car manufacturing industry and the mobility providers. These are necessary to maintain current quality standards in road transport and achieve the ambitious targets set for the years to come. It also includes all systems and infrastructure through which energy and resources are supplied to and managed within the Road Transport System. In addition, the supply of strategic components and recycle schemes for metals, plastics and components is also a key part of this perspective together with refineries and energy supplied to manufacturing.

The transport system consumes large quantities of energy and mineral resources, most of which are mined outside the European Union. Over the last decades concerns were raised on the reliability of these sources to meet the ever growing European demand. The policy is set to get less dependant from unstable regions. This has led to clear policy targets on renewable and alternative energy e.g. biofuels and electricity.

Both strategic fit and sustainability potentials have guided the work of identifying and prioritising key R&D&D efforts needed. Newer technologies will require more integrated R&D&D efforts while more mature technologies work should focus on further development and demonstration of improvements from the very short term. Thus, for the following critical areas of technology development, a series of R&D&D priorities have been identified. The key factors underlined in this aspect are:

- Vehicle – Grid integration
- Recycling and re-use of waste materials and resources
- Advanced fuels and biofuels
- New efficient materials from abundant resources
- Management and policy tools

Research should focus on maximum performance of the supply lines and grids, as well as the service processes over them. In addition, it should focus on minimisation of the dependence from fossil energy sources and from extremely scarce mineral resources currently required for electrification of road transport.

Research and innovation Themes & Topics

Theme: Reliable performance over Smart Grids

All research on designing construction and operating the grids over which the electric energy is supplied to the Road Transport System. This includes the following research topics:

Grid Integration & Reliability

Research is needed on the development of technologies and practices for achieving reliable EV-grid integration and advancement to integrated grid-traffic management solutions for optimal energy efficiency. It involves issues such as recharging technology (Inductive charging; Smart charging systems with online information and interoperability and bidirectional capabilities), recharging networks, protocols/Devices for V2G Communication and Business Models for Charging.

Key Point: Development of technologies and practices for achieving reliable vehicle-grid integration and advancement to integrated grid-traffic management solutions for optimal energy efficiency.

- Recharging technology (Inductive charging; Smart charging systems with online information and interoperability and bidirectional capabilities)
- Investigate Quick Charging
- Develop Contactless Charging
- Develop Bidirectional Charging
- Establish 1st Generation Charging Infrastructure
- Develop Protocols/Devices for V2G Communication
- Research on New High Voltage Power Switches and Connection Equipment
- Power Electronics for Optimal Vehicle-Grid Connection
- Create Business Models for Charging
- Connect Regions by Highways with Charging Spots

- Create network of Quick Charging Stations
- Regulate Coverage with Charging Spots
- Integration of Vehicle Batteries into Grid for Peak Demand Shaping
- Identification of Potential Reliability Issues Related to Grid Operation
- Development of Diagnostic Tools and Failure Prevention Mechanisms
- Risk Assessment of Vehicle Integration into Grid
- Plug-in Hybrid Electric Vehicle Certification and Environmental Assessment Evaluation
- Modeling Alternative PHEV Architectures and Battery Performance Testing
- Impacts of PHEVs on the Electrical Grid and Consumer Behavior
- Mass Transit & Grid Integration
- Review of Large Scale Deployment on Future Infrastructure Operation and Development
- Identification of Potential Early Users – Captive Fleets Grid Integration
- Vehicle Charging Standardisation (Methods & Equipment)
- Smart Component Management for Optimal Performance, Energy Consumption and Pollutant emission
- Development of Communication Tools Encouraging the Use of Electric Vehicles/PHEVs
- Development of Safety Regulations and Specifications for Charging Spots
- User Safety / Charging Hazard Analysis

Energy Storage & Battery systems

Research is needed on the development of new efficient and reliable energy storage systems and batteries that allow EV to cover sufficient operational distances. The focus should be put on the development of high capacity batteries and solutions that are enduring and require minimal recharge time. The research would involve issues such as Battery Cell Degradation, Post-Lithium Cell Technology, battery integration into Vehicle Structure, high voltage topologies and EMC next to precondition of materials availability and waste management.

Key point: Development of new efficient and reliable energy storage systems and batteries is the key for successful introduction of plug-in hybrids and electric vehicles in road transport. Important effort should be put in the development of high capacity batteries and solutions that require minimal recharge time. Materials availability and waste management are of high importance.

- Study Battery Cell Degradation
- Energy Storage and Battery Life Cycle Assessment / Review of Optimal Environmental Pathways
- Establish Battery Testing Facility
- Develop Battery Management Systems
- Materials and Resources for Mass Battery Production
- Cell Materials (Lifetime, Energy Density, Safety)
- Optimized Battery Packs
- Research on Post-Lithium Cell Technology
- Integrate Batteries into Vehicle Structure
- Develop Batteries for Bidirectional Charging
- Establish facilities for Prototyping
- Assess Availability of Raw Material
- Launch Battery Loan Program
- Develop Reuse Concepts for Batteries
- Emphasis on high voltage topologies and EMC for energy storage systems
- Increased power and energy density of high voltage components for electric energy storage systems
- Set European guidelines for Lifetime & Range
- Investigation of Alternative Energy Storage Systems
- PHEV- Fuel Cell Technology Integration
- Supplementary Technologies and Innovations (Solar Panels, Regenerative Braking, Alternative Fossil or Biofuel Application, etc)

System Management and Optimization

Key point: The integration of two energy intensive sectors (transport and electric power) opens a series of possibilities and potential for increasing the sustainability and efficiency of both. New tools and practices are vital for managing and optimizing this integration process. These innovations will be both of technical and managerial nature.

- Investigation of Optimal Energy Sources
- Establish Business Model for Bidirectional Trading
- Intelligent Billing Schemes
- Grid – Traffic Modeling for Optimized Energy Efficiency (parallel road traffic-peak demand management)
- Well to Wheel Analysis and Environmental Assessments

- One-way and Two-way Energy Management
- Energy Sources and Grid Management Tools Development
- Alternative Energy Sources Coupling
- Process Modeling
- Billing Concept Standardization
- Interconnection With Intelligent Traffic Management Systems
- Risk Assessment
- Create Business Models for Grid Operation
- Development of Ad-hoc Distributed Power Production Systems
- Consumer Behavior Analysis / Market Modeling
- Carbon Capture and Storage for Electricity Generation

Theme: Closed Loop recycling

Research is needed on new recycling concepts that would maximise the material use within the Road Transport System itself, over the smallest loop possible. This will include materials, components, schemes/analysis, second life practices and a new approach and re-design of the current automotive waste management systems. Important emphasis should be given to creating the necessary know-how on future techniques for materials and equipment, that will be introduced in the future and that may be potentially harmful, expensive and difficult to handle when wasted. In this context important focus is expected on vehicle electrification-related equipment such as batteries and conductors.

All research on recycling concepts within the Road Transport System itself, over the smallest loop possible. This will include materials, components, schemes/analysis, second life practices and a new approach and re-design of the current automotive waste management systems. Important emphasis should be given in materials and equipment that will be introduced in the future which may be potentially harmful, expensive and difficult to handle when wasted. In this context important focus is expected on vehicle electrification-related equipment such as batteries.

Efficient End-of-Life Vehicle and Equipment Paths and Chains

Research question: How we re-structure existing systems and practices in order to create short-cuts for optimal waste handling, potential for second life application of certain components, improve the environmental profile and reduce the costs of end-of-life vehicle management?

- Review and Analysis of Current and Future End-of-Life Vehicle and Components Paths
- Investigate Possible Shortcuts / Alternatives to Existing Automotive Waste Management Chains
- Development of Integrated Waste Management – Supplier Networks
- Lifecycle Analysis of Different Automotive Waste Management Options
- Future Strategies for Advanced Automotive Waste Material Management
- Second life concepts: (How to reuse materials and components?; vehicle batteries; expensive components; (precious) metals; plastics; …)
- Development of Revalorization Tools for Used Automotive Materials and Components
- Second Life Possibilities for Vehicle Advanced Equipment
- Develop Reuse Concepts / Alternative Applications for Batteries

Materials Recycling Technology

Key point: Automotive waste material recycling may constitute an important source of valuable resources both for automotive or other applications. In addition it is imperative for increasing the environmental profile of road vehicles and can significantly contribute in the reduction of their carbon footprint. In this sense emphasis should be given in improving existing concepts and methodologies and in creating the necessary know-how for advancing to future techniques that will be more efficient and cover a wider range of automotive related waste.

- New Recycling Concepts
- Review of Recyclability of Future Advanced Materials and Components
- Development of new, advanced and sustainable technologies for automotive materials recycling
- Develop Recycling for Li Batteries
- Development of Pre-processing Techniques for Heterogenous Shredder Residue Separation
- Update/optimize Shredder Residue Separation Methodologies

Theme: Advanced Fuels and Biofuels

The demand for cleaner more energy efficient road transport is inevitable linked to the fuels employed and their properties. Advanced fuels and biofuels can and will play a very important role in achieving a more environmentally friendly and energy efficient profile. Fuel technology evolution is highly related to vehicle engine technology and exhaust aftertreatment systems development. Greater use of biofuels for transport forms an important part of the package of measures required if the EU is to comply with CO2 reduction targets set for the near future as well as of any

policy packages set up to meet further commitments in this respect. Advanced fuels and biofuels may play an important supplementary role in vehicle electrification and the vehicle-grid integration envisaged for the next decade.

Advanced Fuels Production

Research is needed on the production technologies for new high quality automotive fuels from conventional sources. The research should in the short term should focus on optimisation and development of the conventional refinery process e.g. towards hydro treated conventional fuels or DME Production and Properties Optimisation, whereas in the mediate term it should focus on more advanced conversion and synthesis processes such as gas phase Chemistry. In the long term it should focus on the cost-effectiveness of hydrogen production processes based on fossiel resources including investigating the possibility for using renewable sources. Emphasis on integrating advanced fuels research with the development of future powertrain systems in order to achieve optimal performance on a well to wheels basis.

Research Question: How to improve the environmental profile of existing fuels and production process while adapting to the increasing demands and needs of future powertrain systems and regulations? Investigate technologies and practices that will improve the well to wheels profile of fossil fuels. How to produce new high quality automotive fuels from conventional sources?

- Advanced Fuels Lifecycle / Well to Wheel Analysis
- Process Modeling
- Optimized Refining Processes
- Hydrotreated Conventional Fuels
- H2 Production Processes from Conventional Refineries
- Advanced Crude Oil Based Fuels
- DME Production and Properties Optimization
- Hydrogen Production from Renewable Energy Sources
- H2 Cost-effectiveness increase
- New Methods for Low-carbon Hydrogen Production
- Technologies for Decreasing the Carbon Footprint of Conventional Fuels
- Mechanical, Physical and Thermochemical Pretreatment for Advanced Gasification Systems.
- Improve Knowledge of Fuel Conversion and Gas Phase Chemistry

Biofuels Production

Research is needed on cost-effective second and third generation biofuel production processes, that can tap into a wider raw materials base, thus making advanced biofuels socially and economically sustainable in the long term. The research on the raw materials base not only should address abundant (liquid and gaeous) waste products and waste biomass but also the development of new land and marine crops specially applicable for biofuel production purposes. The latter would hold a constructive alliance with European Biofuels Technology Platform. Emphasis on integrating biofuels research with the development of future powertrain systems in order to achieve optimal performance on a well to wheels basis.

Today, biofuels production in the large volumes required to meet ambitious EC targets is not fully sustainable because of limited availability of raw materials and high costs of production. New technologies should focus on fully exploiting biofuels benefits (GHG reduction, reducing dependency on oil products) while facing challenges as widening the raw materials base towards waste products and waste biomass, development of new production process and reducing manufacturing costs thus making advanced biofuels socially and economically sustainable in the long term.

- Biofuel Well-to-Wheel Analysis
- Energy Production from Biomass and Waste
- Development of New Land and Marine Crops Specially Applicable for Biorefinery Purposes
- Development of Biofuels from Cellulosic Materials
- Second Generation Biofuels Lifecycle Analysis
- Biofuel Resources Availability Analysis
- Biomass Logistics
- Improvements and Technology for Existing Bio-fuels Production
- Production Technologies for Gaseous Biofuels
- Cost and Greenhouse Gas Reduction for 2nd Generation Biofuel Production
- Investigation of Biofuel Production Emerging Technologies
- Production of Ethanol via Enzymatic Fermentation
- Biomass Gasification and Liquid Fuel Synthesis
- Optimization and Scaling Up of Model Fischer-Tropsch Processes
- Investigation of Social Pressures and Costs of Biofuel Application
- Synthesis Gas Conditioning (treatment, separation, purification)
- Biofuel Production Process Modeling

- Biofuels Centralized - Decentralized Production
- Develop availability-cost curves for different sources of biomass (energy crops, forestry and agriculture residues, wastes) and geographical locations.
- Develop new high-yield and low-input agricultural and forest systems with breeding of crops and trees optimised for biofuel production.
- Develop efficient biomass logistic systems (harvesting/collection/storage) for different conversion concepts at different scales
- Improve current conversion processes to their full potential (biodiesel, bioethanol from starch-sugar) for higher GHG reduction, increased flexibility for different raw materials and lower cost.
- Develop thermochemical and biochemical conversion processes with feedstock flexibility for different lignocellulosic biomass (BtL, L-C bioethanol)
- Develop integrated biorefinery concepts making full use of a variety of biomass feedstocks to obtain diverse high-value bioproducts
- Demonstrate both at pilot and industrial scale reliability and performance of new technologies
- Coal co-gasification
- Development bio-based Catalytic Processes
- Technologies for Supporting Biorefinery Concept

Fuel Distribution and Re-fuelling Infrastructure

Research is needed on technologies and logistical networks to effectively promote the introduction of new, advanced fuels and biofuels. The research should adress the variety of issues involved such as: in-pump blending; communication technology, equipment and protocols to allow for EMS – Fuel Pump/Pump – Engine Communication; Optimized Blends Delivery / Use; Intelligent Control of Charge Weight; Analysis and Development of Full Biomass Supply Chains; Fuel Distribution and Refuelling Infrastructure for Wide Range Application; Establish conditions for compatibility of biofuels and biofuel blends with existing logistics; Gaseous Biofuels Distribution; Distributed Biofuel Production; Custom Fuel Delivery; Fuel Blending for Optimal Engine Efficiency and Emissions; Hydrogen ICE Re-Fuelling; Hydrogen Storage & Distribution Systems

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Research Question: How we develop technologies and networks to effectively promote the introduction of new fuels and biofuels? Creating fuel blends of custom properties and characteristics is an important challenge both from a technical and a logistics and fuels distribution point of view.

- In-pump Blending of Designer Fuels
- EMS – Fuel Pump Communication Technology and Equipment
- Pump – Engine Communication Protocol For Optimized Blends Delivery / Use
- Intelligent Control of Charge Weight
- Analysis and Development of Full Biomass Supply Chains
- Hydrogen ICE Re-Fuelling
- Gaseous Biofuels Distribution
- Custom Fuel Delivery
- Fuel Blending for Optimal Engine Efficiency and Emissions
- Hydrogen Storage & Distribution Systems
- Fuel Distribution and Refuelling Infrastructure for Wide Range Application
- Distributed Biofuel Production
- Establish conditions for compatibility of biofuels and biofuel blends with existing logistics

Alternative Fuel – Biofuel Oriented Powertrains

Research Question: How we promote parallel development of future powertrain systems and fuels, integrating research in both fields, in order to achieve optimal performance on a well to wheels basis? Promote the role future fuels can have in the vehicle-grid integration effort.

- Targeted Fuels for Efficient New ICEs and Zero Impact Emissions
- Multifuel Engines
- Multifuel Fuel Vehicle Fuel Storage Systems and Materials

- Flex-Fuel Vehicles
- Impact of Biofuel Blending on Combustion
- Combustion Characteristics of Alternative Fuels
- Fuel Quality Engine Adaptability
- On Board Fuel Quality Evaluation Systems
- 2nd generation Bio-fuels & Lubes for Future ICE
- Hybrid Electric Powertrains and Biofuels Coupling for Environmental Performance Maximization
- Application of Different Quality Fuels in Hybrid Electric Powertrains
- Exhaust After-treatment Systems for Biofuel Powered Engines
- Exhaust Gas Management Technologies for Multi-Fuel Engines
- Powertrain Calibration for Multi Fuel Operating Schemes
- Highly Efficient Fuel Cell Powertrains
- Gaseous Biofuels Powered Engines
- Develop Vehicle Modifications for Neat Biofuels and High Blends
- Generate Engine-fleet Test Data and Set Sound Quality Standards for Biofuels
- Develop in-depth Understanding of Relationship Between Biofuel Quality and Engine Performance

Theme: High Performance from Abundant Materials

Key to maximizing the sustainability profile of future road transport is research on the development of alternative materials from more abundant and less environmental harmful resources, that will meet the required performance specifications and functions of the components and constructions in future road vehicles. The research involved should first determine what key materials are necessary for extensive vehicle electrification and the integration of the electric vehicle to the grid. Secondly, the research should address the development of reliable and efficient alternatives from abundant materials, especially focussed on lightweight composites, advanced alloys and non-precious metal catalysts.

Increasing energy efficiency, safety and reliability of future road vehicles calls for new materials. Today many of these technologies are based on expensive, rare and environmentally harmful materials and production processes. Development of new technologies that will use more abundant materials and resources is a key aspect in maximizing the sustainability profile of future road transport. In the same context a series of new materials and resources need to be developed and optimized in order to support a wide scale implementation of important breakthroughs at vehicle and infrastructure level such as vehicle – grid integration.

Advanced Materials for Future Vehicles

Research Question: How we develop advanced, lightweight, cheap and eco-friendly materials from abundant resources in order to adequately fill the demands of future vehicle development and improve vehicle safety, reliability and environmental performance?

- Life Cycle Analysis of Common / Alternative Materials
- Identification of Materials with Non Favorable Environmental Profile
- Non-precious Metals – Rare Materials in Vehicle Components
- Non-precious Metal Catalysts
- Light Weight Composites for Future Vehicles
- Multi-Fuel Compatible Materials for Future ICEs
- Lightweight composites
- Advanced alloys

Materials for Extensive Vehicle Electrification

Research Question: What are the key materials necessary for extensive vehicle electrification and vehcle-grid integration and how we develop reliable and efficient alternatives from abundant materials?

- Magnets
- Materials for Batteries (Li, Ni)
- Conductors (in addition to batteries and magnets), copper as a special case
- Semi-conductors: (How to ensure adequate supply of the required semiconductors and circuit-boards?)
- Assess Availability of Raw Materials Required for Wide-Range Electrification
- High performance polymers
- Films and Membranes
- Material research (light weight and high conductance)

Theme: Economic Modeling for Decision Making and Understanding

Although addressed separately this theme practically covers all aforementioned themes. Economic modeling for efficient resources and production management is a key point for achieving optimal reliability and efficiency. In addition

is the factor that will reveal the interactions between phenomenally unrelated technologies and practices and in the end define the viability of each technological option investigated.

Impact Assessment & Modeling

Develop Indicators and Coherent Methodology to Assess and Monitor the Three Dimensions of sustainability: Economic, Environmental, Social; Development and Application of LCA Methodologies; Generate and collect data required and carry out sustainability assessment of existing and potential promising production chains; Impact of Technologies Introduction in Vehicle and Fuels Market; Customer Behavioral Analysis; Feasibility Studies; Marketable Products Development

- Develop Indicators and Coherent Methodology to Assess and Monitor the Three Dimensions of sustainability: Economic, Environmental, Social.
- Development and Application of LCA Methodologies
- Generate and collect data required and carry out sustainability assessment of existing and potential promising production chains
- Impact of Technologies Introduction in Vehicle and Fuels Market
- Customer Behavioral Analysis
- Feasibility Studies
- Marketable Products Development

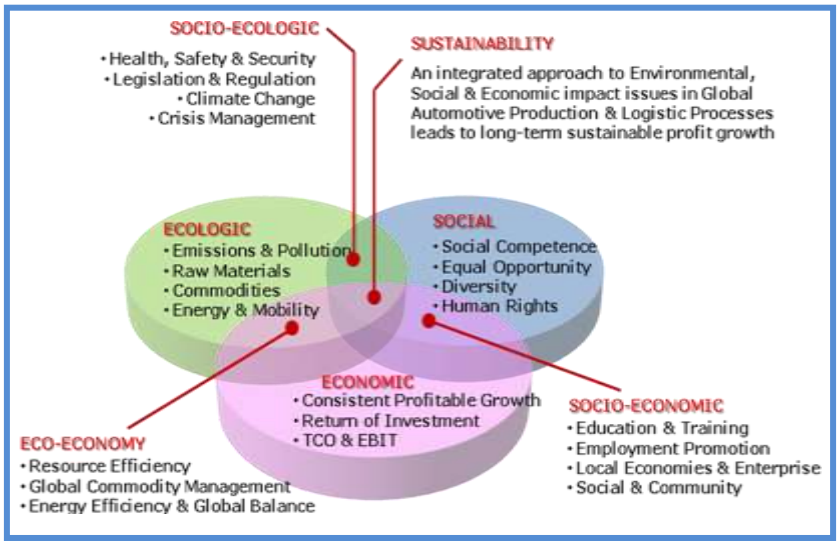
Policy and Harmonization

- Coherent Long Term Policy Harmonisation
- Investigation of Joint public/private financing for R&D for Biofuels Introduction and Vehicle-Grid Integration
- Demonstration of New Production Routes and end-use Applications
- Biofuel quality standards Based on sound science
- Development of Global Certification System to Assure Environmental Sustainability of Different Technologies
- Communication and Public Consultation Pathways

Sustainable Production Systems

Scope & Setting

During the next decades the motor industry has to meet the unprecedented challenge of achieving the change from fossile fuel to electric propulsion with at the same time shrinking resources, the ever increasing demand to protect the earth's environment on a multi-dynamic global market place with new competitors. In this context the three pillars of Sustainability: "Economic Success", Ecologic Impact" and "Social Responsiveness" frame the range of activities that need to be tackled by the European Automotive Industry partnership in order to defend its leading position. Next to the vehicle technology and the vehicles' environment and infrastructure it is the vehicle production system that has enormous impact on the competitiveness of the Industry and hence the welfare of the society. This production system comprises the full automotive supply network and its production facilities, the highly complex global logistics, the sourcing of commodities, materials and energy, as well as a globally organized and educated staff. The development of standards, be it technical, organizational or social in terms of labour standards, will be crucial to avoid loosing influence in major fields. Given the fact that the Automotive Industry is a sector of the highest global complexity, reactivity and value creation it is paramount to address its respective RTD needs separately. Changes in the global business scenarios will be taken into account during the regular updates of this SRA. In consideration of the major areas of challenge, the respective Roadmap is structured according to the economic, ecologic and social requirements that were identified by the GC partnership.



ECONOMIC SUCCESS

Business Processes

Technical Standards for EVs and their Impact on Global Market Penetration

The institutionalized rule systems, particularly of technical standards, and regulations for EVs need to be analyzed how they affect market share growth of corporations worldwide and to trace their effects on various aspects of supplier relations in the automotive supply grid and an evaluation of performance outcomes must be performed. The relationship in the degree of stability and consistency in systems of comparable technical standards between different global market places have to be examined and the interdependence to more predictable and consensual relations between companies described. The deliverable will be a code-of-practice for greater mutual trust – based on the technical regulation of inter-company relations - that encourages more long-term and closer technological collaboration in supplier relations and help boost European technology-based competition.

Real-Time Reactivity on Changes in the Global Business Scenarios

Unstable global markets and business scenarios require the reliability of global forecasts and the real-time sharing of information between actors in the supply network are of utmost importance. Therefore, measuring the forecast accuracy throughout the supply grid and establishing a correct and consistent information process across the supply network is crucial to the real-time reactivity of the entire supply base to market changes. The deliverable will be a system that allows less overproduction & minimum inner-system transport and reverse flows. In this respect, "Turbulence Indicators" identify upcoming "disturbances", such as substantial market fluctuations & events, quantify them and develop an according projection method and tool

Production Processes

Production Flexibility in Assembly of Traditional Cars, HVs/PHEVs and EVs & their components on the Same Assembly Line

To enable the co-existence of traditional cars, HVs, PHEVs and EVs in an economic manner, it would be advantageous if they could be produced (i.e. assembled) on the same assembly lines, thereby facilitating the exploitation of economies of scale. This results in the need to enhance the flexibility of the final assembly lines accordingly and potentially to design and develop products and their components to support the flexibility needed across the entire value chain,

either at the product and process technical levels or when managing a large number of product types with relatively short production series. Manufacturing execution systems and tools (MES) have to be developed and implemented to organize rapid responses with reasonable costs in the event of contingencies. They will be focused on rapid planning and re-planning of production in case of contingencies, changes or problems, with adequate tools and constant updating of the in-plant as well as cross-company situation and processing of information in real time

Global Responsiveness by Decentralized/Downsized Sites; Decentralized Global Production Grids

This topic addresses the global supply to/from decentralized sites and mini production plants in the automotive industry with respect to robustness of the process, site utilization and in consideration of the respective sustainability constraints. The shift towards e-mobility leads to new constellations of players in automotive production. This shift requires new forms of production networks, especially sustainable decentralized approaches. It is of utmost importance to the profitability of the industry and the consistency of the markets to develop a process that pragmatically supports and manages the transition and implementation. Electric Vehicles will bring about a new dimension in modularization with modules produced in a globally decentralized manner according to strict rules of profitability and ecologic constraints. This in turn requires a next generation logistics system as overall complement.

Mutual Interdependence Between the "Highly Reactive and Complex Automotive Sector" and Less Flexible Industries

The algorithms to determine the proper buffer stock "damper" systems need to be developed that allow the necessary product flexibility for the volatile automotive market (in terms of total volume and composition of variants) in a most economic way, and at the same time enable the respective cash flow efficiency for the less flexible industry. For this purpose innovative processes and contracting structures need to be concluded between the industry partners to generate commercial effectiveness and robustness in supply. ERP (Enterprise Resource Planning) systems must go in parallel to the implementation of cross industry cooperation models that reach beyond the conventional competitive market approach: compete for new business, cooperate to run the business in a supply chain. An important complementary aspect lies in the development of the requisite tools to improve the transparency for supply constraints throughout the supply chain.

Optimization of the Global Automotive Production Footprint

The location of international industrial sites – concerning sourcing, production and sales (potentially enhanced towards engineering) is a key factor of the overall global competitiveness for the automotive industry, since industry needs to be closer to its markets and responsive to the global spread of markets. Additionally, the trade-off between the use of energy and the concurrent control of emissions & pollution in global production and logistics needs to be examined and crucial parameters developed. In addition, it is essential to address the development of regional industry partners: The global supply chain of today is complex and characterized by long distances. To ensure short reaction times, and consider ecological aspects while looking for the increasing amount of product variants, only regional producing companies are able to react very flexible. Here local development of SMEs will lead to regional employment. Necessary infrastructure of local and high flexible transportation systems has to be developed accordingly. Strategic decisions should be viewed in a multi-criteria perspective. In particular, the issue of capacity investments and flexibility are extremely critical in this area and need to be addressed by innovative approaches.

Step-change Increase in Variants without Deficits in Product Quality; Brand + System Suppliers = Car 2.0

The ongoing trends towards low in-house production depths at OEMs and increasing engineering & production responsibilities of the suppliers open possibilities for new automotive production networks. Could the lasting tendency towards niche cars and e-mobility be the enabler for a complete new automotive value chain? (e.g. the OEM focusing on branding & requirements and the suppliers not only as system suppliers but complete solution providers. How could the resulting network be operated? How could the shift be guided? What would be the consequences for and requirements on suppliers? In this context Predictive Quality Planning will be mandatory during product development prior to start of production, focusing on defect prevention. Today existing FMEA method has to be upgraded by feasibility studies during product concept and design phases along the complete supply chain partners. A design for manufacturing method has to be developed using lessons learned and standard manufacturing technologies with lowest failure rates.

Risk Mitigation in Decentralized or Localized Automotive Production Networks:

In future the globalized market place of the automotive industry is characterized by the rectangle of challenges:

- the availability of raw materials and energy (the commodity squeeze)
- the impact of transport of materials and products (carbon & economic footprint)
- the customer locations (commodity & skills proximity)
- the after sales requirements (recycling).

The risks emerge in an imbalance of those critical – and industry specific -parameters, which are of major impact on the competitiveness. Therefore, instruments need to be developed that allow a business case specific solution to problems, such as: more small factories near to customer or near to the source of commodity, or new approaches to (risk-minimized) modularization with regard to new products and products with high commodity usage (e.g. copper for future electric motors).

Logistics Processes

New Production Networks for Enabling electrification of the vehicle

Enabling the shift from ICEs via PHEVs to EVs and the according new set of »players« including completely new production networks, as well as the distributed approaches researched in the context of MFRCs (Micro-Factory and Retail Centers) Transformation requirements on the different levels involved (Strategy, Organization, Culture, Information Technology, Processes

ICT, Methods, Tools & Standards for Sustainable Global Production

The European Automotive Industry enhaances its from designing and producing goods to the management of the entire goods' life-cycles, including an extended range of services. This radical innovation depends strongly on the development of an integrated value-chain that takes into account: (a) a strong customization of the products, driven by the aim to addressing user needs to larger and more articulated extent; (b) a quick (almost immediate) delivery to the intermediate and/or final customers; (c) less environmental impact; (d) higher compatibility with ethical and social responsibilities; (d) sustainability in economical and cost-benefit terms (high quality products at minimum costs). In order to achieve these challenging goals the manufacturing industries must innovate their design and production processes along the whole supply chain by establishing interactive instruments that enable the simultaneous interaction with their respective service systems. For this purpose, novel data intelligence ICT tools are the name of the game: new methods and support services are needed for the acquisition/provision of required knowledge management (KM service), as well as and for the complex management of the social interaction (MSI services) associated with collaborative decision making (on planning, production, resources, monitoring etc.) of involved distributed network participants and competence centres in collaborative networks.

Shortening Lead-Time Through a Radically New "Localization" Approach

Design of „one employee – one product" factories that can be set up fast and most close to the market. Form the central power-plant approach in manufacturing to the de-centralized windmill approach: The next dimension of "Lean Thinking"

Design free freight trade areas to optimize loading of transport means. Design of appropriate „copy & paste" methods to set up and transfer production: Universal production system to make training and implementation of knowledge easier and more robust. Design of „from-mine-to-market" supply chains to reduce CO2 emission and transport

ENVIRONMENTAL AWARENESS

Logistics Processes

Optimized Transport Flow - "What is where at which point in Time"

The application of system dynamics & simulation techniques will enable optimal planning and control of transport flows by means of the construction of models and sub-models suitable for assessing dense, free flowing and safe traffic inside any supply routes and at different day times. The aim will be at optimizing transport flow with a view to making it cost-effective and efficient in terms of logistics, minimizing delays. Reliable and validated databases will be needed (economic situation at various levels (enterprise, regional, national, incl. related regulations). Moreover, optimization techniques are needed that allow the application of system dynamics and simulation or multi-objective optimisation techniques.

Production Processes

Renewable Energies and Environmentally Neutral Materials in Global Automotive Production & Logistics:

Methods for integrating environmental criteria in the design and development of a product, service or process, considering the whole lifecycle in order to reduce environmental impacts by means of the implementation of the Life Cycle Assessment (LCA) tool. Methods for measuring and evaluating sustainability of products, processes & materials and industrial practices (such as Life Cycle Assessment (LCA), Life Cycle Cost (LCC), Environmental Risks Assessment (ERA),...) in order to assess manufacturing sustainability within global networks, considering the entire product lifecycle, including disassembly, reuse and revalorisation of waste.

Business Processes

Network Simulation Studies

It is essential to carry out simulation campaigns for observing enterprise networks that operate under the suggested regimes. Such studies will generate novel behavioural patterns and contribute to our better understanding of the relationships of competition, cooperation, responsibility and trust in today's economy. These studies also alleviate the transfer of theoretical results to applications. Simulation studies would support investigations and also greatly increase the validity and attractiveness of elaborated concepts and methods. It is essential to carry out large-scale simulation experiments in two areas:

- Simulation of the behaviour of real-time cooperative enterprise networks
- Detailed simulation of individual production systems. Evaluation of location decisions, measurement of inventories, energy, resource consumptions, etc.

Global Sourcing Commodity Management for Automotive Components

The high volume production of future EVs at affordable prices calls for the development of the requisite commodity management, which is the process of providing a systematic approach to the entire usage cycle for the strategic materials needed. Best practice in commodity management has to be elaborated, which include:

- examination of internal buying patterns in the network
- understanding the market forces in the commodity
- using this information to drive lowest total installed cost, including improving quality, reducing cycle time, driving component commonality and design for manufacturability andmaintainability, along with lowered unit cost.

Assessment of the Eco2 Balance Optimum and Implementation

Examination of the production & logistic caused CO2 emissions at global scale and their inter-dependence with the economic benefit from company and European perspective. Major influence parameters for the highly complex automotive supply & production network need to be determined and the relation to global business models investigated. A decision support and management tool for globally active automotive industry has to be developed in order to provide guidance in selecting the optimum economic and ecologic balance.

SOCIAL RESPONSIBILITY

While international cooperation will become a more and more imporant element of business processes in a globalised world, principles of social responsibility have to maintained and European intellectual property has to be protected sufficiently, so that the benefits of technological advances to the long-term competitiveness of the European industry and finally to social welfare can be fully utilised.

Business Processes

"COMPEDIA": The wiki for Global Competence Rating of Research Establishments and Academia in Automotive Matters

Local development of automotive components and systems requires the involvement of local research teams in order to use all intellectual resources, properly. In order to asses these capabilities in a fair and transparent way, the expertise of institutes and researches that come into consideration need to be assessed against a set of criteria and updated regularly. Development of Improved collaboration models between industries and universities as well as extended organisation concepts with common strategies on learning and knowledge building activities.

Collaborative Distributed Engineering

The complexity of products is still increasing, which results in the need for the incorporation of experts from all over the world in engineering projects. Current RTD has been supporting collaboration in engineering and was mainly focused on information technology. But to implement a Collaborative Distributed Engineering in industries, a comprehensive approach supporting not only the lifecycle of products but the lifecycle of projects and engineering teams is needed. Therefore, instruments have to been developed that support from the early identification of experts to distributed team building and on to the collaboration of dislocated teams in RTD / engineering of products and production. This will enable enterprises to compete in global markets by properly employing international leading experts in engineering.

Labour standards and their implications on the automotive industry for global competitiveness:

.One of the principal arguments for inclusion of core labour standards in the automotive industry is that weak labor standards provide an illegitimate boost to competitiveness and may result in a "race to the bottom" in labour standards worldwide. If the violation of labour standards results from discrimination against particular workers in export industries, employment, output, and competitiveness will be reduced since employment is determined by the short side of the market. If the problems arise from abuse of market power by employers, competitiveness will be similarly reduced. Only if freedom of association and collective bargaining were intended to allow workers in some sectors to restrict output and drive up wages would the absence of these standards raise competitiveness. However, if product markets are competitive, it is likely that association rights would increase output and competitiveness by raising productivity. The competitiveness argument seems either to reflect analytical confusion or to represent a cover for protectionist interests. Ignorance to minimum labour standards, however, poses a risk to sustainable competiveness as society will no longer accept products made on the basis of insufficient standards With regard to new forms for production facilities (e.g. Micro-Factories, etc.) new labour standards need to be developed and implemented.

I. Glossary

BRIC nations Brazil, Russia, India, China
CNG Compressed natural gas
DME Di-methyl ether
e-Freight ICT application capable of following the movement of goods
EPoSS European Technology Platform on Smart Systems Integration
ERTRAC European Road Transport Research Advisory Council
EBIT Earnings before interest and taxes
EMC Electro-magnetic compatibility
ERA Environmental risks assessment
ERP Enterprise resource planning
ETSC European Transport Safety Council
EV Electric vehicle
HDI Human development index
HMI Human-machine interface
HV Hybrid vehicle
ICE Internal combustion engine
ICT Information and communication technology
LCA Life-cycle analysis
LCC Life-cycle costing
LPG Liquefied petroleum gas
MFR Micro-factory retailing
PHEV Plug-in hybrid electric vehicle
RFID Radio frequency identification
SRA Strategic Research Agenda
SmartGrids European Technology Platform for the Electricity Networks of the Future
TCO Total cost of ownership
v2g Vehicle-to-grid
v2i Vehicle-to-infrastructure
v2v Vehicle-to-vehicle
VRU Vulnerable road user
WMS Warehouse management systems

II. References

ETSC 2010: *Open Letter to Commissioner Kallas on Setting Ambitious EU Road Safety Targets for 2020.* ETSC. 15 February 2010.

ERTRAC 2009a: *ERTRAC Road Transport Scenario 2030+ 'Road to Implementation',* October 2009.

ERTRAC 2009b: *European Roadmap: Electrification of Road Transport*. October 2009. ERTRAC, EPoSS, SmartGrids.

EU 2010: *EUROPE 2020, A strategy for smart, sustainable and inclusive growth.* March 2010. European Commission, Brussels. (COM(2010) 2020).

LUND 2009: *The Lund Declaration: Europe must focus on the Grand Challenges of our time*. July 2010.

III. Acknowledgements

Rapporteur: Ruud Smit (Rijkswaterstaat)

The preparation of this Strategic Research Agenda was coordinated by the following Working Group Leaders:

Urban Mobility: Sylvain Haon (Polis)

Long Distance Freight Transport: Helene Niklasson (Volvo)
Ian Knight (TRL)

Energy & Environment: Kenneth Rose (CONCAWE)
Frank Seyfried (Volkswagen)

Road Transport Safety & Security: Gianfranco Burzio (CRF)

	Lali Ghosh (Delphi)
Global Competitiveness:	Jean-Luc di Paola-Galloni (Valeo)
	Gloria Pellischek (Continental)

Road Transport Safety and Security

WG Leaders	Gianfranco Burzio (CRF)
	Lali Ghosh (Delphi)
Members	Magnus Rilbe (Volvo)
	Kerstin Mayr (Bosch)
	Peter Urban (IKA)
	Stefan Deix (Arsenal Research)
	Anna Nilsson-Ehle (SAFIER Chalmers)
	Maxime Flament (ERTICO)
	Simon Godwin (EUCAR)
	Ton Versmissen (TNO)
	Tom Robinson (Ricardo)
	Peter Van Vliet (RWS)
	Stijn Donders (LMS)
	Marie Line Gallenne (LCPC)
	Yann Goyat (LCPC)
	Bengt Hallstrom (Swedish Trasport Administration)
	Jaume Prat (Ficosa)
	Cliff Funnell (Marine Technology)