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THEME 7

Transport including Aeronautics

FUture prospects on TRansport evolution and innovation challenges for the competitiveness of Europe

FUTRE Project

FUture prospects on TRansport evolution and innovation challenges for the competitiveness of Europe

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Executive Summary

The deliverable at hand reflects the work carried out in work package 4 of the FUTRE project. The focus of this work package is on the supply side of the transport system, on emerging or anticipated technical and organisational innovations and their potential impacts on the competitiveness of the European transport sector.

Identification of relevant transport innovations

Chapter II describes upcoming transport-related products, services, and infrastructure innovations until 2030 and beyond which are considered as being relevant for FUTRE. In doing so, it summarises the work carried out in task 4.1. The process of selecting relevant innovations was initiated by compiling a long list of upcoming innovations in the transport sector. The long list entails innovations that are described in several FP-7 projects and in other documents. Based on expert judgment this long list was cut down to a short list. The following criteria were used to assess what is relevant for FUTRE: Relevant innovations should be of systemic relevance for the transport sector, rather radical than incremental, and potentially sensitive to external factors (changes in demand patterns, scarce resources, political goals and/or others). The innovations in the short list were then clustered into seven so-called innovation fields:

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The innovation fields are then described in relation to their general relevance for FUTRE and for the issue of competitiveness. Challenges, controversies and barriers for further development and market penetration are discussed. Where data are available, the results from the patent analysis carried out in work package 2 of the project are taken into account. In an outlook the future prospects of the innovations field are summarised.

It can be concluded that there is a broad range of innovations with potential for inducing changes of systemic relevance in the transport sector. Some of these are well known and already discussed and assessed in several studies, such as the field of fuel and propulsion technologies. Alternatives to oil based fuels are anticipated to experience a far-reaching market penetration in the next decades. But it is not clear yet, what exactly will be the fuel of the future in the different segments of the transport sector. Electric drives are likely to come in the passenger sector, but it is still open whether they will be fuelled by batteries or by hydrogen and fuel cells. Further progress is expected in both of these fields, but also in the field of hybrid technologies, which will surely become a more important technology in the next decades. But also for biofuels and gaseous fuels further progress is likely which might improve their competitiveness compared to other options. Both are discussed as an alternative for road freight and for shipping. In these areas European transport industries are relevant for a significant share in patent releases on global scale, even if the field is mostly dominated by Japan.

In contrast to fuels and propulsion technologies, the innovation field of autonomous driving systems was not reflected extensively in transport related literature so far. Still, autonomous driving systems have the potential to reposition the road transport within the overall transport landscape, but not on a short term-basis. Beyond 2030, however, the introduction of full autonomous driving in road transport is considered to be of potentially disruptive character. Driverless cars could dramatically change perceptions and attitudes towards this new kind of road transport. Taking the systemic level of the overall transport system into account, autonomous driving might therefore significantly reposition the status of the road transport mode. Still, there is a high degree of uncertainty as regards fundamental issues such as the degree in automation that will be achieved, the impacts on the transport system or the development of user preferences.

The innovation field “improving the means of transport” illustrates, that innovations can improve all means of transport, i.e. the respective vehicles, mainly contributing to improved efficiency. This includes e.g. lightweight materials, improved aerodynamics and new construction technologies. Until 2030, developments can be expected to focus on incremental improvements of existing technologies. A reason for this is that improved efficiency of existing vehicle types is the most cost-effective strategy for reducing emissions and fuel use. More “radical” innovations as well can be observed already today, e.g. the Renault Twizy car model that comes with a new style of a small and lightweight electric city car. Again, European industries are highly active in this field. Aviation and rail-bound innovations show high shares of patent applications coming from European countries, with a German focus on rail-bound innovations and a French focus on aviation.

The innovation field “intelligent transport systems” is ranking high on the agenda of European transport policy. ITS integrate telecommunications, electronics and information technologies with transport engineering in order to plan, design, operate, maintain and manage transport systems. It can be assumed that ITS will play a significant role in improving and supporting transport and in contributing to a cleaner, safer and more efficient and accessible transport system. Innovations in this field are strongly influenced by the high dynamics in the area of information and communication technologies.

The innovation field “services and organisational innovations” entails approaches, which bring together supply and demand in a new and innovative manner. In particular the shift from vehicle ownership towards vehicle usage is rather radical and can be expected to become systemically relevant in the future. Significant developments can also be expected for integrated ticketing. The basic idea behind integrated ticketing is that the integration of tariffs, operators and modes has a positive impact on transport demand as the combination of modes and the transfer between them is facilitated for the users. The long-term objective of electronic ticketing supply is to provide a system that does not need any passenger’s action. Also in the freight sector, new logistics concept will be a significant challenge for the respective industries to adapt logistic chains and their business organizations.

The innovation field “infrastructures” considers innovations that contribute to the improvement, adjustment and extension of infrastructure of existing transport modes as well as to the introduction of new kinds of transport infrastructure. This chapter considers rather different approaches such as the (rather incremental but effective) extension of the rail network or complex approaches such as the introduction of dynamic pricing. Due to the long time horizon of infrastructure investments, mainly improvements of existing infrastructures can be expected until 2030. However, budgetary constraints will be a challenge.

The innovations listed in the field “out-of-the-box transport innovations” describe a range of more uncertain technologies or even new transport modes. In these fields certain technologies might be already visible, but it is still open whether these will become reality, at which point in time. But if they get commercialised, it is likely they will become relevant for the European transport sector and for the competitiveness of European transport industries. An overview on selected candidates is given, including urban cable cars, personal rapid transport, CargoCaps, inductive charging for electric vehicles and personal air vehicles.

Constraints on innovations

While the first task in this work package of the FUTRE project focussed on the identification of key transport innovations and their techno-economic characteristics, the second task consists of an analysis of potential future constraints for such innovations. For more than a decade, growing scarcity of fossil fuels and energy in general was considered to be a constraint on innovation. Having a look at today's innovation activities in the transport industry, this trend even enforces innovations like in the case of electric mobility or energy efficiency. Therefore, other constraints are getting in the spotlight. A shift from a fossil fuel based transport system towards a system mainly driven by renewable energy carriers significantly changes the demand for specific raw materials. Elements like copper, lithium, rare earths and scandium will be required to enable the transition towards a sustainable transport system.

Therefore, an estimation of the future level of criticality of a raw material is crucial to identify bottlenecks and intensify research for substitutes. In FUTRE a qualitative assessment of the implications of 15 key transport innovations on critical raw materials was carried out for the time horizon until 2030. In a second step, two diffusion scenarios focusing on road mode were set in order to quantify the impacts on some exemplary raw materials.

The first element evaluated was copper (Cu). Copper plays a central role in the one of the major transport innovations: electric vehicles. Copper is one of the major components of electric engines. A plug-in hybrid electric vehicle (PHEV) requires 3 times more copper for its production than an internal combustion engine (ICE) vehicle. Furthermore, the integration of renewable electricity production into grids presupposes the extension of grids which again leads to a growing demand for copper. According to the analysis copper demand passes the line of supply in terms of reserves under consideration of a strong diffusion of EVs until 2050.

A similar quantitative assessment has been carried out for lithium (Li) which is the key component of advanced battery systems used in each type of electric vehicle but also for other mobile electric applications. As opposed to copper, the projections for total demand for lithium until 2050 show that Electric Vehicles require the largest share of total demand for their battery systems. Similar to copper the demand for lithium could reach a critical level in 2050.

Besides constraints on innovations induced by critical raw materials, there are further factors hampering transport innovations. Even if key transport innovations are mainly developed by large companies and global players, financial constraints can affect innovation activity of smaller companies in the transport supply chain. The political framework can also negatively influence innovation process by setting too narrow frameworks or by policies that are designed to achieve only short-term targets.

Impacts of transport innovations on the competitiveness

The scope of this task, following the first task which identified the transport technologies and the second one that conducted the analysis of potential future constraints respectively, is to identify factors leading to a comparative advantage or disadvantage in relation to the collected major innovations until 2030 and beyond. The evaluation of the technologies is very important to estimate the competitiveness that will be configured in the European transport sector until 2030. For this reason, the main part of the task was to have a dialogue with a small number of experts in order to gather their opinion about each innovation field and technology and their potential impact that will have on the transport sector.

The evaluation of the technologies was based on an online questionnaire. The objectives of the task were the following:

- The development of an integrated questionnaire. The questionnaire was formed including questions for all the technologies by innovation field.
- A workshop with all the transport experts as participants.
- The results have been combined with the additional feedback provided during the workshop
- Overall conclusions have been recognized and presented in the end of this task.

The workshop was organized on 28-29 November 2013 in the premises of the European Council of Transport Research Institutes (ECTRI) in Brussels in Belgium. The focus of the workshop was on: 'Emerging Transport Innovations & Technologies'. The scope of the workshop was an expert assessment of the effect of supply-side innovations on the competitiveness of the European transport industry. Key experts were invited to provide input in the framework of a qualitative assessment on the list of key innovations/technologies for the transport sector. Within the workshop, ten experts filled out an electronic questionnaire and participated in an open discussion in relation to the likeliness of technological breakthroughs in the future in the corresponding field and the potential impacts on the transport system and on global competitiveness of the European transport sector. Also they expressed their opinion about the restrictions and barriers which the technological advancements will face.

The scope of the development of the questionnaire was to collect more specific and detailed answers according to the opinions of the transport experts. Specifically, the aim was to develop an overall view about what impacts the transport innovations will have on transport sector competitiveness until 2030. The ten experts had to evaluate the technology per innovation field and write some comments.

For each Innovation /Technology the ratings in the questionnaire assessed the level of expertise, the likeliness of the technology, the impacts on travel costs, the environmental impact and the benefit to European transport industry. The results of the questionnaire were presented in diagrams.

The conclusions produced upon completion of the workshop are the following:

- Enhancing the role and the importance of ICT systems and technologies to the transport services.
- Full autonomous driving is expected to be mainstream in the next 20-30 years. More and more efficient driver assistance systems will be implemented in road vehicles.
- Technologies related to energy (e.g. renewable energy technologies) are one of the most important innovation fields in the transport system. There is a need for cheaper solutions or for becoming less dependent on energy imports.
- There should be a focus on the creation of persistent and cheap materials for roads. Since the EU is implementing the "Pay per use" philosophy for the road transport sector, it is essential to find more resistant materials for roads, so that the maintenance shall be cheaper in the long term.
- Strong development of electric vehicles (e-cars and e-bicycles). Rise of the role of e-mobility to the global transportation system.
- Research will be intensified in the field of lightweight materials, because less weight means less energy consumption and this is a very important factor for freight (as well as passenger) transport (especially for the aviation sector).
- Ubiquitous internet access to harmonized traveler information (passenger) and tracking information (freight) will be part of any transport system.
- Major developments in warehouse logistics (intra-logistics). This type of logistics constitutes a challenge to evolve into a new strength for European logistics systems manufacturers.
- Major development in innovative sharing services (car sharing, bike-sharing etc.). There will be a strong "sharing" attitude of the "ownership" of vehicles especially in urban areas.

- Use of innovative transshipment technologies for rail, inland waterways and shipping on seamless intermodal freight.

In the end the results from the filled out questionnaires were analyzed for identifying the most promising/beneficial technologies overall in terms of user cost reduction, environmental benefit and benefit to EU competitiveness (by calculating an overall score). The results are summarized as follows:

- The most beneficial technology according to the experts will be the “Internet access to harmonized traveler information (passengers) and tracking (freight)”.
- From the field of automation of road transport the most beneficial technology is the “advanced driver assistance systems”.
- From the field of fuels and propulsion technologies the most promising one is the “Hybrid technology (allowing pure electric drive for a certain distance)”.
- From the field of services and organizational aspects the “smart ticketing schemes” are ranked highly
- From the field of the Infrastructures, the “Innovative transshipment technologies” are the most promising ones.

The aforementioned technologies had the highest overall scores based on the results obtained from the ranking of the experts. Finally, the technology “Lightweight materials (e.g. carbon fibers)” had also a relatively high score although lower compared to the aforementioned innovations.

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List of abbreviations

ADAS	Advanced driver assistance systems
Al	Aluminum
BEV	Battery electric vehicle
CEC	Commission of the European Communities
CH_4	Methane
CNG	Compressed natural gas
CO_2	Carbon dioxide
CU	Copper
EC	European Commission
ECTRI	European Council of Transport Research Institutes
ETP	European technology platform
EU	European Union
EV	Electric vehicle
FCEV	Full cell electric vehicles
FP7	Seventh Framework Programme of the EU for research and development
FUTRE	FUture prospects on Transport evolution and innovation challenges for the competitiveness of Europe (project title)
GDP	Gross domestic product
GHG	Greenhouse gas
H_2	Hydrogen
HEV	Hybrid electric vehicle
HMI	Human machine interface
HSR	High-speed rail
ICE	Internal combustion engine
ICT	Information and communication technology

IEA	International energy agency
IMO	International maritime organization
IPCC	Intergovernmental panel on climate change
ISI	Fraunhofer Institute for systems and innovation research
ITAS	Institute for technology assessment and systems analysis
ITS	Intelligent transportation systems
LI	Lithium
LNG	Liquefied natural gas
LPG	Liquefied petroleum gas
Mg	Magnesium
NFC	Near field communication
PHEV	Plug-in hybrid electric vehicle
PRT	Personal rapid transport
R&D	Research and development
RFID	Radio frequency identification
SC	Scandium
T&E	European federation for transport and environment
UBA	Umweltbundesamt (German federal environment agency)
WP	2011 Transport white paper of the European Commission (CEC, 2011b)
WTO	World trade organization

I. General information

The deliverable at hand reflects the work carried out in work package 4 of the FUTRE project between November 2012 and December 2013. The focus of this work package is on the supply side of the transport system, on emerging or anticipated technical and organisational innovations and their potential impacts on the competitiveness of the European transport sector.

Structure of the deliverable

In a first step, this deliverable focuses on relevant upcoming transport-related products, services, and infrastructure innovations until 2030 and beyond on a global scale. It looks at emerging and anticipated technologies and concepts as well as on potential technological breakthroughs. This work was done in **task 4.1** and is described in chapter I.

Possible constraints and barriers, in particular the problem of scarce resources, are of utmost importance for the development of technologies and thus for their potential impacts. Constraints were analysed in **task 4.2** and are discussed in **chapter III**.

The assessment of the impacts of innovations that are not yet on the market is faced with many uncertainties. The effect of supply-side innovations on the competitiveness of the European transport industry was therefore subject to an expert assessment that was conducted in **task 4.3**. The results of this expert assessment are presented in **chapter IV**.

The deliverable will – together with the respective deliverable from work package 3 – prepare the ground for the integration of the research results into the holistic scenarios to be developed in work package 5 of the FUTRE project.

II. Identification of relevant transport innovations*

This chapter describes the work carried out in task 4.1 of the FUTRE project.

Task 4.1 aims at identifying the most relevant upcoming transport-related innovations. The focus is on radical innovations, which are expected to lead to significant improvements of global relevance and/or to have systemic effects on the transport system. The task considers innovations on a global scale, as a high share of all innovations are developed by global players in the transport market. Transport-related innovations are differentiated by the following three types:

- Product innovations (such as, fuel/energy efficiency and alternative fuel innovations),
- Service innovations, and
- Infrastructure innovations.

Product innovations may include fuel efficiency, use of ICT, new materials or new design. Service innovations imply for example innovative mobility or logistics concepts controlled by ICT. Infrastructure innovations include innovations in constructing of transport networks as well as energy production and distribution innovations relevant for increasing the share of renewable energy carriers for transport.

The identification of upcoming transport innovations is carried out in two steps. In the first step, all potential innovations until 2030 are collected based on the findings of the patent analysis in WP2 and a comprehensive desk research. The desk research leads to a summary of findings by a number of European studies carried out in the last five years. The second step considers transport innovations entering the market with a higher level of uncertainty or even radical transport technology breakthroughs after 2030.

1. Methodology

The desk research on upcoming innovations is based mainly on the results of several studies in the transport from the recent years were analysed with regard to innovations that they assume to important in the future. These studies are mostly settled in the European context, e.g. being carried out within other FP7 research projects. The most important projects in this context are: GHG-TransPoRD, Market-Up, REACT, EU Transport GHG: Routes to 2050, TOSCA, U-STIR, TRANSvisions, FREIGHTVISION and INNOSUTRA. Furthermore, the analyses are strongly based on the STOA projects “Urban transport” and “Eco-efficient transport” (Schippl & Puhe, 2012; Schippl, Edelmann, Puhe, & Reichenbach, 2013)

Innovations described in these studies are presented in a longlist in section 2. An internal workshop of the project team and additional experts served to decide on a shortlist of innovation fields to be further analysed within WP4. The workshop approach is briefly presented in section 3, and the resulting shortlist is presented in section 4.

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2. Longlist of innovations

Results from the projects GHG-TransPoRD, Market-Up, REACT, EU Transport GHG: Routes to 2050, TOSCA, U-STIR, TRANSvisions, FREIGHTVISION and INNOSUTRA have been analysed in order to collect the relevant innovations in the transport sector for the FUTRE purpose. Because these studies come from different perspectives and because they use different approaches, not all of the results could be directly used in the context of FUTRE. The longlist of innovations is therefore composed of a selection of the most useful results of the studies mentioned above. The studies and their use within WP4 are briefly described below.

- The GHG TransPoRD project analysed measures to reduce greenhouse gas (GHG) emissions in the transport sector in great detail (see Schade et al., 19.03.2013). These results are well suited to be included in FUTRE and the project deliverables do also include all relevant information to include the innovations in the modelling in the later stages. Because of this degree of detail and the broad range of innovations covered by GHG TransPoRD, this project serves as a starting point for completing the innovation list by input from other studies.
- The TOSCA project also looked at promising technology and fuel pathways to reduce the GHG emissions from the transport sector. The final report presents technological feasibility details and characteristics of the analysed innovations (see Schäfer et al., 27.05.2011). These results are used for the creation of the longlist in WP4.
- The REACT project developed a strategic research agenda for climate-friendly transport systems and services (see REACT, 05.08.2011). While many elements can function as innovation fields in FUTRE and are thus incorporated in WP4, some others deal with planning approaches and policy approaches (e.g. in the field of education and campaigning). These elements are listed in the longlist below for systematic reasons but are partly excluded from the further work in WP4 which is focussed on innovations on the supply side.
- The FREIGHTVISION project covered a huge number of expected and potential innovations in the range of infrastructure and ITS technologies, engine technologies, and logistics technologies (see Böhmann et al., 27.04.2010). These innovations feed into the longlist.
- The INNOSUTRA project analysed innovation processes in the transport sector. For doing so, an analysis evaluated positive and negative impacts from several case studies in order to come to an assessment whether the respective case had been a success story or a failure. The technologies at which INNOSUTRA looked are existing ones, and the results can therefore not directly be used in the context of FUTRE's prospective approach. Innovations that still seem relevant are supposed to be covered by the above projects.
- The MARKET-UP project analysed the market uptake of new technologies in the transport sector and, more specifically, focussed on a detailed analysis of the framework of research and technology development funding in a first step (see Market-up, 22.02.2012). This approach highlights overall research and development (R&D) processes but does not give detailed insights into innovations of specific relevance for the future supply side of the transport sector. The project's results do not feed into the longlist of innovations.
- The EU Transport GHG: Routes to 2050 project worked on the development of an "enhanced understanding of the wider potential impacts of transport GHG reduction

policies" (Hill et al., 06.08.2012, p. iii). In the following steps, the SULTAN scenario was further developed and sensitivities for transport GHG emission reductions were analysed. The project results are focussed on policy measures and not on specific innovations on the supply side of the transport sector. They are therefore not further evaluated within WP4.

- The TRANSvisions project looked at how Europe and, more specifically, the European transport sector, could look like in 2050 (see TRANSvisions). The final report on transport scenarios with a 20 and 40 year horizon gives only very brief reference to specific technologic innovations and future developments (Petersen et al., 2009). The task 1 report dealing with the qualitative analysis covers external technological drivers (information and communication technologies, and nanosciences and nanotechnology) and internal drivers (transport infrastructure, vehicles and fuel technology, intelligent transportation systems) as well only very briefly (Sessa et al., 2009). Relevant innovations are supposed to be covered by the above projects.
- The U-STIR project looked at new technologies in surface transport stimulated by users. Results of the project are not public (or no longer available), and only an overview on the project's work package structure is available at the European Commission's website (see CEC, 2011a). Results can therefore not be used within FUTRE.

The selection process leads to the long list of innovations. To ensure readability of the deliverable, the list is presented in Annex 1. The list contains the innovations gathered from the relevant studies in their original wording (sometimes containing excerpts only). This means that there is no coherent overall structure or categorisation of the list, as it follows each source project's respective structure. There are overlaps between those studies (explicitly bringing up innovations several times or referring to them in different levels of detail), and there may be as well 'outliers' where the relevance for FUTRE is worthy of discussion.

Corresponding to the selected approach within FUTRE, however, a further elaboration of the long list does not seem appropriate as it mainly serves as a trigger to select key innovations field that will be presented in the subsequent sections of this deliverable. Still, those innovation fields refer to elements of the long list.

3. Internal workshop to discuss innovation fields

In order to bring down the above longlist of innovations to a reasonable amount of information to be considered in the framing of integrative scenarios in WP5, FUTRE draws on the broad expertise of the partners involved in task 4.1 (ITAS and ISI). Therefore, an internal workshop was organised and held on May 14th, 2013 in Karlsruhe. In this informal workshop, colleagues beyond the project team were invited to discuss the project team's preliminary results and to shape the ground for the next steps in the task.

3.1. Workshop approach

Experts from both institutes were provided with background information on the project and, more specifically, on the objectives of WP4 and task 4.1, and the longlist of innovations to be considered was presented to them along with an explanation of the challenge of selecting key innovation fields. It was explained to the experts that not all of the listed innovations could be considered in detail within FUTRE, and they were made familiar with the intention of clustering them into innovation fields.

The term 'innovation field' refers to the definition introduced by (Markard, Stadelmann, & Truffer, 2009). They apply the term "as a general reference to a domain of technological change" (Markard et al., 2009, p. 655), and it therefore allows for the framing of such fields in a way that takes off from the detailed level of single and specific innovations, facilitating the necessary systemic perspective on the transport system as a whole.

In order to ease the discussion, a preliminary selection of potential innovations fields was presented to the experts participating in the workshop (see Table 1), accompanied by short descriptions of the respective fields. It was made explicit that these were only to be seen as a trigger, leaving it open to the participants to reframe them, to skip them, or to introduce additional innovation fields. Instead, participants were asked to help in framing 10–15 innovation fields that could be further developed by the project team. Participants were confronted with the challenge to select such innovation fields that are:

- of systemic relevance,
- rather radical than incremental, and
- potentially sensitive to external factors (changes in demand patterns, scarce resources, political goals and/or others).

The crucial point were advice from the experts was expected was that not all potential innovation fields seemed equally clear regarding their scope and degree of detail. For example, it can be taken for granted that the development of energy storage technologies for mobile applications is an important issue that can easily be reflected as an innovation field. Other fields are more difficult to frame, e.g. progress in autonomous driving and related developments in robotics, the general relevance of developments in the ICT sector for transport, or innovations related to the upgrading or maintenance of infrastructure.

Participants of workshop are listed in Table 2. The innovations fields as selected by the workshop participants are presented in section 0.

Table 1: Preliminary list of innovation fields as presented to the participants of the internal expert workshop on May 14th, 2013 in Karlsruhe.

Innovation Field (Note: The list does not imply any hierarchy.)
Fuels and propulsion technologies
Improving the means of transport
ICT
Services & organizational innovations
Infrastructures
Planning, modeling, simulation
Financing schemes

Table 2: Participants of the internal expert workshop on May 14th, 2013 in Karlsruhe.

Participants	
ITAS	Michael Decker, Markus Edelmann, Torsten Fleischer, Reinhard Heil, Maike Puhe, Max Reichenbach, Jens Schippl, Saskia Ziemann
ISI	Jonathan Köhler, Michael Krail, André Kühn, Anja Peters, Florian Senger

3.2. Workshop discussions

In the beginning of the workshop, some introductory issues referring to the overall project context and, more specifically, to WP4 were discussed. These discussions are briefly reported here.

In general, participants agreed with the proposed preliminary list of innovation fields so that the list (presented in section 4) only underwent minor changes.

'Transport sector' and 'competitiveness'

The definition of the crucially relevant terms 'transport sector' and the transport sector's 'competitiveness' were discussed in order to frame the workshop. As the term of competitiveness is considered in WP2, its definition is beyond the scope of WP4. However, questions of the workshop participants on what direct and indirect influences to take into account when talking about competitiveness repeatedly pointed at the need for a proactive and sound communication of the definition of 'competitiveness' within FUTRE.[1] For the purpose of the workshop, it was explained to the participants that FUTRE will not take into account the capacities of the transport system as a factor of overall economic competitiveness (also because there are several other research projects dealing with this issue), but will instead look at the competitiveness of transport-related industries.

Structure of innovation fields

The question was raised how the innovation fields are structured. They could, e.g., either be shaped in order to contain a homogenous number of innovations. In another perspective, innovations can be relevant in more than one field and have heterogeneous effects, so that for some of them could be analyzed as cross-cutting issues in more than one field.

The selected innovation fields essentially focus on their usability as building blocks for the integrative scenarios to be built in WP5. The framing of innovation fields should allow for some heterogeneity in order to fulfil the requirement of providing a complete picture about innovations of the future, without skipping such innovations that might otherwise escape predetermined framings. This is well in line with the workshop participants' proposal that specific innovations could be relevant in more than one field, which could facilitate the integrative perspective approach.

Additional topics and fields

During the workshop, automation evolved as a major issue of significant relevance that should surely be considered in FUTRE (see box below). Developments in the automation sector are relatively new and they therefore could not be considered in detail in the studies analysed during the desk research. Automation is thus reflected as an additional innovation field in section 4.

[1] For example, the inclusion or exclusion of the manufacturers of construction vehicles was used during the workshop discussions in order to illustrate the difficulty of setting clear limits to the transport sector.

Several topics were additionally mentioned during the workshop. They provide insights into the experts' perspectives on issues of major relevance for the future of the transport system. However, they are either sub-elements of innovation fields already considered, or they lack the required systemic relevance that would make it appropriate for FUTRE to look at them in more detail. Thus, they are only briefly reported in Table 3.

Brief summary: Discussion on automation (internal workshop, May 14th, 2013)

Automation was rated as very important by the workshop participants and current developments were discussed extensively.

The thesis was raised that automation / autonomous technologies will first be introduced to assist in specific traffic situations (e.g. to prevent accidents), which can already be seen today, and will then spread to more and more applications. For understanding the goals of automation it is important to keep in mind the varying contexts of automation, as goals might differ or even conflict between e.g. the vehicle and the transport system level.

With vehicles getting fully autonomous, consequences might reach out far beyond 'traffic' alone. If cars lose their characteristic of the driving experience by restricting users' behaviour, this might contribute to more efficient and rational car usage, but at the same time will probably cut back the perceived benefit and attractiveness for some users. As automation also suggests good suitability of autonomous vehicles for sharing concepts, all this might lead to a significant reduction in the overall demand for vehicles.

Safety, security and responsibility issues are very important within and beyond technological progress in autonomous technologies. Responsibility is not only morally and ethically relevant, but also for the regulatory framework, e.g. thinking of accountability in case of any accidents that automation might still not be able to prevent. Security is a general issue in interconnected systems, and safety might seem a technical problem but is still a challenge. Today, autonomous systems are still mostly implemented where transport systems are newly built with separate infrastructure and some kind of physical guidance. Experiences from the field of robotics show that developers do not even expect technologies to be fully tested under laboratory conditions but in the real word instead. This means that there will have to be some type of co-existence of autonomous vehicles and conventional technologies in the transport system, even complicating the challenge.

Similar considerations apply to the freight transport sector and to railway transport. Beyond high-speed trains that do already operate mostly autonomous on some sections of the network, new concepts for single-wagon loads can be imagined, e.g. making use of virtual coupling and drawbar systems. Rail-like operation on roads is imaginable as well as road-like operation on railway infrastructures.

Table 3: Additional topics (or innovation fields) mentioned by the participants of the internal expert workshop on May 14th, 2013 in Karlsruhe.

Additional topics mentioned by workshop participants
intermodal freight transport / alternatives to the container
mobility concepts / interactions between transport modes
semi-public concepts as competitors of 'classic' public transport
complex views on materials (e.g. regarding recycling & reuse of transport systems and their parts)
intermodal transport and ICT
CargoLifter / heavy lift blimps
hybrid solutions in road/rail transport
lightweight construction
new concepts in urban transport that would e.g. have busses from cities' outlying districts coupled in the city centre, allowing for flexible change inside the coupled vehicles
hybrid propulsion solutions (which seem very important at least during the necessary transitions of the transport system as bridging solutions)
flexible propulsion / changing propulsion systems while staying in the same 'passenger cabin' (new kind of hybridization)
electrified motorways
air transport: biofuels (challenge: energy density), open rotors (up to 20% energy savings), tilt rotors, ground traffic management, magnetic acceleration, SESAR (e.g. for continuous descent) (while flying wings are still very far from reality)
myCopter: technical challenges by the necessary traffic density in dense urban areas if an actual systemic effect on the transport system is to be reached, while in less densely populated areas there is no real demand imaginable
bicycle and walking: great potentials of e-bikes / pedelecs (by expanding possibilities instead of restricting them as in the case of electric cars with insufficient driving ranges), possibly for delivery services as well
new types of vehicles or even transport modes challenging urban planning

4. Shortlist of innovation fields

This section presents the selected innovation fields (see table 4) with a brief description of every field. Key innovations within the respective field are listed in the respective sub-section. The order of the innovation fields implies no ranking by importance or other characteristics.

Note: Parts of the text in this section build on the work carried out by (Schippl et al., 2013).

Table 4: Selected innovation fields.

Section	Innovation field	Page
4.1	Automation of road transport	30
4.2	Fuel and propulsion technologies	33
4.3	Improving the means of transport	44
4.4	Intelligent transportation systems	48
4.5	Services & organizational innovations	51
4.6	Infrastructures	62
4.7	Out-of-the-box transport innovations	65

The 2011 transport white paper (WP) of the European Commission (CEC, 2011b) sets ambitious targets for the transport sector, and these targets are closely linked to a development of the transport sector that is sustainable under an environmental, social and economic perspective (see (Condeço et al., 2013) (FUTRE Deliverable 2.1)). A cross-check of the innovation fields that have been selected within the FUTRE project with the ten goals set out in the WP can therefore serve as an indicator whether the innovation fields in their entirety cover the broad range of relevant topics that are touched by the WP. The results of this cross-check can be found in Table 5. The cross-check clearly shows that all WP goals are touched by at least two of FUTRE's innovation fields. For every WP goal, at least one of FUTRE's innovation fields is expected to deliver significant contributions to the required developments, except the last WP goal (full application of "user pays" and "polluter pays" principles) which is apparently more about policy and regulatory innovation.

Table 5: Interrelations between the ten goals of the European transport white paper (CEC, 2011b, goal denominations are shortened to ensure readability) and the selected FUTRE innovation fields (+ / ++ = some / significant contribution of the innovation field to the white paper goal). Source: own assessment.

White paper goals / FUTRE innovation fields	Clean urban transport	Low-carbon fuels (aviation, maritime)	freight shift from road transport	EU high-speed rail network	multimodal TEN-T network	connection of airports and seaports to rail	modernized traffic management	multimodal transport information, management & payment system	close to zero fatalities in road transport	full application of "user pays" and "polluter pays" principles
Automation of road transport	+						++		++	+
Fuel and propulsion technologies	++	++								
Improving the means of transport	+	+	+							
Intelligent transportation systems			+				++	++		
Services & organizational innovations	++		++				+	++		
Infrastructures	+		++	++	++	++			+	
Out-of-the-box transport innovations	n.a.									

Linking innovations to the results of the patent analysis

Within the context of FUTRE's work package 2 (Condeço et al., 2013), a patent analysis was carried out in order find out in which technological areas European countries are most competitive in terms of patenting activity. In the description of innovation fields, these results will be used as a reference to describe the situation of the innovations in the respective field in relation to the corresponding European patenting activity. Main figures from (Condeço et al., 2013) are given below (Figure 1, Figure 2).

Figure 1: Results from the patent analysis carried out by (Condeço et al., 2013) (FUTRE Deliverable 2.1): Patent applications worldwide. Source: Fraunhofer ISI, own data assessment (taken from Condeço et al., 2013).

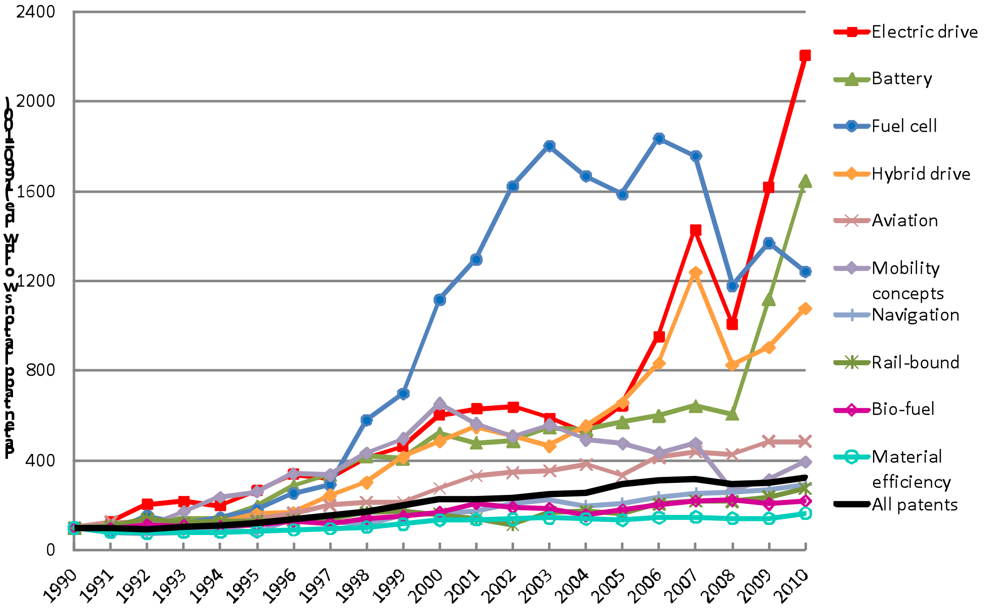
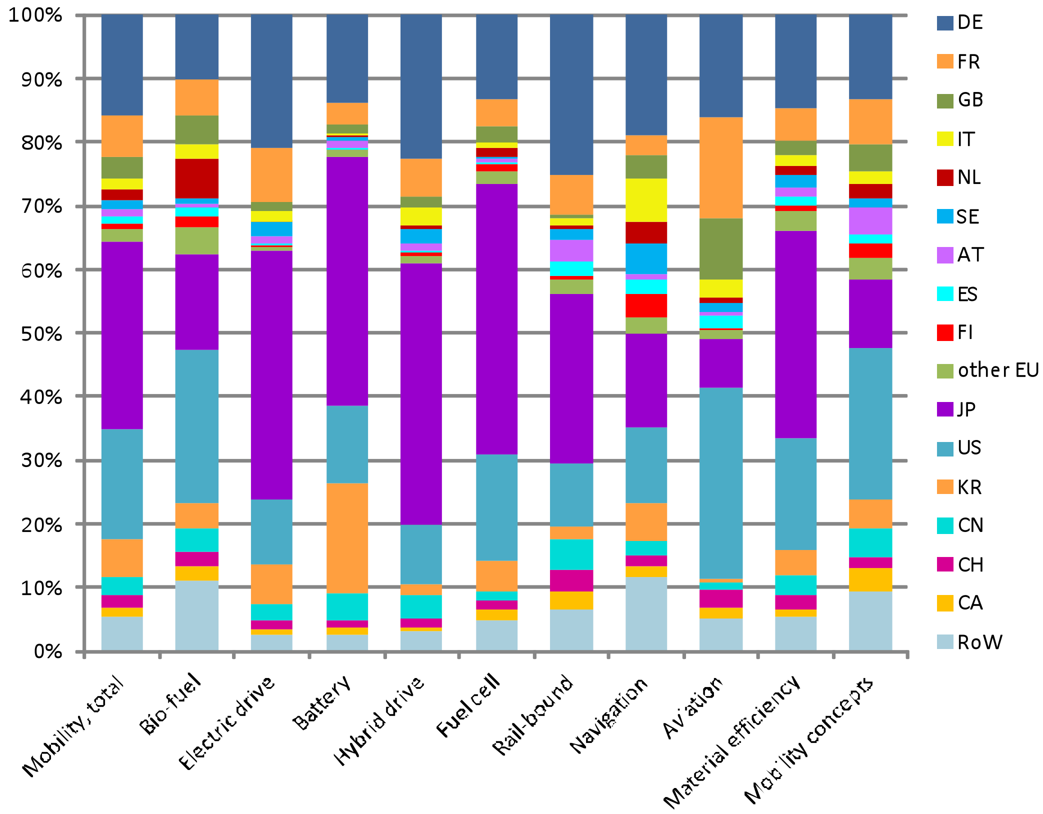


Figure 2: Patent shares of the most relevant applicant countries (share >= 1%) for different mobility-relevant technology areas in 2008 to 2010. Source: Fraunhofer ISI, own data assessment (taken from Condeço et al., 2013).



4.1. Automation of road transport

Automation has been a trend for some time in industry and many areas of every-day life. Industrial robots are common in manufacturing facilities, and robots are slowly getting common in households as well, e.g. for cleaning duties. In the transport sector, automation can be seen in the railway sector with modern signalling systems that do only need little or no action by a driver and in shipping and aviation as well, where autopilot systems have been implemented that relieve pilots and commanders from many routine tasks.

It is therefore not astonishing that in road transport automation technologies are being developed as well. More and more, and ever more efficient driver assistance systems are implemented in modern road vehicles. But similarly to the other transport modes, full autonomous systems have not been introduced commercially until now, with the ultimate responsibility and the ultimate option of intervening always remaining with the driver. As an innovation field within FUTRE, however, automation of road transport is explicitly considered to include the introduction of autonomous driving technologies that ultimately take the responsibility from the driver, making the driver a passenger.

Relevance for FUTRE

In a survey on potential future developments in the European transport sector, 40 % of the respondents considered it realistic that after 2030 half of the kilometers travelled by car will make use of autonomous driving technologies (Schippl et al., 2013).

Autonomous driving systems have the potential to reposition the road transport mode within the overall transport system landscape. While increased application of driving assistance systems can be considered an incremental innovation in relation to the road vehicle as a whole, the introduction of full autonomous driving would give the driving of road vehicles a radically new characteristic. Due to this potential repositioning of road transport, the effects of autonomous driving technologies are highly sensitive to parallel developments in other parts of the transport sector, e.g. innovations for the slow modes or public transport. As described below, autonomous driving promises more efficient use of expensive infrastructures and increased road safety, but potential side-effects have to be analyzed.

Referring to the innovation categories considered in FUTRE, the incremental introduction of driver assistance technologies can be considered product innovations. Inter-vehicle communication and vehicle-infrastructure communication require infrastructure adaptations and innovation. If considered in the perspective of full autonomous driving as a new kind of transport, automation technologies can also be considered as service innovations.

Characteristics and relevant developments

Traditionally, vehicle components and infrastructure components did not directly interact with each other. Cooperative ITS could now connect these components and allow vehicles to communicate with each other and with the surrounding infrastructure. Co-operative systems are based on the real time transfer of information from vehicle to vehicle (V2V), vehicle to infrastructure (V2I) or infrastructure to infrastructure (I2I). As such, vehicles can function as sensors to report traffic, road and weather conditions to reduce congestion, improve safety and service (CEC, DG Mobility and Transport, 2011). Moreover, cooperative systems aim at improving large-scale and real-time traffic management. Three main categories in respect to their functionalities exist: safety, efficiency and comfort applications (Dar, Bakhouya, Gaber, Wack, & Lorenz, 2010).

Safety

Collision avoidance applications (e.g. using proximity radars) allow warning users before possible collisions, for example through a safe distance application to dynamically adjust distance dependent on the actual traffic situation. In such situations the vehicle adjusts its speed automatically to the vehicle in front by directly taking over the control of the braking systems. Such technologies can reduce the still significant numbers of fatalities in road transport (Campbell, Egerstedt, How, & Murray, 2010, p. 4667). Another option is emergency vehicle warning that warns the driver of an emergency vehicle that is approaching and proposes the right track.

The strive for safe road transport is an important driver for the development of autonomous driving technologies, according to Daimler's management board member Thomas Weber (cf. Lamparter, 13.06.2013). Moving on to full autonomous driving, however, increases the challenge of integrating multi-sensor information, as the system has to be capable of dealing with inconsistencies (Li & Leung, 2004) and redundancy for core elements is required (Lamparter, 13.06.2013).

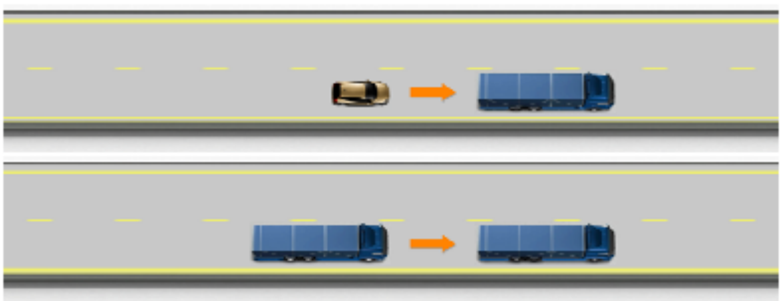
Comfort

As a comfort function of autonomous driving, for example parking booking assists drivers in finding and reserving a suitable parking bay. This is especially interesting for urban freight transport (see section 4.5.3).

Efficiency

Automated platooning enables a number of vehicles to drive under precise automatic control at close spacing (1 m) (see Figure 3). This means that a number of vehicles are travelling together and are electronically connected. A lead vehicle is controlled manually by a trained driver and followed by a number of vehicles that are controlled electronically. The lead vehicle gives commands to steer, break or accelerate and the following vehicles within the platoon will be driven without intervention of a driver.[2] By driving in platoons, vehicles can travel at high densities and with reduced aerodynamic drag and thus might reduce fuel consumption and environmental emissions as well as relief congestion (Bergenhem et al., 2010; Böhmann et al., 27.04.2010).

Figure 3: Automated platooning. Source: (Bergenhem et al., 2010).



Relevant technological approaches range from central decision-making by the platoon-leading vehicle to cooperative exchange of information between the various vehicles in a platoon and even full autonomy of vehicles (Michaud, Lepage, Frenette, Letourneau, & Gaubert, 2006). Mere technical questions such as where to place antennas for inter-vehicle communication (Bergenhem, Hedin, & Skarin, 2012) also still remain an issue in this field.

[2] Autonomous platoons can not only increase efficiency but can as well again improve safety, e.g. by sending warnings about dangerous situations across all vehicles in a certain platoon and by collaborative reactions.

On the transport system level, autonomous driving implies cooperative behaviour of vehicles and/or drivers. Communication across vehicles and with infrastructure elements such as traffic lights can lead to more efficient use of infrastructure, eventually reducing congestion in densely populated areas. This can be achieved through traffic flow control systems that introduce a certain degree of centralistic, hierarchical control of vehicles and platoons (Baskar, Schutter, & Hellendoorn, 2012).

Challenges, controversies and barriers

Main concerns about automation in road transport relate to the co-existence of autonomous and conventional technologies and to systemic effects of autonomous driving.

The co-existence of autonomous and conventional technologies is expected by experts. The issue was raised during the internal expert workshop (see section 3) and e.g. Thomas Weber as a Daimler representative also expects an incremental introduction of autonomous technologies (cf. Lamparter, 13.06.2013). If drivers that are still ultimately responsible for their vehicle rely too much on automation, this can lead to a loss of drivers' routine, which in turn can lead to dangerous situations. An unpublished study of the American Federal Aviation Administration, referred to by (Knight, 16.04.2013), was able to show this effect for the case of aviation. Moreover, human habits have to be taken into account, as human 'irrationality' can e.g. be frightened by tightly calculated clearance distances (cf. Saffarian, Happee, & Winter, 2012).

Ethical and normative challenges arise when the possibility of inevitable accidents is considered. The feasibility of implementing moral decision-making rules (e.g. whom to kill in case of such an accident) into autonomous driving systems is questioned by experts (Bendel, 15.03.2013). This can as well be brought down to a regulatory challenge with new responsibility and accountability requirements urging for adjustments of legal framework settings such as even the United Nations' 1968 Convention on Road Traffic (cf. United Nations Conference on Road Traffic, 1968).

At the transport system level, technical challenges e.g. arise through the necessity of coordinating heterogeneous data sources (Campbell et al., 2010, p. 4669) or through data security concerns relating to both data privacy and protection against data manipulation. Non-technical issues relate to potential side effects of autonomous driving systems. While the accessibility of the transport system for disabled people could be significantly improved, rebound effects could occur by the car becoming more attractive and convenient. If this reduces the relative attractiveness of public transport and slow transport modes, the efficiency gains through autonomous technologies might actually be devoured by an increased demand for road transport; and strategies to shift transport to more efficient modes might directly be counteracted. This issue was also raised during the internal expert workshop.

Consistently, in the survey referred to above 27.5 % of respondents expect a negative impact of autonomous driving on an aspired reduction of transport volumes, while about half of the respondents see European and/or national legislation/regulation, a lack of societal acceptance and remaining technical problems as additionally impeding factors of automation (Schippl et al., 2013).

Results from the patent analysis

The patent analysis conducted in work package 2 of the FUTRE project did not include autonomous driving technologies in the selection of technology areas (cf. Condeço et al., 2013). There are thus no results that could be referred to in this description of the innovation field.

Outlook

As outlined in section 3.2 (results of internal expert workshop), a sudden introduction of full autonomous driving in road transport is not expected by experts. Autonomous driving technologies are expected to be introduced incrementally by continuous improvements of existing technologies and by the introduction of additional driver assistance systems. This is consistent with the actual technological innovations that have been considered in the desk research and in the longlist of innovations. This estimate of incremental innovation applies to a mid-term time horizon until 2030.

Beyond 2030, however, the introduction of full autonomous driving in road transport is considered to be of potentially disruptive character. Driverless cars could dramatically change perceptions and attitudes towards this new kind of road transport. Taking the systemic level of the overall transport system into account, autonomous driving might therefore significantly reposition the status of the road transport mode. While several technologies for autonomous driving are already being developed, tested and applied in present products, other necessary elements are still in an early phase of development. But beyond technologies, and more important, non-technical controversies and barriers as referred to above (e.g. side-effects in the transport system, legal and regulatory aspects) will require time to find reasoned solutions, making full autonomous driving a vision in the long-term horizon only.

4.2. Fuel and propulsion technologies

Overview and relevance for FUTRE

This innovation fields encompasses a broad range of technological approaches that are all aiming at changes concerning fuels and propulsion technologies. Still, European transport is mainly running on oil; in 2006, almost 97% of the energy used in the EU-27 (i.e. including data from all present members of the EU, regardless of when they became members) for transport (including all modes) was based on petroleum products. At present, most vehicles on European roads still operate on the basis of internal combustion engines (ICEs), mainly using gasoline or diesel oil. Almost 72% of the total oil product deliveries to the EU are consumed by the transport sector, which is accordingly the largest consumer of oil products in the EU. One of the key challenges outlined in the 2011 White Paper is "to break the transport system's dependence on oil without sacrificing its efficiency and compromising mobility" (CEC, 2011b, p. 5) One of the central goals of this White Paper is formulated as follows:" Halve the use of 'conventionally-fuelled' cars in urban transport by 2030; phase them out in cities by 2050; achieve essentially CO_2-free city logistics in major urban centres by 2030 (ibid, p.9).

However, there are several drivers for an increased efficiency and/or the market penetration for non-oil based fuels and propulsion technologies in the transport sector:

- The question of energy security that was raised above.
- Climate security: The recently published White Paper on Transport emphasizes that greater efforts are needed in this area: "A reduction of at least 60% of GHG [greenhouse gas] by 2050 with respect to 1990 is required from the transport sector, which is a significant and still-growing source of GHGs" (CEC, 2011b, p. 3).
- The need to reduce emissions of pollutants (other than GHG) to human health and the environment: An increasing number of cities around the globe at least partly ban the usage of unclean engines (see also White Paper goal quoted above). Prominent examples can be found in China. But also in the countryside and in maritime areas regulations are implemented (for example Sulphur Emission Control Areas).

- The increasing global competition in the transport sector is another driver – and a key topic of the FUTRE project.

Against this background it is not astonishing that many efforts can be observed to increase the efficiency of conventional technologies and to phase in alternative fuels and propulsion technologies. There definitely is a lot of dynamics in this field. Since there are good reasons to presume that the drivers mentioned above will gain in force in the coming decades, it can be concluded that the high dynamics will remain characteristic for this innovation field over a longer period of time. The drivers affect the whole transport sector; innovations in the field of fuels and propulsion technologies are relevant for all transport modes. Cars, truck, trains, vessels and airplanes are affected and recently it become obvious that even the propulsion system of cycling is a subject of significant changes with pedelecs and electric bicycles rapidly gaining market shares.

Fuels and propulsion technologies are one of the most important innovation fields in the transport system. A broad range of rather different approaches exist. It is obvious that specifically the eco-efficiency of all the alternatives to oil-based fuels is strongly dependent on other developments in the energy sector. Biomass can be used in stationary as well as in mobile applications; the same is true for hydrogen and, of course, also for electricity and natural gas. For electric engines the most open questions – in terms of eco-efficiency – are related to the production of electricity or hydrogen as well as to the integration of these production pathways into the energy system. Thus, the integrated perspective on the transport and the energy system is becoming highly relevant. This is underpinned by the fact that it is actually not the propulsion system itself but the conversion and/or on-board-storage of energy which is the main technical bottleneck for progress of non-oil-based fuels. However, it would definitely go beyond the scope of the FUTRE project to consider also innovations in the energy sector, even if they are of importance for developments in the transport sector. Only where absolutely necessary, developments in the energy sector are mentioned in the following description of innovative subfields.

The following subfields are identified for the innovation field fuels and propulsion technologies:

- Battery electric vehicles (BEVs) and hybrid electric vehicles (HEV)
- Hydrogene and fuel cells
- Biofuels
- Methanol
- Compressed natural gas (CNG) and liquefied petroleum gas (LPG)

As the patent analysis carried out in Deliverable 2 of the project illustrates, an increasing number of patents were released in several of these fields over the last years (see Figure 1, p. 29). European transport industries are highly active in several of these fields (see Figure 2, p. 29).

4.2.1. BEVs and HEVs

Characteristics and relevant developments

BEVs are seen as an important element of future transport by many observers; they have become an important issue in public debate and research funding activities. A lot of progress was made in this field. After long years of intensive research and development activities several automakers are about to commercialize BEVs. The same is true for hybrids, which entered considerable market shares for example on California, where the Toyota Prius was the top-selling car in 2012 (In California up until recently, hybrid cars allowed to be driven in "High Occupancy Vehicle" lanes even with only one occupant). The example of California illustrated that hybrids can be far more than a niche product, whereas sales of pure battery electric vehicles are still in low level all over the world.

In particular BEVs come along with several innovations. Some of these are dealt with in the chapter on "vehicles". Here the focus is on innovations in the field of fuels and propulsions. In this context the main area of innovations is the battery technology. The crucial point is that pure electric vehicles are currently unable to provide the same performance characteristics in terms of range and speed (Kaiser, Meyer, Schippl, & Zweck, 2011). One main reason for this is the much lower energy density of current batteries. Compared to the conventional liquid fuels (diesel and gasoline), with an energy density of around 12 kWh/kg, today's batteries have — at the very best — an energy density of 200 Wh/kg (Kaiser et al., 2011). Even if the combustion engine can only use a fraction of the energy contained in fuel for propulsion, one kilogram of fuel still contains twenty times more energy usable for propulsion than modern Lithium-ion batteries (Kaiser et al., 2011; Heymann, Koppel, & Puls, 2011). This relatively low energy density is not expected to improve very quickly; experts assume an increase rate in storage capacity of around 5% per year (Service, 2011). These technical conditions lead to a series of performance and usability characteristics such as shorter range, lower maximum speed and longer time frames for charging batteries as compared to average ICE cars. Additionally, the high cost and weight of the battery are further obstacles to a fast market penetration by electric vehicles.[3]

A means to his shortages is the usage of range extender. In general an electric engine is supported by a combustion engine. The latter is not used to directly propel the vehicles but to convert fuel into electrical energy for the battery while in operation. This concept reduces the range limitation and the need for a large-sized battery. The Opel Ampera is a well-known current example of this technology.

Further concepts with different levels of hybridization exist (see table 6); these range from electrified assistance functions, such as automatic engine start-stop and regenerative braking, to various levels of hybrid electric propulsion and even to pure electric driving which is realized in the BEV (Karden et al., 2007).

The Plug-in hybrid electric vehicle (PHEV) concept is similar to that of the HEV, but goes one step further and generally has a stronger electric drive train and a larger sized battery, which is not only recharged by on-board processes like recuperation, but can also receive an external input of electricity through power outlets (Heymann et al., 2011).

[3] Offer, Howey, Contestabile, Clague, and Brandon (2010) name the example of 150 kg battery weight for lithium ion cells to provide a range of 200 km.

Table 6: Overview of different hybrid vehicle types and their functionalities. Source: (Karden et al., 2007).

Hybrid System Type \ Hybrid Main Function	Engine Stop/Start	Regenerative Braking	Motor Assistance	Electric Drive
Conventional	Possible	Minimal	No	No
Micro 14V	Yes	Minimal	Minimal	No
Mild ~42V (e.g. BMW Active Hybrid 7)	Yes	Modest	Modest	No
Medium ~144V	Yes	Yes	Yes	Modest
Full >200V (e.g. Toyota Prius, BMW Active Hybrid X6)	Yes	Yes	Yes	Yes

Challenges, controversies and barriers

The question as to whether battery technology will make progress in terms of cost, range, loading time and reliability is also critically discussed. The question has been raised: At what point will electric mobility become competitive? Do lower ranges and longer loading times fit in with most of the travel patterns of European citizens or not? Will customers get used to the specific characteristics of BEVs or do BEVs need to provide the same performance as conventional vehicles?

Another serious challenge is the availability of raw materials, in particular raw earth and lithium. Materials that contribute to lightweight construction are also crucial.

Further, there are controversies related to the environmental benefits of BEVs and PHEVs. The overall energy and CO_2 balance is strongly depending on the well-to-tank branch of the whole chain of energy conversion. When the electric power is taken from the power grid, the question of the source of the energy is a key factor in estimating their GHG emission potential.

Results from the patent analysis

The patent analyse carried out in work packages 2 provides data for the fields of electric drives, for batteries and for hybrid electric vehicles (see Figure 1, p. 29). For electric drives and for batteries very high growth rates can be observed for the last years. There is no indication yet that these high growth rates will flatten in the next years. For hybrid drives there was peak with more than 1200 patents in 2007 that was followed by decline during the economic crisis. Already in 2008 the number of patents started to grow again, but did not reach the 2007 levels up now. Also in this field it looks as if further growth can be expected for the coming years.

Figure 1 (p. 29) illustrates that all three fields are dominated by Japanese companies, which are responsible for the highest shares in patents released in 2010 in these fields. The highest contribution for Europe is coming from Germany, which provides strong contribution in electric drives and in hybrid drives, whereas the share in the fields of batteries is slightly lower. For France and Italy, on a lower level a similar pattern is visible.

Outlook

In many European countries ambitious plans to foster electric mobility where implemented. The European Commission has set the targets to phase-out conventionally fuelled in urban areas until 2050 and to achieve ‘essentially CO2-free city logistics’ in major urban centres by 2030 (CEC, 2011b). Germany aims at having one million electric cars on the road in 2020 which is an ambitious plan (in 2012 only 4,000 e-cars were sold). The target is getting easier achievable when e-bikes are taken into account as well. In many European countries the purchase of an e-car is financially supported by the government. The example of Norway recently illustrates, that such financial support combined with other incentives (e.g. free charging at public stations in Oslo; allowance to use bus lanes) can strongly accelerate the market penetration of BEV’s. In Norway, during the year 2013, the battery electric vehicle Tesla reached higher market shares (5.1 % in September 2013) than the VW Golf (4.6% in September 2013). Also in other countries the commercialization of electric vehicles is strongly fostered (e.g. China). In Europe, plans are made to increase the number of charging points considerably.

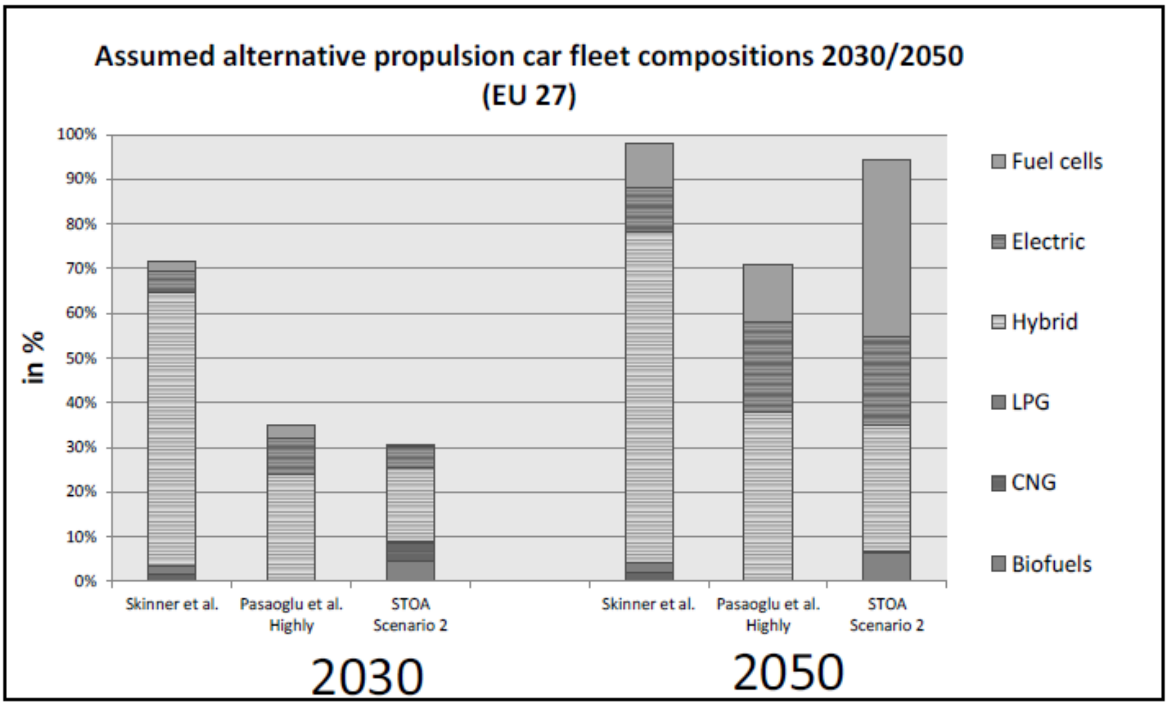
Furthermore, in the last years a trend was to find niches for electric cars: where their capabilities in terms of range are already sufficient, or where other attributes such as low noise level or zero tailpipe emissions make them attractive. One of these sectors is the delivery service sector. For example Deutsche Post, together with industry and research partners, started the development of a future electric car specially designed for their postal and parcel delivery (Deutsche Post AG & Streetscooter, 2011).

On a mid-to-long term, breakthroughs in battery technology might change the competitiveness of battery electric vehicles. Innovations that increase ranges, loading-times and reliability are of utmost importance. A potential candidate for progress in this field is the lithium-air battery: actually the technology is investigated since the 1990’ties. It offers the potential to increase the energy density of batteries by factor 10-20. But there still are considerable technical hurdles to overcome before a commercialisation is becoming realistic. Another example is the development and application of nano-materials in batteries (carbon nano-tubes for batteries). At the same time, modern lithium ion batteries and electric drive systems are depended and some scarce resources (see chapter III). Developing batteries and drive system as far as possible in basis of resources that are less scarce might become a dominating imperative in case that demand for such materials increases heavily and/or in case that supply of such materials is restricted by geo-political constellations.

To sum up: taking into account the success of policy strategies in countries such as Norway, the ongoing search for “niches” for BEV and, last but not least, the expectation that further technological progress is likely, a strong increase of the global demand for electric vehicles can be assumed for the next years. Scarce resources and also progress in other fields (e.g. fuel cell vehicles) might hamper progress. For Europe it appears to be not unlikely that the market shares are increasing heavily in the next decades. From an optimistic perspective it is imaginable, that the market penetrations of BEVs will be clearly about 60% until 2050.

On the other hand, several scenarios for 2050 show lower market penetrations of BEVs. All the examples illustrated in figure 4 assume high market shares for hybrids and the calculations made for the STOA project come to relative high shares in fuel cell vehicles. So, it must be concluded that the future markets penetration of BEVs is highly difficult to predict, since it does not only depend on technological progress; it depends to considerable extent on political regulation and incentives, on progress made in competing fields and – last but not least – on the development of users preferences and related attitudes (see Schippl and Puhe 2012).

Figure 4: Car Fleet composition for 2050 in scenarios of different authors. Note: the figure excludes gasoline and diesel cars (Graph adopted from Schippl et al. 2013; for "STOA Scenario 2" see also Schippl et al. 2013)



4.2.2. Hydrogen and Fuel Cells

Characteristics and relevant developments

Until only a few years ago, many experts considered a combination of hydrogen and fuel cells to be the most promising option for the future of car-based transport (Bakker et al., 2011). In the meantime, BEVs are seen as a favorite by many observers and have become an important issue in public debate and research funding activities. It is still uncertain whether or not this situation will change again; thus, it is not yet clear which of the two will be dominant in the future — hydrogen, batteries or a combination of both.

Hydrogen can be burned directly in an ICE or it can be used in a fuel cell to generate electric power, which is then used in an electric engine. Because of its low efficiency and the problems involved in storing the needed amounts of hydrogen on board, direct burning is not considered an interesting option by most experts. In the meantime, the use of hydrogen in a fuel cell has become feasible. In field trials over the last decade, hydrogen was usually stored on board in gaseous form at 300 or 700 bar. Some experiments with liquefied hydrogen (H_2) were done to reduce the volume. However, the need to cool H_2 down to -253 °C in order to keep it liquefied made this route less attractive. Another promising option seems to be provided by the metal hydrides, which offer an interesting hydrogen-storage capacity: They absorb the hydrogen molecules like a sponge.

Daimler recently started a field trial with 200 B-Class vehicles featuring fuel cells and gaseous hydrogen storage. Ranges are supposed to be around 400 km, reloading is to take only a few minutes. It has been announced that the vehicles are to be made commercially available in 2015. The main obstacles to a fast market penetration seem to be a lack of infrastructure, questions if reliability as well as the price for the vehicle, which needs to be competitive with hybrid vehicles.

Challenges, controversies and barriers

The main controversies relate to the energy balance of hydrogen — and are thus strongly related to the eco-efficiency of this technological approach. For the electrolysis route, the conversion of electric energy into chemical energy (H_2) and then again into electrical energy leads to considerable losses (cf. e.g. Bossel, 2006). Fuel cell vehicles will not only have to compete with conventional cars, but also with battery electric vehicles. The advantages are the longer ranges and the shorter loading times. The deficits in term of energy balance might be somewhat balances by using excess energy for renewable sources (for example in off peak hours excess energy form wind can be used to produce hydrogen via the so called power-to-gas route).

Another issue in the discussion about hydrogen is the need for building a new infrastructure for transport and storage, which is technically feasible but would require considerable investments. Different concepts are conceivable, for example a more centralized generation close to the energy sources or a decentralized generation closer to the consumers.

Results from the patent analysis

Similar to the fields of electric drives and battery technology, Japan is releasing most patents related to fuel cell vehicles. Furthermore, the US appears to be quite strong in this field. In Europe Germany is leading followed by France and the UK.

Outlook

As regards infrastructures, a more dense networks is planned in different countries. The German „H2 Mobility“ initiative (build of Air Liquide, Daimler, Linde, OMV, Shell, Total) recently announced to set up a nation wide network of hydrogen filling stations. It is intended to install 400 H2-stations in Germany until 2023 (today there are only 15). [4]

About ten years ago, in his book on the “hydrogen economy”, Jeremy Rifkins framed hydrogen as the “next great economic revolution” (Rifkins, 2002). One key element of his vision is that hydrogen will replace oil as the primary energy carrier. Even if one does not follow his far-reaching vision, the book clearly illustrates that the integration of H_2 production into the energy system could become a crucial factor for its use in transport. Thus, the further development of hydrogen surely depends not only on technical progress (also in batteries) and the development of the automotive sector, but also on the future design of the European energy system. As figure 4 illustrates, under certain assumptions scenario calculations can results in high shares of fuel cell vehicles for 2050.

4.2.3. Biofuels

Characteristics and relevant developments

The term biofuels encompasses a broad range of rather different technologies, which all have in common that they use biomass as a basis for the production of fuels (Schippl, Dieckhoff, & Fleischer, 2007). Diesel as well as gasoline can be produced from biomass. In Europe, blends are usually used; examples include E10 (10% bioethanol, 90% conventional gasoline) or B5 (5% biodiesel). Current vehicles are already E10 (for the model years 2005 and upwards) and B7 (7% biodiesel) compatible. Compatibility with higher biofuel blends has yet to be proven. However, so-called flexible fuel vehicles for higher blends have been

[4] http://www.now-gmbh.de/de/presse-alt/2013/h2-mobility-initiative.html

commercialized. For example, E85 is widespread not only in Brazil, where sugar cane can be used as feedstock, but is also available in Sweden and the USA. One of the most striking advantages of biofuels is that existing infrastructures can be used, even if some adjustments may be necessary. Biofuels can be used in conventional ICEs; thus, the established vehicle concepts do not have to be changed.

An important distinction is made in relation to the feedstock and processing: First generation biofuels, mainly biodiesel and bioethanol, are already established, at least in some national markets. They have in common that only certain parts of the plants, generally the fruit, are used for their production. A typical example is biodiesel produced from rapeseed or from palm oil. Bioethanol uses different kinds of feedstock, such as corn or sugar cane.

Biomass-to-liquid technology (BTL) encompasses several processes in the production line of the so-called second generation biofuels. The crucial point is that here the whole plant can be used to produce fuel, in contrast to the production of "first generation" biofuels where only parts of the plants (oil, sugar, starch) are used. Thus, for BTL products less land area is required per unit of energy produced compared with "conventional" biodiesel or bioethanol; the efficiency is significantly higher. The second great benefit of the BTL route is the possibility to define the fuel properties by setting the reaction parameters. The specifications of the fuel can be fine-tuned to match the requirements of the engines by altering the form or length of the fuel molecules, what explains the great interest of engine developers in these "designer fuels". In principal, conventional engines do not have to be adapted to BTL, however, in order to guarantee an optimised burning process minor adjustments are useful.The third advantage is that BTL fuel can be derived from substances that mainly consist of lignified cellulose. Thus, there is a wide range of suitable feedstock. Large-scale production has not yet been commercialised. But it is obvious, that there is potential to substitute considerable parts of European fuel consumption by the BTL route. Many research activities can be observed in this field, for example at the Research Centre Karlsruhe, where the corresponding BTL process is licensed under the name Bioliq.

Several other routes for the conversion of biomass are developed and applied; it is not possible to give the full picture in this report. It should only be briefly mentioned is that promising approach is the conversion of biomass into Syngas or synthetic natural gas. Further, there is the option to turn wet biomass into biogas, which then can also be upgraded to natural gas quality (see also chapter on CNG).

Challenges, controversies and barriers

There are several serious controversies: Firstly, the large-scale application of second generation fuels needs to be established, and it is not clear how much time and money will need to be invested. For example, further technological progress is needed to make use of lingo-cellulose as a feedstock. It is also still not fully clear that liquid fuels are the most promising path; the production of biomethane might be another option. The most important controversies, however, are related to the ecological footprint of biofuels and to the competition with food production and natural conversion.

Results from the patent analysis (and other data presented in Del 2)

The patent analysis shows a slightly different and more balanced pattern compared to the ones for electric vehicles, hybrids and hydrogen. The US are in a strong position here. In Europe, France and the Netherlands are nearly as active as Germany.

Outlook

Much remains unclear regarding the prospects of biofuels in the transport sector. It seems clear that biomass will be an important energy carrier in the future; however, it remains uncertain whether the potential of biomass will be used in transport, for power generation or rather for material use. A huge potential for further innovation lies in the area of second generation biofuels. It is likely that biomass will have its role in the future energy and transport system. There will surely be an increasing demand for technology that enable an efficient conversion of biomass into fuels.

4.2.4. CNG, LNG and LPG

Characteristics and relevant developments

The central difference between natural gas and liquefied petroleum gas (LPG) is that natural gas can be found in nature or gained through the production of biogas or bio-methane (Kumar et al., 2011), whereas LPG is an artificial by-product from refining processes or can be extracted from natural gas. LPG, also called Autogas, is a mixture of butane, propane and low amounts of other gases and commonly fuels Otto ICEs. It is important to note that LPG, propane and butane are "automatically" generated during the extraction of natural gas and the processing of methane. So, there is some flexibility in terms of feedstock.

Natural gas is a gaseous fossil fuel consisting primarily of methane (CH_4). It nearly needs no processing for the use in automobiles which is a decisive advantage in terms of feasibility. Since the energy density of natural gas is low compared to diesel, the fuel has to be stored in compressed form as so-called compressed natural gas (CNG) or liquefied natural gas (LNG) at a very low temperature of -161 °C.

Natural gas is a gaseous fossil fuel consisting primarily of methane (CH4). It nearly needs no processing for the use in automobiles which is a decisive advantage in terms of feasibility. CNG is discussed as cleaner alternative to diesel cars, mainly because of lower emissions of particulate matters and NO_x .As regards energy balance and GHG emission, a report form the JRC (2011, 6) concludes for CNG: "Today, the WTW emissions for CNG lie between gasoline and diesel, approaching diesel in the best case. Beyond 2010, greater efficiency gains are predicted for CNG vehicles, especially with hybridisation. WTW GHG emissions become lower than those of diesel. WTW energy use remains higher than for gasoline except for hybrids for which it becomes lower than diesel." The report further emphasises, that the origin of natural gas and the supply pathway are critical to the overall WTW energy and GHG balance. An assumption for the calculation is that the gas is transported over an average distance of 4.000 km. On this basis, Krail and Schade (2011, 283) calculate a reduction of 54 Mt of CO_2 in 2050 by replacing conventional with CNG cars.

LNG offers a higher energy density than CNG, but CNG is much easier to handle. CNG can be transported in pipelines over long distances; the transport of LNG in specialised "reefer" vessels becomes more and more common but is comparatively costly. In terms of security the storage of both CNG and LPG is not dangerous. The advantages of LNG are summarised in the European commission alternative fuel strategy as follows: "Natural gas in liquefied form (LNG) with high energy density offers a cost-efficient alternative to diesel for waterborne activities (transport, offshore services, and fisheries), trucks and rail, with lower pollutant and CO2 emissions and higher energy efficiency." (CEC 2013c)

In several countries LNG is high on the agenda. For example in the Netherlands in 2012 a Green Deal was supported by the new government that aims at wider application of natural gas in the transport sector (TNO et al. 2013). The goal is to achieve the usage of 2.5 million tons of LNG in 2025 in the Netherlands. This would substitute 10-15% of the diesel use in the transport sector. TNO et al. (2013) point out that several studies indicate that this kind of LNG volume is only realistic for 2030 or later.

An advantage of natural gas or rather of methane is that it can as well be produced from renewable sources. Biogas can be derived from biomass. The main components of biogas are methane with 50 to 60% and CO_2 with 40 to 50%. In addition, it contains several trace elements. By separating CO_2 and the trace elements, it can be cleaned to the quality of natural gas, which consists primarily of methane (CH4). Thus, biogas can be mixed with natural gas, distributed with the same infrastructure and burned in Otto engines that run on natural gas.

Recently, the so called power-to-gas route is subject of several research and demonstration projects. In first demonstration plants field trials (for example in Frankfurt a.M./ Germany) wind power is used to produce hydrogen via electrolyse whereby an efficiency of more than 70% is reachable. Up to a certain amount the hydrogen can be stored in the natural gas network. It is also possible to use hydrogen for the production of natural gas via process called methanisation. The process needs additional CO_2 that could be gained from fossil fuel burning power plants (carbon capture and usage (CCU)). The transformation process of wind power to natural gas is possible with an efficiency of above 60%.[5] So, this process provides either hydrogen or renewable gas (methane) for a variety of applications. Both products can be employed in the transport sector. Of course, the electric power could also be used directly to charge BEVs. These kinds of approaches need to be fostered since they are highly relevant for the transformation of the energy system.

Challenges, controversies and barriers

The JRC estimates that infrastructure and market barriers (e.g. cost, acceptance) are likely to be the main factors constraining the development of CNG (JRC, 2011, 6). Other aspects seen as important are governmental support (e.g. tax shelters) and in general the higher vehicle costs (Palmer et al., (2010).

The commercialisation of CNG cars is surely hampered by the lack in filling station in Europe, even if the situation has improved over the last years. Further, CNG car provide lower ranges than conventional cars. However, bivalent cars are also on the market. They usually have a small gasoline tank that can be used by moving a switcher when the gas tank is empty.

Both, CNG and LPG are fossil fuels, as long as they are not produced from biomass. Some observers see Natural Gas as the next dominant fossil fuel on a global scale. On the other hand, it is argued that Natural Gas and also LPG are imported to a large extent in the EU from politically sensitive regions which significantly reduce their potential contribution to Europe's mid-term energy security. If you consider the phasing out of coal (and nuclear power in some countries), the overall demand for Natural Gas is expected to grow strongly and it's use for transport has to compete with its application for the generation of electricity and heating.

Results from the patent analysis

No specific data available

Outlook

In particular for the shipping sector, LNG might become an alternative in future, but also the usage in the trucking sector is considered. At any rate, an increased market penetration of LNG strongly depends on the provision of the necessary infrastructure for storage and

[5] See http://www.greenpeace-energy.de/engagement/unsere-gasqualitaet/die-technik.html

fuelling. For a large scale deployment of LNG, considerable investments in infrastructures are needed. The Commission (CEC 2013c) recently supported the strategy to implement LNG in 139 TEN-T core ports (inland/maritime) until 2025; in the same alternative fuel strategy it is stated that LNG truck filling stations should be located every 400 km on TEN-T core roads.

The example of power-to-gas illustrates well that there is a clear potential for further innovation in relation to a renewable production of natural gas. Given that future energy systems will have to integrate large amounts of fluctuating renewable power (such as wind and sun), flexibility in relation to production, storage and fields of usage will become an even more important requirement for energy carriers. It is well imaginable that natural gas will pay a significant role in the transport system of the future. As regards natural gas supply the EU is strongly depending on non-European countries, which might be an additional motivation to foster the renewable production of natural gas inside the EU.

4.2.5. Methanol

Characteristics and relevant developments

Methanol is discussed and tested as a transport fuel for longer times, since it offers a range of advantages compared to conventional fuels. The main reason of considering it as being relevant for FUTRE is related to the high flexibility not only in terms of its usage but also in terms of its generation. Besides industrial production from natural gas and coal, methanol can be made from anything that is, or ever was, a plant. [6] So, in contrast to electric energy it offers an option to store renewable power in a convenient way. Furthermore, not too many changes in infrastructure are needed for large scale commercialization.

Methanol can be produced from a wide range of feedstock, including different forms of renewable energy. Typical routes are the production via CNG or from biomass. Other options are imaginable, such as the generation of methanol from hydrogen and carbon dioxide, with a relative unfavourable overall energy balance, but with the advantage of producing a clean fuel and, at the same time, enabling a sort of $C0_2$-recylcing. Olah (2010) is a prominent supporter of this idea of a carbon-cycle based on methanol. The different conversion steps go at the expense of the energy balance. But of these pathways argue that surplus energy for example for wind power in off-peak hours could be used. In Iceland, Carbon Recycling International (CRI) recently built a plant utilizing CO_2 flue gas and electricity from a geothermal power plant to make renewable methanol for vehicles and trucks. The plant, which produces around 2 million litres of Renewable Methanol (RM) per annum, was completed at the end of 2011.[7]

The burning of methanol in conventional engines only requires small modifications. It can be used in blends together with conventional gasoline or in its pure form. Extensive field trials were made in California the 1980'ies and 1990'ies, but were then abandoned because of several reasons, amongst them the low prices of conventional fuels. Methanol can as well be used in fuel cells. There is as well the option to use it in a Direct Methanol Fuels cell (DMFC). A different concept is using methanol for on-board energy storage only. An on-board reformer is then producing hydrogen from the methanol. The hydrogen can then be used to fuel a Proton Exchange Membrane Fuel Cells (PEMFC). Further, there is the option to use methanol via Dimethyl ether (DME). It is the simplest of all ethers. Its heating characteristics

[6] http://www.methanol.org/Energy/Resources/Alternative-Fuel/Methanol-Flexible-Fuel-Vehicles.aspx

[7] http://www.carbonrecycling.is/index.php?option=com_content&view=article&id=14&Itemid=8&lang=en

are similar to those of natural gas. Currently, DME is produced mainly from natural gas-derived methanol. DME can also be manufactured from methanol derived from coal or biomass; the production is similar to that of methanol and can be based on a broad variety of pathways. DME can be liquefied by low pressure and then used in diesel engines. Thus, it is also usable for trucks and buses.

Storage and distribution would be quite similar to that of LPG. As a fuel for compressed ignition engines it has very attractive characteristics such as clean burning and producing virtually no particulates. “DME can be produced from natural gas or biomass with better energy and GHG results than other GTL or BTL fuels. DME being the sole product, the yield of fuel for use for Diesel engines is high.” (JRC, 2011, 7).

Challenges, controversies and barriers

Methanol is the simplest alcohol; it is a light, flammable and toxic liquid. It is one of the safest fuels, because it is much less flammable than gasoline. A serious disadvantage is the fact that methanol is toxic. Another problem is its corrosivity to some metals. Methanol is playing an important role in the chemical industry. The largest use of methanol by far is in making other chemicals. There is profound experience in handling and storing of methanol.

Still, controversies are related to the safety in usage and to the toxicity of Methanol. If methanol is generated from biomass, controversies similar to those described in the biomass pathways emerge. The hydrogen/CO2 pathway is critically discussed in terms of energy balance and economic feasibility.

Results from the patent analysis (and other data presented in Del 2)

No specific data available.

Outlook

It was mentioned in the section on hydrogen that, in 2003, Jeremy Rifkin envisioned the hydrogen age in his book on the hydrogen economy. In a similar way George Olah argued for methanol in his book called “Beyond Oil and Gas: The Methanol Economy” (Olah, 2010). As for other alternatives to fossil fuels, the future role of methanol strongly depends on developments in the energy system. Methanol is extremely flexible in terms of feedstock, but so is hydrogen, electricity or methane. The striking advantage is that is allows for energy storage in liquid form. It offers an easily manageable form of storage with relatively high energy density per volume and per weight. Key questions are whether there will be a need to store large amounts of energy in form of Methanol and whether there will be strong demand for liquid fuels in the future? This surely depends on the general development of the energy systems in European countries and it depends on the technical and economical progress that is made in the fields of batteries and hydrogen/fuel cells. Attracting investments in plants such as the one built in island also depends on the development of the European carbon trading systems. If emissions of CO_2 will become more expensive companies such as Carbon Recycling International (see above) might be in position to derive revenues from the carbon credit and renewable fuel markets.

4.3. Improving the means of transport

For all transport modes, innovations can improve the means of transport, i.e. the respective vehicles, mainly contributing to improved efficiency. The innovation field at hand is about any other innovations contributing to more efficient means of transport. This includes e.g. lightweight materials, improved aerodynamics and new construction technologies.

Alternative fuels and innovative propulsion technologies, service innovations easing or changing the usage of existing modes of transport, and infrastructure innovations as well are covered in their separate innovations fields (sections 4.2, 4.5 and 4.6, respectively).

Relevance for FUTRE

Efficiency gains for the different means of transport can be of direct relevance for users in the transport system. Changing vehicle characteristics, varied operational costs as well as lower production costs through innovative measures can influence the relative advantages of transport modes and affect users' mode preferences. From the perspective of the European transport industry, innovativeness in improving the means of transport produced by this industry will be an important factor to stay or become competitiveness in a worldwide competition.

While small and incremental improvements are important as well, a focus of this innovation field is on radical innovations. Wide-scale application of lightweight materials in car manufacturing could e.g. require new car designs from total scratch, with a disruptive character compare to familiar car engineering. Overall, this innovation field is clearly about product innovations, with process innovations additionally contributing to improved manufacturing processes for these products.

Because this innovation field is so much about radical innovations, it is as well sensitive. The breakthrough of technologies cannot be planned right away and additionally, venturing into new technologies does not promise to be rewarded. This is particularly valid in an international perspective. However, this can also be an opportunity. The lead market concept described in (Condeço et al., 2013) (FUTRE Deliverable 2.1) points at the chances that reasoned regulation e.g. on efficiency standards can open by stimulating targeted innovation and providing the basis for the creation of lead markets that can serve as the starting point for becoming and staying competitive in a specific field.

Characteristics and relevant developments

For reasons of readability, the description of the characteristics and relevant developments in this innovation field will follow the different transport modes.

In the road transport sector, and beyond alternative fuels and propulsion systems, various technological developments are expected to improve the efficiency of road vehicles, mainly the environmental efficiency. In the passenger car sector, these developments include improved heating and cooling management (10% / 14%), lightweight construction (8% / 17%), improved aerodynamic construction (7% / 9%), the electrical systems (5% / 7%), and drive and transmission technologies (3% / 6%), with the numbers in brackets indicating potential relative CO_2 emissions savings until 2020 / until 2050 according to (Akkermans et al., 22.02.2011, p. 34). Aerodynamic design is particularly relevant as well for road freight transport by truck, with expected CO_2 emission savings ranging from 2% up to 10% according to (Law, Jackson, & Chan, 17.01.2012). Like this, several other innovations from the passenger car sector can as well be applied to trucks; however, so-called 'mega-trucks' offer an additional potential of improving truck efficiency. Such trucks are longer and heavier than conventional trucks (up to 25.25m length and up to 44t load) and recent EU legislation roughly points towards the introduction of such mega-trucks (cf. CEC, 15.04.2013), but controversies remain if mega-trucks could cannibalize the even more efficient freight transport on rail and inland waterways.

Other studies support the increasing importance of lightweight materials in the car sector, which reflects well the higher demand for lighter cars induced by CO2 regulations and the envisioned market penetrations of BEVs. For example, McKinsey (2012) states that in 2010 30% of a car is built of light weight components; the same study assumes this value to rise up to 70% in 2030. At the same time, a strong reduction in production costs is assumed for light weights. In an "aggressive" scenario the cost difference between carbon and aluminium parts is projected to go down from 77% in 2010 to 26% in 2030.

In the railway sector, main innovations relate to the issues of lower aerodynamic drag, lowered train mass (e.g. by lightweight materials), energy recovery (during braking), space efficiency for passenger trains and higher loads for freight trains, and improvement of the energy efficiency of the train equipment and supply systems (Schäfer et al., 27.05.2011, p. 7, see Annex 1 for more detailed innovation descriptions).

In aviation, many potential innovations again relate to the introduction of alternative fuels, but significant efficiency improvements could also be achieved through radically new aircraft designs. The so-called flying wing, where the crew, passengers and other load, and most of the equipment is placed inside the main wing structure, are expected to significantly reduce the energy consumption per passenger or ton kilometer (Åkerman, 2005). However, until now this is only a long-term perspective.

In the shipping sector, additional R&D and ongoing developments in new technologies over the last few years as triggered by the International Maritime Organization's (IMO) regulations may lead to a more efficient usage of energy in the maritime transport sector. New developments include supportive technologies are being discussed that add to the conventional engines, e.g. Skysails or Flettner rotors. New propeller designs can as well be used to make the water flow more efficient. Beyond technologies directly used to propel the ships, innovations relate to operational changes (e.g. slow steaming and weather-dependent routing) or lower steaming resistance by improved hull design or even by air lubrication (Edelmann & Schippl, 2013). Following the assumptions from several studies (AEA Energy & Environment, 2008; Buhaug et al.; Faber et al., 2009; Alvik, Eide, Endresen, Hoffmann, & Longva, 2010; Eide et al., 2013; International Council on Clean Transportation, 2011; Bazari & Longva, 2011), fuel consumption reductions as well as reductions of CO_2 emissions from vessels can be expected in the range of 30-55% by 2030 (Haifeng & Lutsey, 2013, pp. 7f.).

Innovations apply both to maritime shipping and inland shipping, and often inland shipping benefits from developments in the maritime shipping market. However, because of the small market and long service lifetimes of inland ships, market penetration of new technologies in the inland shipping sector is slower and more restricted by economic constraints. In general, the long lifetime of ships is a challenge for the uptake of innovations, but recent studies as well reveal complex relationships between average fleet ages, actual fleet usages and GHG emissions (Haifeng & Lutsey, 2013, p. 16). Further details regarding the shipping sector can be found in (Edelmann & Schippl, 2013).

Challenges, controversies and barriers

The breakthrough of new technologies generally is a challenge. While e.g. the lead markets concept introduced in (Condeço et al., 2013) (FUTRE Deliverable 2.1) suggests that regulation can stimulate innovation, the concept's second step, namely the creation of first-mover advantages and a respective lead market through such innovation is more controversially discussed. The use of Innovative technologies often increases the cost of a product and it depends on the market situation and regulations whether such an innovation becomes competitive. For FUTRE it is therefore be crucial to reasonably assess potential innovations' impacts on competitiveness (see chapter IV).

Besides the success or failure of specific innovations or technologies, the benefits of innovations have to be carefully balanced with negative side-effects and other negative implications related to their introduction. This is illustrated by the case of lightweight materials in car manufacturing. Lightweight is only one goal in car construction;

performance indicators such as crashworthiness and cost-efficiency are other characteristics that have to be considered (Cui, Zhang, Wang, Zhang, & Ko, 2011). Moreover, a life-cycle assessment study by (Witik, Payet, Michaud, Ludwig, & Månson, 2011) concludes that despite mass reduction and corresponding fuel savings during the life-span of the respective vehicles lightweight materials can be problematic and have negative environmental impacts due to the high energy input during production and due to the difficulty of recycling such materials. The issue of recycling is also addressed by (Sakundarini, Taha, Abdul-Rashid, & Ghazila, 2013) who demonstrate a multi-material selection approach that explicitly considers recyclability and therefore provides an example for the necessary multi-criteria decision process in introducing innovations.

Beyond all expected progress in improving the existing means of transport, foreseeing radical innovations and new means of transport remains a crucial challenge. The Hyperloop proposed by Elon Musk, CEO and product architect of Tesla Motors and CEO and chief designer of SpaceX, provides an example for such radical innovations (cf. Musk, 12.08.2013). The proposed concept of small capsules circulating in low pressure tubes is suggested by (Musk, 12.08.2013) to be a faster and still more cost-efficient alternative to air travel and high speed railway lines for distances below 1,500 km. However, experts underline that similar ideas have spread around the world in the past without becoming reality, e.g. the so-called 'Swissmetro' (Messikommer, 13.08.2013). The Hyperloop concept could share the same experience and proves to be very optimistic particularly when referring to costs, as neither emergency exits nor rescue concepts are reflected in the current proposal that would increase the cost at least fivefold, according to (Messikommer, 13.08.2013). Assessment of such far-away innovations remains therefore difficult and uncertain.

Results from the patent analysis

Three of the technology areas considered in the patent analysis relate to improving the means of transport: Rail-bound innovations[8], aviation and material efficiency (cf. Condeço et al., 2013). In contrast to some more specific technology areas in the patent analysis, all three belong to the broader technology areas which might give reason for them not to show specific dynamics in the past (Condeço et al., 2013, p. 93). Aviation and rail-bound innovations show high shares of patent applications coming from European countries, with a German focus on rail-bound innovations and a French focus on aviation (Condeço et al., 2013, p. 96; see Figure 2, p. 29). Among the EU countries Austria, Spain, Germany and the Czech Republic show a patent specialization in rail-bound innovations; France, Great Britain and Spain show a specialization in aviation; and Latvia, the Czech republic and Austria show a specialization in material-efficiency (Condeço et al., 2013, p. 98). Further details and numbers can be found in (Condeço et al., 2013) (FUTRE Deliverable 2.1).

Outlook

Until 2030, developments can be expected to focus on incremental improvements of existing technologies. A reason for this is that improved efficiency of existing vehicle types is the "most cost-effective strategy for reducing emissions and fuel use" (Romm, 2006, p. 2609) in the near future. However, a more heterogeneous vehicle fleet is expected as e.g. electric propulsion (see also section 4.2) will increasingly spread to a multitude of vehicle types like motorbikes, bicycles or delivery vans (Grünig, Witte, Marcellino, Selig, & van Essen, 27.04.2011, p. 61), and some of these developments can already be seen today. In the shipping sector, efficiency gains (particularly for inland water transport) can be expected from the European NAIADES II initiative (CEC, 2013a).

[8] Rail-bound innovations also include certain rail-bound infrastructure innovations or innovations that closely link the means of transport with infrastructure requirements like magnetic levitation trains (Condeço, Vieira, Krail, Reichenbach, and Schippl (2013, p. 92)).

More radical innovations as well can be observed already today, e.g. the Renault Twizy car model that comes with a new style of a small and lightweight electric city car. However, a wide-scale roll-out of such new vehicle concepts that are radical in certain way and that have the potential of significantly affecting usage patterns etc. can only be expected in the mid-term to long-term horizon, i.e. after 2030. This is consistent with the findings of (Akkermans et al., 22.02.2011, p. 34) who state that e.g. lightweight construction will only achieve its full efficiency gain potentials of 17% by 2050, although already 8% are expected until 2020. Breakthroughs of new means of transport (cf. the Hyperloop example above) as an even more radical kind of innovation can also be expected only in the long-term horizon, despite the general uncertainty of respective assessments as outlined above.

4.4. Intelligent transportation systems

In December 2008 the European Commission published an Action Plan to foster the deployment of intelligent transportation systems (ITS) in order to curb road fatalities, reduce congestion and greenhouse gas emissions. Since then, ITS is ranking high on the agenda of European transport policy. ITS "are advanced applications which without embodying intelligence as such aim to provide innovative services relating to different modes of transport and traffic management and enable various users to be better informed and make safer, more coordinated and smarter use of transport networks. ITS integrate telecommunications, electronics and information technologies with transport engineering in order to plan, design, operate, maintain and manage transport systems" (European Parliament & European Council, 2010, p. 1). ICT plays a significant role in improving and supporting transport and might contribute to a cleaner, safer and more efficient and accessible transport system. However, the idea of ITS is not new, applications exist since the 1990s, e.g. in form of transport telematics. Some member states of the European Union have already been making extensive use of these applications, though deployments remain fragmented and uncoordinated throughout the European Union and beyond. The novelty of today's developments is the vision to set up an EU wide integrated framework that aims to realise synergies between previously isolated systems (Crainic, Gendreau, & Potvin, 2009); and indeed on a European level cooperation is increasing (CEC, DG Mobility and Transport, 2011).

Main aim of ITS is to increase reliability and efficiencies (cost-efficiency, efficiency of use, energy efficiency), as well as to reduce congestion and accidents (Böhmann et al., 27.04.2010).

Relevance for FUTRE

The developments in this innovation field correspond to FUTRE's requirement of analysing such innovations that have systemic effects on the transport system as a whole. Advanced logistics and improved traffic management and information systems can be used to (Huschebeck, Piers, Mans, Schygulla, & Wild, 2009; WWF Sweden, 2008):

- Make public transportation more efficient;
- Substitute physical travel by digital information flows;
- Optimise travel patterns and improve driving styles;
- Increase flexibility and quality of systems;
- Enable the collection of user charges;
- Optimise the energy use of travel modes;
- Optimise logistic chains;
- Improve traffic flows;
- Promote co-modality or modal shift to less polluting modes of transport;
- Reduce road fatalities;
- Exploit new technologies (such as RFID, Smart Tags or advanced ICT platforms).

Characteristics and relevant developments

Today, there is a wide variety of applications for the different modes of transport. In order to categorise the different ITS applications; four key areas can be distinguished:

- Pre- and on trip travel information
- Cargo and vehicle tracking and tracing
- Cooperative systems
- Urban logistics (see section 4.5.3)

In the following, an overview of the most relevant developments will be given. ITS is a cross-cutting issue that touches upon most other areas described in this deliverable. This chapter should therefore serve as an overview on relevant developments that are seen as promising.

Pre- and on trip travel information

In-vehicle information systems inform the driver either before or during the trip about relevant door-to-door information, including travel conditions, such as congestion, weather conditions or real-time traffic flow. This allows users to take well-informed decisions on which route to take or which mode to use. As such it allows drivers to dynamically change route, to cope with a foreseeable situation on the route or it enables the forwarding agent/ person to select a different mode of transport. In doing so, pre- and on-trip travel information might lead to less fuel consumption, fewer km travelled and eventually to time savings. Multimodal journey planners e.g. provide door-to-door information on several modes of transport, including public transport and non-motorized forms of transport. Several national approaches exist but there is yet no European-wide travel information for interconnections across Europe. This might facilitate multimodal travelling.

Regarding motorized transport, in-vehicle information can be used to avoid congestion and to reduce accidents by better informing motorists on unexpected traffic situations and thus allow drivers to better anticipate or avoid dangerous situations. Another aim of information systems is navigation. Dynamic route planning for example allows carriers to find the best possible route for each delivery job. Due to the information available on current truck loadings (e.g. through RFID/ GPS equipped goods) and on travel conditions, a system can ideally react on sudden changes of supply, for instance if new or cancelled deliveries or pick-ups need to be integrated into the route. The benefits of dynamic route planning are that it can reduce distances that must be covered while at the same time lowering the time required to complete a tour (Puhe & Schippl, 2010). For a full deployment of in-vehicle information systems the whole network of motorways had to be equipped with sensors to collect the necessary information. (Böhmann et al., 27.04.2010) question whether it is ever possible to reach a 100% coverage of the road network by stationary sensors. However, already today a lot of roads are equipped with such sensors, but they still show some restrictions, especially for freight transport. Recommended alternative routes are often not suited for heavy vehicles (Böhmann et al., 27.04.2010).

The impact of pre- and on-trip travel information depends on the diffusion of technology, the number of times the data is accessed by users and on how the information actually influences travel behaviour (Böhmann et al., 27.04.2010). In principle more data than ever before is available, but it is often difficult to actually receive access to this information as this requires access to different sources of information with a variety of commercial and legal conditions (van de Ven, Tom & Wedlock). Therefore, main task is to define the roles of the private sector and the public authorities as well as to set up the rules for cooperation on data exchange (CEC, DG Mobility and Transport, 2011).

Cargo and vehicle tracking and tracing

Cargo and vehicle tracking is the ability to trace goods from origin to destination. Main aim of tracking vehicles and cargo is to improve accountability and to enable improved freight management. The (CEC, 2007) denotes the vision of a "paper-free, electronic flow of information associating the physical flow of goods with a paperless trail built by ICT. It includes the ability to track and trace freight along its journey across transport modes and to automate the exchange of content-related data for regulatory or commercial purposes." (CEC, 2007, p. 3). This idea is also known as "e-freight". Technologies are needed that spot the location and condition of goods and vehicles online. It is linked to information transfer using either discrete tracking systems (Barcoding or RFID) or continuous tracking systems (GPS or GSM). It is an important element of supply chain planning, as it allows identifying the actual status of shipments or goods during transportation (Kandel & Klumpp, 2012).

RFID tags or barcodes are a common solution to store and provide information or data about products. RFID tags are, however, far superior to barcodes, as they can also process data or communicate with other RFID tags and are thereby compatible with existing contactless infrastructure. RFID systems consist of a reader that can wirelessly read and write data, in real-time, to a RFID tag using radio waves. Real-time indication of processes and flow of goods is fundamental for freight transport and a basis for process improvement (Puhe & Schippl, 2010). RFID or barcode equipped products are, however, only tracked at predefined fixed positions, whereas GPS or GSM localize the position of the vehicle or good at any time. These solutions can both be combined, e.g. when the shipment is equipped with discrete tracking systems and the vehicle itself is equipped with a continuous tracking system. This is the case for the "Smart Truck". The truck uses RFID sensors on-board the vehicle and optimises its own route by satellite-based positioning data and additional real-time data on traffic flow. This enables the respective driver to deliver in the most effective way; (Deutsche Post AG, 24.09.2010, p. 91) estimates the potential CO_2 emission savings to be around 10–15 %.

Cooperative systems and other applications

Advanced ITS technologies are as well a basic requirement for the automation of road transport. Beyond technologies such as free-flow tolling, an infrastructure application communicating with vehicles to collect toll electronically, cooperative system technologies also allow to directly influence and control the driving behaviour of vehicles. The characteristics of this kind of ITS applications are described in more detail in section 4.1 (Automation of road transport).

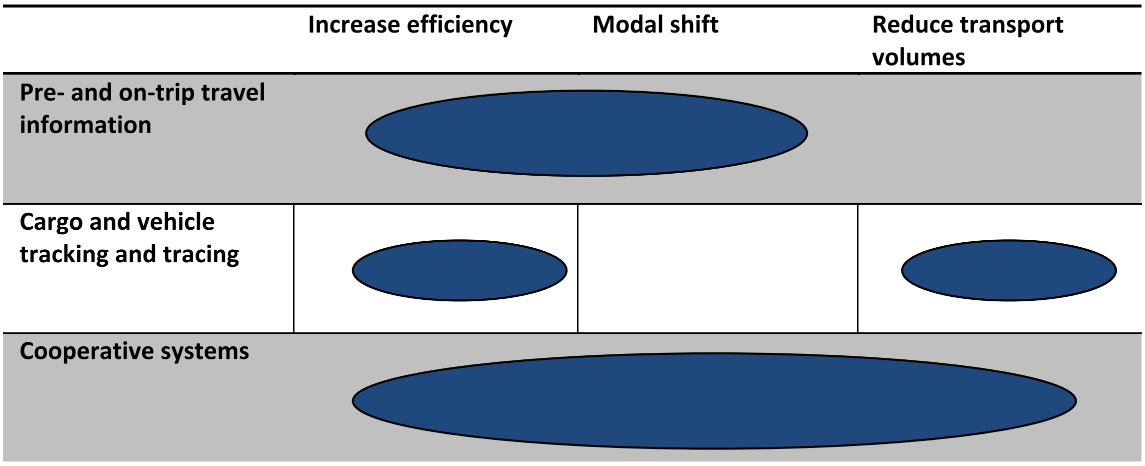
Additionally to the developments described in this chapter, many other ITS applications come into practice in urban areas. Many of them are linked to innovative business models and organizational approaches aiming at fostering modal shift or setting up new distribution opportunities. Several of these applications are therefore described in section 4.5 (Services & organizational innovations).

Challenges, controversies and barriers

ICT have definitely a great potential to support sustainable development. However, critical mass market needs to be reached in order to exploit its potential. Therefore, interoperability is needed and common specifications and standards need to be developed, also on a global scale.

Though, several authors emphasize that it could also hold the risk of becoming counterproductive to environmental sustainability. It is reasonably assumed that it might generate new transport demand because travelling becomes easier and more enjoyable, as well as to increased urban sprawl as it is no longer necessary to live in proximity to office or shopping facilities (see e.g. Banister & Stead, 2004; Black & van Geenhuizen, 2006; Hilty, Som, & Köhler, 2004). According to (Hilty et al., 2006) ICT applications have to be implemented by taking into account the interactions between the developments of ICT and its impacts on socio-economic systems.

Figure 5: Impact of ITS application areas on transport system. Source: own figure.



Results from the patent analysis

The technology area of new mobility concepts includes data processing to optimize the operation and facilitate the use of public transportation, and navigation systems (identifying the most efficient route). Patents in this area are therefore relevant for the innovation field. However, new mobility concepts form one of the broader technology areas in the patent analysis, so that dynamics in the past are more difficult to analyse (Condeço et al., 2013, p. 93). In the European comparison, Austria shows a patent share in this area above average; but in an international perspective, the United States dominate this area (see Figure 2, p. 29). While there are no dominant companies in this field, Finland and Ireland show a significant patent specialization in this area (Condeço et al., 2013, p. 98). Further details and numbers can be found in (Condeço et al., 2013) (FUTRE Deliverable 2.1).

Outlook

According to the (European Road Transport Research Advisory Council, 2009), several ITS elements will be commonly implemented before 2030, both, at the vehicle/ infrastructure level as well as the systems level (e.g. for logistics management). The authors propose that fuel consumption reductions of 10 – 20% are possible by ITS solutions. Most potential is seen for tracking and tracing technologies, the authors estimate that half of the personal vehicle fleet and most of the freight vehicle fleet will be equipped with vehicle positioning technology. But as well for cooperative systems the authors see potential and estimate that V2V and V2I communication will be common and reduce the number of road fatalities notably. However, road authorities definitely play a decisive role in this. It is only when they decide to install intelligent infrastructures that the automotive industry will develop features in their vehicles to communicate with that infrastructure (Bouwhuis, 2012).

4.5. Services & organizational innovations

Service and organizational innovations in transport refer to enhancements in the logic of use and accessibility of different transport modes. It is, however, difficult to quantify the effects of organizational approaches on the overall efficiency of the transport sector, again because of possible rebound effects. Though, they have the potential to:

- bring together demand and supply in a more efficient way (e.g. through better load factors, more efficient use of vehicles and existing infrastructures),
- modal shift (e.g. by making public transport and freight rail more convenient to use) and
- help to reduce volumes (e.g. through tele-working; video-conferencing)

In passenger transport, the car is still the most dominant means of transport. Compared to the car, public transportation is often perceived to lack in flexibility. The car offers individuals to autonomously decide where to go and at what time. Public transport on the other hand is determined by specific routes and fixed timetables (Maertins & Schmöe, 2008). Information and communication technologies (ICT) promise to enable more flexible solutions to their users, accommodating more individually the user needs, according to given circumstances. Service and organizational innovations enable individuals to decide more independent from time and organisational constraints which mode of transport to use for a certain trip. However, such concepts should match common lifestyles, support existing routines; services should be easily accessible and easy to understand (Maertins & Schmöe, 2008).

In passenger transport, concepts that represent organizational innovations either relate to the ownership of vehicles (e.g. car- and bikesharing) or the access to public transport (e.g. integrated information portals and ticketing). For freight, a variety of innovative approaches to make freight transport and delivery more efficient is changing traditional logistic businesses; these approaches are described further below.

Correspondingly, the broad variety of services and organizational innovations gives reason to analyse a number of prominent approaches separately. The following subfields are considered in this deliverable:

- Vehicle sharing
- Integrated ticketing
- New logistics concepts

Relevance for FUTRE

As outlined above, services and organizational innovations bring together supply and demand in a new way. In particular the shift from vehicle ownership towards vehicle usage is rather radical and can be expected to become systemically relevant in the future: The transport sector's space demand in dense city areas might be reduced and manufacturers will have to face challenging adaptations of their business models. Also in the freight sector, new logistics concept will be a significant challenge for the respective industries to adapt logistic chains and their business organizations. The innovations in this field are therefore clearly relevant for FUTRE.

Results from the patent analysis

The patent analysis results from (Condeço et al., 2013) regarding the technology area '(new) mobility concepts' are reflected in the innovation field 'Intelligent transportation systems' because the patents reflected in this technology area focus on data processing and navigation systems and are therefore less suitable here.

4.5.1. Vehicle Sharing

Vehicle sharing is a mobility concept that enables users to use a (passenger) car or a bike at any time, without the need to individually own that vehicle. Members have access to a vehicle fleet from which they choose and book a vehicle for a specific period of time. Payment is usually based on time and mileage. In the early days of car-sharing, booking was done on the telephone. Nowadays, internet booking is common and most organizations offer modern applications for handheld devices. Even though, the idea of sharing vehicles is not new, developments in information and communication technologies have radically facilitated access to shared vehicles. While in the early days of car- and bike sharing, users as well as operators were primarily ecological oriented, nowadays users tend to be much more milieu-indifferent. For car sharing it can be said that the typical user is male, between 26 and 49 years old and has a good formal education. The environment is not the main reason for subscribing to a car sharing scheme anymore, cost considerations and convenience are becoming increasingly important (Loose, 23.06.2011).

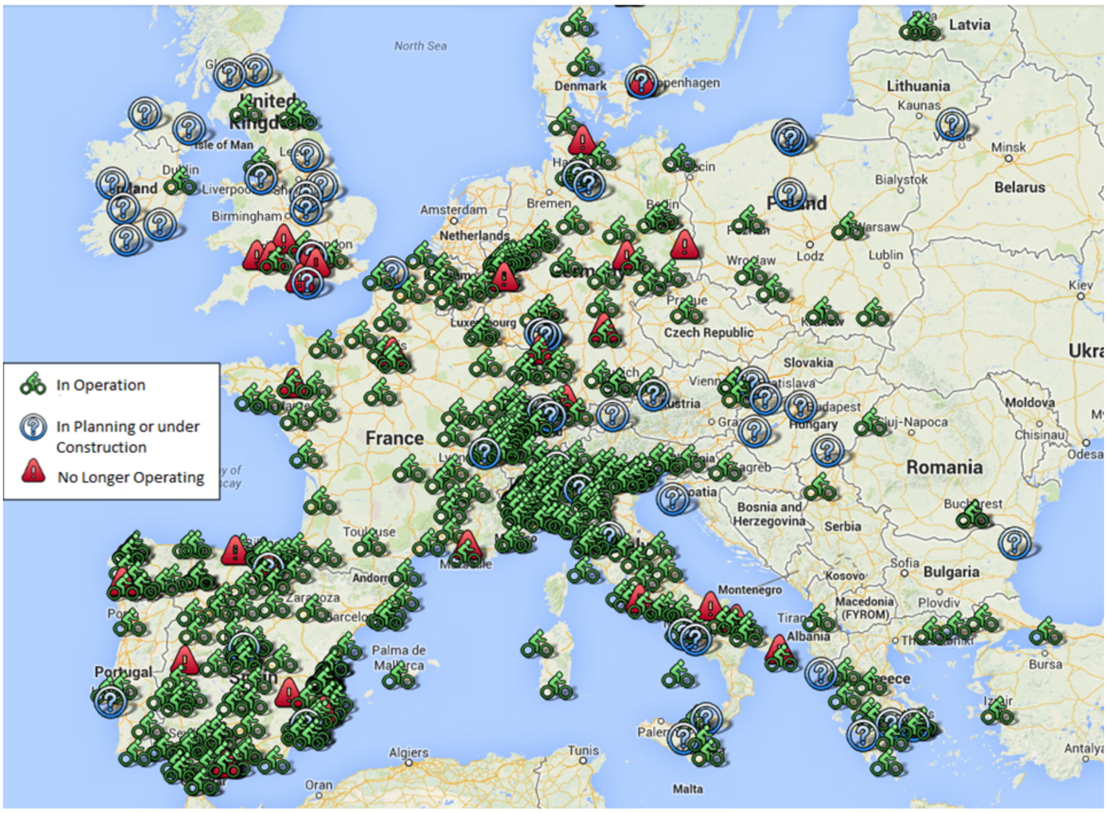
Regarding environmental, wider economic and social benefits, vehicle sharing combines several advantages. Land consumption and GHG emissions are reduced, the number of vehicles in the city can be significantly reduced (Firnkorn & Müller, 2011), and shared vehicles can be a niche market for alternative fuels and propulsion systems. Bike sharing in particular is highly relevant in combination with public transport to assure "last mile" connections and it is relatively inexpensive compared to other infrastructure measures.

Bike Sharing

Characteristics and relevant developments

The main principal behind bike sharing is that individuals can take a bike and return it after usage, either at the same, or at another location for the next person to use it. The last few years have shown constant growth rates in bike sharing schemes all over the world. In 2001 only very few bike sharing schemes existed in Europe, by 2011 about 400 bike sharing schemes have been established in many European agglomerations and regions (OBIS, 09.06.2011) (see Figure 6).

Figure 6: Bike Sharing in Europe. Source: https://maps.google.com/maps/ms?msid=214135271590990954041.00043d80f9456b3416ced&msa=0&ll=51.151786,10.107422&spn=21.864086,39.506836 (access 12.08.2013).



The idea of bike sharing isn't new, the first large scale urban bike sharing scheme has been set up in Copenhagen in 1995, but through the use of smart technologies for reservations, pick-up, drop-off and information service bike sharing gained worldwide popularity. Since the success of *Vélib* in Paris and *Bicing* in Barcelona (both 2007) it has been spread to many other European, Asian and American cities. Interestingly, countries that do not have an explicit cycling tradition operate the largest schemes with the highest usage rates (France, Spain, and Italy); while usage is lower in Central and Northern European countries with its relatively good cycling infrastructure. Very few schemes have been implemented in Eastern European countries. However, successful schemes show that bike sharing can promote a cycling culture as bicycles become a visible transportation mode, moreover it can stimulate public investments in the cycling infrastructure. It is very well suited to solve the "last urban mile" problem. If bike sharing replaces car trips, there is a notable potential for reductions in GHG emissions.

Challenges, controversies and barriers

A number of specific challenges that relate to using bicycles as a shared vehicle are listed below:

- Space is limited, especially for station-based bikes: one solution is mobile stations that can be removed if necessary. Stations need to be very well planned to match user's needs. Planning of stations could be done through crowd-sourcing.
- Redistribution of bicycles is costly; in large scale programmes redistribution costs can make up to 30% of the budget (OBIS, 09.06.2011).
- Bike sharing is possible in the most diverse settings: very dense urban areas and more regional surroundings. This requires the adaptation of systems; a one-size-fits-all approach will not work.

Outlook

Bike sharing systems now exist for a while, and further developments and innovations can be expected as next steps:

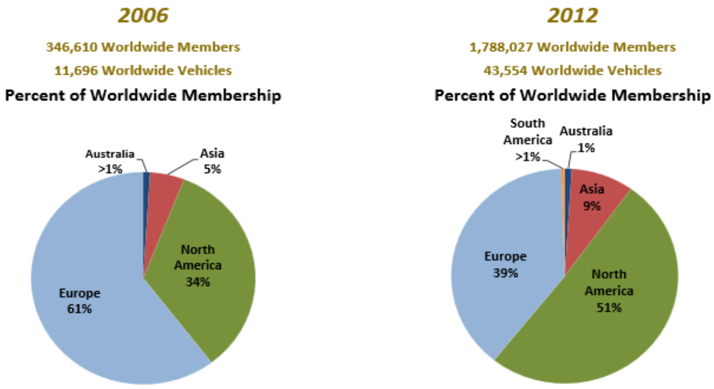
- In addition to shared conventional bicycles, bike sharing can be extended to electric bikes (bicycles with an electrical assistant motor) and also shared cargo bikes; for example, the myloop electric bike share system in Copenhagen promotes GPS-tracked electric bicycles that can be attached to one another like shopping trolleys (myloop, 08.11.2009).
- Bike sharing can be better integrated with other services like public transport. Bike sharing stations could also offer additional services (e.g. sell public transport tickets, maps for pedestrians).

Car Sharing

Characteristics and relevant developments

Car sharing vehicles can be rented by individuals for short periods of time, often by the hour, traditionally from a separate organization. In recent years, nearly all countries that have implemented car sharing schemes have experienced growth rates. Only recently, North America has replaced Europe in being the epicentre of car sharing activity. While in 2006 61% of the worldwide members have subscribed in Europe, in 2012 this share declined to 39% (see Figure 7).

Figure 7: Worldwide Carsharing Then and Now. Source: (Shaheen & Cohen, 05.12.2012).



Most of the concepts are available in urban areas. Today car sharing is available on five continents, in 26 nations and 1.100 cities worldwide (Shaheen & Cohen, 2013). In Europe, car sharing is available in 14 countries with almost 390.000 customers (Loose, 23.06.2011). Even though, car-sharing does not have particularly high shares on modal split yet, there seems to be a huge potential in the market (Frost & Sullivan, 2009). Enormous dynamics in setting up business models and bringing in new players can be observed that accelerate the growth of the market.

While car sharing initiatives have traditionally been bottom-up approaches, more recently other stakeholders entering the market and introduce new business models that can rather be categorized as top-down approaches. Traditional car rental companies like Sixt, Hertz, or Avis (usually renting cars on 24 hours basis) have entered the car-sharing market offering hourly pricing options. In recent years they have begun to set up large scale programs with a clear growth-oriented approach. Acquisitions are taking place and the larger car rental companies are taking over regionally operating car sharing organizations (Shaheen & Cohen, 2013). According to (Shaheen & Cohen, 2013), 4% of the worldwide car sharing membership account for car sharing services based on rental cars.

Likewise most of the biggest car manufacturers have taken up the topic and are trying out new mobility services. BMW, Daimler, VW, General Motors, Honda, Mitsubishi, Toyota, and Peugeot have all entered strategic partnerships or have set up car-sharing programs. This either includes the incorporation of car sharing technology (e.g. RFID readers to identify various users) into car sharing vehicles, acting as a vehicle supplier for car sharing operators or the operation of a car sharing programmes. Daimler was the first to set up a professional car-sharing scheme. The so called car2go is currently serving 18 cities in Europe and North America, being the fastest growing car-sharing company in the world. After 2 ½ years, more than 100.000 users have registered (Daimler, 2013). According to (Daimler, 2013), car2go will expand its services to 40-50 cities in Europe and America within the next five years. Daimler's car2go, BMW's DriveNow, Hertz on Demand, CommunAuto and Autolìb, they all operate so called free floating (or point-to-point) car-sharing schemes, meaning that users can start and end at any point within a specified area, allowing one-way journeys. In October 2012 free floating car-sharing schemes are operated in seven countries worldwide (Shaheen & Cohen, 05.12.2012). (Shaheen & Cohen, 2013) expect that some of the larger car sharing operators will increasingly emerge into multi-national operators. In August 2013, Hertz-on-Demand operates in seven countries (Germany, Spain, UK, France, USA, Canada and Australia), more than any other operator.

However, in some cities, such as in Berlin, a variety of car sharing providers offer their services to the customers. In order to profit from such a variety, a start-up company has developed a car sharing app that integrates all services on one platform to help customers find the closest car, no matter which provider (see http://www.carjump.de/).

Outlook

Since 2007, a new form of car sharing is available. So called *personal vehicle sharing* (or *peer-to-peer sharing*) offers the opportunity to rent out or hire privately owned cars to strangers. In May 2012, 33 personal vehicle sharing operators existed worldwide, with 20 of them being located in Europe (Shaheen, Mallery, & Kingsley, 2012). This form of car sharing also includes an operator, but they do not offer the vehicles, but make transactions among car owners and renters possible by providing the organisational resources needed (e.g. online platform, customer support, insurance, and technology). A great hindrance to this form of car-sharing is the need of the renter to somehow receive the key to the car. Carzapp, a young German start-up company, addresses this issue by providing a hardware solution that enables users to locate, open and close subscribed cars with their smartphone. The key is then located in the glove box (carzapp, 2013). This "unattended access mechanism" can also be provided by lockboxes, key fobs, or smart cards. While traditional car-sharing is usually located in high-density urban areas, personal vehicle sharing has the potential to expand to the suburbs. However, the worldwide potential for personal vehicle sharing is yet unclear (Shaheen et al., 2012).

4.5.2. Integrated Ticketing

Characteristics and relevant developments

Integrated Ticketing has been on the agenda of European transport policy for over a decade now. The transport White Paper from 2001 already notice "to facilitate transfers from one network or mode to another, encouragement needs to be given to the introduction of ticketing systems which are integrated (and thus ensure transparency of fares) between rail companies or between modes of transport (air - coach - ferry - public transport - car parks)." (CEC, 14.09.2001, p. 80). The overarching idea of integrated ticketing is that a number of operators work together and combine their products on a single card, ideally throughout different operating regions. In its electronic version they are able to store information and pursue a multi-service approach. And indeed, many countries have implemented or are about to introduce integrated ticketing systems. In Europe, most of the countries have such a system at least in their capital. However, so far existing schemes have remained relatively small and mutual acceptance is currently not possible (International Association of Public Transport, 11.04.2007). Against this background, standardization is an important term. However, agreeing on the same standards appears to be difficult, especially for operators or countries that have already introduced an integrated ticketing scheme and do not want to give up initial investments they have already undertaken.

Two modern fare media can be distinguished: smart cards and mobile ticketing. Smartcards are still the most common form of integrated e-ticketing; most of them are equipped with RFID technology from a variety of suppliers. For mobile ticketing applications, mobile phones are used as an electronic version of a ticket. Therefore users can send a SMS to receive a ticket, they receive an image that functions as a code (e.g. QR code) or the phone has an NFC chip embedded. For the future it is more likely that ticketing applications evolve to be integrated into bank cards and/ or NFC enabled smartphones. Ticketing is expected to be one of the main drivers to bring NFC technology forward, with public transport being a likely platform to do so. Since most contactless operating systems in public transport use RFID technology, the existing infrastructure is compatible with NFC standards in most cases (sometimes an upgrade for interoperability with NFC is needed). Other features, such as tickets to amusement parks, museums, events, theatres, libraries, fast food restaurants, etc., are also potential applications for multi-application smartcards and NFC and could be embedded into the schemes (Tuikka & Isomursu, 27.08.2009).

The basic idea behind integrated ticketing is that the integration of tariffs, operators and modes has a positive impact on transport demand as the combination of modes and the transfer between them is facilitated for the users. Compared to paper based tickets, e-ticketing is perceived to "be a lot more reliable, convenient, faster and easier to use" (AECOM, 13.10.2011, p. 10). The survey conducted during this project points into a similar direction. Almost 80% of the stakeholders found the idea of an interoperable ticketing system desirable or very desirable. The main factor to impede the development was seen in "uncoordinated institutional action" that almost 65% identified as a barrier for the introduction. Nevertheless, 65% believe that an integrated ticketing system for Europe will come true before 2030. There seems to be a latent public support for integrated ticketing solutions. For instance, the Flash Eurobarometer on the future of transport reveals that one in two EU citizens said they would definitely use public transport more frequently if a single ticket for their complete journey covering all possible modes of transport was available (The Gallup Organization). However, there is at least a reason to doubt that the introduction of integrated ticketing alone will have large effects on modal share. Improvements that are designed to increase reliability, speed, or frequency play a decisive role as well (Redman, Friman, Gärling, & Hartig, 2013). For existing users, however, integrated ticketing could remarkably enhance the quality experience.

Challenges, controversies and barriers

Main controversies result from data security issues. E-ticketing it is not only a means of payment but a source of huge amounts of precise information on peoples travel behavior, spending habits and preferred places to be. This opens up new opportunities in (tailor-made) service provision and for a better exploitation of the network's capacity. On the other hand, it includes potential risks for privacy and data protection.

Outlook

The long-term objective of electronic ticketing supply is to provide a system that does not need any passenger's action. While traditional check-in/ check-out processes require the customer to actively hold the smartcard (or mobile phone) in front of a reader, modern be-in/be-out systems automatically detects and registers the presence of a smartcard in a vehicle. It is then possible to automatically calculate the best price, according to distances, periods and classes travelled.

4.5.3. New logistics concepts

Until 2007, before the economic crisis, freight transport consistently grew faster than the economy (see Figure 8), with road and air transport showing the largest increases (CEC, 2012). From 2009 to 2010 freight transport grew by 5,3%, while the GDP grew by 2% (in comparison: passenger transport shrunk by 1%). Road transport is dominating the EU-27 freight transport sector to a large extent. 46% of all trips are done by road transport (see Figure 9).

Figure 8: Transport growth EU-27. Source: (CEC, 2012, p. 21).

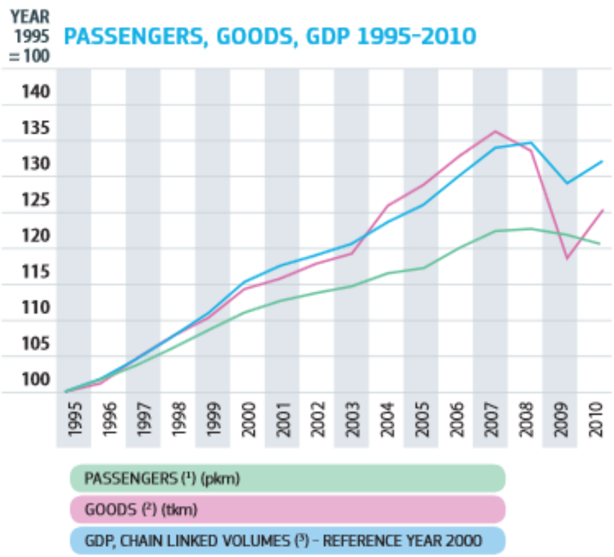
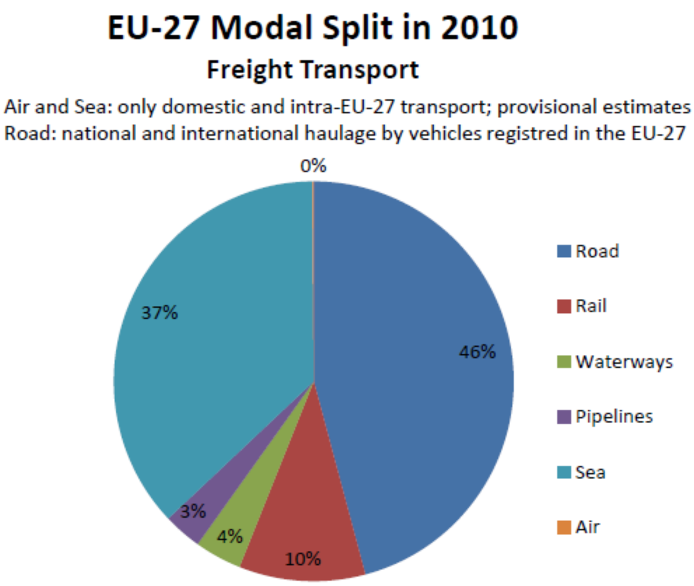


Figure 9: Modal split freight transport. Source: own figure, based on (CEC, 2012, p. 36).



Service and organizational innovations are urgently needed to tackle existing problems. Goods vehicles contribute significantly to congestion, pollution, safety problems and noise. On the other hand the logistics sector is a major employer, and thus concerns the competitiveness of industries considerably. The challenges become even more obvious in urban agglomerations in the industrialised world, where an average city dweller generates about 0.1 deliveries per day (that represents one delivery in 10 days) (Vidyasekar, 2013). These deliveries are primarily made by road. The recently published study by DG MOVE on urban freight transport lists the following inefficiencies that need to be solved (MDS Transmodal Limited & Centro di ricerca per il Transporte e la Logistica (CTL), 18.04.2012):

- Low load factors and empty running (which is particularly evident within the fragmented distribution services to small retailers)
- A high number of deliveries made to individual premises within a given time period
- Long dwell times at loading and unloading points

However, logistics service providers and governments alike are developing and implementing innovative services and organisational approaches to improve the overall efficiency of the supply chain. Especially urban areas, mostly the last mile of deliveries, seems to be a highly dynamic and crucial area of the logistics industry.

Characteristics and relevant developments

Urbanisation and the increase of online retailing are major drivers for the development of innovative services within the logistics industry. The number of peoples living in urban areas is constantly increasing and it becomes increasingly difficult for suppliers to cope with congestion problems as well as with access restrictions or parking and loading problems. Furthermore, deliveries to city centres are increasing. Online retailing has gained importance in the EU-27. While 2004 only 15% of the Europeans ordered or bought goods or services for private use over the internet, it was already 35% in 2012; with large differences between individual member countries. In the UK (64%), Norway (62%), Denmark (60%), Sweden (58%) and Luxembourg (57%) more individuals buy services and goods over the internet than in Romania (3%), Bulgaria (6%), Italy (11%) or Portugal (13%) (Eurostat, 2013). These developments make it necessary to achieve better planning and optimise transport routes and capacities.

Potential to modal shift:

The freight transport sector is still dominated by road transport and there is a lack in well-structured intermodal (or multimodal) transport chains. Especially last urban mile deliveries are almost 100% done by road based transport. Incentives are needed that help the sector to switch to more sustainable modes of transport. Several promising examples exist of how to shift deliveries from road to other modes of transport.

- According to the EU funded project “cyclelogistics” 4 out of 10 motorized trips (42%) could equally done by cargo bikes. It can be assumed (no coherent data is available) that an average share of 15% of all urban trips can be allocated to freight trips (the other 85% are personal trips). Out of these, 12% are light weight good deliveries (more than a handbag, less than 200 kg) that have a big potential to be shifted to cargo bikes. Of course, goods transport by bike is especially suited for short distances and light goods; a suitable distance for bicycles or pedelecs is said to be at around 7 km. The trip distance (between stops) of light good transport done by professional carriers is at 6 km on average (Reiter & Wrighton, 2013). These trips might be involved in a trip chain. However, there is no accurate data available, but (Reiter & Wrighton, 2013) indicate that analysis from different cities show that only a small share of city freight transport is integrated into complex trip chains. They further argue that the biggest potential for shifting from car to bike does not lie with professional carriers, but with private logistics (e.g. shopping transport). There are great differences in European cities, in Copenhagen (520.000 inhabitants) for example already today 35.000 cargo bikes are already in use.
- An example for shifting inner city freight transport to rail is the freight tramcar in Dresden, Germany. The project involves cooperation between different partners on local level: the local cargo enterprise DVB, Volkswagen Car-Manufacture Dresden Ltd., as well as local authorities. The basic idea was to find a competitive solution compared to road transport to bring pre-fabricated car products just-in-time from one (fixed) point of the city to another by using the already existing tramway tracks. However, this example is not necessarily transferrable to other cities, as the automobile production is right in the city centre and transportation was needed for point-to-point logistics (Dresdner Verkehrsbetriebe AG). However, besides Dresden Zurich and Vienna operate cargo trams and Siemens and DHL even suggest to use a

cities metro system for delivering goods (Siemens AG, 2013). However, therefore solutions would be needed that goods can easily be transferred from the metro station to the final destination.

- Freight distribution centres (freight villages) are multimodal settlements that provide access to at least two modes of transport for transport-oriented companies, logistics service providers and logistics-intensive trade and production enterprises. The idea is that not every delivery is considered in isolation, but as an integrated logistics system which can be optimized through coordination and consolidation. They provide several inter-modal infrastructure facilities, such as roll-on/ roll-off facilities, rail sidings and warehouses. Key benefits are that they are faster and more fuel efficient than the air-road mix. The possibility to better organise cooperation among stakeholders in an important task of the centres in order to allow a shift to low-emission vehicles for the final distribution. They are particularly prominent in Western Europe (Vidyasekar, 2013). According to (Siemens AG, 2013), the urban consolidation centre at London Heathrow Airport has reduced truck usage by 250.000 kilometres per year.

Innovative delivery concepts

As outlined above, online retailing has increased significantly and thus the amount of small deliveries to individuals. Additionally changes in demographics (e.g. more people active in labour market, more single households) have led to the fact that less people are at home during day. This leaves only a small time slot for deliverers to successfully deliver their products, usually in the early mornings or late afternoons to early evening. The result is an increasing amount of failed delivery attempts to private customers. Therefore, the sector is working on solutions that increases the number of possible distribution points or that do not require the receiver to be present when the parcel is being delivered, e.g. by placing goods in a secure container or storage room, or at the receivers private car.

- The Belgian start-up company Cardrops for example has developed a service that enables deliverers to place parcels into the receivers' trunk of their car, no matter where the car is located by the time of delivery. Therefore a starter kit is installed into the customers' private car that captures the GPS coordinates of the car when it hasn't moved for 15 minutes and that enables trusted delivery partners to open the car electronically. Based on these data Cardrops creates a map of the locations where the car is parked most often (e.g. in front of office) to estimate where and when the parcel can be delivered best. This information is given to the delivery partner. In case that the car is moved, the delivery can be interrupted until the very last moment. Customers have the possibility to snooze the tracking of the car at any time, but delivery is not possible while the tracking is snoozed (Board of Innovation, 2013). The idea is that receivers can choose Cardrops as their shipment method. However, the service is still a vision, until today they haven't started operation but are in search of cooperative partners (SpiegelOnline, 18.03.2013).
- Another way of offering additional delivery solutions has been developed by DHL in Germany. So-called delivery boxes ("Packstationen") are basically fully automated and self-contained kiosks for dispensing and mailing envelopes and parcels. More than 2.500 have been set up in Germany already, allowing customers to decide individually when to receive and send their parcels. Parcels are not sent to a delivery box automatically, but when customers choose it as their preferred pick-up point. They are accessible through a personalised identification number; additionally each delivery box has a certain number that enables customers to choose different delivery boxes for different deliveries. Customers receive a identification number for their shipment; this number can be used for tracking their delivery and to open the

box where the shipment is kept (Petrovic, Harnisch, & Puchleitner, 2013). Many internet based mail order companies already provide a special input field for the number of the delivery box in their forms (DHL). Delivery boxes are famous for retouring, but they are also used for first-deliveries. However, the service is only available in Germany.

- My Ways is a pilot project run by DHL in the city of Stockholm and an approach to involve city residents into the last-mile delivery of online-ordered products. A specifically developed app connects individuals that ask for more flexible deliveries and those that offer to transport parcels along their daily routes (or only a short detour away). People that offer to deliver parcels are rewarded with small amounts of money; the fee is provided by the recipient and automatically transferred to the deliverer after both have confirmed the delivery, all within the same app. The recipient can choose both, time and location for the delivery as well as individually determines the delivery fee. The parcel is registered at one of DHL collection locations and becomes visible to all MyWays users which can decide if they would like to transport that parcel and at the specified time. The pilot will run until end of December 2013 (DHL Media Relations, 2013). The idea of My Ways goes back to an idea called "bring buddy" that has been developed by design students in cooperation with DHL.
- The start-up company Shutl offers unconventional logistics services and breaks the tradition of warehouses by coordinating deliveries with local same day couriers (Vidyasekar, 2013). It offers a service to enable deliveries at the same day the purchase has taken place. The innovation is that Shutl doesn't operate own truck fleets or runs any warehouse infrastructure, but offers a technology platform that connects various logistics providers with local retailers. Shutl therefore uses an algorithm to find the best suitable courier for each product. That allows local retailers to offer their in-store stock online; customers can reserve their choice of product in a shop that is closest to them and receive it within the same day by a local courier - it can even be a cycle courier (see above). According to the founder of Shutl, the service can be offered in any city where retailers and customers are within ten miles to each other (Charlton, 2009). The service is currently available in the UK and only if retailer and buyer are in the same area. However, in October 2013 Ebay announced its agreement to acquire Shutl and proposes that it is possible to expand the service across the UK when sellers have nationwide stores (Woollaston, 24.10.2013).

Transport Management:

Automatic vehicle location and monitoring technologies are commonly used by commercial fleet operators to monitor their vehicles in real-time and to inform them about any incidents and delays (e.g. congestion). While GPS is the most common solution for location, the European Galileo system is supposed to be more accurate. However, in order to reduce the number of trips and to better organise distribution at the point of delivery, ITS applications can be adopted by municipalities to better organise the increasing amount of freight transport in their area. Relevant applications are for example (MDS Transmodal Limited & Centro di ricerca per il Transporte e la Logistica (CTL), 18.04.2012):

- Automatic booking of loading bays might reduce the time waiting/ searching for a parking bay suitable for loading/ unloading shipment and increases planning efficiency for the carrier
- Access control, e.g. according to maximum size or weight of trucks, age, environmental criteria (e.g. only recent loaded trucks are permitted), or time windows for delivery (mostly between 7 and 11 a.m.)

- Provision of information on loading and travel times, again to increase planning efficiency for the carrier, but as well to better manage the information flow among the different stakeholders involved, e.g. manufacturers, logistics service providers and retailers.

Challenges, controversies and barriers

The urban freight market is characterised by a vivid dynamic aiming at solving the before mentioned inefficiencies, many innovative service and organisational approaches are coming up to cope with these inefficiencies. However, if applied in isolation it seems that many of these service approaches may end up with major rebound-effects. When distribution becomes faster and more convenient, or if congestion can be solved; it might generate more transport. Multi-instrumentality appears to be the key success factor. Municipalities need to set up urban freight transport strategies to cope with the changing circumstances of urban freight.

Potential impacts for freight distribution centres and ICT solutions in freight transport are given in Figure 10.

Figure 10: Individual scoring averages and potential range of CO_2 reduction. Source: (Lopez-Ruiz et al., 2013).

Avoid	Shift	Improve	Economic	Social	Environmental	Potential Reductions Ktons CO_2	City Network	Urban Sprawl	Rural Area	Small Compact City
MED	LOW	MED	MED	MED	MED	951 - 1 192	MED	LOW	MED	LOW

Source: Calculated from the scorings based on experts' opinions in the KONSULT, EC-FREIGHT, EPOMM and TransProd studies. *Note: MED stands for MED **Note: - stands for not available

Outlook

Especially the introduced delivery concept outlined above are latest service developments, some of them, such as the idea of delivering parcels to the trunk of private cars, are ready to be implemented but have not yet proofed to work in reality. The idea of a platform to connect local couriers and retailers have as well not yet been implemented on wider scales, but since global market player are seriously interested in such approaches, it is likely that they will find wider implementation. Especially this example might be suited to change online shopping behaviour; local solutions become competitive to globally operating approaches. It might even support the use of more environmental friendly modes of transport, as cargo bikes might become a competitive alternative for small inner-urban deliveries.

4.6. Infrastructures

This innovation field considers innovations that contribute to the improvement, adjustment and extension of infrastructure of existing transport modes and the introduction of new kinds of transport infrastructure.

Note: Infrastructure that is required for implementing the wide-scale application of alternative fuel and propulsion systems is considered in section 4.2.

Relevance for FUTRE

The transport system provides an important basis for economic activities and a functioning transport infrastructure is crucially relevant to guarantee an operational transport system. Innovations in the transport sector, many of them being represented in other innovation fields in this report, often rely on excellent infrastructure or can only be implemented together with infrastructure innovations.

This is in line with the goals of the European Commission 2011 White Paper goals on the completion of a European high-speed rail network (goal 4), on the Trans-European Transport Network (TEN-T, goal 5) and on the connection of core airports and seaports to railway services and inland waterways (goal 6) (CEC, 2011b). While these three goals directly relate to infrastructures, the goal on modal shift to rail and waterborne freight transport (goal 3) underlines the importance of a co-evolution of other innovations with infrastructure improvements by stating that “this goal will also require appropriate infrastructure to be developed” (CEC, 2011b, p. 9).

Infrastructure innovations may not only be incremental developments of existing kinds of infrastructure; instead, new elements in the transport system landscape like magnetic levitation trains or underground freight transportation systems can be imagined as well. Because infrastructure is often cost-intensive and investments have to be planned in a long-term perspective, infrastructure investments tend to be particularly sensitive to financial framework conditions and often lack sufficient and/or suitable funding.

Regarding the issue of competitiveness, FUTRE does not address the function of infrastructure as an enabler of a competitive economy in a broad sense; this would be beyond the project’s scope as outlined in (Condeço et al., 2013) (FUTRE Deliverable 2.1). While e.g. in the vehicle manufacturing sector the direct relation of innovations to the competitiveness of the European transport industry is quite obvious, this is less clear for infrastructure innovations. However, examples like the tunnelling machine manufacturers Herrenknecht from Germany or NFM Technologies from France, or the Austrian manufacturer of rail track maintenance systems Plasser&Theurer show that expertise gained through European reference infrastructure projects can also have a direct impact on the European transport industries.

Characteristics and relevant developments

In the road transport sector, infrastructure capacities are often scarce. New infrastructures and the extension of existing road infrastructure may help in some cases but will be neither efficient nor sufficient in other cases. Therefore, important innovations relate to a more efficient use of existing capacities.

This is possible e.g. by promoting higher occupancy levels of passenger cars by the introduction of high occupancy lanes that are reserved to vehicles carrying at least two persons and public transport. Such measures can be particularly effective where problems arise mainly in peak hours.

A more complex approach is dynamic pricing or mobility pricing. It can be used to manage traffic flows by making transport behaviour choices more efficient from a macro-economic perspective, eventually leading to more traffic volumes spreading more evenly across the day or inducing modal change of users e.g. to public transport or cycling. Mobility pricing can reduce congestion and contribute to shorter travel time (Beevers & Carslaw, 2005b), furthermore it can help to improve urban air quality and reduce road casualties (Atkinson et al., 2009; Beevers & Carslaw, 2005a; Li, Graham, & Majumdar, 2012). The European-level public consultation on ‘Charging of the use of road infrastructure’ revealed great support for the application of the ‘user pays’ and ‘polluter pays’ principles to be supported by mobility pricing schemes (Skinner, 06.12.2012). This is in line with the findings from (Schippl et al., 2013) where experts stated in a survey that an interoperable European road charging scheme would be quite desirable.

In the rail sector, classic infrastructure investments are still more relevant to close network gaps, to extend the network and to particularly separate passenger and freight train flows (cf. Schippl, Puhe, Meyer, & Edelmann, 2011). Furthermore, infrastructure innovations are expected that contribute to simplified intermodal transport. Many technologies that could make railway transport more efficient, particularly in the freight rail sector, are already available today (e.g. modern electronic signaling systems), but experts are concerned about uncoordinated political action, a lack of political vision and diverging interests of stakeholders, despite assessing the soon and wide-spread application of such technologies as very desirable (Schippl et al., 2013).

For maritime and inland shipping, besides investments in capacity extensions of e.g. inland waterways, there is a range of technologies that facilitate intermodal transport by easing transshipment between vessels and rail and road hubs. These technologies contribute to make intermodal transport more competitive and to facilitate the choice of the most efficient transport mode.

For the active transport modes like cycling and walking infrastructure investments can also significantly contribute to unburden urban agglomerations' transport systems, encouraging increased usage of these modes and contributing to significant modal shifts to these modes (Akkermans et al., 22.02.2011).

Generally, new financing instruments are considered by experts as another relevant element of ensuring the further development of European transport infrastructures (Schippl et al., 2013).

With regard to entirely new infrastructures comprising more radical infrastructure innovations, the Hyperloop example described in section 4.3 may again serve as an example of more far-away innovations that still could become relevant in the long-term. Another example of this kind are so-called freight tubes that would provide access to congested city centres for goods transport by providing access from logistics centres outside the city centres to urban delivery. However, such kinds of new infrastructures would require huge investments and could interfere with existing underground infrastructures. A similar approach for medium distances with tunnels below the existing motorway is analysed in Switzerland (Cargo sous terrain, 2013).

Challenges, controversies and barriers

While the relations between infrastructures, infrastructure investments and economic have been analysed for many cases in many studies (cf. e.g. Kovács & Spens, 2006; Lakshmanan, 2011, Phang, 2003; Meijers, Hoekstra, Leijten, Louw, & Spaans, 2012; Pradhan & Bagchi, 2013), the analysis of the relation between infrastructure development and the competitiveness of the European transport sector is difficult to separate, challenging the work in Task 4.3.

The financing of infrastructures is a challenge as well. While the participation of the private sector in infrastructure investments, e.g. through public-private-partnerships, has been intensely promoted in the last years, a study by (Benito, Montesinos, & Bastida, 2008) partly questions the success of such approaches and concludes for the Spanish example that there is often 'creative accounting' implying that, despite private involvement in infrastructure investments, "payments are finally made by the Government by means of its budgetary resources" ((Benito et al., 2008, p. 963). For the case of high-speed rail infrastructure investments in France, (Cohen & Kamga, 2013) similarly conclude that "public credit is the sine qua non of financing high speed trains" (Cohen & Kamga, 2013, p. 62). Experiences from Switzerland show that the introduction of a new financing scheme required a "long and complex process with different stakeholders and parties involved" (Rudel, Tarola, & Maggi, 2005, p. 2012).

Financing issues are also related to the long-term character of infrastructure investments which as well complicates reasoned perspectives on what kind of infrastructures to develop most usefully, as parallel developments within and outside the transport sector mostly cannot be planned in similar long-term timescales.

A challenge of different character are the civil society movements against centralistic infrastructure planning that have come up more intensively in the last years in cases were planning does not reflect the needs and expectations of relevant affected societal groups. The protests against the reconstruction of the train station in Stuttgart, Germany, are a prominent example. This development can be a barrier for future infrastructure projects and requires them to consider all relevant stakeholders' needs at a very early stage. In some cases, however, participative involvement cannot solve these problems, particularly in cases where the NIMBY (Not In My Backyard) problem applies and infrastructure that is necessary from a societal viewpoint is not accepted by the local public in any place.

Results from the patent analysis

In the patent analysis, only the technology area of rail-bound patents touches infrastructure innovations, but the technology area focuses more on patents regarding vehicles and coaches or infrastructures that are closely linked to the respective vehicles like in the case of magnetic levitation trains. The results of the patent analysis for rail-bound patents are therefore considered in section 4.3.

Outlook

Due to the long time horizon of infrastructure investments, mainly improvements of existing infrastructures can be expected until 2030. However, budgetary constraints will be a challenge and will eventually require new instruments particularly for financing new infrastructure. The above-mentioned challenges regarding societal conflicts regarding new infrastructures will require careful governance approaches.

In the long-term perspective after 2030, radically new types of infrastructures can be as well expected. However, they are – like for other innovation field – difficult to foresee and assess and again, the long lifespan of infrastructure of infrastructure and the requirement of significant investments will imply only slow build-up of such infrastructures.

4.7. Out-of-the-box transport innovations

The innovation fields listed until here consider such innovations that can be expected to become of major relevance for the transport system within the course of the next decades. Some innovations might experience their market earlier, others later, and the dimension of their importance in the future transport system is sometimes also disputable. Still, incremental technology improvements and ongoing R&D activities (partly mapped in the patent analysis referred to above) clearly show that these innovations clearly will be of significant relevance for the future European transport system.

However, there is a range of more uncertain technologies or even new transport modes, where certain technologies might well be already visible, but where it is much more uncertain whether these will become reality at all, when this could happen and whether this would have any significant impact on the transport system. An exemplary overview on a potential range of such technologies is given below – but it is self-evident that the very nature and character of these "out-of-the-box innovations" does neither allow a detailed description nor an analysis of potential impacts as they have been demonstrated for the other innovation fields.

May of the innovations listed below consider new types of infrastructure, new types of vehicles that are often more flexible for variable personal needs, and they do often make use of the 'third dimension' by using either underground space or the airspace. Further details and examples can also be found in (Puhe & Schippl, 2010) and in (MCRIT).

Urban cable cars

Cable car systems are well known from alpine ski resorts and mountainous tourist regions. With only minimal adaptations, however, these systems can also be used as an alternative means of urban transport. While there have been some urban applications of cable car systems in very specific cases (e.g. the Roosevelt Island Tramway in New York, USA), it has been only in recent years that urban cable cars have started to move into the wider perspective of urban transport planners. Urban cable cars show a number of advantages: Infrastructure construction requires only little space, installations are easily possible in complex terrain (particularly in dense urban settlements), and systems can have high capacities (up to 6,000 persons per hour and direction, according to Alshalalfah, Shalaby, Dale, & Othman, 2012).

Integrated into existing or growing public transport and tariff schemes, it can be supposed that urban cable cars have a significant potential to improve public transport and local accessibility (Muschwitz, Monheim, & Philippi, 2009). However, it is after some success particularly in a number of cities in South-American countries still not certain to which dimension urban cable cars will grow towards a new transport mode of broader relevance – even with recent applications also in cities like London (with the 2012 "Emirates Air Line" crossing the river Thames) that already have extensive public transport networks.

Personal rapid transport

Personal rapid transport is a new type of semi-public transport which offers on-demand service for individuals or small groups on dedicated infrastructure (NICHES+). This means that advantages of individual mobility like flexibility and privacy are combined with those of public transport (efficiency, costs). Personal rapid transport also makes use of several innovations described further above, as vehicles are operated electrically and fully automated (by central control).

While similar systems have been planned and tested since the 1960s, in recent years there are first applications in the real world, mainly a system at London Heathrow airport (used to access parking lots and opened in 2011, further extensions planned; see Ultra Global, 2013) and the plans for a bigger-scale system in Masdar City in Abu Dhabi (Bulls, 2009). Still, with only little applications and a long of history of big ideals it is difficult to assess whether this mode of transport will be of particular significance in the future transport system.

CargoCaps

The CargoCap is a new mode of freight transport that is designed to be mainly applied in dense urban centres. Proudly, it is described as "the fifth transportation alternative to the conventional systems of road, rail, air and water. It is a safe and economical way to carry goods quickly and on time in congested urban areas by underground transportation pipelines." (CargoCap). The system uses pipelines similar to those of drain-off sewage lines and is installed under public streets and next to existing underground infrastructure. It uses electric propulsion and automated control mechanisms to transport goods in two euro-pallet size boxes for each cabin.

The company that owns the concept claims that needs to be financially viable and attractive for investors. And in fact, a study stated the low operational costs of the systems will compensate for the high investments costs in the long run, which makes the system competitive compared to truck transport (Ministerium für Wissenschaft und Forschung des

Landes Nordrhein-Westfalen, 15.04.2005). However, the idea and the concept have been there for a whole number of years and until now, only a first application to be opened in 2015 has been announced in 2013 – and this application is yet only planned to serve transport needs within a single manufacturing site and not in the originally intended city scale (SEW-Eurodrive, 08.04.2013). It is therefore disputable whether CargoCap or similar technologies will find broader application in the close future.

Inductive charging for electric vehicles

The provision of adequate charging infrastructure is still a major challenge for the diffusion of electric vehicles. Problems with complicated and varying technical standards as well as safety issues (e.g. dangers from uncovered cables) could be addressed by using inductive, contact-less charging of batteries. This would also require intelligent infrastructure networks to control charging of vehicles; and eventually, full grid integration of electric vehicles (parked cars providing electric power to the grid) could be made possible in this way. Inductive charging has also got a number of other advantages like slow charging speeds which are positive for battery lifetimes, but at the same time a major disadvantage applies in terms of significant transmission losses (E.ON, 2009; IAV).

While tests with inductive bus charging (while busses are stopping during their regular rides) have successfully shown the operational feasibility of inductive charging systems (Conductix Wampfler), the possibility of a wider application of such charging systems is still discussed.

Personal aerial vehicles

The vision of personal aerial vehicles can be traced back to the 1950s. Many engineers worked on developing small aircrafts that are designed to be used as a kind of air taxi. Aerial vehicles do not require large-scale infrastructure on the ground (unlike e.g. conventional public transport or private road transport) and seem promising as they make use of the third dimension which is currently not used – which is believed to have a potential to reduce congestion etc.

However, while engineers are still confident to develop operational vehicles and the required operational systems to carry out (automated) personal aerial transport safely, other studies claim that personal aerial transport systems may not because of technical difficulties regarding the vehicle itself. Instead, (Jump et al., 2011) argue that the main reason that the respective systems have not yet and are not expected to become reality in the close future is that the required operational infrastructure and questions about the socio-economic viability of such systems have not been properly addressed. (Decker, Fleischer, Meyer-Soylu, & Schippl, 2013) also claim that the main challenge will not be technological, but about the integration of personal aerial transport into the existing transport system, concluding that beyond mere technology the future role of personal aerial transport is still uncertain.

Foldable city cars

The foldable city car is a vision of researchers at the MIT Media Lab. It is a fully electric vehicle specifically designed for shared use. It can be folded and then stacked away like a shopping trolley in order to use the possible minimum of urban space when not being in use. It also includes features like individually controlled motors in all four wheels which allow O-turns instead of U-turns, even further reducing the car's space requirements. A prototype has been presented in 2012 (MIT Media Lab, 2013).

As a radically new design of a car, it is not foreseeable if and when this specific type or similar approaches will find broader application in the urban landscape.

Innovations mentioned at the internal expert workshop

During the internal expert workshop (see section 3, particularly Table 3), a number of additional technologies of potential relevance for FUTRE have been mentioned. Following their characteristics some of them clearly fall into the category of uncertain out-of-the-box innovations. These include the CargoLifter concept, new concepts in urban transport that would e.g. have busses from cities' outlying districts coupled in the city centre (allowing for flexible change inside the coupled vehicles), electrified motorways, or flying wings as a new type of aircraft design.

III. Constraints on innovations

1. Introduction

Among economists there is a consensus about the general linkage between innovations and competitiveness. There is no doubt that new products and services increase the probability of a stimulation of global demand and thus of an increased competitiveness of an industry or service sector. Unfortunately, this is only one side of the medal. Competitiveness in its core sense requires selling products and services with margin which presupposes to consider the cost-efficiency of innovations. The process of innovation and the decision whether or not to be innovative is therefore based on financial constraints. Companies have to invest at first in research and development, in the production of the new products and services and into product launch and market entry. And even for innovative new products there is no guarantee about the successful market entry.

Other important constraints on product innovations can emerge due to the increased need of specific, scarce raw materials. In the worst case, the scarcity directly limits the number of units of a product innovation that can be produced. Even before, the scarcity of raw materials and also of energy will lead to growing production costs which determine the success or the failure of an innovation on global markets. Hence, strategic forecasts of the impacts of innovations on the use of scarce raw materials are essential to estimate the impact of an innovation on competitiveness.

There are even more constraints on innovations. Another factor preventing companies from developing innovative products and services can be policy regulation. As an example, the automotive industry tries to develop aerodynamic and fuel efficient trailers for trucks which will be beneficial for fuel consumption of trucks but are not allowed due to European regulation on maximum length, width and height of trailers.

This deliverable focuses mainly on those constraints on innovations induced by scarcity of raw materials. Therefore, results of a quantitative assessment of the impact of the diffusion of key transport innovations on scarce raw materials will be presented in the following chapters.

2. Scarcity of raw materials

Meeting the European GHG reduction targets until 2050 requires significant structural changes of the European transport system. Technological innovations as well as behavioral change in transport products, services and infrastructures are essential for this purpose. A shift from a fossil fuel dependent transport system towards a transport system driven by renewable energy carriers can evoke scarcities of other resources or raw materials (inter alia: Angerer et al. 2009; Moss et al., 2013). Due to technical constraints, i.e. of storage systems for hydrogen and electricity, their use is so far limited to road mode. According to studies like GHG-TransPoRD (Schade et al. 2011), GHG mitigation technologies for planes and ships have to focus on energy efficiency until 2050. But even the production of innovative energy efficiency technologies can induce scarcity of raw materials.

Before heading towards specific examples it is crucial to understand the term critical when speaking about scarcity or raw materials. The *Raw Materials Initiative* from the European Commission (European Commission 2008) determined a definition of critical raw materials. The first criterion is the relevance of a raw material for a key economic sector. In this case, the transport sector is without any doubt a key sector for the European Union as the EU transport industry employs about 10 million people and is responsible for 5% of the total GDP (European Commission 2011). The second criterion is related to the supply side of raw materials. All raw materials for which the EU faces a high risk of supply in the future are considered to be critical. The final characteristic of a critical raw material stems from the technical option to substitute the material by a less scarce one. If there is a lack of substitutes, the raw material will be accounted to the group of critical raw materials.

Based on this definition and the identification of mode-specific and cross-cutting transport innovations in task 4.1 of the FUTRE project a qualitative assessment of potentially critical raw materials has been carried out. Table 7 offers an overview of key transport innovations respectively the components within the innovation that are related with critical raw materials. In order to assess the criticality of a raw material in the context of a transport innovation, the potential future market of this technology needs to be projected. We assigned each innovation in the list according to roadmaps of the European Technology Platforms (ETP) and expert workshops into the following categories for 2030:

- Introduction: the innovation will only be in the market entry stage in 2030 and only early adopters are demanding the technology.
- Use: the innovation will be in the middle of the innovation curve in 2030.
- Saturation: the innovation will be in the falling area of the innovation curve with only laggards demanding the technology.

Table 7: Assignment of critical raw materials to key transport innovations

	Components	Environmental Technologies	Raw materials	Market 2030			Raw materials demand 2030			
				Introduction	Use	Saturation	Non-critical	Intensive	Sensitive	Very sensitive
1	**Permanent magnet**	**Electric traction motors for hybrid-, electric-, fuel cell vehicles and pedelecs** Innovative electric motors for motor vehicles	Rare Earth (Fe-B-Nd, SmCo, Dy, Tb, Pr)		X					X
2	**Oxidation-, Storage- and SCR- Catalyst**	**High efficient emission cleaning system for diesel-powered vehicles** particle filter for emission cleaning to otto engine standard	Oxidation-catalyst: Pt, Pd SCR: W, V			X		X		
3	**Carbon super capacitor**	**Super capacitors for traction support of hybrid, electric and fuel cell vehicles** Buffering of electricity and fast discharging while dynamic tops during operation.	C, carbon aero gels, Ta, Al, Ti, polymers, organic solvents		X		X			
4	**Hydrogen energy storage**	**Metal-hydride hydrogen storage** Energy storage with high storage densities.	Ni, Co, La, Nd		X					X
5	**Electricity storage**	**Lithium-ion electricity storage** Electricity storage with the highest performance- and energy density for verhicles, mobile electric tools and power tools.	Co, Li		X			X		
6	**Vehicle electronic**	**Hybrid-electric motor vehicles** Autarchic full hybrid- and plug-in-hybrid vehicles with feeding energy back into the grid.	Electronic: Cu, Si, Sn		X					X
7	**Adaptronic**	**Adaptronic** Active systems for damping of vibration- and noise in vehicles and planes.	Sensors and actuators: quartz (SiO_2), $LiNbO_3$, $GaPO_4$ $BaTiO_3$ electronic: Cu, Si, Sn	X			X			
8	**Fuel production**	**Biomass to Liquid (BtL)** Fuel production of wood, straw and other biomasses. Mineral oil production and transition technology to hydrogen economy.	Steel, Co, Pt, Pd, Rh, Re Cat. e.g. 98% Co + 2% Ru		X				X	
9	**High-temperature resistant materials**	**High-efficient plane engines** High-temperature materials for future generations of energy-efficient and super-silent jet engines.	Cr, Co, Ti		X		X			
10	**Combustion engines**	**HCCI combustion engines** Homogeneous charge compression ignition as efficient, low-emission combustion engines for motor vehicles.	Fe, Al, Mg		X		X			
11	**Light-weight steel construction**	**Light-weight construction for motor vehicle** Weight reduction with light and local high-strength materials for saving fuel.	light-weight steel construction (Tailored Blanks), Steel-Al hybrid light-weight construction, Mg pressure die casting, Ti,			X				
12	**Light-weight construction of planes**	**New light-weight materials in plane construction** New type of alloys for inexpensive manufacturing and for saving fuel.	Al-Mg-Sc, Al-Li, composites		X				X	
13	**Fuel cell**	**PEM-fuel cell for electric vehicles** Fuel cell as traction-power-source in vehicles.	Pt		X				X	
14	**Thermal power production**	**Thermoelectric transformation of energy** Power production from heat with thermoelectric generators.	Semiconductor: Te, Sb, Ge, Ag, Bi ; wires: Cu ceramic cover plate	X				X	X	
15	**Reduction of road noise**	**Low-noise tires**	Nd			X			X	

Source: Fraunhofer-ISI

This assignment is crucial for a qualitative assessment of the implications on raw material demand. The level of scarcity of a raw material is then allocated to four categories from non-critical up to very sensitive. There is no diffusion scenario assumed which would consider significantly changing raw material demand by innovations from other sectors as this would increase the level of complexity significantly.

As Table 7 demonstrates, many innovations are expected to create at least a sensitive raw material demand until 2030. The chemical element Copper (CU) is for example widely used for electric engines which are key elements of powertrains of battery electric vehicles (BEV), plug-in electric vehicles (PHEV), hybrid electric vehicles (HEV) and fuel cell electric vehicles (FCEV). Hence, copper has at least the potential to be a critical raw material in the future. A similar demand is created for lithium as the major chemical element of battery systems used in each electric vehicle (EV).

In the following sections the criticality of copper (CU) and lithium (LI) under the framework of a shift from fossil fuel towards electrified vehicles. In order to demonstrate also impacts from another mode, the element scandium (SC) is analyzed as a raw material of high importance in the context of increasing application of lightweight materials in the future aviation sector.

2.1. Raw materials for battery electric vehicles

The question of the availability of the raw material base for vehicles takes on a new dimension when one thinks of new technological developments. The currently most discussed development that has far-reaching consequences for the automotive sector is the electric mobility, which also includes fuel cell vehicles. In addition to the debate about the range of petroleum is the feared climate change a second important driver. Extensive studies from institutions like the IPCC (Intergovernmental Panel on Climate Change) and the IEA (International Energy Agency), show that the transport sector must reduce its greenhouse gas emissions significantly (e.g. IEA 2010; Kahn Ribeiro et al. 2007). Otherwise ambitious climate protection goals cannot be achieved.

If the two-degree target of global warming should be achieved, the specific CO_2 emissions from passenger cars must be reduced to around 20 g per km in 2050. Such a value is with petrol and diesel-driven cars technically unreachable, due to the Carnot cycle (for comparison, Well-to-Wheel CO_2 emissions of petrol-driven passenger cars are currently at approx. 150 g / km). For this, the above mentioned growth is to carry on traffic performance with a reduction of fossil raw materials. Therefore, almost all studies conclude that the motorized individual traffic needs a conversion to electric vehicles (including fuel cell vehicles).

A significantly positive greenhouse gas balance, however, can only be achieved with electric mobility, when CO_2-poor or -free energy sources, such as renewable energy, are used (see Wietschel et al. 2011). Regarding the use of renewable energy sources, however, there is also a strong competitive situation, in relation to the energy use such as electricity or heat or to carbon-based industrial products. There can also be a competition of land use with the food production.

The transition to electric mobility affects first and foremost the powertrain. Here, the internal combustion engine is replaced by a battery with an electric motor. The expected boom in the demand for raw materials includes lithium as charge carrier in the lithium-ion battery with about three kilograms, some kilogram nickel, manganese, cobalt and others depending on the used cathode material, as well as about a kilogram neodymium/dysprosium for the permanent magnets in the traction motor. In addition platinum is used as a catalyst in fuel cell cars. The biggest increased demand is approximately 40 kilogram copper for motor and electric cables in the vehicle.

2.1.1. Copper as a critical raw material

Copper is an important raw material for electric mobility. Table 8 shows the copper inventories for different propulsion systems. Due to its properties, copper is used also in many other fields, especially in electrical applications. Other uses include inter alia pipes for water supply, heat exchangers, various consumer products or architecture.

Table 8: Copper inventories of various vehicle systems (Source Angerer et al. 2009; Erdmann 2004)

		ICE	HEV	PHEV	BEV	FCEV
Electric motor power	kW	0	20	50	50	50
Battery capacity	kWh	0	1,4	20,0	20,0	1,4
Copper inventory	**kg Cu**	**25,0**	**43,5**	**77,2**	**65,2**	**58,5**
Electric motor	kg Cu	0	18,0	45,0	45,0	45,0
Combustion motor	kg Cu	12,0	12,0	12,0	0	0
Li-Ion-Battery	kg Cu	0	0,5	7,2	7,2	0,5
Other components	kg Cu	13,0	13,0	13,0	13,0	13,0

ICE: Internal Combustion Machine
HEV: Hybrid-Electric-Vehicle
PHEV: Plug-In-Hybrid Vehicle; BEV: (Battery-Electric-vehicle),
FCEV: Fuel-Cell (powered) Electric Vehicle

For copper, detailed analyses are carried out at the Fraunhofer Institute for Systems and Innovation Research ISI (Angerer et al. 2010). Two scenarios for the development were considered until the year 2050. In the first scenario, so called “pluralism scenario”, it is assumed that the market penetration of electric vehicles worldwide reaches 50 percent of new registrations for private motorized transport. The other 50 percent are alternative drive concepts.

In a second scenario, the “domination scenario”, electric vehicles are expected to have an 85 percent market share in new vehicle registrations. For copper provide the analysis that consumption is affected in the next 40 years very little by electric mobility. In the first scenario only 14 percent of the copper are used for the electric mobility in the year 2050, in the domination scenario this share is 21 percent (see figure 11). The secondary copper here covers nearly 26 percent of the total demand in 2050.

The major growth market for copper is the energy transfer sector with about 34 percent. However, the geological reserves of copper are sufficient to meet demand in all application areas in the coming decades. But in both scenarios the economically recoverable copper reserves (with the technology available today) will be exhausted in the mid-30s of the 21 Century. This means that new copper deposits have to be tapped, which exploitations will cause comparatively higher costs. These deposits are registered in the figure as geological resources and are - including copper in deep-sea manganese nodules - estimated at about 3.7 billion tons

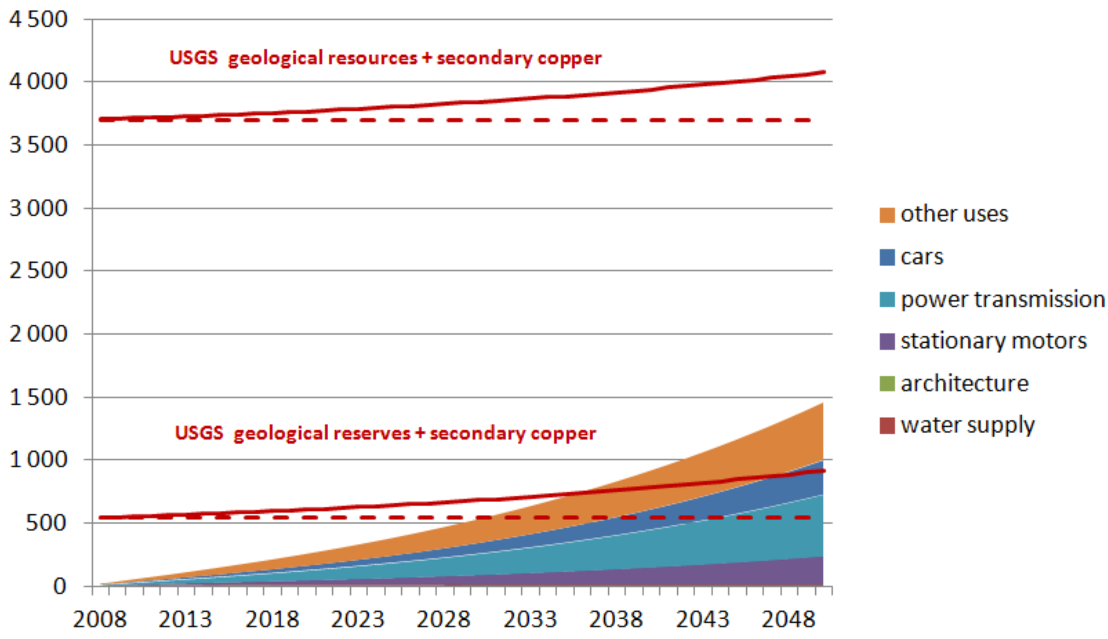


Figure 11: Accumulated copper consumption worldwide [million t Cu] (domination scenario; Angerer, G. et al., 2010)

This development can be counteracted by various measures. The main mean is the founding of new mining sites. However, their founding leads to increased costs, affecting the price of copper. To ensure a continuous supply of the world economy with copper, the opening of new mines in the next ten to 15 years must be planned due to the long lead times.

The expansion of global recycling and therefore the use of the obtained secondary copper is needed to promote conservation of natural occurrences. While Germany and other developed countries have reached already high usage rates of secondary copper, there is a great potential in developing countries still waiting for realization. This can be supported by know-how transfer of recycling measures in these countries. Another further measure is the “mining” of copper accumulated in landfills worldwide.

These deposits are estimated at over 400 million tons of copper - more than 20 times the present world production. And, finally, copper may be substituted for other materials. In electrical applications, for example in electric motors and cables, copper may be replaced by aluminum, however, at the cost of serious deterioration of the energy efficiency. Fiber optic cable or wireless transmission are substitutes for telecommunications. In the water supply copper can be replaced by plastic or zinc plated steel pipes.

2.1.2. Lithium as a critical raw material

Lithium-ion batteries seemed to be particularly suitable for use in electric vehicles, because of their high energy and power density and the resulting low weight. They are also used in other mobile applications such as laptops and small electronic devices that have high growth rates. Due to its chemical properties, further applications are glass-ceramics, car tires, pharmaceuticals and aircraft lightweight construction (see Angerer et al. 2009). Against the background of this growing demand, the availability of lithium is crucial to achieve mass market of lithium-ion batteries equipped electric vehicles.

Lithium has been studied at Fraunhofer ISI taking into account the use of secondary lithium from recycled material, as well as the demand for lithium for other applications (such as, for example, cooking plates (Ceran), heat-resistant oven windows, aluminum smelters for the reduction fluorides or lithium hydroxide for greases) (Wendl et al. 2009). After this analysis, in the pluralism scenario by 2050 only about 20 percent of the world's lithium resources will be consumed. This calculation implies a cautious estimate of the deposits. The recycled lithium covers about 25 percent of the total demand in 2050.

In the dominant scenario an 85 percent market share of electric vehicles in new registrations is assumed for the year 2050. In this scenario also, it does not come to a depletion of lithium resources by 2050. However, the known reserves will be exhausted in the dominance scenario at the end of the observation period. That means, the cost of lithium will rise in the medium term. Another challenge is that the lithium deposits are only in a few countries. This leads to high dependency on political developments in this countries. Hence, there is a need to develop new deposits. There should be established at an early stage a recycling system for lithium and in the long-term alternative types of batteries that do not require lithium should be developed.

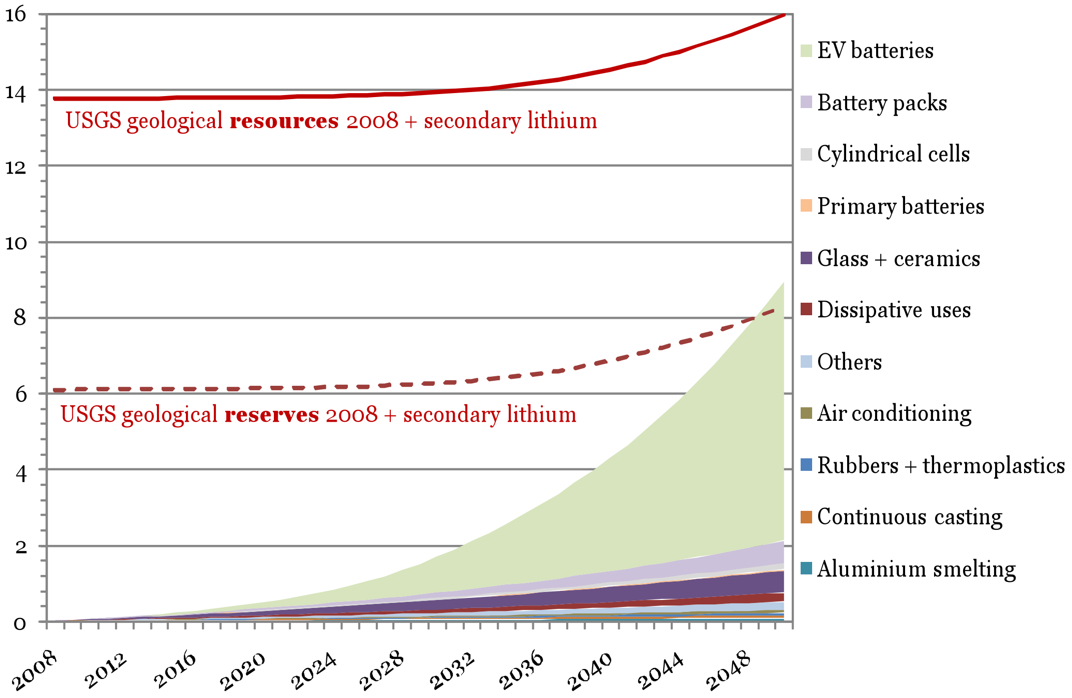


Figure 12: Cumulative lithium consumption worldwide (dominant scenario, Wendl et al. 2009)

2.2. Scandium as an alloying element in aircraft

Scandium increases as an alloying element of aluminum its strength. In addition, scandium in Al-SC alloys reduces the particle size, which is important for the rolling and welding. These properties make Al-Sc alloys to a potentially suitable material for the aircraft construction. Due to the limited availability of scandium, Al-Sc alloys have been used so far mainly for the construction of military aircraft. In the face of rising cost pressures and increasing importance of climate protection, Al-Sc alloys are a promising option for lightweight construction in civil aviation (Angerer et al. 2009):

- Aircraft wing, are made of Al- Sc alloys, need not be painted. This leads to a 1-2 percent weight saving with respect to the entire aircraft weight.
- Although scandium is very expensive, in a systemic consideration Al-Sc alloys are however around 15% cheaper than today's aircraft materials. This is because they need not be clinched but can be welded with lasers (Eaglefield 2005). Other research

institutions focus on the production of wires for welded joints of aluminum-scandium alloy.

In the TANGO project of the EU Growth program, numerous new construction materials for the aircraft industry were examined. These included aluminum-lithium alloys, aluminum-magnesium- scandium alloy, fiber-metal laminates and new carbon fiber reinforcements. Table 9 gives as an example the weight-percentages of an Al-Mg-Sc alloy from Airbus.

Table 9: Proportion of materials in an Al-Mg-Sc alloy

Material	Proportion [weight-%]
Scandium	0,2 – 0,26
Magnesium	4,9
Manganese	0,1 – 0,5
Zirconium	0,1
Aluminium	balance

Source: Walter 2008

The Al-Mg-Sc alloy has been qualified for the aircraft. It is suitable as a sheet metal for structural components of the aircraft - particularly for the components that need to be impact or corrosion- resistant (nose, facing the wings, flaps, elevators and rudder units).

The high price of scandium (depending on purity, prices for Sc_2O_3: 900-5900 $/kg (USGS 2013) seems to be a hurdle for the use of Al-Sc alloys. However, the availability and performance of scandium are more important criteria in material selection as the price. For example, Airbus relies on a single supplier for the Al- Sc alloy. As with many functional materials also a fundamental dilemma exists with scandium: the production capacity is low, the availability is bad (single source) and the competition is low, but the supplier is not willing to exploit his deposits because he has no security on demand. Neither the user nor the supplier therefore decides to guarantee the demand or to increase the capacity (Walter 2008).

2.3. The role of critical raw materials for innovations

The described development trends on "Critical Raw Materials” clearly illustrate the need to pay attention to the availability of key raw materials in the development of future technologies. This holds especially with developments in the transport in the context of electric mobility or lightweight construction. Impending shortages of raw materials and the raw materials competitions can be detected early and it can be countered with appropriate measures like intensified R&D on other materials or composites that could substitute critical raw materials in the future.

3. Financial Constraints

Scarcity of raw materials could also be accounted to financial constraints on innovations. Demand and supply in combination with raw material speculations shape the prices of raw materials which can push prices of innovative transport technologies towards a range of costs for users in which the technology is under financial issues not competitive anymore. But there are of course other decisive economic or financial factors that can induce constraints on innovations.

Theory and empirical evidence have stressed the existence of financial constraints in R&D and innovation activities. Recent empirical analyses have shown that financial obstacles negatively affect the propensity of firms to innovate. Segarra et al. (2013) analyses the role of financial constraints on the likelihood of Spanish firms abandoning an innovation project during the period 2004-2010. Their analysis differentiates between internal and external barriers on the probability of abandoning an innovation and they examine whether the effects are different depending on the stage of the innovation process. They conducted a sample for the analysis of about 4,882 potential innovative firms of which 3,779 firms belong to the manufacturing sector and 1,043 firms to the service sector. From the total number of potential innovators, 335 firms did not innovate but felt barriers against them engaging in innovation activities, while 4,487 firms innovated successfully during the analysed period.

Based on the literature on financial constraints and innovation, the authors' main hypothesis is that the lack of access to external funding will be more positively associated with the likelihood of abandoning an innovation project than when the main limitation is the lack of funds within the firm or the group.

With respect to the determinants affecting the probability of suffering financial constraints, the main results are the following. First, the probability of perceiving financial restrictions declines with firm age and size. Evidence shows that smaller firms are more likely to face financing constraints, as they usually cannot provide as much overall collateral value compared to larger firms. In addition, younger firms may be restricted in their R&D investment due to additional factors that affect financing conditions. Second, firms that invest in R&D are more likely to suffer financial constraints, in particular, external funds. Finally, the fact that a firm belongs to a group of firms diminishes the probability of suffering financial constraints.

With respect to the determinants affecting the probability of abandoning a project, the main findings are the following. First, financial constraints in general increase the probability of abandoning a project. One likely explanation may be related to the existence of the high sunk costs of R&D activities. Second, with respect to the incidence of those firms perceiving persistent financial constraints, it could be observed that this variable is only significant on the probability of abandoning the project during the concept stage. Third, other barriers related to knowledge and market increase the probability of abandoning a project. Fourth, with respect to firm age, this impact does not appear to be significant. This result may be due to the fact that young firms assume more risks through lack of experience, while older firms will have more experience but also a larger number of R&D projects. Hence, it is probable that firm age does not show a clear pattern. Fifth, firm size seems to give a positive indication on the probability of abandoning a project.

With respect to the R&D cooperation, our results indicate a positive and significant impact on the likelihood of abandoning a project. Furthermore, investment in R&D has a positive and significant effect on the likelihood of abandoning a project. Finally, for knowledge intensive services, the impact of R&D investment indicates a different impact on the probability of abandonment depending on the stage of the project.

The results show that financial constraints most affect the probability of abandoning an innovation project during the concept stage and that low-technological manufacturing and non-KIS service sectors are more sensitive to financial constraints.

In order to analyse the role of financial constraints on innovations for the European transport industry the structure of the industry must be considered. There are a number of global players in the automotive, the rail and the aviation sector in Europe. As the analysis in Condeco et al. (2013) showed, the respective companies are very active in R&D such that one conclusion might be that financial constraints do not play a significant role for European transport companies. Nevertheless, some examples showed that they are still reflected in the innovation strategies. Taking the development of hybrid technology in the automotive sector, Toyota accepted already in the decision phase that the return on investment might be longer than on average.

4. Other constraints on innovations

Studies like Market Up, GHG-TransPoRD or REACT highlighted the importance of reliable policy frameworks on the innovation culture in the transport industry. Innovation processes from the first idea towards a successful market entry are long-term processes under high insecurity. The framework conditions for innovations are changing continuously like for example demographic structure, energy resources or changing mobility patterns. Under these circumstances, a strategic policy framework harmonized to the needs of the transport industry for enabling the shift towards a sustainable transport industry is essential. Unfortunately, policy and regulations still hamper the development of smart transport innovations.

An example for a policy that builds a constraint for innovations in the automotive sector is Directive (EC) 2007/46 from the European Commission on the approval of motor vehicles and trailers. The shape of the trailer plays on important role as regards fuel efficiency of semi-trailer trucks. Aerodynamic teardrop-shaped trailers would be beneficial for improving fuel efficiency but will lead to higher trailers than allowed. As the trailers are designed to get narrow in the end, the trailer would also need to be longer in order to have the same load than the conventional shaped trailers. Furthermore, the design of the back end of a trailer needs to be different. The EU regulation builds a constraint on the innovative design.

Another example for a constraint on a key innovation by a sort of regulation is the Vienna Convention on Road Traffic. It is an international treaty which was originally designed to facilitate international road traffic and to increase road safety. The treaty standardized uniform traffic rules among the contractors. The treaty came into force in 1977. At this time, one of the key innovations identified in task 4.1 of FUTRE, fully autonomous driving of road vehicles, was still considered to be science-fiction. Hence, the treaty contains some articles which could prevent fully autonomous driving from becoming reality. Article 8.1 tackles this issue by requesting that every moving vehicle or combination of vehicles should have a driver. Furthermore, the driver should at every time be able to control his vehicle. Even if fully autonomous driving systems have been already tested successfully by several companies (e.g. by Google in California or by Daimler in Germany) the critical constraint from the Vienna Convention on Road Traffic could be a severe regulatory constraint on the market diffusion of the mature technology.

As opposed to this constraints on innovations could also be related to missing regulations like in the case for fuel taxes. As for example, the Energy Taxation Directive (2003/96/EC) of the European Commission did not get a majority vote in the Parliament which prevented a common minimum energy and fuel taxation based on its carbon and its energy intensity. Car manufacturers have to address by innovations completely different taxation frameworks in Europe. Countries like Germany with a historically argued lower diesel tax and the induced demand for diesel cars enforce car manufacturers to innovate in diesel technology whereas other European markets with higher diesel taxes or even feebate systems require other innovation. Hence, car manufacturers cannot focus their efforts on key innovations.

Other constraints on innovations like the unequal distribution of raw materials among the earth are directly linked with scarcity of raw materials. They impose another level of constraints. Geopolitical constraints on innovations can emerge.

Other constraints on innovations like the unequal distribution of raw materials among the earth are directly linked with scarcity of raw materials. They impose another level of constraints. Geopolitical constraints on innovations can emerge.

Rare earths feature unique magnetic, heat-resistance and phosphorescence properties. They are used to directly produce highly efficient magnets, metal alloys, phosphors, optical material, battery material, ceramics, special abrasive powders. These materials are key components of many downstream and consumer products such as: wind power turbines, catalysers (for car and oil cracking), energy-efficient bulbs, engines for electric and hybrid vehicles, flat screens and displays (LED, LCD, plasma), hard drives, car parts, camera lenses, glass applications, industrial batteries, medical equipment or water treatment - to name just a few.

China accounts for 97 percent of the world's production of 17 rare earth metals and Beijing has been tightening export restrictions by raising export taxes and reducing export quotas.

China first imposed restrictions in June 2010, when they cut the quota for domestic companies by 32 percent and 54 percent for foreign-invested companies. The quota for exports was slashed to 30,000 tons against demands for 50,000 - 60,000 tons of demand. In the first round of permits in 2011, China cut its export quota for rare earths by another 35 percent. All of this started driving up prices of rare-earths in mid-2010.

According to EU Trade Commissioner Karel De Gucht, China's restrictions on rare earths and other products would violate international trade rules and would have to be removed. These measures would hurt producers and consumers in the EU and across the world, including manufacturers of pioneering hi-tech and 'green' business applications.”

Therefore, The EU, U.S. and Japan have asked the World Trade Organization (WTO) to settle a dispute with China over its restrictions on exports of rare earths that impact high-tech industries and raw materials in March 2012.

IV. Impacts of transport innovations on competitiveness

1. Introduction

The scope of this task is to identify factors leading to a comparative advantage or disadvantage in relation to the collected major innovations until 2030 and beyond. The technologies were evaluated in terms of their possibility to be introduced in the market as well as their impact to the competiveness of the European transport sector until 2030. The main part of the task was to conduct a qualitative assessment by gathering opinions of transport experts in the framework of a Workshop regarding a series of innovation technologies. The methodology was based on the filling out of an e-questionnaire and on triggering an open discussion among the experts using a series of questions.

The objectives of the task were the following:

- The development of a comprehensive questionnaire. The questionnaire was formed including questions for all the technologies by innovation field.
- A workshop with expert participants was organized in Brussels. The questionnaire was answered from ten transport experts in the workshop, online. Simultaneously, there was an open discussion on the survey, minutes of which have been produced.
- The results of the questionnaire were analyzed and presented in figures for each innovation field.
- Overall conclusions have been recognized and presented in the end of this task

2. Description of the Workshop

The effect of supply-side innovations on the competitiveness of the European transport industry was subject to an expert assessment that was conducted on 28-29 November 2013 in the premises of the European Council of Transport Research Institutes (ECTRI) in Brussels in Belgium. The focus of the workshop was on: 'Emerging Transport Innovations & Technologies'.

Specifically, the workshop aimed at gaining an understanding on emerging transport innovations/technologies, on how these are expected to affect transport system efficiency in Europe and on how these are expected to affect the competitiveness of the European transport sector. Ten experts attended the workshop and provided input in the framework of a qualitative assessment on the list of key innovations/technologies for the transport sector.

Within the workshop, the experts filled out an electronic questionnaire and participated in an open discussion in relation to the likeliness of future technological breakthroughs in the corresponding field and the potential impacts on the transport system and on global competitiveness of the European transport sector. Also they expressed their opinion about the restrictions and barriers which the technological advancements will face. The following figure depicts a part of the online questionnaire used during the workshop to capture the opinions of the experts.

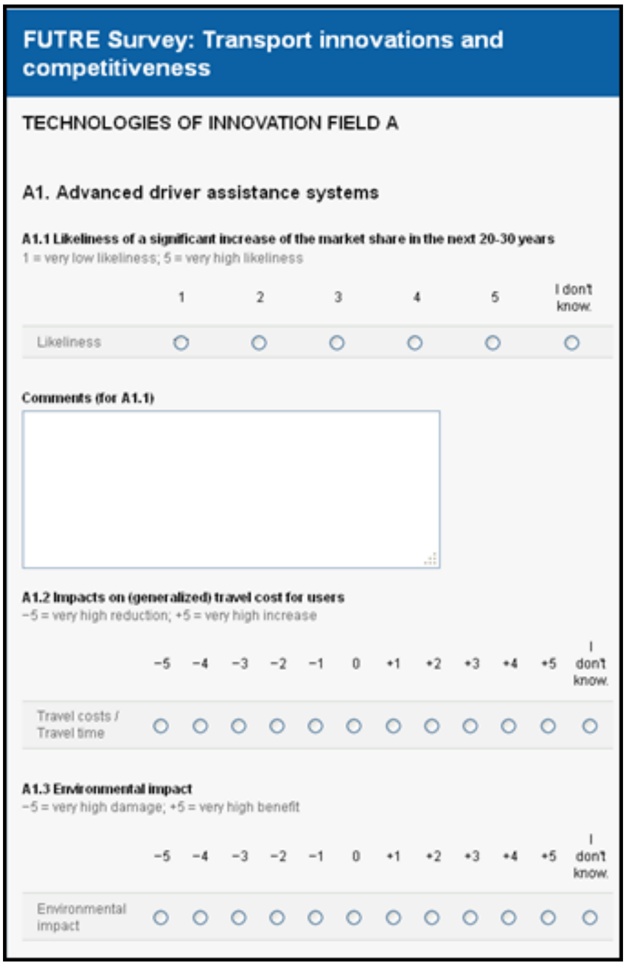


Figure 13. Part of the electronic questionnaire used at the FUTRE workshop

The scope of the development of the questionnaire was to collect more specific and detailed answers according to the opinions of the transport experts. The aim was to develop an overall view about what impacts the transport innovations will have on the transport sector competitiveness until 2030. The experts had to evaluate technologies per innovation field and provide their own assessment, accompanied by short justifications.

3. Structure of the questionnaire

The structure of the questionnaire allowed addressing the same questions to different Innovation Fields and technologies in order to come up with a common understanding and comparison of the emerging transport technologies and how these are expected to affect transport system efficiency in Europe. The questionnaire can be found in Annex 2.

The experts were asked to provide ratings in relation to each Innovation /Technology indicating how high its anticipated impact is and what its likeliness to enter the market is, on a 1-5 scale. The key issues examined, per technology, are the following:

Level of Expertise: is related to a rough estimation of experts' degree of expertise for each specific question/ innovation.

Likeliness: It is associated with the probability of entering and gaining an important share of the respective market within the next 20-30 years (1- Very Low Likeliness, 5- Very High Likeliness).

Impact: It is associated with the implications (positive or negative; a "0" encompasses "no impacts" and a neutralization of positive and negative impacts) of the technology in the case of entering and gaining an important share of the respective market within the next 20-30 years.

Travel cost: This cost refers to the user(s) or shipper(s) cost/time impacts.

Environment: The impact to Environment is considered as the emissions (increase or reduction) resulting from the implementation of the innovation for the same transport "output", E.g. impact of biofuels on Environment: +4

Modal split: Specify the expected modal shift, e.g. Road (Passenger) to Rail (Passenger) or Air to Road (Freight)/ Rail (Freight) or even Private Car (Passenger/ Freight) to New Public Transport Mode.

Beneficial to European transport industry: It is associated with the potential implications of the innovation/ technology to the European transport industry. Transport industry is defined as the manufacturers (automotive industry, civil aeronautics/ aviation, waterborne and rail), the developers of transport infrastructure, the transport service providers and the Intelligent Transport Systems (ITS) companies.

The Rating Scale: was from -5= very high reduction/ negative effect to +5= very high increase/ positive effect.

3.1. Summary of results of the questionnaire combined with the minutes of the workshop

3.1.1. Innovation field: Automation Of Road Transport

Technologies of Innovation Field A

A1. Advanced driver assistance systems

A summary of the questionnaire results regarding the advanced driver assistance systems technologies are given in the figures below.

Figure 14 shows the stated level of expertise of the workshop participants in this innovation field.

Figure 15 presents the likeliness, meaning the possibility of a significant increase of the market share in the future. The majority of the experts believe that this technology has high likeliness for the future, especially for the next 20-30 years. Five out of ten answered that the likeliness is a level 5, which is the highest. According to the comments of the experts during the workshop, it is already known that the European Commission is thinking about creating legislation with the obligation to control drivers' behaviour, promoting ADAS. Of course there is a need for implementations on engines and related technologies, which means that the costs will be increased. The training of the drivers is also very important and necessary even if technology fits into existing user interfaces (e.g. electronic tachometers).

Regarding the benefit of ADAS for the European transport industry (figure 16), according to the expert answers, it can be said that the industry probably will keep financing this type of technology and will support its production worldwide. Despite this fact, the expert opinions show variation on how beneficial they believe this technology will be. The main comments about the advanced driver assistance systems and the European transport industry were that these systems are well selling products, because they are driven by safety concerns (cf. zero fatalities goal from European White paper), therefore these systems will be further developed.

Emergency braking system which is promoted by the EU has also safety objectives, including the challenge for the industry to reduce heavy accidents. The emergency braking systems will increase costs while additional problems may occur due to vehicles not using the same standardized systems. An important question is whether all the vehicles in the future will have these technologies.

Figure 17 shows the travel cost, meaning the travel time for the users. The replies seem to be scattered, therefore it is difficult to draw conclusions although the results present a slightly negative impact on the travel costs of the users from this technology. During the workshop it was mentioned that one important result of using this technology, for the users, is the ability to make driving more efficient, but smoother driving can also increase driving distances.

Regarding the environmental impact (Figure 18) it can be said that the majority of the experts believe that there will be some positive environmental impacts, mainly as a result of shorter trips, resulting in less fuel consumption and CO2 emissions.

As for the modal shift, the experts replied that there is potential for increase of the road transport, a negligible shift from rail to road and from private car to public means of transport.

Figure 14: Level of expertise in the innovations field (Advanced driver assistance systems)

Figure 15: Likeliness of significant increase for Advanced Driver Assistance Systems

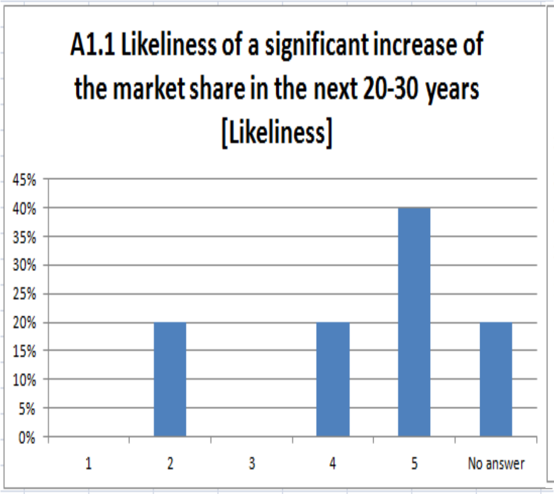


Figure 16: Benefit for European transport industry for Advance Driver Assistance Systems

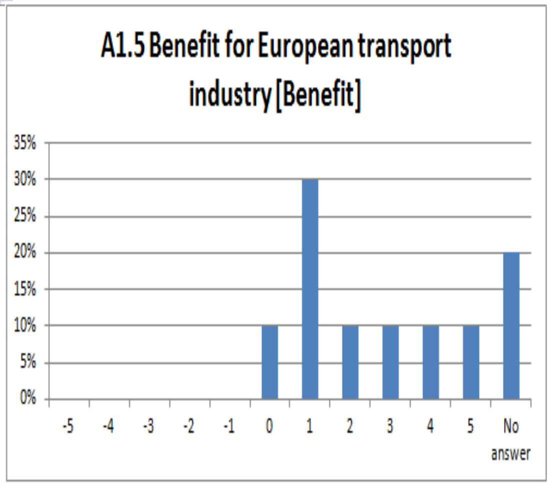


Figure 17: Impacts on travel cost for users for Advanced Driver Assistance Systems

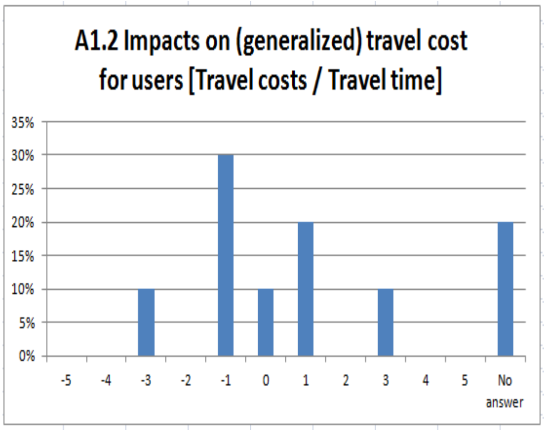
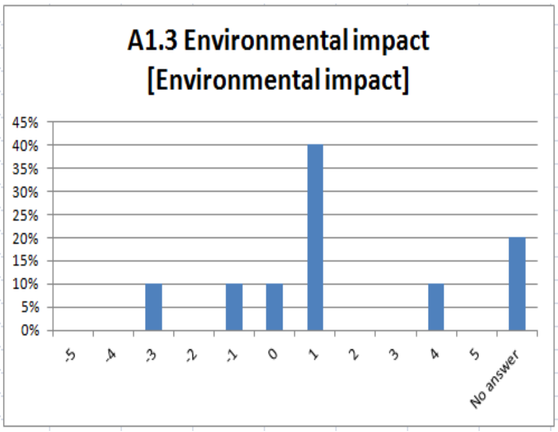


Figure 18: Environmental impact for Advanced Driver Assistance Systems



A2. Full autonomous driving

The level of expertise of the workshop participants is shown in Figure 19. Figure 20 shows a very small likeliness of a significant increase of the market share for Full Autonomous Driving in the future. Thirty percent of the experts replied that there is very low likeliness while a 40% is spread across the remaining answers. According to the comments of the experts during the workshop, this technology will be difficult to be fully implemented by 2030, due to safety reasons. There was a lot of scepticism regarding its future application in open systems while it was though that it is more suitable in closed systems like harbours or airports. Elements of the system already exist although this technology is about using the same systems in an innovative way. Hence, the innovation lies within the integration of these systems.

Figure 21 shows the benefit for the European transport industry of the system. Specifically, the experts believe that the benefit will be positive. According to the comments of the experts from the workshop it is believed that the manufacturers need to solve the legal issues first in order to broadly implement the system in the EU. The automotive industry is aware of users' reactions and there are issues on the demand side. The industry is reluctant to proceed ensuring that the system is secure and that the end user accepts it. Furthermore, heavy investments will be needed since public authorities will be difficult to undertake the costs.

Figure 22 presents the impacts for the users, which according to expert opinions will be negative, thus there will be an increase of the travel costs. During the workshop the experts stated that travel costs would increase due to additional investment requirements.

Figure 23 shows the potential environmental impacts of the system. Expert opinions are split equally between negative and positive impacts on the environment. Experts indicated that the environmental benefit is moderate due to less congestion and better resource and energy efficiency.

Finally, regarding modal shift the experts responded that probably there will be a shift from rail, buses and bikes to individual motor – vehicles. Specifically, there will be a shift towards track based systems, respectively on rail (including virtual tracks), from rail to road. Hence, there will be a negligible modal shift from public to private means of transport.

Figure 19: Level of expertise for Full Autonomous Driving

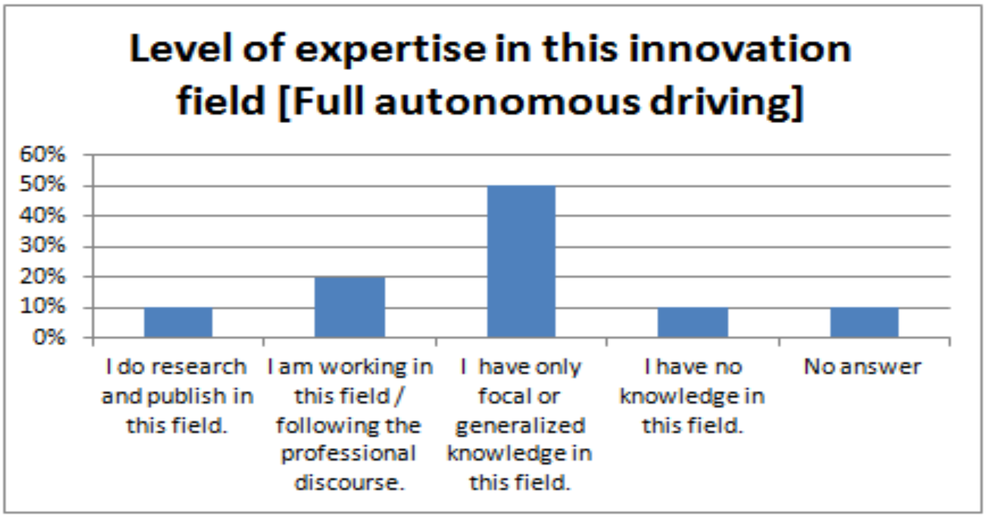


Figure 20: Likeliness of significant increase for Full Autonomous Driving

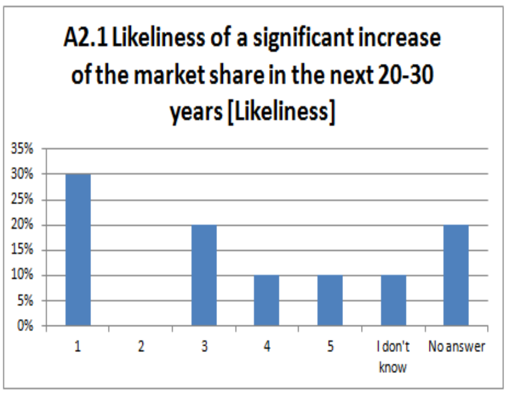


Figure 21: Benefit for the European transport industry for Full Autonomous Driving

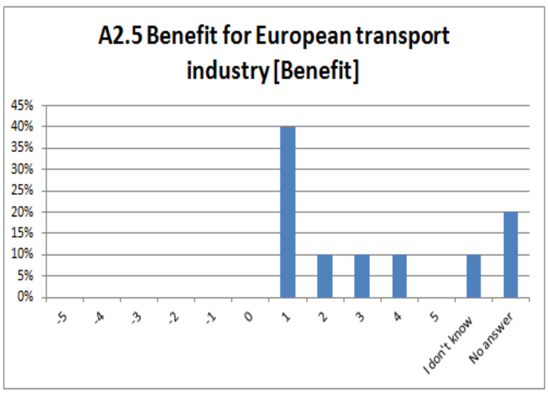


Figure 22: Impacts on travel cost for users for Full Autonomous Driving

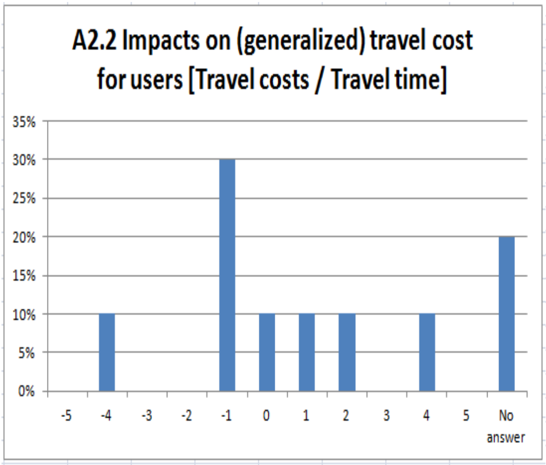
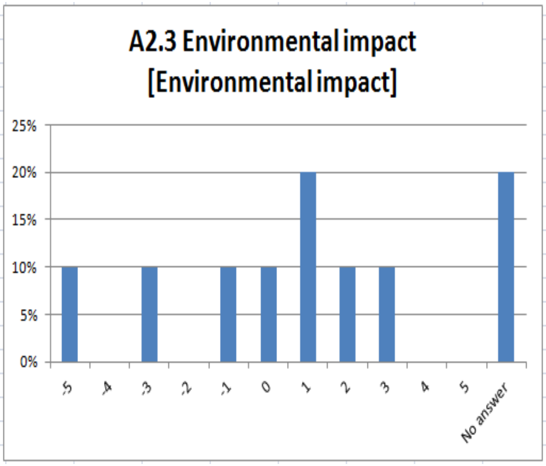


Figure 23: Environmental Impact of Full Autonomous Driving



A3. Intelligent transport communication systems (e.g. Inter - vehicle communication, vehicle-infrastructure communication, intelligent signaling)

The level of expertise of the participants is shown on Figure 24. Figure 25 indicates that there is a high likeliness for a significant increase of the market share in the next 20-30 years for this technology, driven from safety and driver support considerations. The main challenge according to the comments of the experts is data processing and the use (faster and advanced algorithms) of real time data applications. The second challenge is the interface and the interaction (HMI). The experts believe that in 20-30 years these technologies will be a sine-qua-non service.

Based on Figure 26, the benefit for the European transport industry will be only positive and according to the workshop the industry has to ensure that the users will support this technology. According to the comments of the experts, some trends will be towards directly transferring open data strategies and better marketable applications and services. The “Car to X” (driven by automotive industries) as well as the “googlisation" of mobility and transport (real time information services) will be a catalyst for more profits and new business models.

The impacts on travel cost for the users (Figure 27), according to the questionnaire and the majority of the experts, will be negative although there are some positive answers as well. According to the comments of the experts, driver support systems and awareness raising may reduce the cost of travel and the travel time. The cost of the engine will probably be increased as well as the cost of the software installation and training.

Regarding the environmental impact (Figure 28), the majority of the experts indicate that it will be in the lowest level of the positive range. Nevertheless, opinions vary broadly including both positive and negative indications. The comments of the experts about the environmental impact concern multimodal mobility patterns and specifically whether they will reduce the environmental impact and result in less fuel consumption and fewer accidents. Opinions seem to differ as on the one hand the increased efficiency of the transport system due to ITS will reduce the environmental impacts but on the other hand it will also lead to more traffic which in turn will increase the ecological footprint in absolute numbers. The impact on modal shift according to the comments of the experts will be negligible in terms of shifting from rail to road.

Figure 24: Level of expertise for Intelligent Transport Communication Systems (ITCS)

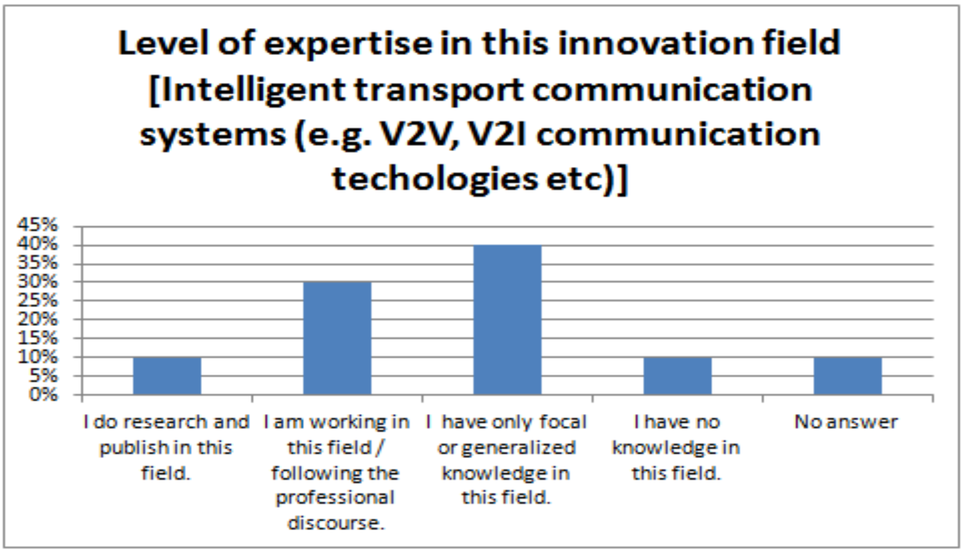


Figure 25: Likeliness of significant increase of ITCS

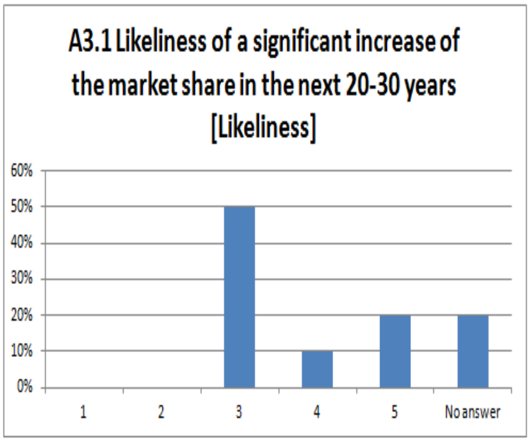


Figure 26: Benefit for European Transport Industry of ITCS

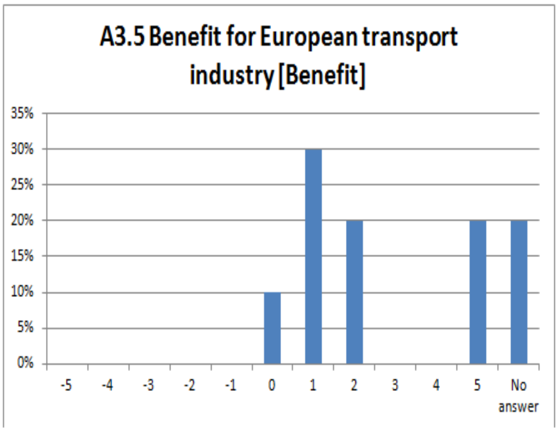


Figure 27: Impacts on travel cost for users of ITCS

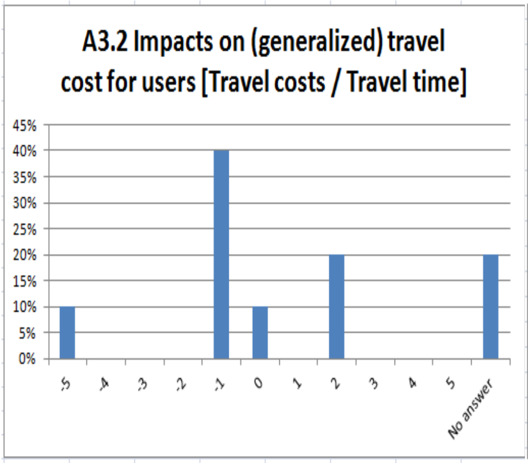
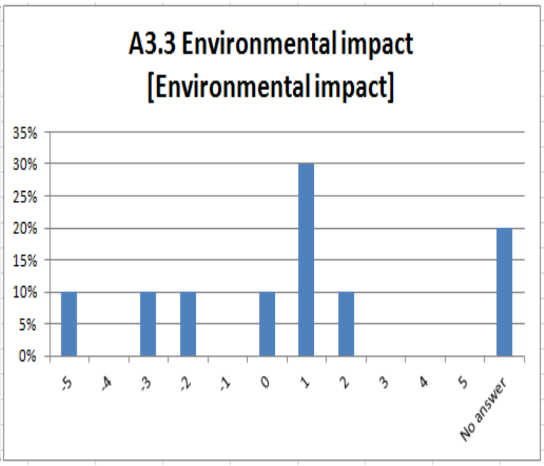


Figure 28: Environmental impact of ITCS



3.1.2. Innovation field: Fuels And Propulsion Technologies

Technologies of Innovation Field B

B1. Battery electric vehicles

Figure 29 shows the stated level of expertise of the workshop participants in this innovation field.

According to the results of the questionnaire and Figure 30 it can be seen that the technology of battery electric vehicles has potential for a significant market share increase in the next 20-30 years. The experts mention in their comments that the market share of EVs will be 40% until 2020 and if there is no disruptive change in technology, the forthcoming decades the EVs will prevail over conventional cars. It is believed that there will be a significant market share at least in urban areas.

According to Figure 31, the benefit for the European transport industry will be rather positive. Only 10% of the experts believe that there will be no benefit. It is mentioned that the industry seems to be moving more and more in this direction, despite the initial reluctance of the European manufacturers. Currently, the manufacturers are committed to electric mobility. The experts indicated that a first strong development could be witnessed in electric 2-wheels, followed by a second stage of e-motor-vehicle dissemination. In China, electric two-wheelers are booming. Cost will be a constraint, although not the only one.

The majority of the experts believe that this technology will have positive impacts on travel costs for users (Figure 32). Opposite opinion indicated that the vehicle fleets will slowly change travel costs, which will generally increase due to rising energy and fuel prices. Costs are expected to increase for the users, while the travel times will not be shorter and safety levels will not increase.

Regarding the environmental impact (Figure 33) the majority of the experts answered that there will be a positive impact. About 20% of the experts indicated that the impact will be negative. In the comments provided it is mentioned that the most important thing about the environmental impact is how the electricity is produced and transported. There will be probably less CO_2 production, but still high level of energy consumption, as electricity has to be produced and transported. According to the experts, the impact on modal shift from conventional ICE to battery is difficult to be assessed.

Figure 29: Level of expertise for Battery Electric Vehicles (BEVs)

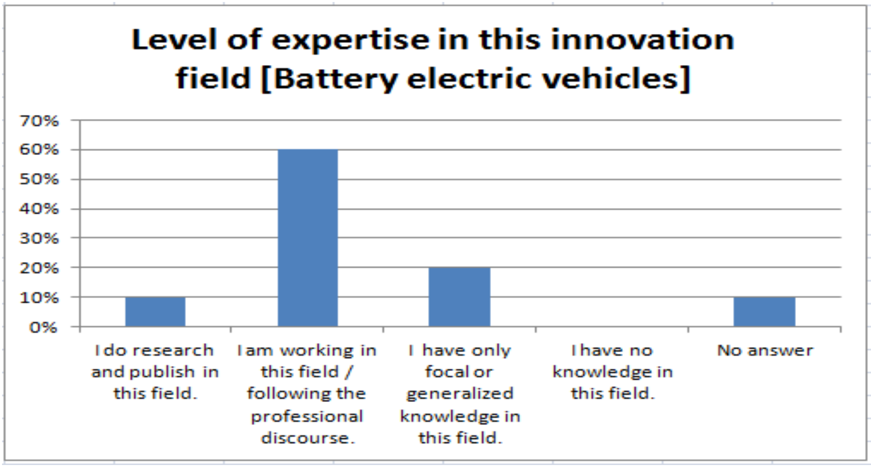


Figure 30: Likeliness of significant increase of BEVs

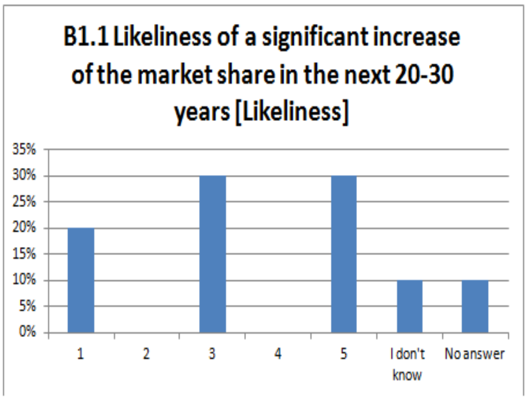


Figure 31: Benefit for European Transport Industry from BEVs

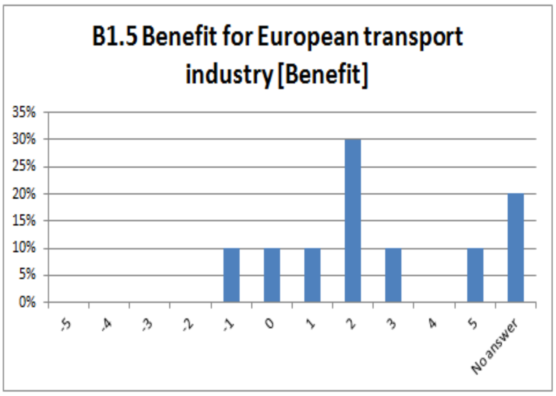


Figure 32: Impacts on travel cost for users of BEVs

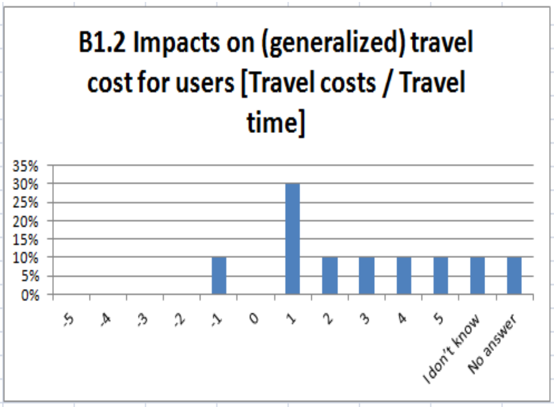
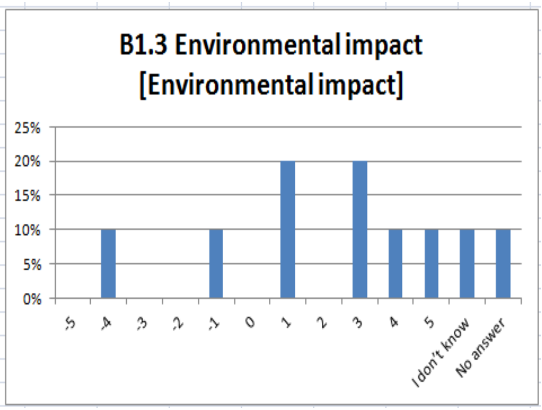


Figure 33: Environmental impact of BEVs



B2. Hybrid technology (allowing pure electric drive for a certain distance)

Figure 34 shows the stated level of expertise of the workshop participants in this innovation field.

According to Figure 35, the likeliness of a significant increase of the market share in the next 20-30 years for this technology is rather positive.

The majority of experts, as indicated in Figure 36, believe that there will be a positive benefit for the European transport industry from this technology. According to the comments, each car manufacturer today has to have a hybrid propulsion system collection within his fleet. It was also noted that ERTRAC predicts that there will be 5 million full electric and plug-in hybrid cars on European roads by 2020. Hybrid vehicle technology is already rather popular in Japan. The take-up of hybrids is also supported by the ongoing debate about particulate matter emissions of diesel cars.

User travel costs related responses, presented in Figure 37, indicate an anticipated increase in these costs. According to the experts' comments the costs are expected to increase while the travel time is not anticipated to be shorter.

Summary of the environmental impact statements is shown in Figure 38. The majority of the experts believe that there will be a positive environmental impact. In their comments, experts indicate that the environmental impact is rather low due to improvement of internal combustion engines and their fuel efficiency. However, hybrid particulates and NOx are the main issue in many regions. Finally, the experts believe that there will be no impact on modal shift.

Figure 34: Level of expertise for Hybrid technology

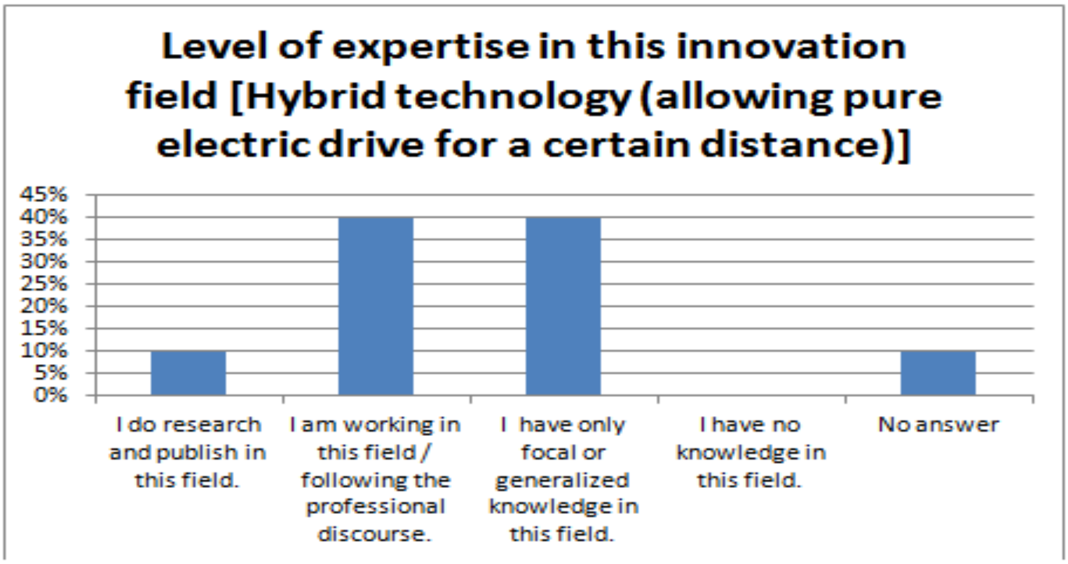


Figure 35: Likeliness of significant increase of Hybrid Technology

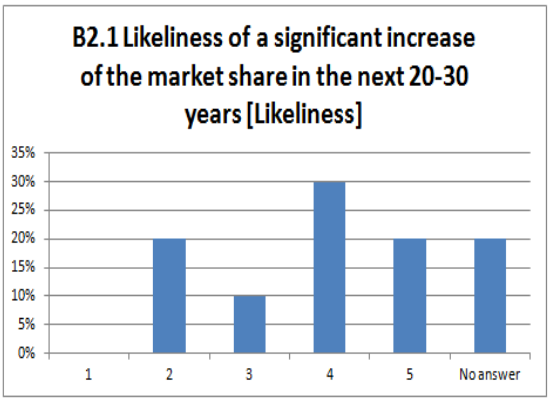


Figure 36: Benefit for European Transport Industry from Hybrid Technology

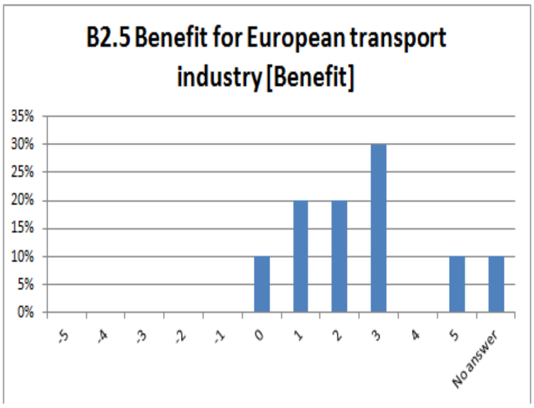


Figure 37: Impacts on travel cost for users of Hybrid technology

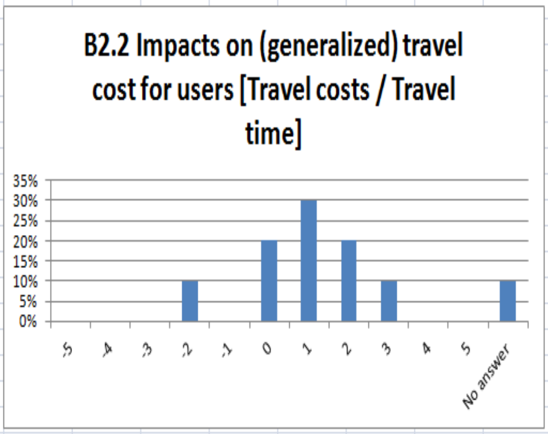
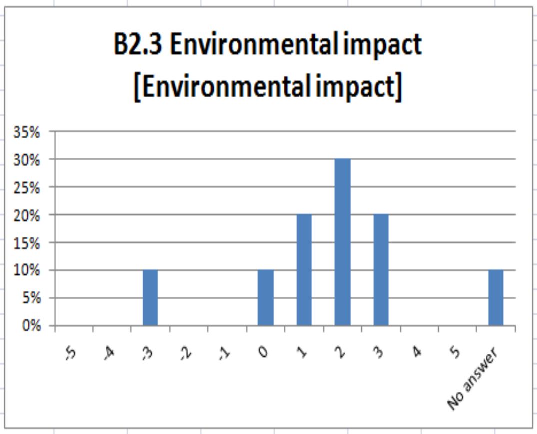


Figure 38: Environmental impact of Hybrid Technology



B3. Fuel cell Electric Vehicles

Figure 39 shows the stated level of expertise of the workshop participants in this innovation field.

Responses on the likeliness of a significant increase of the market share for FCEVs are summarized in Figure 40. The majority of the experts had no formed opinion on anticipated developments on this matter, while the rest of the respondents indicated that there is a small likeliness for this technology.

Regarding the benefit for the European transport industry for FCEVS (Figure 41), the experts indicated that it will be positive, although there were several 'don't know' and 'no answer'. It was also noted that success in several niche areas (e.g. busses, forklifts and commuter trains) has already been achieved.

Figure 42 regarding the impacts in travel costs for users, shows that the majority of the experts believe that there will be a positive impact although there is a small number who indicated 'don't know'.

According to Figure 43 the environmental impact of FCEVs will probably be positive. The experts indicated that the environmental impact depends heavily on the distribution schemes of the fuels and that FCEVs could prove to be a real-life solution.

Regarding the impact on the modal shift the experts do not anticipate any major changes compared to the current conditions and a factor that may affect it is the cost of the new technology for the users.

Figure 39: Level of expertise for Fuel Cell Electric Vehicles (FCEVs)

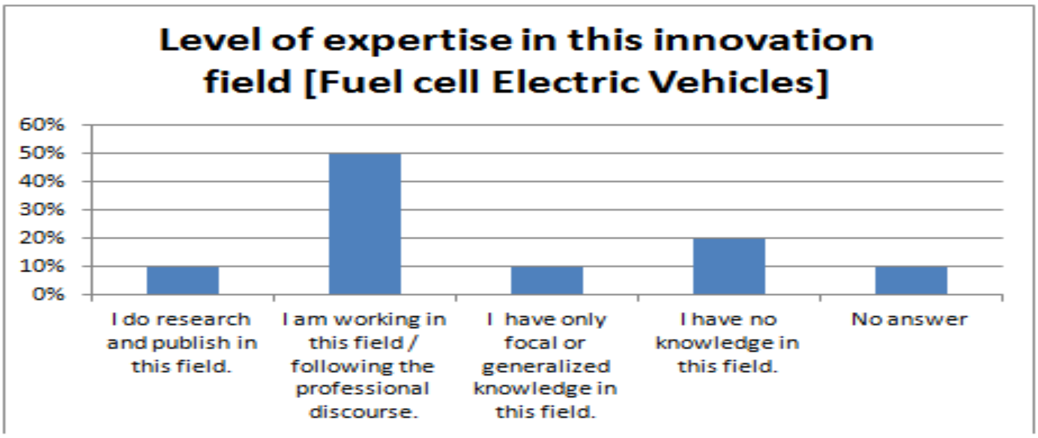


Figure 40: Likeliness of significant increase of FCEVs

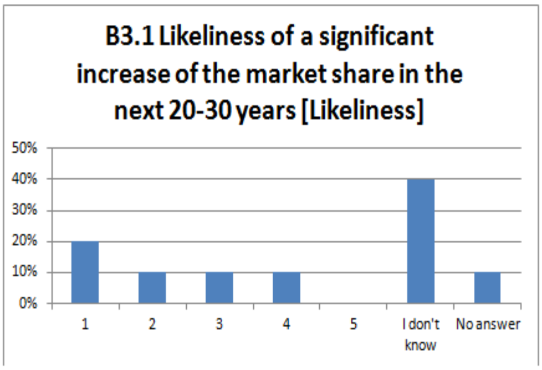


Figure 41: Benefit for European Transport Industry from FCEVs

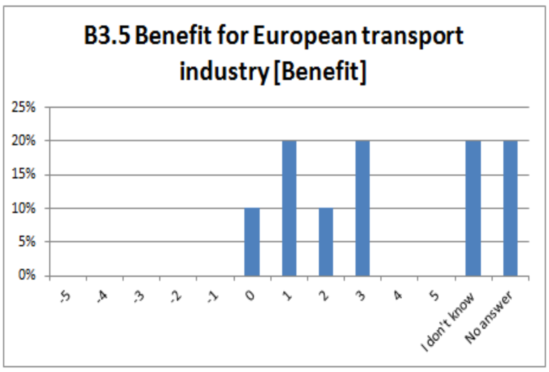


Figure 42: Impacts on travel cost for users of FCEVs

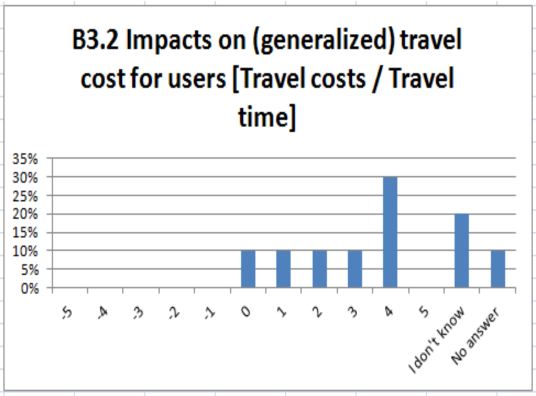
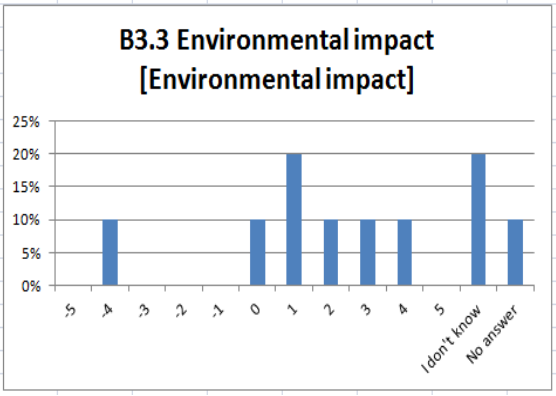


Figure 43: Environmental impact of FCEVs



B4. Second Generation biofuels

Figure 44 shows the stated level of expertise of the workshop participants in this innovation field.

Analysis of the responses in this field, summarized in Figure 45, indicate that there is an anticipated significant increase of the market share for this technology. The experts stated that as technological solutions evolve and mature, the likeliness of a significant increase will be stronger. Synthetic fuels based on biofuel market shares are increasing. The experts said that the German UBA is putting strong emphasis on this solution in particular for heavy duty vehicles. They believe that considering the resilience of traditional internal combustion engines, it is likely that there will be more widespread use of bio-fuels. However this can open an ethical dilemma (it is already an open issue actually), considering how and if bio-fuels production will compete with food production. They mentioned that there is a great feasibility and vehicles are already prepared for this kind of fuel. There is no need for new investments.

Figure 46 summarizes the responses about the benefits for the European transport industry. The majority of the experts believe that the benefit is positive. In their comments, the experts stated that there might be a case that other regions will have a less problematic discussion on the issue (due to more stringent political regimes) and increase their development of such technologies. On the other hand, the 'hungriness' for fuels will push the energy-poor countries (EU, India, and China) to develop these technologies. It is noted that this would be very beneficial for transport and logistics industries, in better calculating their future investments.

According to Figure 47 the majority of the experts believe that the impacts on travel cost for users will be generally positive although an equal number answered that they don't know. According to the comments, the experts believed that biofuels can be developed because of their competitive price against traditional fuels. As a substitute of traditional fuel the final price will remain stable or it will increase, giving a few advantages to the road system.

Figure 48 indicates that the impact of 2nd generation biofuels to the environment will probably be positive. According to the expert comments, it will not improve the competitiveness of the Road Freight Sector. Rising costs of fossil fuels will result in increase of this fuel category.

Finally, the experts do not foresee any impact on modal split as a result of this technology.

Figure 44: Level of expertise for Second Generation biofuels

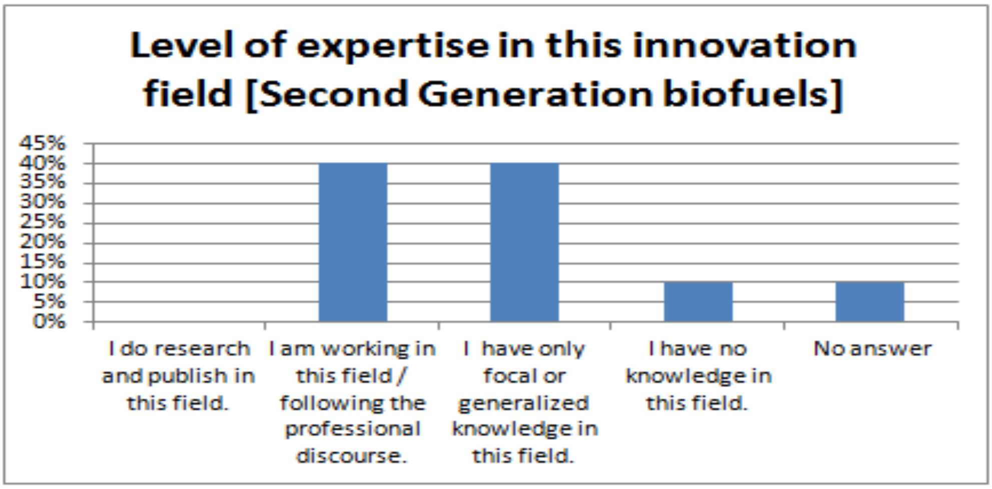


Figure 45: Likeliness of significant increase of Second Generation biofuels

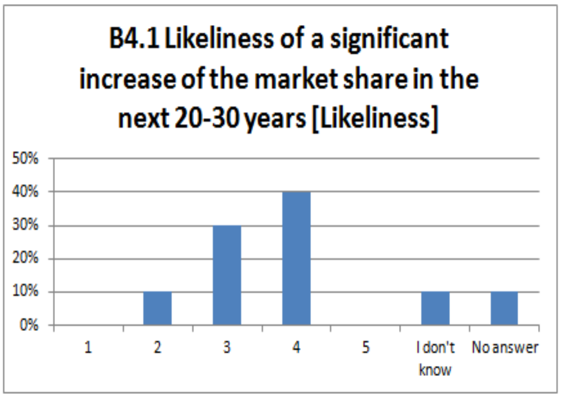


Figure 46: Benefit for European Transport Industry from Second Generation biofuels

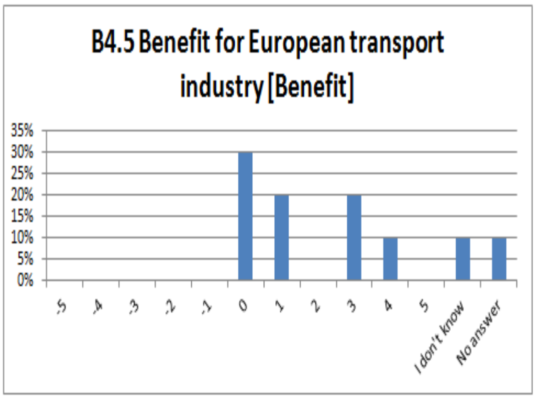


Figure 47: Impacts on travel cost for users of Second Generation biofuels

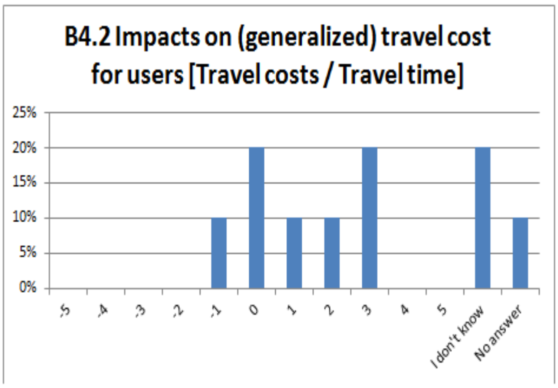
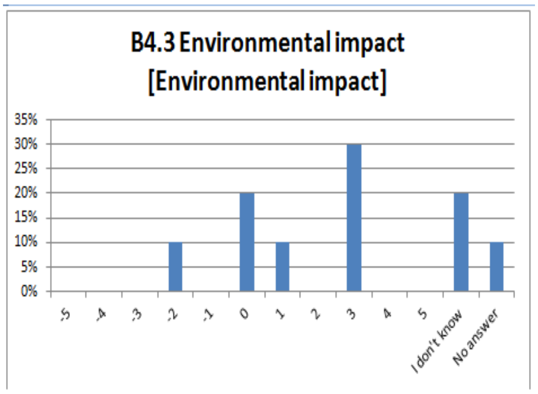


Figure 48: Environmental impact of Second Generation biofuels



B5. Improvements in conventional internal combustion engines (e.g. downsizing)

Figure 49 shows the stated level of expertise of the workshop participants in this innovation field.

Figure 50 presents the likeliness of a significant increase for the market share in the next 20-30 years. Although the numerical scores vary broadly, there seems to be a concentration of opinions indicating moderate and high likeliness. The experts mentioned in their comments that the extraordinary life of internal combustion engines will last until the next decade, or at least it seems so. This would not be only for "path dependency" and lobbying. The improvement of efficiency could be seen as a moderate compromise to environmental issues, final cost of transport and resilience. The experts believe that the next generation combustion engine technologies are due until 2020 and that high pressure injection and multiple combustion air compression systems and existing valve technologies will disappear. There is a constant trend in improving the conventional combustion engines, which, however, is not related to a market share increase.

Regarding benefit for the European industry (Figure 51) it can be said that it will be positive. The experts indicated that an important strategy for the automotive industry, including automotive options for international markets, emerging countries and innovation, is the smaller and less costly cars and light duty vehicles.

Figure 52 summarizes the responses on the impacts to the travel cost for the users. The majority of the responses indicate that the impact will be negative. Travel cost may not have a significant decrease.

Figure 53 about the environmental impact shows a large dispersion of replies regarding environmental impacts. Although it is difficult to draw conclusions from the results perhaps there seems to be a higher concentration of replies towards the positive parts of the data distribution. According to the experts' comments it is stated that higher fuel efficiency with lightweight structures will increase efficiency and smoothen environmental impacts although the probable increase in market share of the conventional cars will affect the environment in a negative way.

Regarding the impact on modal shift, the experts believed that there will be a possible shift in favor of road (and in favor of private motor vehicle) due to lower final costs. This could be counterbalanced by a wider use of private motor-vehicles.

Figure 49: Level of expertise for Internal Combustion Engine (ICE) improvements

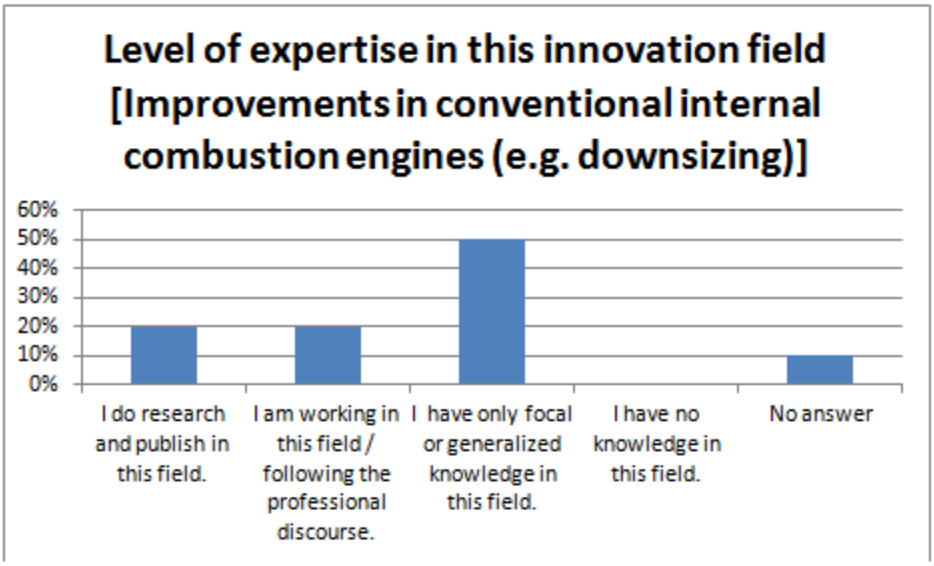


Figure 50: Likeliness of significant increase of Internal Combustion Engine (ICE) improvements

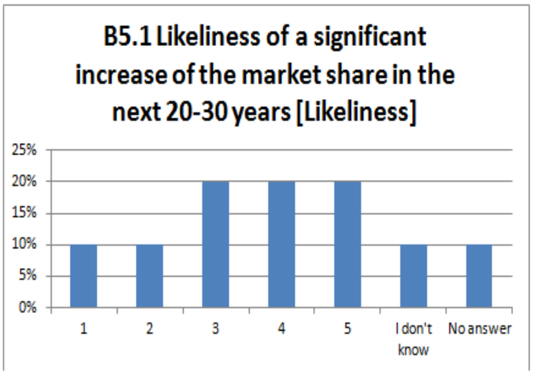


Figure 51: Benefit for European Transport Industry Internal Combustion Engine (ICE) improvements

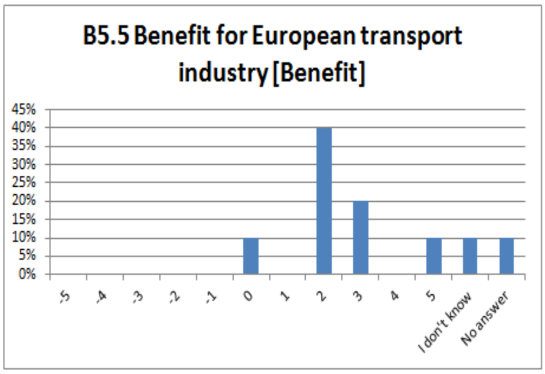


Figure 52: Impacts on travel cost for users of Internal Combustion Engine (ICE) improvements

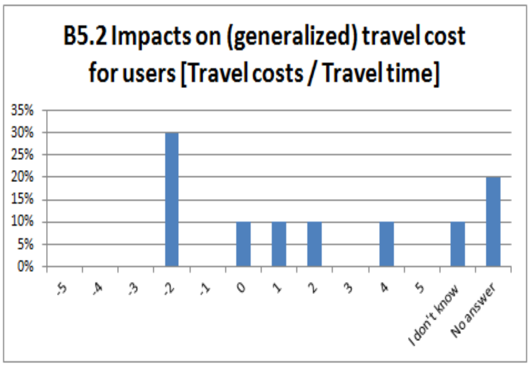
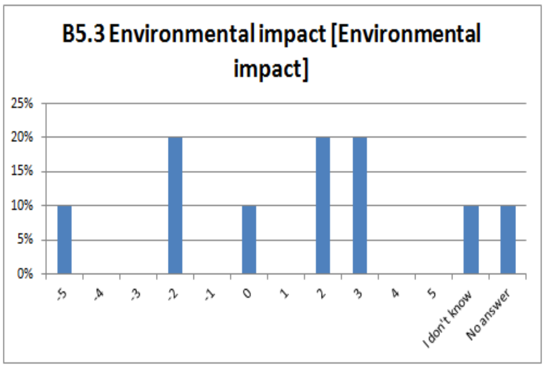


Figure 53: Environmental impact of Internal Combustion Engine (ICE) improvements



B6. Liquid Gas (LNG) for shipping

Figure 54 shows the stated level of expertise of the workshop participants in this innovation field.

Figure 55 indicates that a significant increase in the market share of this technology for the next 20-30 years is anticipated. The experts indicated that the technology seems promising and suggested that research should emphasize on LNG for inland waterways and short sea shipping. Furthermore, the experts indicated that natural gas is much more expensive, making this solution out of reach for shipping industries.

The benefit for the European transport industry (Figure 56), for those who provided a view on the matter, seems to be positive. According to the experts, there is good know how in Europe on this technology.

Figure 57 shows a wide spread of views on the travel costs for LNG.

On the environmental impact, according to Figure 58, expert views seem to be on the positive side. The experts believe that there is a high environmental impact on particulate and NOx. The cost of fueling infrastructure makes the technology more expensive.

No impact on modal shift is foreseen.

Figure 54: Level of expertise for LNG shipping

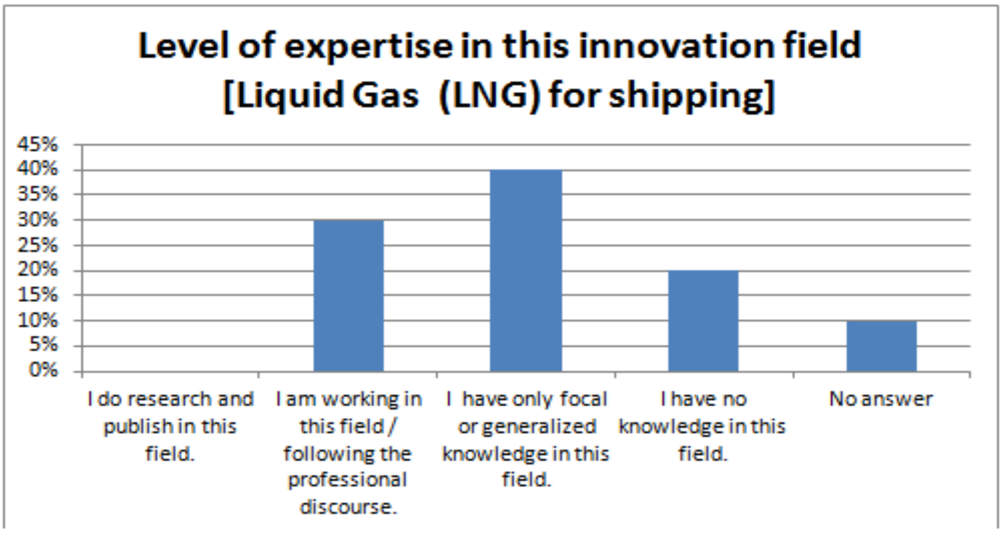


Figure 55: Likeliness of significant increase of LNG Shipping

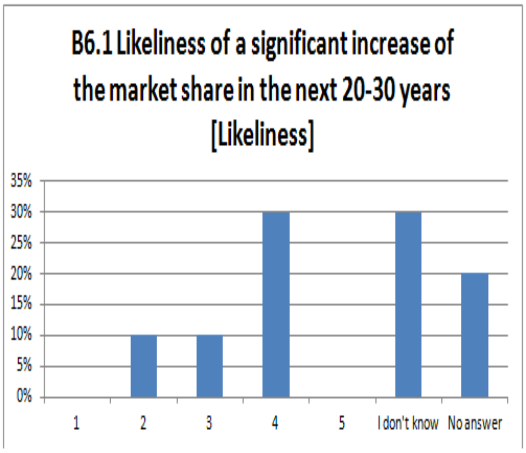


Figure 56: Benefit for European Transport Industry LNG Shipping

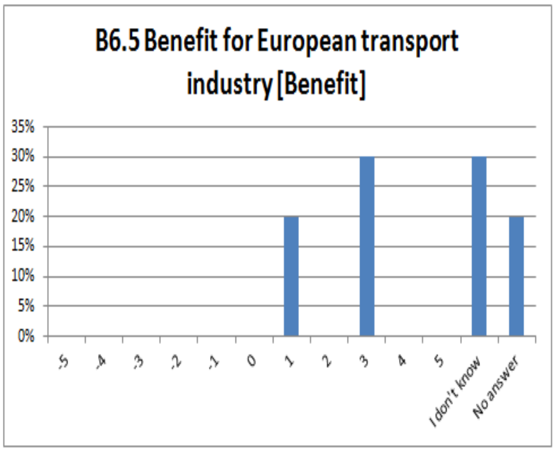


Figure 57: Impacts on travel cost for users of LNG shipping

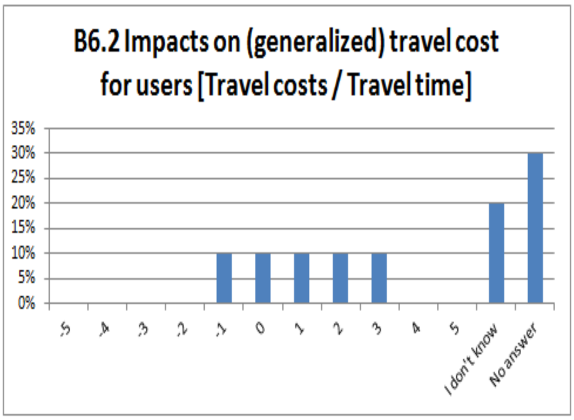
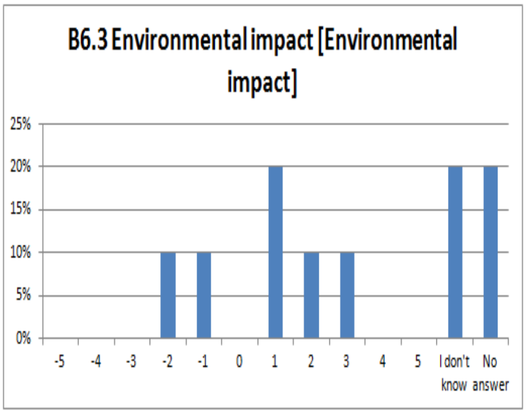


Figure 58: Environmental impact of LNG shipping



3.1.3. Innovation field: Improving The Means Of Transport

Technologies of Innovation Field C

C1. Lightweight materials (e.g. carbon fibers)

Figure 59 shows the stated level of expertise of the workshop participants in this innovation field.

The views on the likeliness of a significant increase of the market share in the next 20-30 years are split between average and high (Figure 60). The experts indicated that there will be a shift towards lightweight materials and that research in the automotive sector is focusing heavily in this direction. In the next 20-30 years a radical change and technological advancement in materials is anticipated, beyond the current knowledge and research in the field will intensify, as less weight means less energy consumption.

According to Figure 61 the benefit for the European transport industry seems to be positive although a significant number of respondents did not reply. The experts indicated that the technology is of benefit to car and light rail manufacturers.

The overall view regarding travel cost for users from this technology is shown in Figure 62 to be on the positive side. The experts indicated that the impact of lightweight materials depends on the transport mode. The impact in aviation, for example, is higher, which is not the case in the trucking industry. There are problems of costs, flexibility, durability, stability/safety (also because trucks are used longer and under heavy conditions).

About the environmental impact according to Figure (63), those who provided a view on the matter indicated that there will be a positive impact. The experts indicated that the environmental impact of lightweight materials is not fully perceived and assessed. Although, there will be less energy consumption, they believe that the very reason for developing lightweight material is indeed to compensate for high energy costs.

The impact on modal shift will be probably a negligible shift from rail to road or none at all.

Figure 59: Level of expertise for Lightweight materials

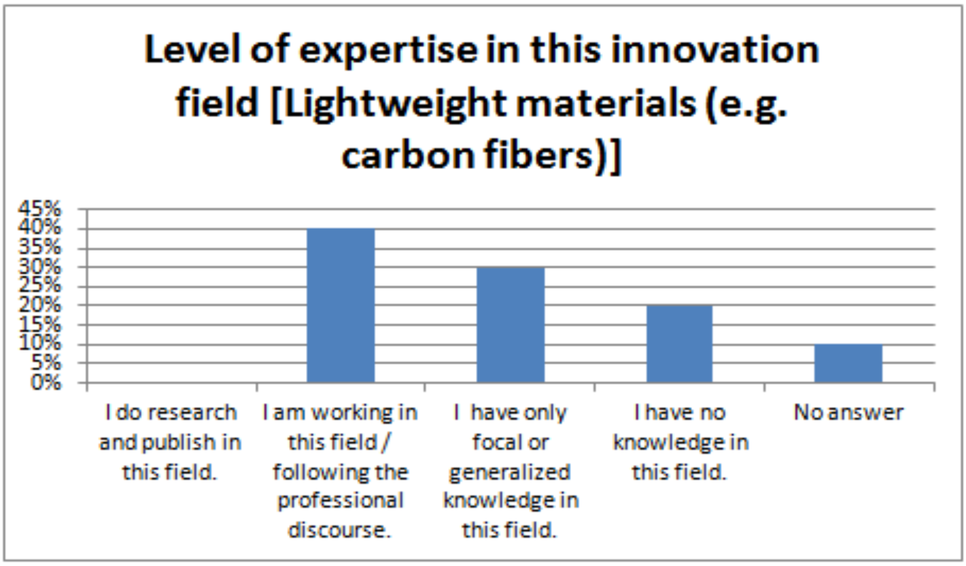


Figure 60: Likeliness of significant increase of for Lightweight materials

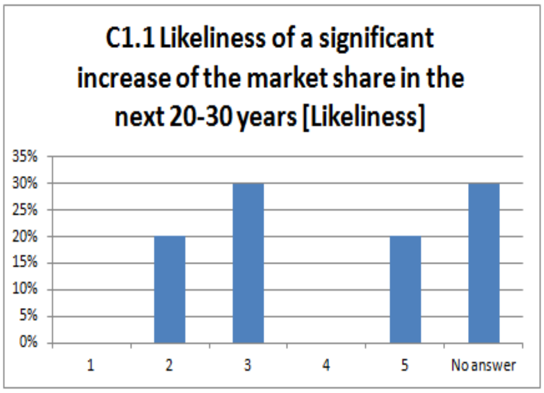


Figure 61: Benefit for European Transport Industry from Lightweight materials

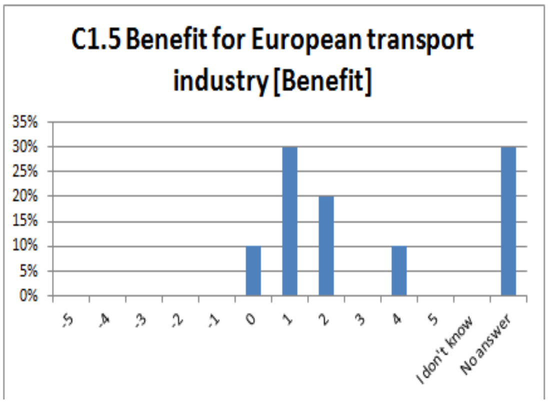


Figure 62: Impacts on travel cost for users from Lightweight materials

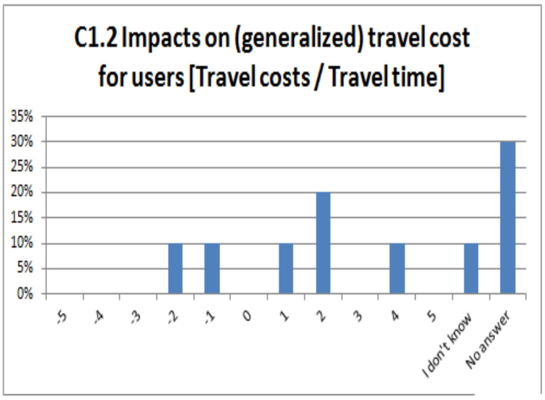
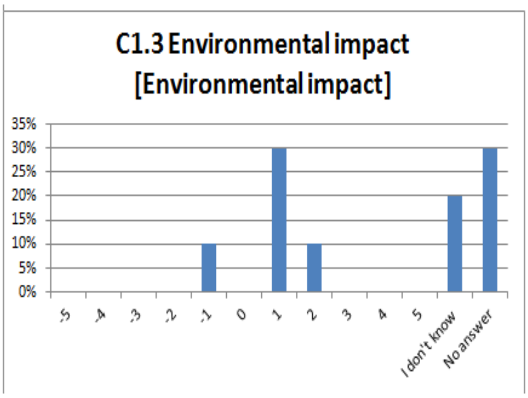


Figure 63: Environmental impact of Lightweight materials



C2. Improved aerodynamics

Figure 64 shows the stated level of expertise of the workshop participants in this innovation field.

Figure 65 indicates that there is a small likeliness of a significant increase of the market share in the next 20-30 years. The experts indicated that there will be a moderate increase of market shares. Aerodynamics is one major field for basic and academic research worldwide relevant for transport sector innovation.

Views on the benefit for the European transport industry according to Figure 66 are on the positive side. The experts mentioned that the road transport sector has made strides in this direction.

Figure 67 shows that the majority of the experts did not answer or did not know about the impacts on travel cost for users from improved aerodynamics.

Figure 68 regarding environmental impact, indicates that there is a small but positive impact from improved aerodynamics. The experts indicated that there will be less energy consumption, especially in the aviation sector in the long term horizon.

Regarding the impact on modal shift the experts believe that there will be a modal shift to HSR from rail to road.

Figure 64: Level of expertise for Improved Aerodynamics

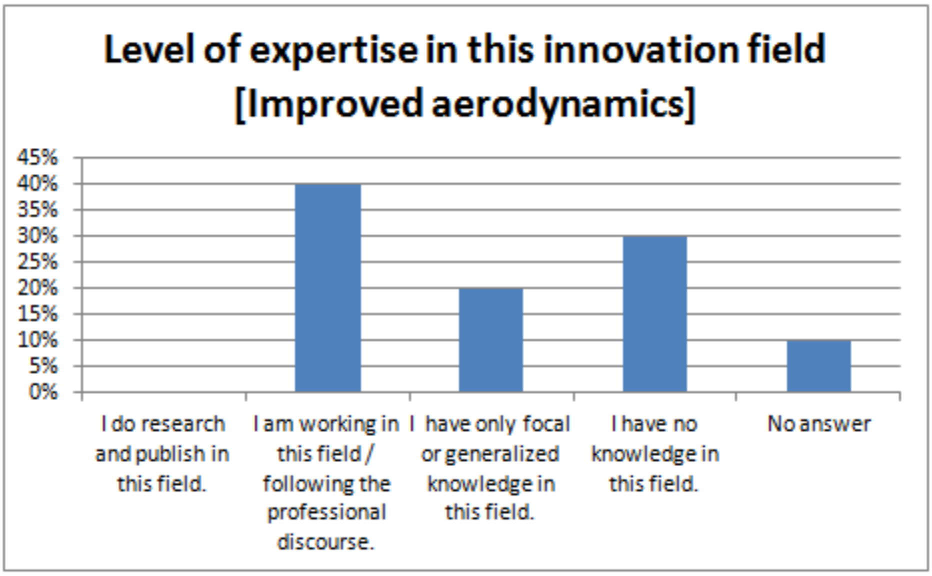


Figure 65: Likeliness of significant increase of Improved Aerodynamics

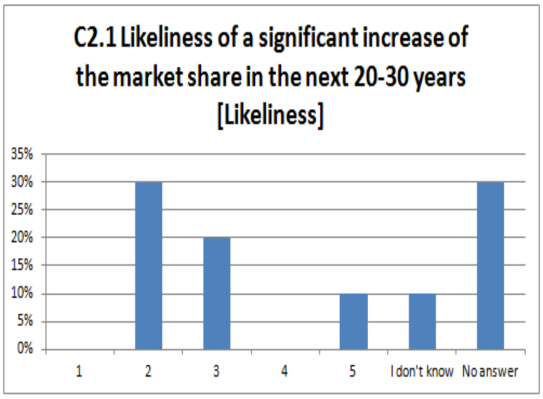


Figure 66: Benefit for European Transport Industry from Improved Aerodynamics

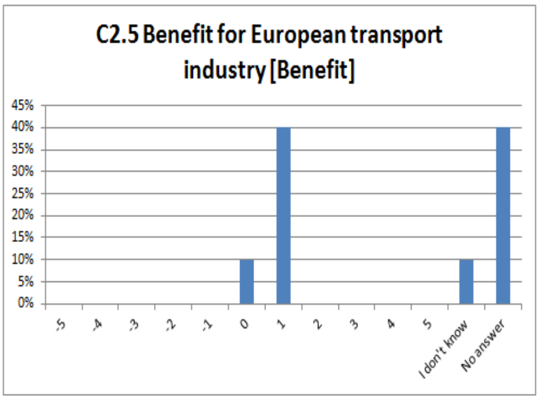


Figure 67: Impacts on travel cost for users from Improved Aerodynamics

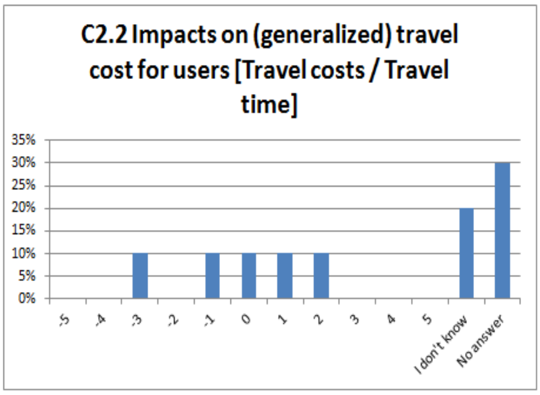
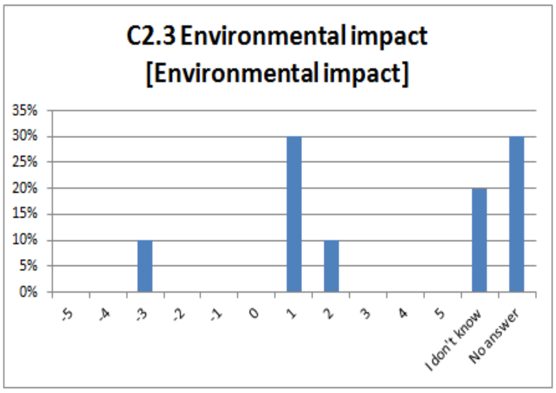


Figure 68 Environmental impact of Improved Aerodynamics



3.1.4. Innovation field: Intelligent Transportation Systems

Technologies of Innovation Field D

D1. Ubiquitous (internet) access to harmonized traveler information (passenger) and tracking information (freight)

Figure 69 shows the stated level of expertise of the workshop participants in this innovation field.

Figure 70 indicates that there will be a significant increase of the market share in the next 20-30 years for this technology. The experts indicated that the innovation is more on the side of passenger than on freight transport, where things are already under development. For passengers this would be a significant step, but there are a lot of difficulties - from technical and legal issues to fragmentation of data and operators. The experts believe that ubiquitous (internet) access to harmonized traveler information (passenger) and tracking information (freight) will be part of any transport system. Googlelisation of transport is high on the intermodal transport agenda and consumers' (traveler) requirements create new challenges for industries.

The benefit for the European transport industry (Figure 71) seems to be on the positive side. According to the experts, in the long run, the European industry can export this model in the future. The experts believe that these systems may increase security within the supply system and reduce administrative costs for companies. There is probably a positive impact for public transport operators.

Figure 72 presents a variation of views on the impacts on travel cost, although the data seem to indicate a decrease in cost.

Figure 73 shows a potential positive environmental impact, although the negative opinions are justified due to the overall increase of the transport 'product'.

Regarding the impact on modal shift the experts believe that the shift will be from individual transport to more mass oriented modes and probably the collective modes will be increased.

Figure 69: Level of expertise for access to information

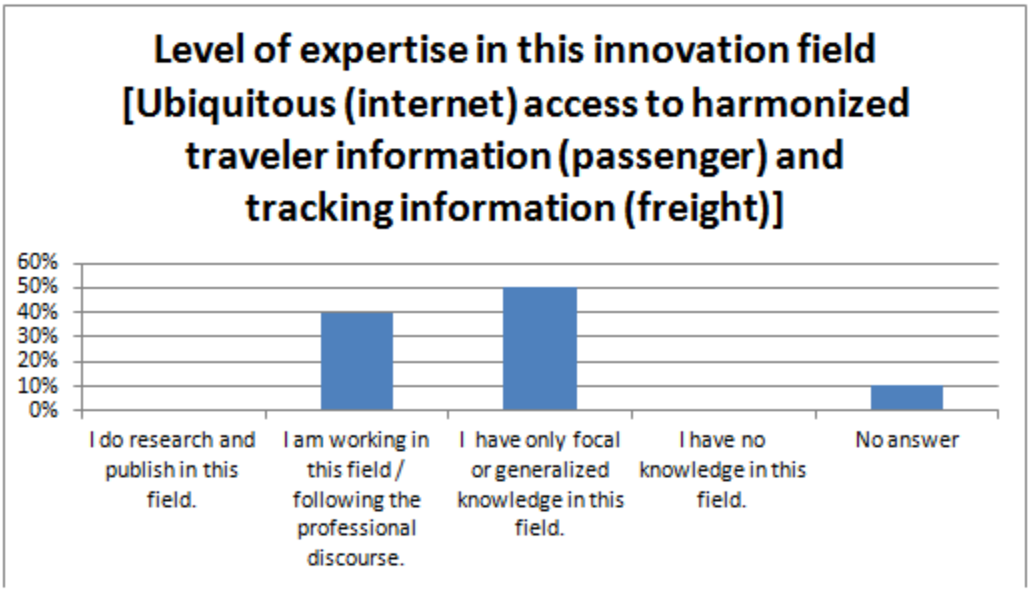


Figure 70: Likeliness of significant increase of access to information

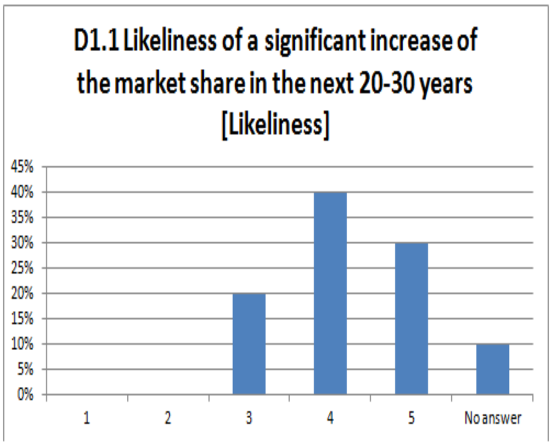


Figure 71: Benefit for European Transport Industry from access to information

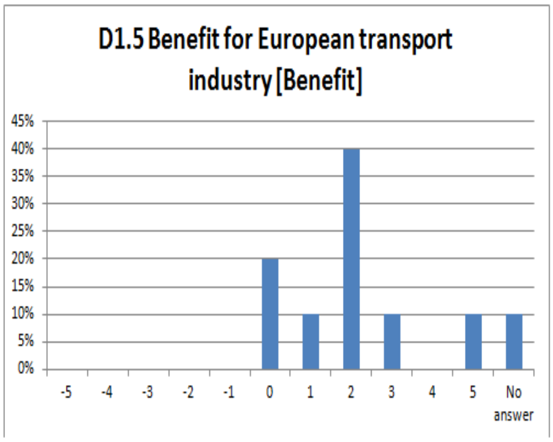


Figure 72: Impacts on travel cost for users from access to information

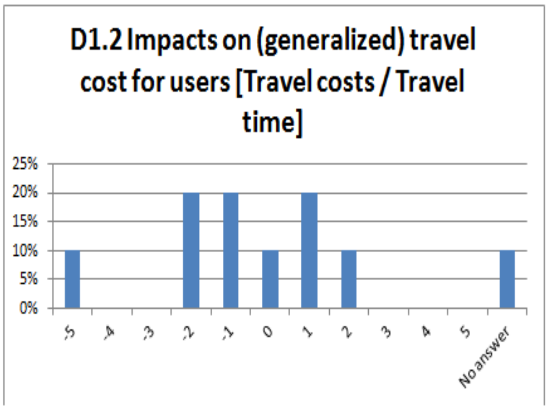
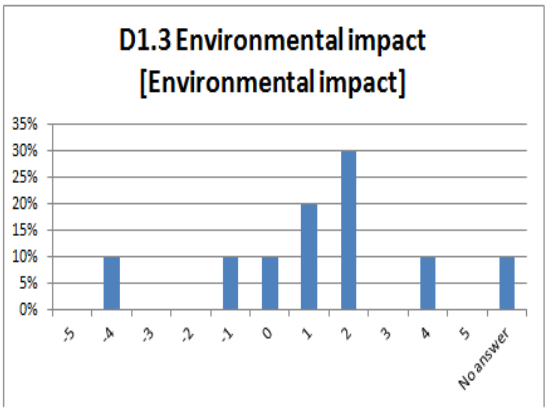


Figure 73 Environmental impact of access to information



D2. Personal Rapid Transport (small automated vehicles operating on a network of specially built guide ways)

Figure 74 shows the stated level of expertise of the workshop participants in this innovation field.

According to Figure 75 the likeliness of a significant increase of the market share in the next 20-30 years for this technology is very low. The experts believe that this technology would lead to some development of PT in urban areas, but it is not certain how far this could go outside of very densely populated areas. Past experiences indicate that users do not show a preference toward PRT.

Figure 76 presents a high benefit for the European transport industry from PRT. In their comments the experts stated that both PT industry and operators are interested for niche applications including cable cars.

Figure 77 shows that the impacts on travel cost for users will probably be positive. A similar picture is given in Figure 78 for the environmental impact of PRT where the majority of the experts answered positively.

Finally, the impact on modal shift will be probably a reduction of car use.

Figure 74: Level of expertise for Personal Rapid Transport

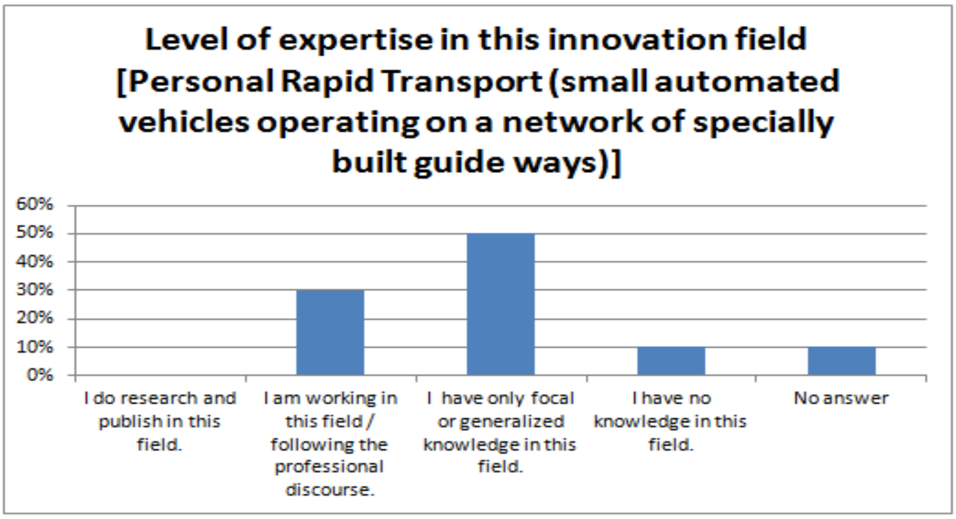


Figure 75: Likeliness of significant increase of Personal Rapid Transport

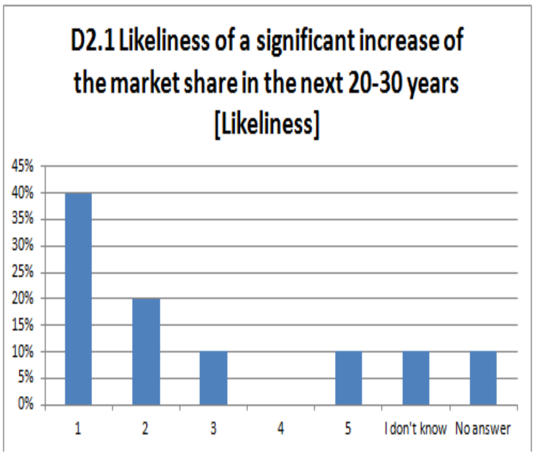


Figure 76: Benefit for European Transport Industry from Personal Rapid Transport

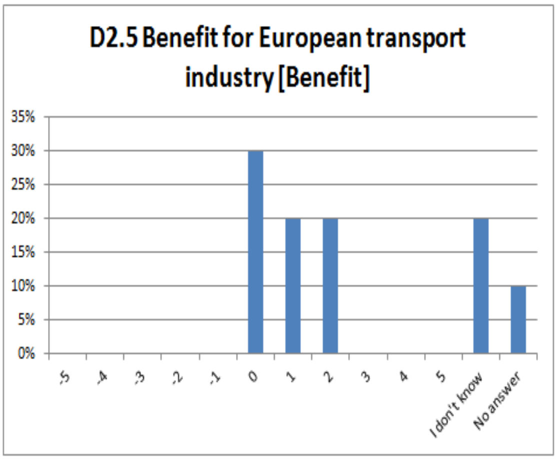


Figure 77: Impacts on travel cost for users from Personal Rapid Transport

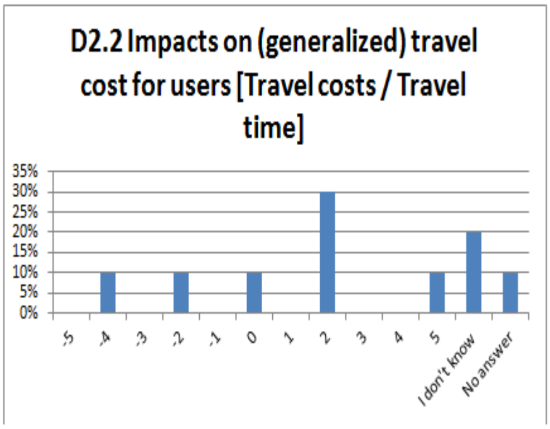
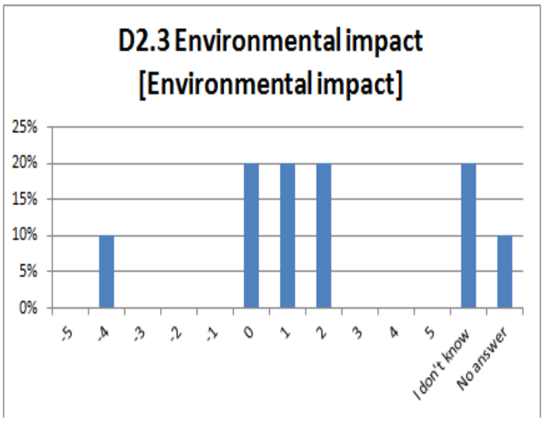


Figure 78: Environmental impact of Personal Rapid Transport



D3. RFID (Radio Frequency Identification) /NFC (Near Field Communication) applications for seamless user interfaces

Figure 79 shows the stated level of expertise of the workshop participants in this innovation field.

Figure 80 indicates that the likeliness of a significant increase of the market share in the next 20-30 years for this technology is average. The experts indicated that the technology will be a prerequisite in all means of transport. It will be an element of the infrastructure.

Regarding the benefit to the European transport industry (Figure 81) the results are scattered in mainly in the low positive side, although most of the respondents indicated that they do not know, or they did not provide an answer. The experts mentioned that some new applications exist, e.g. touch point in Germany, although this technology is not typically the strength of the European industry.

A similar situation exists for the impacts on travel cost for users (Figure 82). The majority of the experts answered that the impacts are not clear. However during the workshop they highlighted that the equipment of this technology is quite expensive.

Regarding the environmental impact of this technology (Figure 83) the majority of the experts answered that there will be a positive impact and an equal number answered that they do not know.

As for impact on modal shift they believed that this technology supports shift to public transport.

Figure 79: Level of expertise for applications for seamless user interfaces

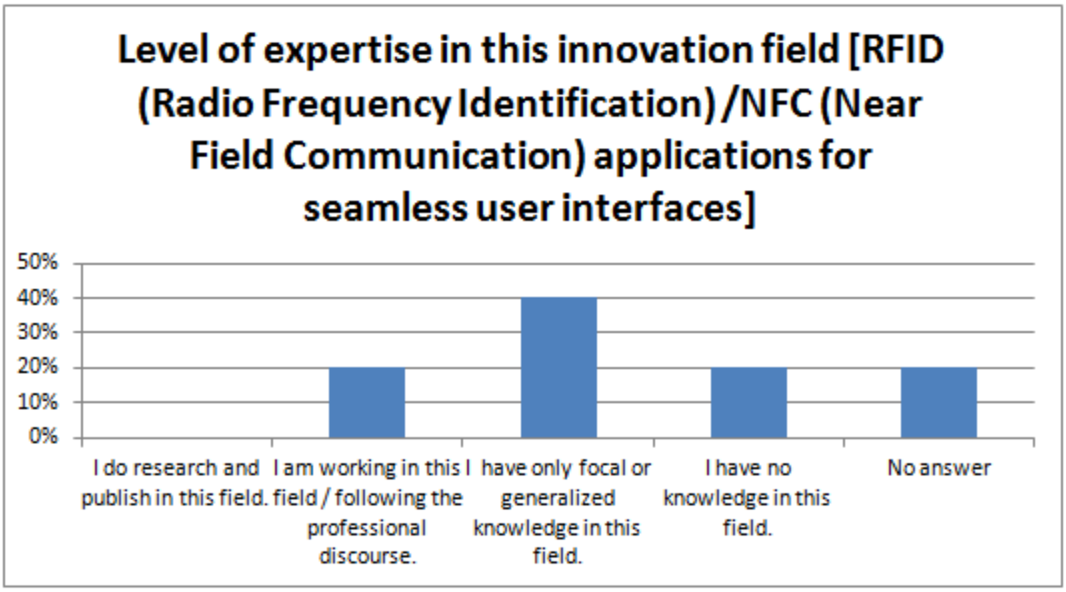


Figure 80: Likeliness of significant increase of applications for seamless user interfaces

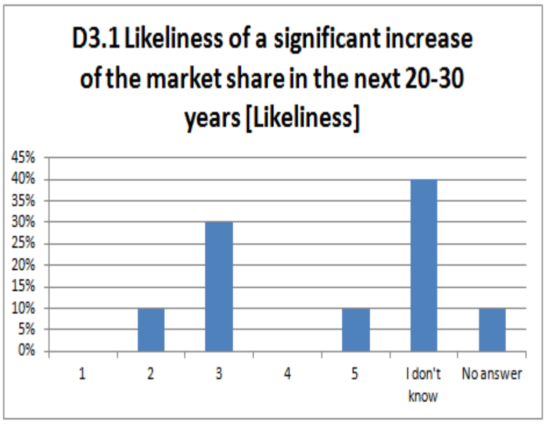


Figure 81: Benefit for European Transport Industry from applications for seamless user interfaces

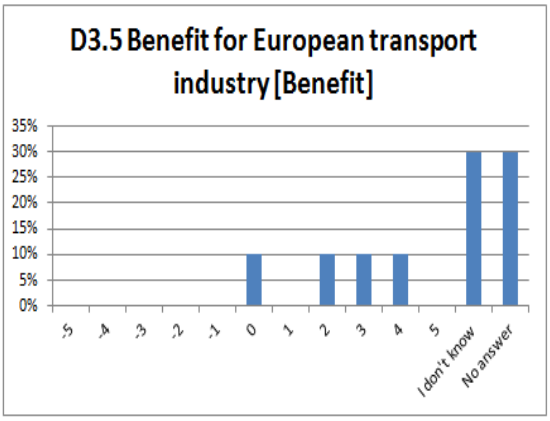


Figure 82: Impacts on travel cost for users of applications for seamless user interfaces

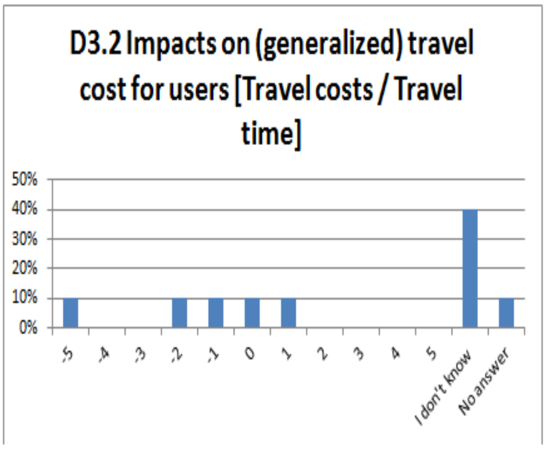
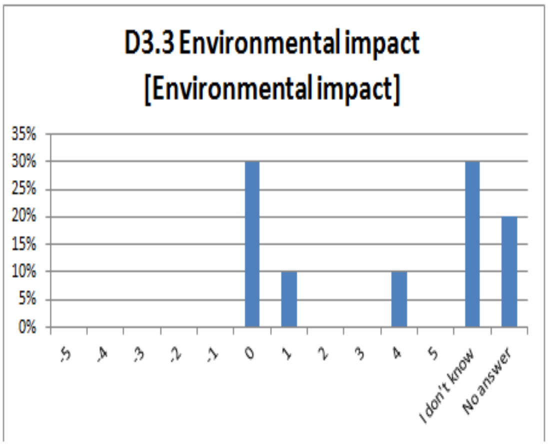


Figure 83: Environmental impact of applications for seamless user interfaces



D4. Autonomous supply chain management for more efficient use of logistics services

Figure 84 shows the stated level of expertise of the workshop participants in this innovation field.

According to the questionnaire results and Figure 85 the likeliness of a significant increase of the market share in the next 20-30 years for this technology, will be very high. In their comments they mentioned that the bottleneck of the supply chain is cost and efficiency.

Regarding the benefit for European transport industry (Figure 86), the majority of experts indicated that the benefit will be positive while an equal number answered that they do not know. In their comments experts stated that this technology will make European transport industry more competitive and it will affect positively the European industry by lowering freight transport costs.

Figure 87 presents the impacts on travel cost for users where a large dispersion is shown. Despite this fact the data seems to be gathered towards the negative side of the figure, implying reduction of cost. In Figure 88, regarding the environmental impact, experts appear to have answered that it will be positive, with the rest indicating that they do not know. During the workshop it was mentioned that the integrated supply chains can be optimized to minimize energy consumption / CO_2 emissions. Hence, according to their comments for the impact on modal shift, they believed that this technology may support shift to rail or just from rail to road.

Figure 84: Level of expertise for autonomous supply chain management

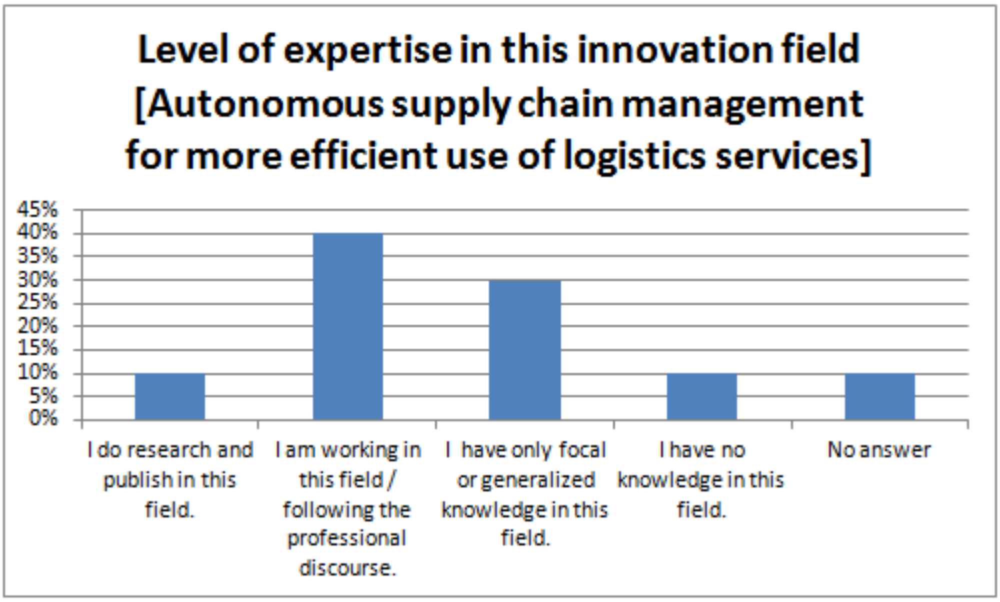


Figure 85: Likeliness of significant increase of autonomous supply chain management

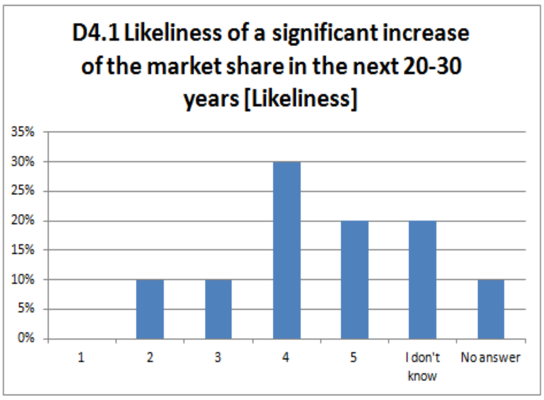


Figure 86: Benefit for European Transport Industry from autonomous supply chain management

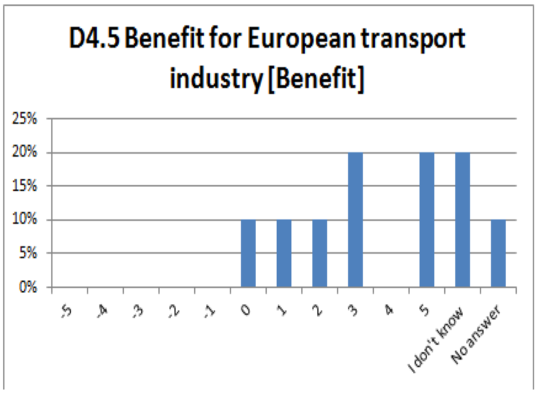


Figure 87: Impacts on travel cost for users from autonomous supply chain management

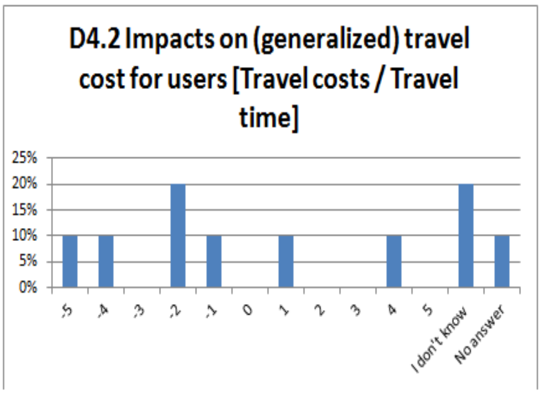
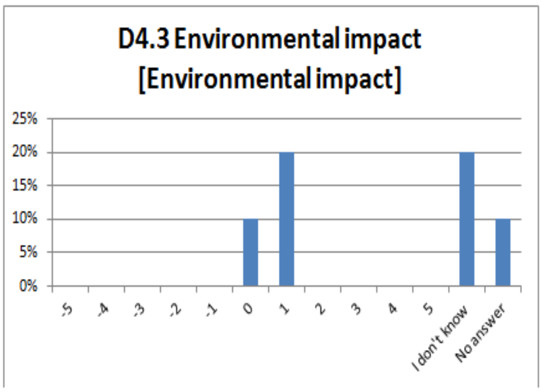


Figure 88: Environmental impact of autonomous supply chain management



3.1.5. Innovation field: Services And Organizational Innovations

Technologies of Innovation Field E

E1. Innovative sharing services (car sharing, bike-sharing etc.)

Figure 89 shows the stated level of expertise of the workshop participants in this innovation field.

According to Figure 90 there is a high likeliness of a significant increase of the market share in the next 20-30 years for this technology. In their comments the experts mentioned that probably there will be a shift to "sharing" services but not as we mostly perceive them today. There will be a strong "sharing" attitude at the "ownership" of vehicles. They believe that emerging economies are a different playfield, but in mature economies there will be at least many factors pushing for sharing. Most importantly, cars are less appealing to younger generations, including a cultural shift from owning to sharing. The experts mentioned that in mature economies sharing is the next big step and already widespread.

Figure 91 indicates that the majority of the experts believe that there is positive benefit for the European transport industry. According to their comments about this technology, the experts indicated that there is a positive impact for operators more than for the automotive industry. It was also mentioned that that there is a chance the automotive industry will sell dedicated car systems for car sharing.

Figure 92 shows that the majority of the experts believe there will probably be a negative impact on travel cost for users. The experts noted that for people deciding on no car ownership it allows for better mobility opportunities. However, the systems are only competitive in densely populated areas.

According to figure 93 the environmental impact will be a positive. Hence, regarding the impact on modal shift according to the comments, there will be a reduction of car use and an increase in intermodal transport.

Figure 89: Level of expertise for innovative sharing services

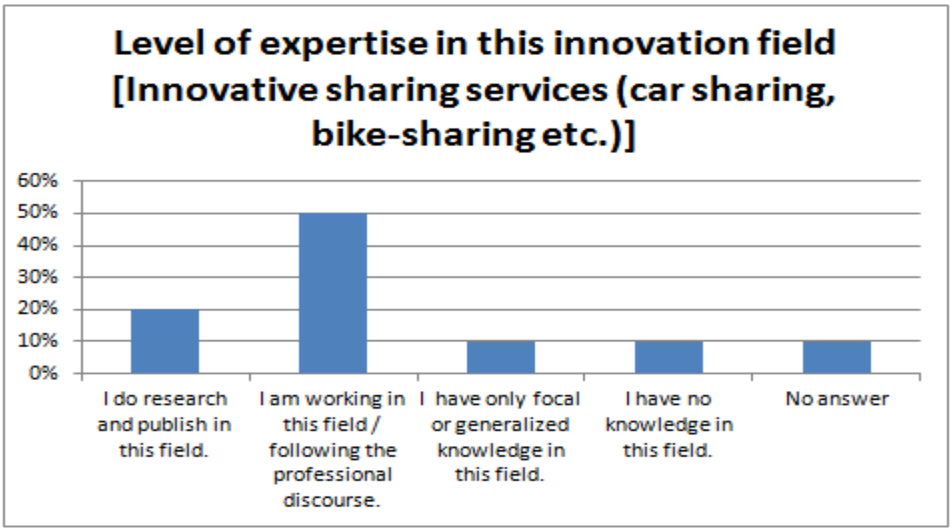


Figure 90: Likeliness of significant increase of innovative sharing services

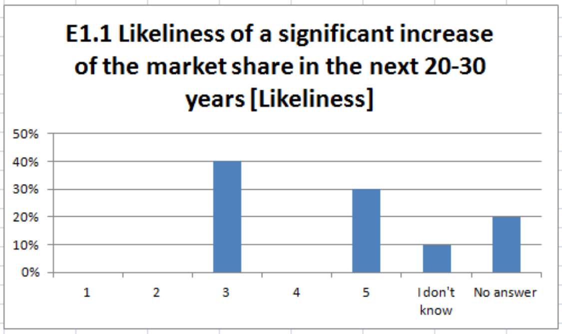


Figure 91: Benefit for European Transport Industry from innovative sharing services

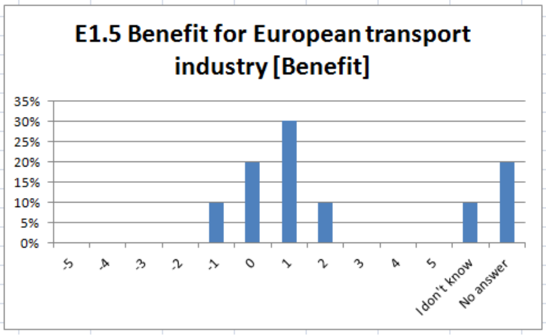


Figure 92: Impacts on travel cost for users from innovative sharing services

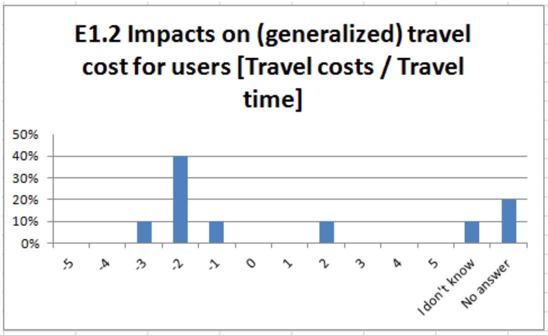
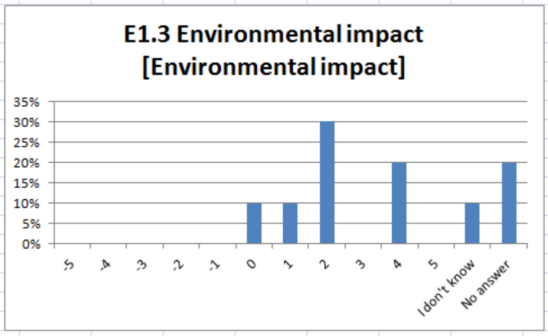


Figure 93: Environmental impact of innovative sharing services



E2. Tele-working, video-conferencing and holographic Conferencing

Figure 94 shows the stated level of expertise of the workshop participants in this innovation field.

According to Figure 95 there is a high probability of a significant increase of the market share for this technology in the next 20-30. In their comments the experts mentioned that probably market shares will increase.

In Figure 96 the majority of the experts answered that there will be positive benefit for the European transport industry. Based on Figure 97 the results are not very clear whether there will be a positive or negative impact on the cost. It was also mentioned that tele-working creates new opportunities that again create travel. Although the travelling for work reasons will decrease, as the standard of living increases the travelling will increase.

As shown in Figure 98, the majority of the experts indicated that there will be probably a positive environmental impact from this technology. Moreover, according to the replies, the impact on modal shift will not cause any travel reduction.

Figure 94: Level of expertise for Teleworking, long distance communication

Figure 95: Likeliness of significant increase of Teleworking, long distance communication

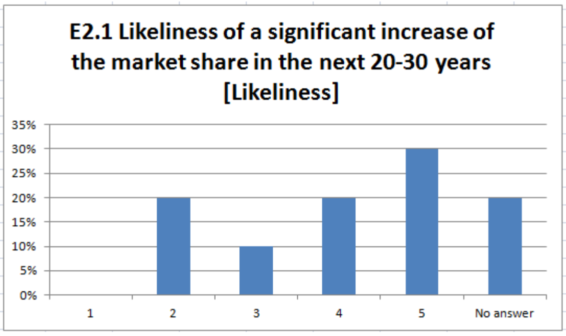


Figure 96: Benefit for European Transport Industry from Teleworking, long distance communication

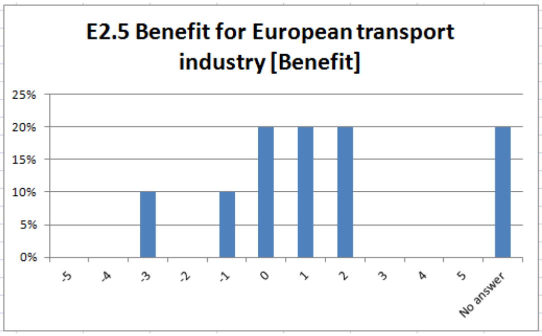


Figure 97: Impacts on travel cost for users from Teleworking, long distance communication

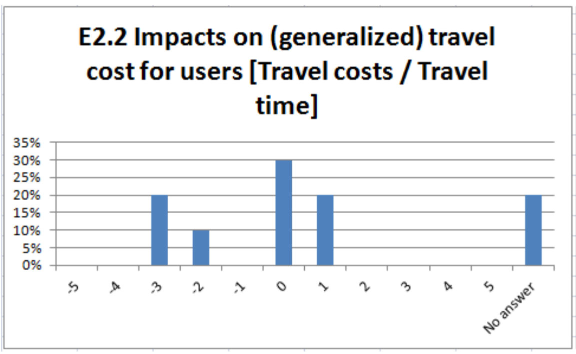
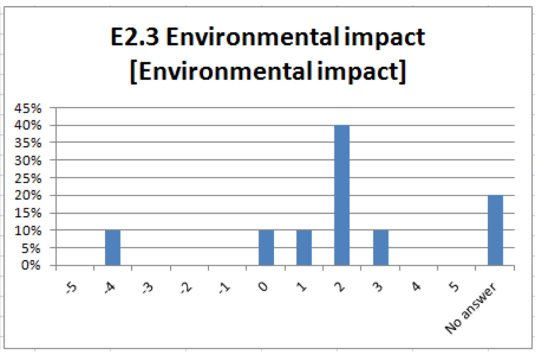


Figure 98: Environmental impact of Teleworking, long distance communication



E3. Smart ticketing schemes

Figure 99 shows the stated level of expertise of the workshop participants in this innovation field.

According to Figure 100 there will be a moderate likeliness for a significant increase of the market share for Smart Ticketing in the next 20-30 years. The experts noted that the need for an active independent regional transport agency is a must in order to achieve this target. Electronic, smart, faster ticketing will enroll.

According to Figure 101 the majority of the experts believe that the benefit for European transport will be a positive. In their comments, the experts mentioned European solutions and systems.

In Figure 102 the majority of the experts' views indicate that there will be negative impacts on travel cost for users (in terms of total time travelled). In their comments they state that Smart Ticketing would make collective modes of transport more attractive and easy to use, so if it will cost less everyone would travel more.

Figure 103 indicates that the environmental impact of this system will be positive. According to the comments regarding the impact on modal shift the experts believed that there will be a shift from private modes of transport or a shift from car to train/bus.

Figure 99: Level of expertise for Smart Ticketing

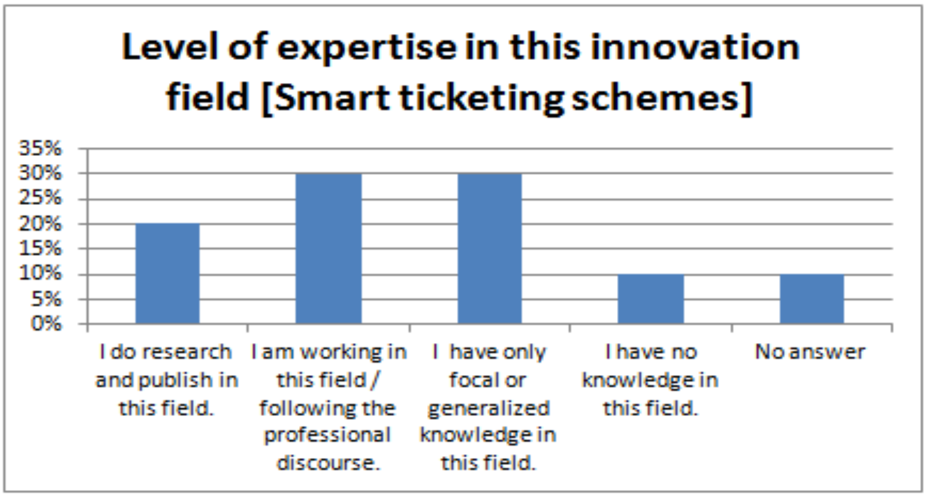


Figure 100: Likeliness of significant increase of Smart Ticketing

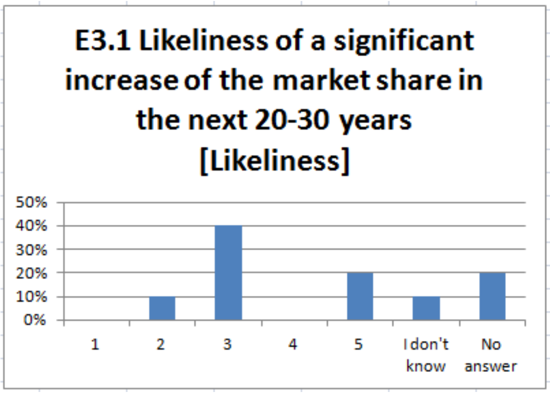


Figure 101: Benefit for European Transport Industry from Smart Ticketing

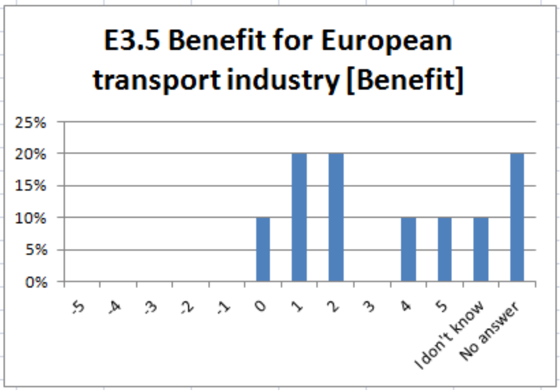


Figure 102: Impacts on travel cost for users from Smart Ticketing

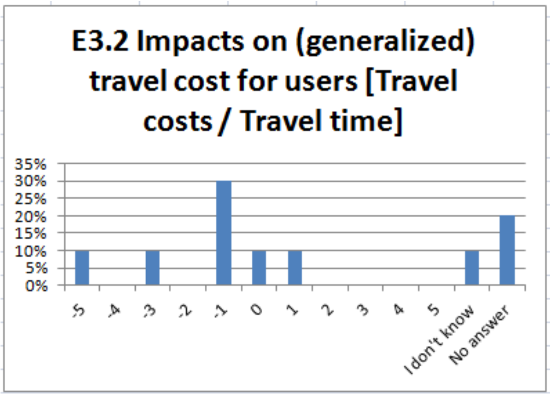
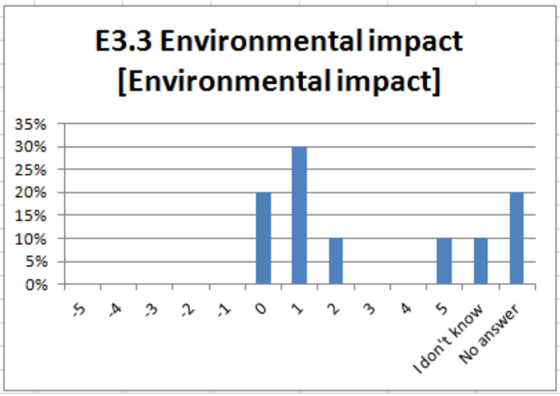


Figure 103: Environmental impact of Smart Ticketing



3.1.6. Innovation field: Infrastructures

Technologies of Innovation Field F

F1. Innovative new types of transport infrastructure (e.g. CargoTube, Hyperloop)

Figure 104 shows the stated level of expertise of the workshop participants in this innovation field.

According to Figure 105 the likeliness of a significant increase of the market share in the next 20-30 years for this technology is very low. In their comments the experts indicate that there will be some new concepts in harbors and hinterland hubs. There is a lot of resistance to the introduction of such innovations, mainly due to the investment costs and the "inertia" of the current set up to some extent, which, however, seems a little futuristic and very unlikely for 2030.

In Figure 106 the majority of the experts did not answer the question on the benefit to the European transport industry. The sector and public administrations are already unable to find money to maintain existing road and rail infrastructures.

The majority of the experts did not have a clear opinion on travel costs for users, as indicated in Figure 107. According to the experts, investment costs are very high, which will be a critical constraint to the broad implementation of these technologies.

According to Figure 108, the environmental impact is expected to be positive. Regarding the impact on modal shift, the experts indicated that there is an anticipated shift from air and sea to rail and road.

Figure 104: Level of expertise for innovative transport infrastructure

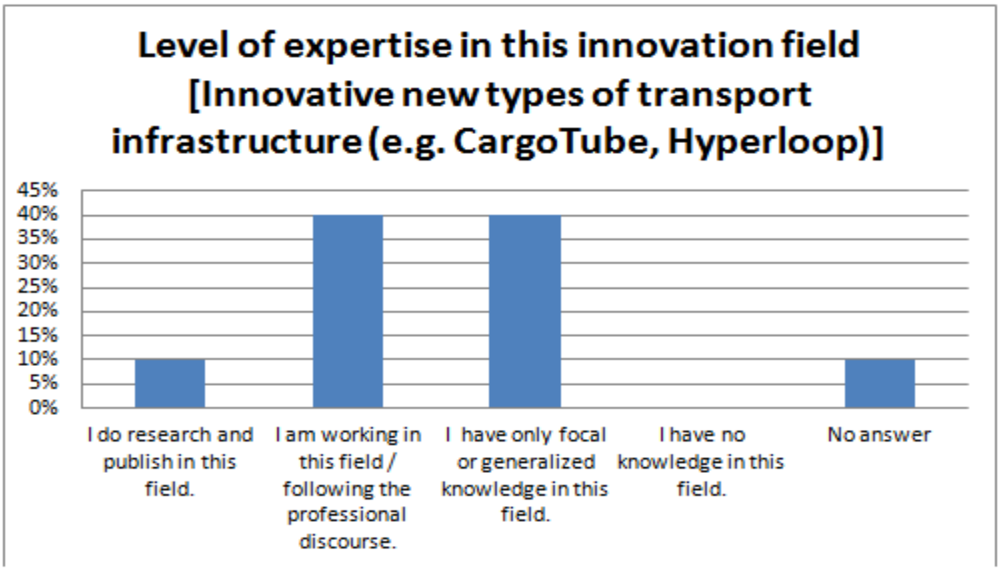


Figure 105: Likeliness of significant increase of innovative transport infrastructure

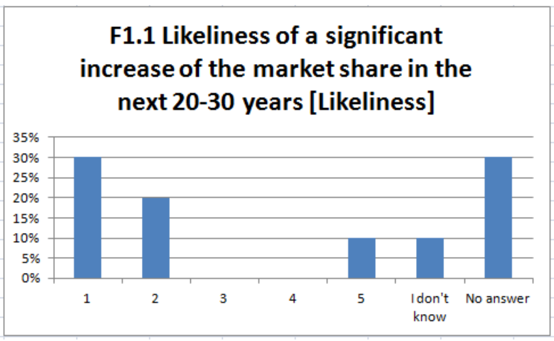


Figure 106: Benefit for European Transport Industry from innovative transport infrastructure

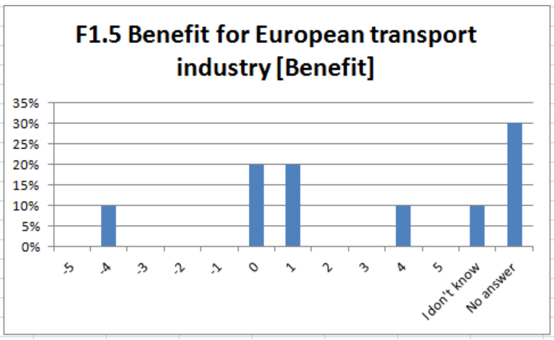


Figure 107: Impacts on travel cost for users from innovative transport infrastructure

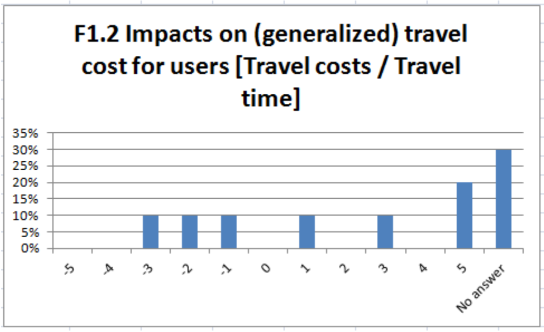
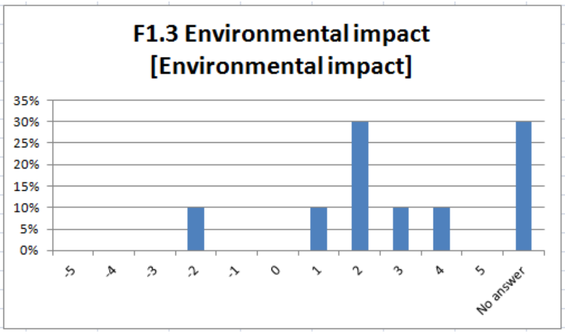


Figure 108: Environmental impact of innovative transport infrastructure



F2. Innovative transshipment technologies for seamless intermodal freight transport

Figure 119 shows the stated level of expertise of the workshop participants in this innovation field.

According to Figure 110 there is a high likeliness of a significant increase of the market share in the next 20-30 years for seamless intermodal freight transport. The experts noted that some important manufacturers are based in Europe. There will be many improvements both in terms of technology and of services organization.

According to Figure 111 the majority of the experts indicated that there will probably be a positive benefit for the European transport industry.

Figure 112 shows the views on the impact on travel cost for users. The majority of the experts indicated that it will probably be negative. The experts mentioned that the cost will probably decrease.

According to Figure 113 the majority of the experts answered that there will be positive environmental impacts. If the total cargo movement increases there will be a negative effect to the environment. Finally, regarding the impact on modal shift, the experts indicated that there will be a modal shift from road to rail.

Figure 109: Level of expertise for seamless intermodal freight

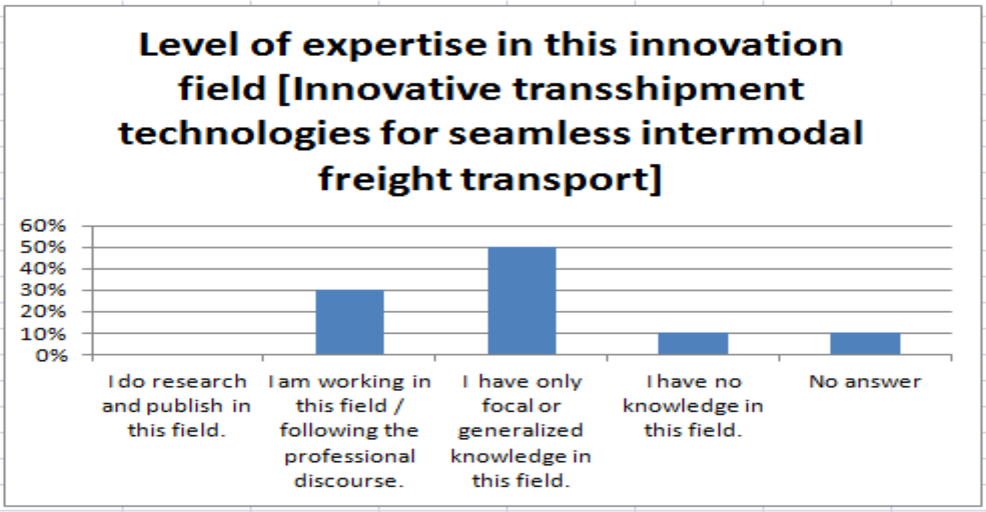


Figure 110: Likeliness of significant increase of seamless intermodal freight

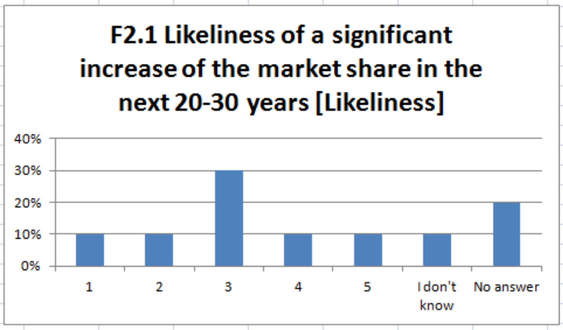


Figure 111: Benefit for European Transport Industry from seamless intermodal freight

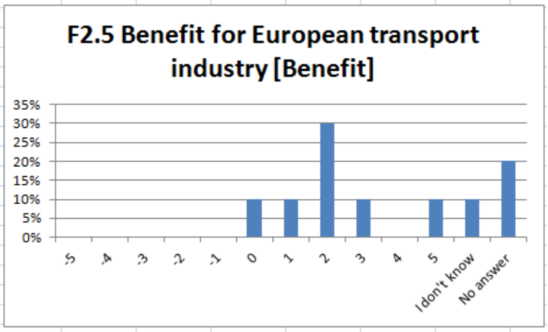


Figure 112: Impacts on travel cost for users of seamless intermodal freight

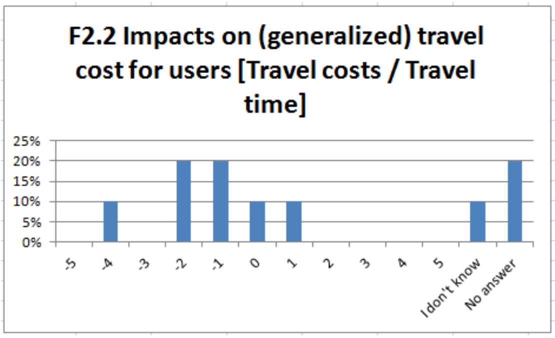
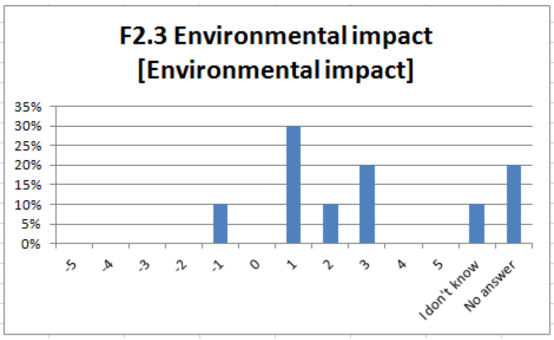


Figure 113: Environmental impact of seamless intermodal freight



F3. Inductive charging infrastructure for electric vehicles

Figure 114 shows the stated level of expertise of the workshop participants in this innovation field.

According to Figure 115 it is slightly uncertain if there will be a significant increase of the market share in the next 20-30 years for inductive charging infrastructure for EV. Hence, a large number of experts did not answer or indicated that they do not know. In their comments the experts mentioned that today, huge investments are needed. If in 20 years from now electric vehicles represent a large share of the market, the situation will definitely change and these investments will be supported.

In Figure 116 the majority of the experts did not provide a response on the benefit for the European transport industry. They indicated that there will probably be one or two niche suppliers.

According to Figure 117, the majority of the experts did not provide an answer regarding the impact on travel costs for users. In their comments the experts indicated that this technology saves time, which essentially reduces costs. In a similar fashion in Figure 118 the majority of the experts did not provide an answer regarding the environmental impact of the technology. Finally, according to the impact on modal shift the experts answered that probably there will be a modal shift from air and sea to rail and road.

Figure 114: Level of expertise for inductive charging for EVs

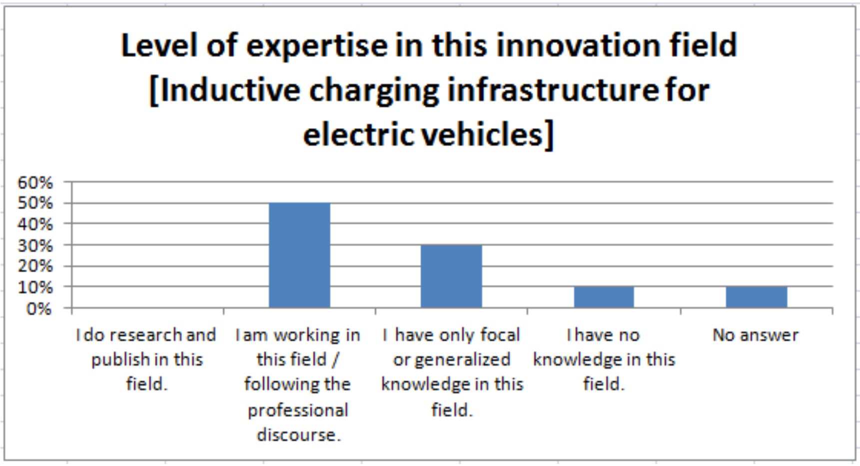
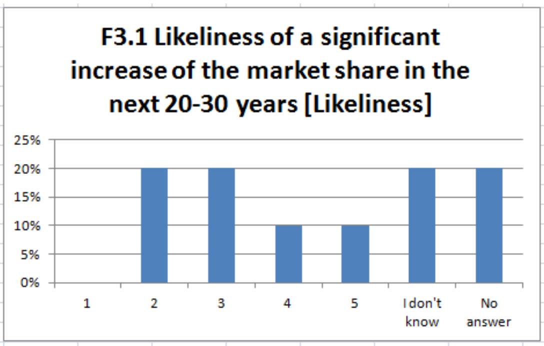


Figure 115: Likeliness of significant increase of inductive charging for EVs

Figure 116: Benefit for European Transport Industry from inductive charging for EVs



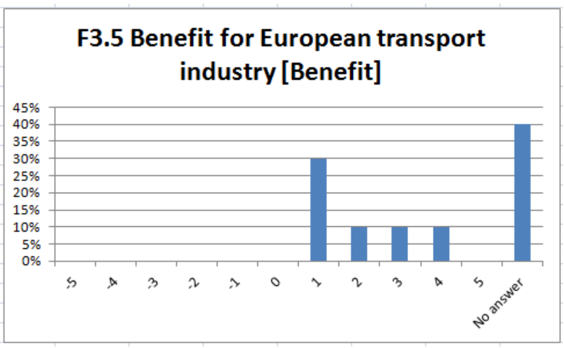


Figure 117: Impacts on travel cost for users from inductive charging for EVs

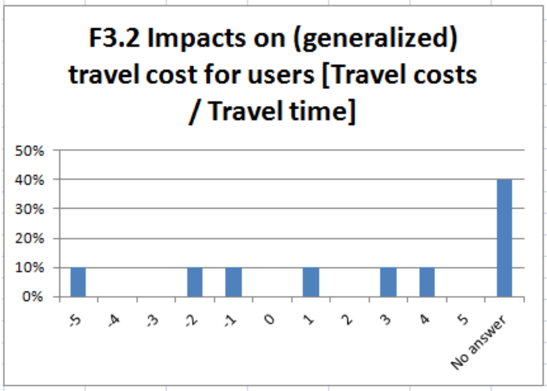
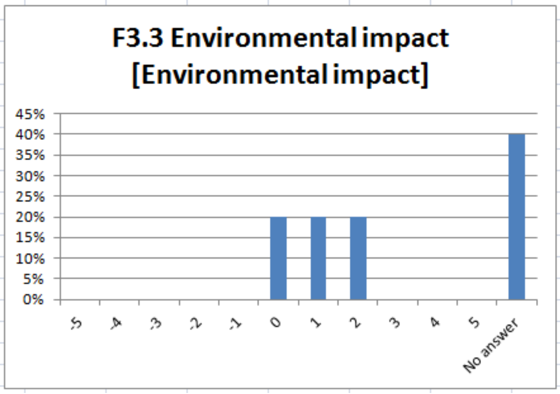


Figure 118: Environmental impact of inductive charging for EV



4. Conclusions

The general conclusions and directions on technological issues, which arose after the completion of the workshop, are the following:

- There is a need to enhance the role and the importance of ICT systems and technologies to the transport services. As ICT systems become part of the infrastructure, they will play a significant role in improving and supporting transport and may contribute to a cleaner, safer and more efficient and accessible transport system.
- Full autonomous driving is expected to be mainstream in the next 20-30 years. More and more efficient driver assistance systems will be implemented in road vehicles. The automation of road transport is the introduction of autonomous driving technologies that ultimately take the responsibility from the driver, making the driver a passenger. This situation will create new and different urban types, because the advanced transit systems need new markets in urban areas for the consumption of the products.
- Technologies related to energy (e.g. renewable energy technologies) are one of the most important innovation fields in the transport system: Currently, 40% of the total cost for the road freight transport industry in the EU is related to fuel prices. So there is a need for cheaper solutions and for becoming less dependent on energy imports. There is a great progress and development in the field of alternative fuels and propulsion technologies. The main objectives to be achieved are the protection of raw materials, the environmental protection and minimization of transport costs.
- There should be a focus on the creation of durable and cheap materials for roads. Since the EU is implementing the "Pay per use" philosophy for the road transport sector, it is essential to find more resistant materials for roads, so that the maintenance shall be cheaper in the long term.

Based on the workshop outcomes, the following findings may be noted:

- There will be a gradual shift from private vehicles to public (shared) means of transport with many passengers and eventually full autonomous driving in PT.

- Strong development in electric vehicles (e-cars and e-bicycles). There will be an enhancement of the role of e-mobility to the global transportation system and regions such as US, India, Europe, China will give emphasis to the electromobility policy. But it is important to maintain the suitable infrastructure, so having large investments in this field will be necessary (which also constitutes a main barrier).
- Research will be intensified in the field of lightweight materials, because less weight means less energy consumption and this is a very important factor for freight transport.
- Ubiquitous internet access to harmonized traveler information (passenger) and tracking information (freight) will be part of any transport system. Googlelisation of transport is high on the agenda of intermodal transport and brings new challenges for industries.
- Major developments are foreseen in warehouse logistics (intralogistics). This type of logistics is evolving into a new strength of European logistics systems manufacturers and it will make European transport industry more competitive by lowering the costs of freight transport.
- Major developments are also foreseen in innovative sharing services (car sharing, bike-sharing etc.). There will be a strong "sharing" attitude at the "ownership" of the vehicle, especially in urban areas. There will be competition between major cities in terms of providing better, innovative sharing services.
- Use of innovative transshipment technologies to rail, inland waterways and shipping for seamless intermodal freight is foreseen. These are expected to reduce transshipment costs and to further increase intermodal freight.

Finally by combining the results from the questionnaire and the workshop discussion some additional qualitative results are described below concerning the most 'beneficial' technologies overall in terms of user cost reduction, environmental benefit and benefit to the EU competitiveness. The ranking of the technologies, which is formed based on the experts' knowledge and opinion, is the following:

- In the field of automation of road transport the technology that according to the experts has the best potential impacts in all the important issues is the advanced driver assistance systems.
- In the field of fuels and propulsion technologies the results showed that the best technology, which will attract the interest of the transport sector is the Hybrid technology (allowing pure electric drive for a certain distance).
- In terms of improving the means of transport, it may be gathered that the best technology is expected to be the Lightweight materials (e.g. carbon fibers).
- In the field of intelligent transportation systems the technology which is seems to be the best is the internet access to harmonized traveler information (passengers) and cargo tracking (freight).
- In the field of the services and organizational innovations the technology of the smart ticketing schemes stands out as an important one. This technology presents a harmony of opinions and positive results in all the important issues. The technology of Tele working- Tele conferencing is rising as well.
- In the field of the Infrastructure the technology that is highlighted is the Innovative transshipment technology.

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Annex 1 Long list of innovations

References: GHG-TransPoRD D3.1: (Schade et al., 19.03.2013); TOSCA Final Report: (Schäfer et al., 27.05.2011); REACT D2.4: (REACT, 05.08.2011); Freightvision D3.1: (Böhmann et al., 27.04.2010).

ID: **1**	Mode: **Road**	Field: **Passenger Cars**	Subfield: **Efficiency**
Innovation Cluster: **Injection (combustion) technology**			
HCCI combines homogeneous charge spark ignition (gasoline engines) and stratified charge compression ignition (diesel engines) such that well-mixed fuel and oxidizer are compressed to the point of auto-ignition.			
Reference: GHG-TransPoRD D3.1, p.149			

ID: **2**	Mode: **Road**	Field: **Passenger Cars**	Subfield: **Efficiency**
Innovation Cluster: **Electrical system – energy supply**			
Solar panels on vehicle roofs, energy efficient alternators, intelligent battery sensors			
Reference: GHG-TransPoRD D3.1, p.155			

ID: **3**	Mode: **Road**	Field: **Passenger Cars**	Subfield: **Efficiency**
Innovation Cluster: **Heat and cooling management**			
Latent-Heat Storage, Exhaust Heat Recuperation, Intercooling, Cooling-Fluid Shutdown System			
Reference: GHG-TransPoRD D3.1, p.160			

ID: **4**	Mode: **Road**	Field: **Passenger Cars**	Subfield: **Efficiency**
Innovation Cluster: **Lightweight construction**			
advanced lightweight design and materials, minimizing or eliminating unnecessary convenience features, smaller capacity fuel tanks			
Reference: GHG-TransPoRD D3.1, p.165			

ID: **5**	Mode: **Road**	Field: **Passenger Cars**	Subfield: **Efficiency**
Innovation Cluster: **Engine control system**			
variable compression ratio, cylinder deactivation, start-stop system, variable valve timing, fuel quality sensor			
Reference: GHG-TransPoRD D3.1, p.170			

ID: **6**	Mode: **Road**	Field: **Passenger Cars**	Subfield: **Efficiency**
Innovation Cluster: **Hybrid vehicles**			
Substitution of conventional by hybrid cars (mild and full)			
Reference: GHG-TransPoRD D3.1, p.175			

ID: **7**	Mode: **Road**	Field: **Passenger Cars**	Subfield: **Efficiency**
Innovation Cluster: **Aerodynamics and resistance**			
improved aerodynamics, reduced engine friction losses, low resistance tires, tire-pressure monitoring system, low viscosity lubricants			
Reference: GHG-TransPoRD D3.1, p.180			

ID: **8**	Mode: **Road**	Field: **Passenger Cars**	Subfield: **Efficiency**
Innovation Cluster: **CNG and LPG vehicles**			
Substitution of gasoline and diesel by CNG cars			
Reference: GHG-TransPoRD D3.1, p.186			

ID: **9**	Mode: **Road**	Field: **Passenger Cars**	Subfield: **Efficiency**
Innovation Cluster: **Battery electric vehicles**			
Substitution of internal combustion engines by electric engines			
Reference: GHG-TransPoRD D3.1, p.190			

ID: **10**	Mode: **Road**	Field: **Passenger Cars**	Subfield: **Efficiency**
Innovation Cluster: **Electrical system – energy demand**			
LED lights, electric power steering, electric vacuum pumps, intelligent fuel pumps			
Reference: GHG-TransPoRD D3.1, p.195			

ID: **11**	Mode: **Road**	Field: **Passenger Cars**	Subfield: **Efficiency**
Innovation Cluster: **Drive and transmission**			
Continuous variable transmission allows changing continuously through an infinite number of effective gear ratios between maximum and minimum values. It enables the engine to run at its most efficient revolutions per minute for a range of vehicle speeds			
Reference: GHG-TransPoRD D3.1, p.200			

ID: **12**	Mode: **Road**	Field: **Passenger Cars**	Subfield: **Efficiency**
Innovation Cluster: **Hydrogen fuel cell electric vehicles**			
Replacement of fossil fuel cars by hydrogen fuel cell electric vehicles (2020: 1 million FCEV in EU27; 2050: 71 million FCEV in EU27)			
Reference: GHG-TransPoRD D3.1, p.204			

ID: **13**	Mode: **Road**	Field: **Passenger Cars**	Subfield: **Efficiency**
Innovation Cluster: **Engine Downsizing**			
Extra strong engine downsizing of ICE with higher turbocharging			
Reference: GHG-TransPoRD D3.1, p.209			

ID: **14**	Mode: **Road**	Field: **MHV / HGV**	Subfield: **Efficiency**
Innovation Cluster: **Rolling resistance**			
low rolling resistance tires, replacement of dual by single wide tires, tire pressure monitoring systems, reduction of rear axles, tire or wheel alignment			
Reference: GHG-TransPoRD D3.1, p.214			

ID: **15**	Mode: **Road**	Field: **MHV / HGV**	Subfield: **Efficiency**
Innovation Cluster: **Intelligent vehicle technologies**			
electric tow bar/platooning, predictive cruise control, navigation and route optimization			
Reference: GHG-TransPoRD D3.1, p.219			

ID: **16**	Mode: **Road**	Field: **MHV / HGV**	Subfield: **Efficiency**
Innovation Cluster: **Diesel engine**			
dual-stage turbocharging with intercooling, electric turbocompound, variable valve actuation, engine friction reduction and, electrification of engine-driven accessories			
Reference: GHG-TransPoRD D3.1, p.224			

ID: **17**	Mode: **Road**	Field: **MHV / HGV**	Subfield: **Efficiency**
Innovation Cluster: **Hybrid electric vehicles**			
This group covers the substitution of fossil fuel driven trucks by parallel hybrid electric vehicle (PHEV) in combination with the following technologies: brake energy recovery, full electrification of accessories, integration of the hybrid system with emission control, engine downsizing in certain applications and engine shutdown at idle.			
Reference: GHG-TransPoRD D3.1, p.229			

ID: **18**	Mode: **Road**	Field: **MHV / HGV**	Subfield: **Efficiency**
Innovation Cluster: **Transmission and driveline**			
low friction lubricants, automated manual transmission			
Reference: GHG-TransPoRD D3.1, p.234			

ID: **19**	Mode: **Road**	Field: **MHV / HGV**	Subfield: **Efficiency**
Innovation Cluster: **Improved aerodynamics**			
Different measures are considered to improve aerodynamics of trucks. Trailers should be designed following a teardrop shape. Other important design measures are cab extenders, sleeper roof fairing, day cab roof deflectors and chassis skirts. MAN (2008) presented an aerodynamically-optimised semitrailer truck at the IAA 2008. The designer Colani (2005) developed a streamlined semitrailer truck with further optimized power to wind ratio.			
Reference: GHG-TransPoRD D3.1, p.238			

ID: **20**	Mode: **Road**	Field: **MHV / HGV**	Subfield: **Efficiency**
Innovation Cluster: **Heat and cooling management**			
exhaust gas energy recovery with heat exchangers			
Reference: GHG-TransPoRD D3.1, p.242			

ID: **21**	Mode: **Road**	Field: **MHV / HGV**	Subfield: **Efficiency**
Innovation Cluster: **Lightweight construction**			
The measure lightweight construction assumes a replacement of steel by aluminum parts where possible to reduce weight of trucks.			
Reference: GHG-TransPoRD D3.1, p.246			

ID: **22**	Mode: **Road**	Field: **Policy Measures**	Subfield:
Innovation Cluster: **Eco-driving**			
Most measures that fall under the common denominator of “eco-driving” are aimed at changing behaviour. This can be done through schooling, media campaigns, incentives, etc. Some technological measures help achieving this goal. For example: gearshift indicators and pedal feedback			
Reference: GHG-TransPoRD D3.1, p.257			

ID: **23**	Mode: **Road**	Field: **Policy Measures**	Subfield:
Innovation Cluster: **Car labelling**			
Mandatory presentation of car labels when buying (firsthand) passenger cars			
Reference: GHG-TransPoRD D3.1, p.257			

ID: **24**	Mode: **Road**	Field: **Policy Measures**	Subfield:
Innovation Cluster: **Feebate**			
Vehicle purchase tax, variable in relation to CO2- emissions			
Reference: GHG-TransPoRD D3.1, p.269			

ID: **25**	Mode: **Road**	Field: **Policy Measures**	Subfield:
Innovation Cluster: **Sustainable logistics**			
Idling reduction, fuel consumption monitoring and benchmarking, optimised vehicle use, and sustainable freight transport.			
Reference: GHG-TransPoRD D3.1, p.276			

ID: **26**	Mode: **Road**	Field: **Policy Measures**	Subfield:
Innovation Cluster: **Vehicle maintenance**			
Vehicle maintenance: use of proper engine lubricants, tire inflation, engine tuning, air filter, etc. This can be combined with mandatory vehicle inspections.			
Reference: GHG-TransPoRD D3.1, p.282			

ID: **27**	Mode: **Road**	Field: **Policy Measures**	Subfield:
Innovation Cluster: **Speed enforcement current limits**			
A variety of possible measures which enforce current speed limits either through use of standard measures such as signing and speed cameras or though use of Intelligent Speed adaptation (ISA).			
Reference: GHG-TransPoRD D3.1, p.288			

ID: **28**	Mode: **Road**	Field: **Policy Measures**	Subfield:
Innovation Cluster: **Speed limit reduction on high speed roads**			
A variety of possible measures which enforce current speed limits either through use of standard measures such as signing and speed cameras or though use of Intelligent Speed adaptation (ISA).			
Reference: GHG-TransPoRD D3.1, p.289			

ID: **29**	Mode: **Road**	Field: **Urban Measures**	Subfield:
Innovation Cluster: **Urban Cordon Charges**			
Road user charging can be considered in terms of urban schemes which are traditionally in the form of closed cordons (as in Stockholm or London). Charges can be per crossing or for entry per day.			
Reference: GHG-TransPoRD D3.1, p.301			

ID: **30**	Mode: **Road**	Field: **Urban Measures**	Subfield:
Innovation Cluster: **Urban Distance Based Charges**			
Road user charging can be considered in terms of urban schemes which are traditionally in the form of closed cordons (as in Stockholm or London). Charges can be per crossing or for entry per day. Others envisage distance based charging within an urban area or cordon.			
Reference: GHG-TransPoRD D3.1, p.302			

ID: **31**	Mode: **Road**	Field: **Urban Measures**	Subfield:
Innovation Cluster: **National Road User Charging**			
National schemes may be restricted to inter-urban tolls (as exists on some motorways) or as all encompassing schemes which have as yet to be implemented (e.g. the Dutch Kilometre based scheme (recently cancelled)).			
Reference: GHG-TransPoRD D3.1, p.303			

ID: **32**	Mode: **Road**	Field: **Urban Measures**	Subfield:
Innovation Cluster: **Urban Traffic Control Systems**			
Responsive urban traffic control systems use real time data (usually from detector loops) to adjust the signal settings in response to variations in demand with the aim of improving traffic flows or some weighted objective related to stops, delays, emissions etc.			
Reference: GHG-TransPoRD D3.1, p.315			

ID: **33**	Mode: **Road**	Field: **Urban Measures**	Subfield:
Innovation Cluster: **Land Use Policy**			
Measures which alter the form of urban areas and promote greater density of activity with a view to reducing travel distance between activities. Such measures are often linked to other measures and can provide a stimulus for other change, such as towards a greater reliance on walking and cycling, or support the development of such policies.			
Reference: GHG-TransPoRD D3.1, p.319			

ID: **34**	Mode: **Road**	Field: **Urban Measures**	Subfield:
Innovation Cluster: **Public Parking Charges**			
Public parking spaces either on-street or off-street are traditionally charged by length of stay within the core urban area. Charges are an effective means of managing demand by trip purpose e.g. short stay versus long stay differentials can be used to discourage commuter parking.			
Reference: GHG-TransPoRD D3.1, p.324			

ID: **35**	Mode: **Road**	Field: **Urban Measures**	Subfield:
Innovation Cluster: **Public Parking Supply**			
The supply of public parking spaces is another means to control overall demand within an area. These spaces should be considered separately to private nonresidential parking spaces.			
Reference: GHG-TransPoRD D3.1, p.325			

ID: **36**	Mode: **Road**	Field: **Urban Measures**	Subfield:
Innovation Cluster: **PNR spaces and WPPL**			
Private non-residential parking spaces are those which are owned by private entities. In city centres they usually represent the majority of spaces and are often used for free by employees or if charged, the charges are at a significantly lower rate than for competing public spaces. Workplace Parking Levy is an annual fee applied to PNR spaces of large companies.			
Reference: GHG-TransPoRD D3.1, p.333			

ID: **37**	Mode: **Road**	Field: **Urban Measures**	Subfield:
Innovation Cluster: **Parking Cash Out Schemes**			
The cash-out scheme varies in application but the basic elements are that the employer offers the employee some form of cash incentive to forgo their parking space or subsidy.			
Reference: GHG-TransPoRD D3.1, p.334			

ID: **38**	Mode: **Road**	Field: **Urban Measures**	Subfield:
Innovation Cluster: **Public Transport Fares Reduction**			
Decreases in fares for urban public transport.			
Reference: GHG-TransPoRD D3.1, p.338			

ID: **39**	Mode: **Road**	Field: **Urban Measures**	Subfield:
Innovation Cluster: **Public Transport Frequency Increases**			
Increasing service levels in urban areas by higher frequency services.			
Reference: GHG-TransPoRD D3.1, p.339			

ID: **40**	Mode: **Road**	Field: **Urban Measures**	Subfield:
Innovation Cluster: **Public transport quality bus corridors/high-tech bus/PRT/feeder schemes**			
Corridor or zone based initiatives have become popular in urban areas with the development of high quality public transport corridors (High Tech bus, BRT packages), new technologies such as PRT (Personal Rapid Transit) and Cyber car schemes.			
Reference: GHG-TransPoRD D3.1, p.344			

ID: **41**	Mode: **Road**	Field: **Urban Measures**	Subfield:
Innovation Cluster: **Walking and cycling BASIC campaigns/packages**			
A range of measures which seek to encourage higher levels of walking and cycling – normally involving some element of infrastructure provision, but mainly focused on measures to encourage and inform.			
Reference: GHG-TransPoRD D3.1, p.350			

ID: **42**	Mode: **Road**	Field: **Urban Measures**	Subfield:
Innovation Cluster: **Walking and cycling campaigns/packages VISIONARY**			
A range of measures which seek to encourage higher levels of walking and cycling – normally involving some element of infrastructure provision, but mainly focused on measures to encourage and inform.			
Reference: GHG-TransPoRD D3.1, p.351			

ID: **43**	Mode: **Road**	Field: **Urban Measures**	Subfield:
Innovation Cluster: **Smarter Choices**			
A range of related 'soft' measures which seek to encourage and inform people about alternative travel modes to the car. Personalised journey planning seeks to provide individuals with specific information about their travel choices and is usually based on a detailed assessment of what they currently do. Car clubs are a measure to try to reduce ownership of cars by providing access to a pool of vehicles which can be 'hired' when there is a specific need. Public transport information and marketing. Cycling and walking promotion. Travel awareness campaigns.			
Reference: GHG-TransPoRD D3.1, p.360			

ID: **44**	Mode: **Rail**	Field: **Product**	Subfield: **Efficiency**
Innovation Cluster: **Aerodynamic Efficiency**			
Change trains shape to reduce their aerodynamic resistance. This has a direct impact on energy consumption and hence on carbon emissions, since reduced air resistance means less required traction power to travel at a given speed.			
Reference: GHG-TransPoRD D3.1, p.377			

ID: **45**	Mode: **Rail**	Field: **Product**	Subfield: **Efficiency**
Innovation Cluster: **Energy efficient package**			
control of comfort functions in parked trains, Passenger information to reduce boarding at stations, Monitoring and documentation of energy consumption, Energy efficient training programmes, Optimization of HVAC systems and lighting.			
Reference: GHG-TransPoRD D3.1, p.381			

ID: **46**	Mode: **Rail**	Field: **Product**	Subfield: **Efficiency**
Innovation Cluster: **Friction Control Measure**			
Some energy expended by the train is lost to wheel-to-rail friction. Reductions in wheel-to-rail resistance can be made via improved lubrication. Efficient lubrication systems, such as top-of-rail lubrication systems, reduce wheel and rail wear and reduce fuel consumption			
Reference: GHG-TransPoRD D3.1, p.388			

ID: **47**	Mode: **Rail**	Field: **Product**	Subfield: **Efficiency**
Innovation Cluster: **Innovative Boogie**			
New-generation of powered bogie with axles directly driven by synchronous motors is already available for light rail vehicles. Traction, running gear and braking technologies are combined in the bogie in order to form a highly integrated mechatronic system.			
Reference: GHG-TransPoRD D3.1, p.392			

ID: **48**	Mode: **Rail**	Field: **Product**	Subfield: **Efficiency**
Innovation Cluster: **Lightweight materials**			
The use of lighter weight components to reduce the weight of locomotive and railcars has the potential to reduce also energy consumption and fuel. Light-weight components include aluminium, plastics, composite materials and carbon fibre.			
Reference: GHG-TransPoRD D3.1, p.396			

ID: **49**	Mode: **Rail**	Field: **Product**	Subfield: **Efficiency**
Innovation Cluster: **Hybrid shunting locomotives**			
Electrical propulsion system, consisting of a battery, a diesel generator, power electronics, electrical motors and mechanical gearbox, is integrated into the existing locomotive.			
Reference: GHG-TransPoRD D3.1, p.400			

ID: **50**	Mode: **Rail**	Field: **Product**	Subfield: **Efficiency**
Innovation Cluster: **Regenerative Braking**			
The energy that is used for train acceleration and movement uphill is “stored” in the train as kinetic and potential energy. Electric or diesel-electric trains can reconvert a great part of this kinetic energy into electric energy by using the motors as generators during the braking phase			
Reference: GHG-TransPoRD D3.1, p.403			

ID: **51**	Mode: **Rail**	Field: **Product**	Subfield: **Efficiency**
Innovation Cluster: **Supercapacitive emergy storage**			
Supercapacitors are new components that can be used for short-duration energy storage. In diesel-electric railway system supercapacitors can be used for recuperation of braking energy (as the same role of the regenerative braking system) or for changing in the diesel engine control. A storage system is added in the locomotive. Similar technology is already available for light rail vehicles. Some of the new generation of tramway systems are allowed to run without the catenary for short distances.			
Reference: GHG-TransPoRD D3.1, p.409			

ID: **52**	Mode: **Rail**	Field: **Product**	Subfield: **Efficiency**
Innovation Cluster: **Energy recovery system**			
From 2007, the main European tramway manufacturer started to develop a new technology based on the energy storage system that allows urban light rail vehicle to reduce energy consumption.			
Reference: GHG-TransPoRD D3.1, p.413			

ID: **53**	Mode: **Water**	Field: **Product**	Subfield: **Efficiency**
Innovation Cluster: **Energy efficiency indices**			
A mandatory CO_2 design index for new vessels would specify a minimum design standard in terms of energy efficiency (and a maximum design standard in terms of CO_2 emissions) for each vessel type.			
Reference: GHG-TransPoRD D3.1, p.425			

ID: **54**	Mode: **Water**	Field: **Product**	Subfield: **Efficiency**
Innovation Cluster: **Automation**			
Ship Routing, Enhanced power management, MC Auto-tuning			
Reference: GHG-TransPoRD D3.1, p.428			

ID: **55**	Mode: **Water**	Field: **Product**	Subfield: **Efficiency**
Innovation Cluster: **Contra-rotating propeller**			
CRP is a thrust system in which the aft propeller recovers lost energy due to rotating flow occurring behind the fore propeller and changes it to thrust, ad furthermore high propelling efficiency can be obtained by the assignment of thrust to two propellers and the reduction of the load borne by each of them.			
Reference: GHG-TransPoRD D3.1, p.431			

ID: **56**	Mode: **Water**	Field: **Product**	Subfield: **Efficiency**
Innovation Cluster: **Dual-fuel engines**			
Dual-Fuel is fitted onto a standard diesel engine, which operates unchanged, except power is generated by mostly clean natural gas. A measured quantity of natural gas is mixed with air just before it enters the cylinder and compressed to the same levels as the diesel engine to maintain efficiency.			
Reference: GHG-TransPoRD D3.1, p.435			

ID: **57**	Mode: **Water**	Field: **Product**	Subfield: **Efficiency**
Innovation Cluster: **Flettner rotor**			
A Flettner rotor is a spinning vertical rotor that converts prevailing wind into propulsive energy. This harnesses wind power irrespective of its direction and can considerably reduce fossil fuel use. It requires free deck space for rotor placement.			
Reference: GHG-TransPoRD D3.1, p.439			

ID: **58**	Mode: **Water**	Field: **Product**	Subfield: **Efficiency**
Innovation Cluster: **Lightweight materials**			
Replacement of steel by lighter weight alternatives in non-structural elements can lead to fuel efficiency gains. Replacing steel with lower weight high tensile steel can also reduce fuel consumption.			
Reference: GHG-TransPoRD D3.1, p.443			

ID: **59**	Mode: **Water**	Field: **Product**	Subfield: **Efficiency**
Innovation Cluster: **Ship resistance**			
Bulbous bow – Sea arrow, Low profile hull openings, Energy-saving paints			
Reference: GHG-TransPoRD D3.1, p.446			

ID: **60**	Mode: **Water**	Field: **Product**	Subfield: **Efficiency**
Innovation Cluster: **Shoreside Power for Marine Vessels at Ports**			
Shoreside power is being tested as ship anti-idling system that can avoid the need for running the ship auxiliary engine continuously while a ship is docked at a port.			
Reference: GHG-TransPoRD D3.1, p.450			

ID: **61**	Mode: **Water**	Field: **Product**	Subfield: **Efficiency**
Innovation Cluster: **Sky sails system**			
The Sky Sails-System is an innovative wind propulsion system for shipping. It aims to reduce fuel consumption of modern shipping by utilization of wind energy.			
Reference: GHG-TransPoRD D3.1, p.453			

ID: **62**	Mode: **Water**	Field: **Product**	Subfield: **Efficiency**
Innovation Cluster: **Waste heat recovery system**			
Capturing and re-converting engine exhaust gas heat into electric energy can reduce direct engine fuel requirements for electric-coupled propulsion systems or reduce auxiliary engine requirements.			
Reference: GHG-TransPoRD D3.1, p.457			

ID: **63**	Mode: **Water**	Field: **Product**	Subfield: **Efficiency**
Innovation Cluster: **Slow steaming**			
Reduction of ship cruising speed, without technological changes to ship propulsion system or structure.			
Reference: GHG-TransPoRD D3.1, p.461			

ID: **64**	Mode: **Air**	Field: **Product**	Subfield: **Efficiency**
Innovation Cluster: **Aircraft replacement**			
Includes all technological improvements for new aircraft, i.e. airframe design, engine improvements, use of lightweight materials, auxiliaries etc.;			
Reference: GHG-TransPoRD D3.1, p.474			

ID: **65**	Mode: **Air**	Field: **Product**	Subfield: **Efficiency**
Innovation Cluster: **Aircraft refitting**			
engines, airframe, e.g. winglets, drag Reduction, cabin material, low energy lighting and cabin entertainment			
Reference: GHG-TransPoRD D3.1, p.479			

ID: **66**	Mode: **Air**	Field: **Product**	Subfield: **Efficiency**
Innovation Cluster: **Improved air operations**			
reduced APU usage, more efficient flight procedures, increase of load factors			
Reference: GHG-TransPoRD D3.1, p.482			

ID: **67**	Mode: **Air**	Field: **Infrastructure**	Subfield:
Innovation Cluster: **Improved ATM / airport operations**			
Single European Sky, reduced vertical separation minima, flex trax etc., improved ground operations			
Reference: GHG-TransPoRD D3.1, p.486			

ID: **68**	Mode: **Air**	Field: **Policy Measures**	Subfield:
Innovation Cluster: **Emission Trading**			
European Emission Trading and voluntary international emission trading			
Reference: GHG-TransPoRD D3.1, p.490			

ID: **69**	Mode: **Air**	Field: **Policy Measures**	Subfield:
Innovation Cluster: **Environmental charges (aviation)**			
Emission based landing charges, national fuel duties, noise charging at airports; removal of VAT exemptions			
Reference: GHG-TransPoRD D3.1, p.494			

ID: **70**	Mode: **Fuels**	Field: **Biofuels**	Subfield:
Innovation Cluster: **Biodiesel**			
Conventional biodiesel is based on transesterification of vegetable oils or animal fats, which are derived mainly from rapeseed and sunflower in the EU. Oil seeds are crushed to produce vegetable oil and oil cake, a byproduct used for animal feed. The oil is combined with alcohol (methanol or ethanol) and transformed into biodiesel, with glycerine as a by-product.			
Reference: GHG-TransPoRD D3.1, p.510			

ID: **71**	Mode: **Fuels**	Field: **Biofuels**	Subfield:
Innovation Cluster: **Bioethanol**			
Conventional (or: first generation) bioethanol is produced by fermentation from biological feedstock that contains sugar or material that can be converted into sugar such as starch or cellulose.			
Reference: GHG-TransPoRD D3.1, p.520			

ID: **72**	Mode: **Fuels**	Field: **Biofuels**	Subfield:
Innovation Cluster: **Ligno-cellulosic ethanol**			
Ligno-cellulosic ethanol (or cellulosic ethanol) does not depend on a sugar- or starch-based feedstock but can use a much broader variety of feedstock, such as straw, maize stalks and woody residues. In the biochemical process, the ligno-cellulosic biomass (i.e. made of cellulose, hemicellulose and lignin) first undergoes a pretreatment phase followed by cellulose hydrolysis with enzymes in order to extract sugar glucose for ethanol production.			
Reference: GHG-TransPoRD D3.1, p.531			

ID: **73**	Mode: **Fuels**	Field: **Biofuels**	Subfield:
Innovation Cluster: **Synthetic fuels - BtL**			
Second generation of biodiesel (or synthetic biodiesel; BtL) does not rely on vegetable oil as feedstock, but can make use of virtually all kinds of biomass (forestry residues, energy crops). The production of second generation biodiesel is generally achieved by means of the thermo-chemical conversion process (also known as Biomass-to-Liquids, BtL). As part of the thermo-chemical process, firstly a synthetic gas is produced which is then further converted into a wide variety of gaseous and liquid biofuels, e.g. BtL ("Biomass to Liquid") diesel, biomethanol, heavier alcohols, dimethyl ether (DME) but also bio-SNG and bio-H2.			
Reference: GHG-TransPoRD D3.1, p.542			

ID: **74**	Mode: **Fuels**	Field: **Biofuels**	Subfield:
Innovation Cluster: **Biomethane**			
Broadly speaking, biomethane is the 'renewable' version of natural gas. It is sometimes called 'green gas' and is generally defined as upgraded biogas (produced from anaerobic digestion of biomass), SNG (Synthetic Natural Gas, obtained from biomass or coal gasification followed by methanation) and landfill gas (similar to biogas). There are typically two ways of producing biomethane: via the biochemical route (biogas) or via the gasification of cellulosic materials (thermo-chemical route, producing Bio-SNG).			
Reference: GHG-TransPoRD D3.1, p.553			

ID: **75**	Mode: **Fuels**	Field: **Biofuels**	Subfield:
Innovation Cluster: **Hydrotreated Vegetable Oil (HVO)**			
Hydrotreated Vegetable Oil (HVO) is produced on the basis of vegetable oils and fats via a hydrogenation process. The HVO fuel is similar to diesel, has a high cetane number, and is free of sulphur and aromatics. As it is a synthetic fuel, the final product has the advantage of being usable in aviation.			
Reference: GHG-TransPoRD D3.1, p.563			

ID: **76**	Mode: **Fuels**	Field: **Alternative Fuels**	Subfield:
Innovation Cluster: **Hydrogen from natural gas**			
Hydrogen is produced on a large scale by reforming natural gas. Reforming of natural gas is defined as the chemical processing of natural gas in order to modify its composition under the effect of temperature and pressure in the presence of a catalyst. Depending on the type of reforming, natural gas reacts with steam or oxygen to produce a gas composed of H2, CO, CO2, CH4 and H2O. There are three main reforming processes namely steam reforming (SMR), partial oxidation and autothermal reforming (ATR).			
Reference: GHG-TransPoRD D3.1, p.628			

ID: **77**	Mode: **Fuels**	Field: **Alternative Fuels**	Subfield:
Innovation Cluster: **Hydrogen from coal gasification**			
Hydrogen production by gasification is similar to the partial oxidation of heavy hydrocarbons. Syngas is produced in one reactor, by mixing coal with oxygen or air and steam. In the highly exothermal overall reaction, syngas is produced. Subsequently the hot syngas is cooled down and passes through a gas clean-up section. This section serves to remove different fractions of the syngas, for example filters to remove ash and dust particulates, scrubbers of fixed bed reactors to remove halogen compound and sulphur compounds.			
Reference: GHG-TransPoRD D3.1, p.629			

ID: **78**	Mode: **Fuels**	Field: **Alternative Fuels**	Subfield:
Innovation Cluster: **Hydrogen from water electrolysis**			
Electrolysis of water is a well-known process of using an electrical current to break water into hydrogen and oxygen. This process takes place in an electrolyser that can be considered as the reverse of a fuel cell where hydrogen is consumed and electricity is produced.			
Reference: GHG-TransPoRD D3.1, p.630			

ID: **79**	Mode: **Fuels**	Field: **Alternative Fuels**	Subfield:
Innovation Cluster: **Hydrogen from biomass**			
Several pathways exist to convert biomass into hydrogen, which can be separated into thermochemical processes (e.g. gasification, pyrolysis) and biochemical processes (e.g. fermentation, biophotolysis).			
Reference: GHG-TransPoRD D3.1, p.631			

ID: **101**	Mode: **Road**	Field: **Product**	Subfield: **Fuels**
Innovation Cluster: **Passenger Cars**			
Alternative fuels: bioethanol blend (E85) from wood feedstock, hydrogenated vegetable oil (HVO), biosynthetic natural gas (Bio SNG)			
Reference: TOSCA Final Report, p.2			

ID: **102**	Mode: **Road**	Field: **Product**	Subfield: **Fuels**
Innovation Cluster: **Passenger Cars**			
Plug-in-hybrid electric vehicle (PHEV)			
Reference: TOSCA Final Report, p.2			

ID: **103**	Mode: **Road**	Field: **Product**	Subfield: **Fuels**
Innovation Cluster: **Passenger Cars**			
Battery electric vehicle (BEV)			
Reference: TOSCA Final Report, p.2			

ID: **104**	Mode: **Road**	Field: **Product**	Subfield: **Fuels**
Innovation Cluster: **Passenger Cars**			
Fuel cell hybrid electric vehicle, with natural gas derived hydrogen (FC-HEV)			
Reference: TOSCA Final Report, p.2			

ID: **105**	Mode: **Road**	Field: **Product**	Subfield: **Fuels**
Innovation Cluster: **Light Duty Trucks**			
Hybrid electric vehicles (HEV)			
Reference: TOSCA Final Report, p.2			

ID: **106**	Mode: **Road**	Field: **Product**	Subfield: **Fuels**
Innovation Cluster: **Light Duty Trucks**			
Fuel cell hybrid electric vehicle, with natural gas derived hydrogen (FC-HEV)			
Reference: TOSCA Final Report, p.2			

ID: **107**	Mode: **Road**	Field: **Product**	Subfield: **Efficiency**
Innovation Cluster: **Medium and Heavy Duty Trucks**			
Resistance reduction (Res. Red.)			
Reference: TOSCA Final Report, p.2			

ID: **108**	Mode: **Road**	Field: **Product**	Subfield: **Efficiency**
Innovation Cluster: **Medium and Heavy Duty Trucks**			
Idling reduction (Idle Red.)			
Reference: TOSCA Final Report, p.2			

ID: **109**	Mode: **Road**	Field: **Product**	Subfield: **Efficiency**
Innovation Cluster: **Medium and Heavy Duty Trucks**			
Alternative fuel: Hydrogenated Vegetable Oils (HVO) and biomass-to-liquids (BTL)			
Reference: TOSCA Final Report, p.2			

ID: **110**	Mode: **Air**	Field: **Product**	Subfield: **Efficiency**
Innovation Cluster: **Aircraft**			
Replacement narrowbody aircraft			
Reference: TOSCA Final Report, p.5			

ID: **111**	Mode: **Air**	Field: **Product**	Subfield: **Efficiency**
Innovation Cluster: **Aircraft**			
Fast open rotor engine powered narrowbody aircraft			
Reference: TOSCA Final Report, p.5			

ID: **112**	Mode: **Air**	Field: **Product**	Subfield: **Efficiency**
Innovation Cluster: **Aircraft**			
Reduced speed open rotor engine powered narrowbody aircraft (unswept wings)			
Reference: TOSCA Final Report, p.5			

ID: **113**	Mode: **Air**	Field: **Product**	Subfield: **Fuels**
Innovation Cluster: **Aircraft**			
Second generation drop-in biofuels			
Reference: TOSCA Final Report, p.5			

ID: **114**	Mode: **Air**	Field: **Product**	Subfield: **Efficiency**
Innovation Cluster: **Aircraft**			
Replacement turboprop aircraft			
Reference: TOSCA Final Report, p.5			

ID: **115**	Mode: **Air**	Field: **Product**	Subfield: **Efficiency**
Innovation Cluster: **Aircraft**			
Improvements in Air Traffic Management			
Reference: TOSCA Final Report, p.5			

ID: **116**	Mode: **Rail**	Field: **Product**	Subfield: **Efficiency**
Innovation Cluster: **Aircraft**			
Low aerodynamic drag			
Reference: TOSCA Final Report, p.7			

ID: **117**	Mode: **Rail**	Field: **Product**	Subfield: **Efficiency**
Innovation Cluster: **Rail**			
Low train mass			
Reference: TOSCA Final Report, p.7			

ID: **118**	Mode: **Rail**	Field: **Product**	Subfield: **Efficiency**
Innovation Cluster: **Rail**			
Energy recovery at braking			
Reference: TOSCA Final Report, p.7			

ID: **119**	Mode: **Rail**	Field: **Product**	Subfield: **Efficiency**
Innovation Cluster: **Rail**			
Space efficiency (passenger) and heavy trains (freight)			
Reference: TOSCA Final Report, p.7			

ID: **120**	Mode: **Rail**	Field: **Product**	Subfield: **Efficiency**
Innovation Cluster: **Rail**			
Eco-driving (driving advice)			
Reference: TOSCA Final Report, p.7			

ID: **121**	Mode: **Rail**	Field: **Product**	Subfield: **Efficiency**
Innovation Cluster: **Rail**			
Energy efficiency (train equipment and supply systems)			
Reference: TOSCA Final Report, p.7			

ID: **122**	Mode: **Fuels**	Field: **Product**	Subfield:
Innovation Cluster: **Fuels**			
Gasoline replacement: bioethanol (sugarcane, wheat, and wood feedstocks), Compressed Natural Gas (CNG), Liquefied Petroleum Gas (LPG), Bio-SNG (wood feedstock), hydrogen (natural gas feedstock), hydrogen (wood feedstock)			
Reference: TOSCA Final Report, p.12			

ID: **123**	Mode: **Fuels**	Field: **Product**	Subfield:
Innovation Cluster: **Fuels**			
Diesel replacement: Biodiesel (rapeseed feedstock), Fischer Tropsch (FT) Diesel via Gas-to-Liquids (GTL), FT Diesel via biomass-to-liquids (BTL) using short rotation coppice as feedstock, Hydrogenated Vegetable Oil (HVO) using palm oil feedstock			
Reference: TOSCA Final Report, p.12			

ID: **124**	Mode: **Fuels**	Field: **Product**	Subfield:
Innovation Cluster: **Fuels**			
Jet A1 replacement: FT Diesel via GTL, FT Diesel via BTL using short rotation coppice as feedstock, HVO) using palm oil feedstock			
Reference: TOSCA Final Report, p.12			

ID: **125**	Mode: **Fuels**	Field: **Product**	Subfield:
Innovation Cluster: **Fuels**			
Heavy fuel oil replacement: FT Diesel via GTL, FT Diesel via BTL using short rotation coppice as feedstock			
Reference: TOSCA Final Report, p.12			

ID: **126**	Mode: **Road**	Field: **Product**	Subfield: **ICT**
Innovation Cluster: **Road ICT**			
Driver Assistance Systems (DAS): These include a whole range of information and communication technology in-vehicle systems which support drivers in maintaining a safe speed and distance, driving within a given lane and avoid overtaking in critical situations.			
Reference: TOSCA Final Report, p.14			

ID: **127**	Mode: **Road**	Field: **Product**	Subfield: **ICT**
Innovation Cluster: **Road ICT**			
Automated Highway System (AHS): These involve computer-controlled wireless communications between vehicles and infrastructure. Vehicles can organize themselves into platoons and be linked together by communication networks, which allow the continuous exchange of information regarding speed, acceleration, braking and obstacles.			
Reference: TOSCA Final Report, p.14			

ID: **128**	Mode: **Road**	Field: **Product**	Subfield: **ICT**
Innovation Cluster: **Road ICT**			
Commercial Vehicle Operations (CVO for freight transport): These ITS applications require roadside equipment, databases, and in-vehicle transponders or other tags for: Electronic Credentialing, Electronic Screening and Clearance and Fleet Management.			
Reference: TOSCA Final Report, p.14			

ID: **129**	Mode: **Rail**	Field: **Product**	Subfield: **ICT**
Innovation Cluster: **Rail ICT**			
European Rail Traffic Management System (ERTMS)-(ETCS/Level 3): This European system is designed to replace the existing partly incompatible safety and signaling systems throughout Europe and to enable interoperability throughout the European rail network.			
Reference: TOSCA Final Report, p.14			

ID: **130**	Mode: **Rail**	Field: **Product**	Subfield: **ICT**
Innovation Cluster: **Rail ICT**			
Operation of Heavier/Faster freight trains: This means both increased axle load and loading gauge as well as longer freight trains and reduced effective transport time.			
Reference: TOSCA Final Report, p.14			

ID: **201**	Mode: **Air**	Field: **Traffic Management**	Subfield:
Innovation Cluster: **Airspace management and control**			
Aircraft environment signature database, real time environment monitoring system, new airways with flight speed reduction, dynamic airspace management system, integrated air/ground 4D trajectory system, dynamic optimised traffic allocation…			
Reference: REACT D2.4, p.17			

ID: **202**	Mode: **Air**	Field:	Subfield: **Traffic management**
Innovation Cluster: **Flight / ground tests and numerical models for simulation**			
Fast Time Simulation for training on best practices for Air Transport System efficiency			
Reference: REACT D2.4, p.17			

ID: **203**	Mode: **Air**	Field:	Subfield: **Traffic management**
Innovation Cluster: **High lift devices and high altitude aircrafts**			
High lift system design for high climb number and steep take-off			
Reference: REACT D2.4, p.17			

ID: **204**	Mode: **Air**	Field:	Subfield: **Flight physics**
Innovation Cluster: **Airframe Aerodynamics**			
Optimised airframe design for high L/D cruise and low thrust approach, integrated nacelle/wing design for UHBR engines, highlift engine airframe integration, hybrid laminar flow, morphing airframe, adaptive winglets			
Reference: REACT D2.4, p.18			

ID: **205**	Mode: **Air**	Field:	Subfield: **Flight physics**
Innovation Cluster: **Metallic and composite materials and basic processes**			
Use of lightweight materials and processes for airframe, friction-reducing surface coatings (nanotechnology), paintless a/c			
Reference: REACT D2.4, p.18			

ID: **206**	Mode: **Air**	Field:	Subfield: **Design and materials**
Innovation Cluster: **Manufacturing and assembling technologies**			
Low environmental impact materials and manufacturing (airframe engines, equipment), use of non toxic materials (inflammability, cabling), green coolants for machining			
Reference: REACT D2.4, p.18			

ID: **207**	Mode: **Air**	Field:	Subfield: **Design and materials**
Innovation Cluster: **Design for environment and recycling**			
Re-use of systems / components and new repair technologies, lifetime increasing technologies (coating improved sealing), environmental friendly processes			
Reference: REACT D2.4, p.18			

ID: **208**	Mode: **Air**	Field:	Subfield: **Design and materials**
Innovation Cluster: **Performance and propulsion aerodynamics**			
High temperature materials and coatings, turbo machinery efficiency and stall margins, variable pitch for high thrust at low speeds, no-thrust approach, efficient cooling technologies, lightweight architecture and materials for rotors and structures.			
Reference: REACT D2.4, p.18			

ID: **209**	Mode: **Air**	Field:	Subfield: **Design and materials**
Innovation Cluster: **Combustion**			
Re-use of systems / components and new repair technologies, lifetime increasing technologies (coating improved sealing), environmental friendly processes			
Reference: REACT D2.4, p.18			

ID: **210**	Mode: **Air**	Field:	Subfield: **Propulsion equipment**
Innovation Cluster: **Air - breathing propulsion**			
High temperature materials and coatings, turbo machinery efficiency and stall margins, variable pitch for high thrust at low speeds, no-thrust approach, efficient cooling technologies, lightweight architecture and materials for rotors and structures.			
Reference: REACT D2.4, p.18			

ID: **211**	Mode: **Air**	Field:	Subfield: **Propulsion equipment**
Innovation Cluster: **Nozzles, vectored, thrust, reheat**			
Thrust reverser, technologies for weight reduction			
Reference: REACT D2.4, p.19			

ID: **212**	Mode: **Air**	Field:	Subfield: **Propulsion equipment**
Innovation Cluster: **Engine controls**			
Optimized engine controls for reducing fuel burn			
Reference: REACT D2.4, p.19			

ID: **213**	Mode: **Air**	Field:	Subfield: **Propulsion equipment**
Innovation Cluster: **Electrical power generation and distribution**			
All electric aircraft, fuel cell for on-board energy supply (during cruise and on-ground)			
Reference: REACT D2.4, p.19			

ID: **214**	Mode: **Air**	Field:	Subfield: **Energy management systems**
Innovation Cluster: **Unconventional aircraft concepts and configurations**			
High aspect ratio/low sweep configuration ("green slider"), Inter-Cooler Recuperator engine (ICR), Blanded Wing Body configuration (BWB)			
Reference: REACT D2.4, p.19			

ID: **215**	Mode: **Air**	Field:	Subfield: **Energy management systems**
Innovation Cluster: **Breakthrough technologies**			
Designer materials tailored for multifunctional applications; Hydrogen-based engine concepts, a/c concepts with hydrogenbased propulsion			
Reference: REACT D2.4, p.19			

ID: **216**	Mode: **Air**	Field:	Subfield: **Airport and ground operations**
Innovation Cluster: **Airport operations**			
Zero emissions people transporters (e.g. maglev trains, electric vehicles), low weight cars with hybrid transmission, reliable / embedded intermodal links to ensure predictable home-to-gate time and reduce emissions			
Reference: REACT D2.4, p.19			

ID: **217**	Mode: **Air**	Field:	Subfield: **Energy management systems**
Innovation Cluster: **Ground operations**			
Minimization / elimination of ground vehicles by automated services at the gate, e.g. fuel hydrant, electrical and air plug-in points, hydrants for waste disposal, conveyers for luggage and catering long duration batteries, light weight fuel cells vehicles			
Reference: REACT D2.4, p.19			

ID: **218**	Mode: **Rail**	Field:	Subfield: **Traffic Management**
Innovation Cluster: **ICT applied to traffic flows and railway networks**			
ICT tools and systems for optimizing the distribution of traffic flows, freight and passenger transport demand and supply over railway networks, simulation and modeling tools,			
Reference: REACT D2.4, p.21			

ID: **219**	Mode: **Rail**	Field:	Subfield: **Propulsion equipment**
Innovation Cluster: **Reduction of air pollutants**			
Diesel anti - particulate filters, emission optimization within engine			
Reference: REACT D2.4, p.21			

ID: **220**	Mode: **Rail**	Field:	Subfield: **Design and materials**
Innovation Cluster: **Design of lightweight materials and aerodynamics**			
Impacts of frontal winds and lateral atmospheric turbulences on train aerodynamics, airframe friction-reducing, surface coatings (nanotechnology), reduced mass with reinforced polymers, sandwich structure or aluminum car bodies			
Reference: REACT D2.4, p.21			

ID: **221**	Mode: **Rail**	Field:	Subfield: **Energy management systems**
Innovation Cluster: **Braking energy recovery**			
Braking energy recovering by heating a fluid or super capacitors in fixed installation or on board, energy storage by batteries			
Reference: REACT D2.4, p.21			

ID: **222**	Mode: **Rail**	Field:	Subfield: **Emerging technologies**
Innovation Cluster: **Alternative technologies**			
Fuel cell and levitation technology, use of solar panels for on board services (air conditioning, lighting, pantograph raising and electric locking)			
Reference: REACT D2.4, p.21			

ID: **223**	Mode: **Rail**	Field:	Subfield: **Emerging technologies**
Innovation Cluster: **Alternative propulsion systems**			
Hydrogen engine, natural gas engine or turbines			
Reference: REACT D2.4, p.21			

ID: **224**	Mode: **Rail**	Field:	Subfield: **Methods and tools**
Innovation Cluster: **Environmental impact of railway infrastructure**			
Minimization of the environmental impacts, including the landscape impact, the emissions linked with the construction of the infrastructure.			
Reference: REACT D2.4, p.22			

ID: **225**	Mode: **Rail**	Field:	Subfield: **Design and materials**
Innovation Cluster: **Rail track engineering and design**			
Performance of railway track systems in response to train loadings, improving duration of components, low impact track designs			
Reference: REACT D2.4, p.22			

ID: **226**	Mode: **Road**	Field:	Subfield: **Human-machine-road interface**
Innovation Cluster: **Intelligent transport systems (vehicle - driver)**			
ICT tools and systems for assisting the human-machine road interactions: navigations aids, forecasting, driving assistance, managing risky situations, …			
Reference: REACT D2.4, p.24			

ID: **227**	Mode: **Road**	Field:	Subfield: **Advanced fuels and technologies**
Innovation Cluster: **New combustion concepts**			
New combustion concepts such as HCCI, CAI, and integrated combustion processes for more efficient and less emissive engines.			
Reference: REACT D2.4, p.24			

ID: **228**	Mode: **Road**	Field:	Subfield: **Advanced fuels and technologies**
Innovation Cluster: **Biomass derived fuels**			
Optimization of production processes, optimization of land use, mixing with carbon fuels, second generation of biofuels (thermo and bio chemical conversion of cellulosic materials hydrogen production from fermentation…).			
Reference: REACT D2.4, p.24			

ID: **229**	Mode: **Road**	Field:	Subfield: **Advanced fuels and technologies**
Innovation Cluster: **Advanced internal combustion engines**			
High specific torque, flexible components, advanced fuel injection, downsizing, boosting, lean operation, variable systems, optimized natural gas engines, CAD tools.			
Reference: REACT D2.4, p.24			

ID: **230**	Mode: **Road**	Field:	Subfield: **Design and materials**
Innovation Cluster: **Energy saving design and materials**			
Control systems, batteries, low friction engines, lubrificants, tyres, lightweight vehicle components, packaging, renewable materials			
Reference: REACT D2.4, p.24			

ID: **231**	Mode: **Road**	Field:	Subfield: **Hybrid-intelligent energy management**
Innovation Cluster: **Hybrid technologies**			
System simplification and integration, cost reduction, specialized hybrid components			
Reference: REACT D2.4, p.24			

ID: **232**	Mode: **Road**	Field:	Subfield: **Hybrid-intelligent energy management**
Innovation Cluster: **Non conventional hybris systems**			
Electric power splitter in the power train, plug-in hybrids, superconducting hybrid, hydraulic hybrids.			
Reference: REACT D2.4, p.25			

ID: **233**	Mode: **Road**	Field:	Subfield: **Hybrid-intelligent energy management**
Innovation Cluster: **Full electrical vehicles**			
Electric drive and components, functional safety and durability, battery and energy storage technology, flow and nano batteries, ultra capacitors and regenerative breaking systems.			
Reference: REACT D2.4, p.25			

ID: **234**	Mode: **Road**	Field:	Subfield: **Hybrid-intelligent energy management**
Innovation Cluster: **Components**			
Control systems, energy storage (batteries, ultra-capacitors), materials, electric motors			
Reference: REACT D2.4, p.25			

ID: **235**	Mode: **Road**	Field:	Subfield: **Hybrid-intelligent energy management**
Innovation Cluster: **Vehicle energy management**			
Air conditioning, cooling, advanced transmissions and integrated operations			
Reference: REACT D2.4, p.25			

ID: **236**	Mode: **Road**	Field:	Subfield: **Hybrid-intelligent energy management**
Innovation Cluster: **In-use performance**			
Advanced sensors, improved On Board Diagnosics (OBD), On Board Monitor (OBM), real-world performance, anti-tampering			
Reference: REACT D2.4, p.25			

ID: **237**	Mode: **Road**	Field:	Subfield: **Hybrid-intelligent energy management**
Innovation Cluster: **Vehicle emissions reduction systems**			
Reduced engine-out emissions, advanced emission control systems, cold/off cycle, improved cost and durability, advanced & nano-catalyst materials, mode management			
Reference: REACT D2.4, p.25			

ID: **238**	Mode: **Road**	Field:	Subfield: **Hybrid-intelligent energy management**
Innovation Cluster: **Fuel cell technologies**			
High temperature membranes, bi-polar plates, air system, humidity management, low weight, low cost, high efficiency, durability			
Reference: REACT D2.4, p.25			

ID: **239**	Mode: **Road**	Field:	Subfield: **Fuel cell vehicles and low carbon / hydrogen fuels**
Innovation Cluster: **Fuel cell vehicles**			
Auxiliary Power Units, full propulsion systems, on-board reformers			
Reference: REACT D2.4, p.26			

ID: **240**	Mode: **Road**	Field:	Subfield: **Fuel cell vehicles and low carbon / hydrogen fuels**
Innovation Cluster: **Hydrogen storage on vehicles**			
Low cost, high capacity storage (chemical and mechanical), safety and monitoring systems			
Reference: REACT D2.4, p.26			

ID: **241**	Mode: **Road**	Field:	Subfield: **Infrastructure for fuel cell vehicles and low carbon / hydrogen fuels**
Innovation Cluster: **Hydrogen production from non fossil sources**			
Biomass, renewables, nuclear electricity			
Reference: REACT D2.4, p.26			

ID: **242**	Mode: **Road**	Field:	Subfield: **Infrastructure for fuel cell vehicles and low carbon / hydrogen fuels**
Innovation Cluster: **Hydrogen distribution infrastructure**			
Handling, transportation, dispensing			
Reference: REACT D2.4, p.26			

ID: **243**	Mode: **Road**	Field:	Subfield: **Vehicle infrastructure**
Innovation Cluster: **Intelligent transport systems (vehicle - infrastructure, vehicle to vehicle)**			
Vehicle to vehicle and vehicle to road interacting systems, onboard equipments, short range communications technologies.			
Reference: REACT D2.4, p.26			

ID: **244**	Mode: **Water**	Field:	Subfield: **Traffic management**
Innovation Cluster: **Shipping operations and traioning**			
Environmental friendly shipping operations, manoeuvring, rough whether shipping operations, winter navigation, communication systems, sea transport networks			
Reference: REACT D2.4, p.28			

ID: **245**	Mode: **Water**	Field:	Subfield: **Traffic management**
Innovation Cluster: **Inland navigation**			
Promotion of inland navigation, competitiveness of inland navigation in logistic transport chains, innovative and sustainable inland navigation concepts			
Reference: REACT D2.4, p.28			

ID: **246**	Mode: **Water**	Field:	Subfield: **Traffic management**
Innovation Cluster: **Door to door applications**			
Express, secure port network systems and procedures for more rapid and secure transit of goods throughout their entire transportation from door to door including inter-port transshipment.			
Reference: REACT D2.4, p.28			

ID: **247**	Mode: **Water**	Field:	Subfield: **Waste and emissions management**
Innovation Cluster: **Vehicle emissions reduction systems**			
Economic retrofit-packages for existing ships; exhaust gas monitoring equipments.			
Reference: REACT D2.4, p.28			

ID: **248**	Mode: **Water**	Field:	Subfield: **Propulsion equipment**
Innovation Cluster: **Alternative propulsion systems**			
Non-fossil based propulsion (nuclear, solar and wind) solutions for economic application on large ships			
Reference: REACT D2.4, p.28			

ID: **249**	Mode: **Water**	Field:	Subfield: **Design and materials**
Innovation Cluster: **Innovative and hydrodynamic vessel concepts**			
Improved hull design and smooth bottom paint to reduce drag			
Reference: REACT D2.4, p.28			

ID: **250**	Mode: **Water**	Field:	Subfield: **Energy management systems**
Innovation Cluster: **On board power generation and management**			
Use of fuel cells on merchant ships for climate friendly on board power generation			
Reference: REACT D2.4, p.29			

ID: **251**	Mode: **Water**	Field:	Subfield: **Design and materials**
Innovation Cluster: **Port operations**			
Optimization of the operations within the ports, including the loading and the internal transports			
Reference: REACT D2.4, p.29			

ID: **252**	Mode: **Water**	Field:	Subfield: **Design and materials**
Innovation Cluster: **Oil spill response**			
Oil spill management, devices, policies			
Reference: REACT D2.4, p.29			

ID: **253**	Mode: **Water**	Field:	Subfield: **Design and materials**
Innovation Cluster: **Accidents prevention technologies**			
High quality maintenance of vessels, methods, systems and technologies addressing the safety performance of vessels during their lifetime			
Reference: REACT D2.4, p.29			

ID: **254**	Mode: **Water**	Field:	Subfield: **Design and materials**
Innovation Cluster: **Manufacture and meintenance**			
Cost effective and environmental friendly manufacturing and maintenance			
Reference: REACT D2.4, p.29			

ID: **255**	Mode:	Field: **Planning, social sciences and economy**	Subfield: **Spatial Planning**
Innovation Cluster: **Integration of spatial planning, urban planning, transports planning and economic policies**			
Transport saving spatial planning, network planning to promote modal shift and reduce travels			
Reference: REACT D2.4, p.31			

ID: **256**	Mode:	Field: **Planning, social sciences and economy**	Subfield: **Spatial Planning**
Innovation Cluster: **Land use taxation**			
Taxation of the use of distant / rural spaces to promote low-transport land use			
Reference: REACT D2.4, p.31			

ID: **257**	Mode:	Field: **Planning, social sciences and economy**	Subfield: **Spatial Planning**
Innovation Cluster: **Alternative fuels distribution infrastrucutre planning**			
compression of the hydrogen at the refueling site, technologies to produce, store and transport hydrogen, pipelines, relations between production plant and refuelling stations			
Reference: REACT D2.4, p.31			

ID: **258**	Mode:	Field: **Planning, social sciences and economy**	Subfield: **Spatial Planning**
Innovation Cluster: **Traffic planning**			
Traffic planning, traffic elements, traffic calming, environmental areas, pedestrian areas			
Reference: REACT D2.4, p.31			

ID: **259**	Mode:	Field: **Planning, social sciences and economy**	Subfield: **Spatial Planning**
Innovation Cluster: **Non-motorised mobility planning**			
Pedestrian and bicycle planning, infrastructure, signalization			
Reference: REACT D2.4, p.32			

ID: **260**	Mode:	Field: **Planning, social sciences and economy**	Subfield: **Spatial Planning**
Innovation Cluster: **Public transport planning**			
Road, railway and waterway network planning, Intermodality			
Reference: REACT D2.4, p.32			

ID: **261**	Mode:	Field: **Planning, social sciences and economy**	Subfield: **Spatial Planning**
Innovation Cluster: **Motorway speed limits**			
Effects of speed limits on fuel consumption and emissions, speed control strategies, variable speed limits, optimization of speed limits for minimizing accidents and emissions			
Reference: REACT D2.4, p.32			

ID: **262**	Mode:	Field: **Planning, social sciences and economy**	Subfield: **Freight transports**
Innovation Cluster: **Gathering of emissions information along the supply chain**			
Measurement methods, integration into the information systems/platforms for logistic chain			
Reference: REACT D2.4, p.32			

ID: **263**	Mode:	Field: **Planning, social sciences and economy**	Subfield: **Freight transports**
Innovation Cluster: **New logistic concepts**			
Integrated demand, third - party logistics providers, geographical dimension of logistics, interactions of geographical systems of production (firms) and systems of consumption (urban regions)			
Reference: REACT D2.4, p.32			

ID: **264**	Mode:	Field: **Planning, social sciences and economy**	Subfield: **Freight transports**
Innovation Cluster: **Supply chain, route planning, avoidance of empty trips**			
Distribution planning, size and location of terminals, urban freight movements in supply chain,			
Reference: REACT D2.4, p.32			

ID: **265**	Mode:	Field: **Social and behavioural measures**	Subfield: **Innovative transport systems**
Innovation Cluster: **Car-pooling, car-sharing, bike-sharing**			
Optimization algorithms, ICT solutions for users profiling and management, connections with Public Transport network, distributed and shared systems, keyless approaches.			
Reference: REACT D2.4, p.34			

ID: **266**	Mode:	Field: **Social and behavioural measures**	Subfield: **Pricing and taxation**
Innovation Cluster: **Congestion charging**			
Emission related congestion charges/ city tolls			
Reference: REACT D2.4, p.34			

ID: **267**	Mode:	Field: **Social and behavioural measures**	Subfield: **Pricing and taxation**
Innovation Cluster: **Parking pricing**			
Optimization of control strategies, cruising times, urban parking pricing problem, parking management, tariffs			
Reference: REACT D2.4, p.34			

ID: **268**	Mode:	Field: **Social and behavioural measures**	Subfield: **Pricing and taxation**
Innovation Cluster: **Motorway pricing**			
Allocation of infrastructure cost, capacity choice, stochastic traffic			
Reference: REACT D2.4, p.34			

ID: **269**	Mode:	Field: **Social and behavioural measures**	Subfield: **Pricing and taxation**
Innovation Cluster: **Fuel taxation**			
Fuel taxation for road vehicles, reduction of tax subsidies on kerosene, carbon emission related motor vehicle tax, reduction of tax subsidies for business vehicles			
Reference: REACT D2.4, p.34			

ID: **270**	Mode:	Field: **Social and behavioural measures**	Subfield: **Education and campaigning**
Innovation Cluster: **Awareness campaigns**			
Campaigns for climate friendly transport, for walking/cycling, promotion of multi-modal lifestyles, marketing for public transport, user information on public transport system			
Reference: REACT D2.4, p.34			

ID: **271**	Mode:	Field: **Social and behavioural measures**	Subfield: **Education and campaigning**
Innovation Cluster: **Sustainable transport education**			
Programs encouraging students to choose alternative modes of transport, understanding of renewable and sustainable energy technologies, teachers formation, travelling to school action plans			
Reference: REACT D2.4, p.35			

ID: **272**	Mode:	Field: **Social and behavioural measures**	Subfield: **Education and campaigning**
Innovation Cluster: **Climate friendly travel to office, school, public institutions**			
Subsidies for public transport tickets, installing showers, homework-home travels planning			
Reference: REACT D2.4, p.35			

ID: **273**	Mode:	Field: **Social and behavioural measures**	Subfield: **Education and campaigning**
Innovation Cluster: **Eco driving**			
Research on parameters of change in mobility behaviour, driver training for a fuel-saving driving style, on board devices			
Reference: REACT D2.4, p.35			

ID: **274**	Mode:	Field: **Social and behavioural measures**	Subfield: **Trip avoidance**
Innovation Cluster: **Teleworking, internet shopping**			
Decentralised organizational structure, technological supports, flexibility of human resources management, control mechanisms, consumers risk aversion, broadband access.			
Reference: REACT D2.4, p.35			

ID: **275**	Mode:	Field: **Industry and economy**	Subfield: **Regulation**
Innovation Cluster: **European regulation on emission performance standards**			
Efficiency and distributional impacts of environmental taxes, effects of performance standards on incentives, car labelling,			
Reference: REACT D2.4, p.36			

ID: **276**	Mode:	Field: **Industry and economy**	Subfield: **Regulation**
Innovation Cluster: **Competition regulation**			
Effective, transparent competition between different modes of transport and different public transport service providers.			
Reference: REACT D2.4, p.36			

ID: **277**	Mode:	Field: **Industry and economy**	Subfield: **Flexible measures**
Innovation Cluster: **Integration of transport into emission trading schemes**			
Imposing reduction targets on fuel suppliers, imposing reduction targets on car manufacturers, imposing reduction targets on car owners			
Reference: REACT D2.4, p.37			

ID: **278**	Mode:	Field: **Industry and economy**	Subfield: **Subsidies and incentives**
Innovation Cluster: **Subsidies for development of low emissions cars, e-mobility**			
Incentives for speeding up the rate of fleets renewal, substitution of a old polluting car with a new low emission vehicle.			
Reference: REACT D2.4, p.37			

ID: **301**	Mode: **Road**	Field: **Infrastructure technologies and intelligent transport systems**	Subfield: **ICT**
Innovation Cluster: **Pre- and On-trip Travel Information**			
The category traffic and travel information exists relating to Pre-Trip Information and On-Trip Driver Information. Pre-Trip Information informs the driver mostly via internet about real-time traffic flow, weather conditions, speeds and congestion on the planned route. It also makes suggestions for alternative routes. Pre-Trip Information influences the traveller on the choice of transport mode, the choice of routes, departure-times and the question whether to travel at all. Regarding freight transport the influences are limited to the choice of routes and the departure-time. On-Trip Information also informs the traveller about traffic flow, weather conditions, speeds and congestion and allows the user to make informed decisions regarding alternate routes and arrival times. The information is spread via wireless devices, telephone services, radio and in-vehicle signing such as navigation systems.			
Reference: Freightvision D3.1, p.21			

ID: **302**	Mode: **Road**	Field: **Infrastructure technologies and intelligent transport systems**	Subfield: **ICT**
Innovation Cluster: **Traffic Control – Variable Message Signs**			
Variable Message Signs (VMS) can be used to provide travellers with weather-related travel information as well as information about congestion, real-time traffic flow and current travel speed due to traffic flow and weather condition. In some countries like Germany and Austria, there is the distinction between signs influencing the traffic flow on defined sections of routes (lane control) and within a transport net (network control). First application of signs exist giving speed instructions or other instructions of traffic control (e.g. “Do not overtake!”) due to weather or traffic conditions. The second application of signs influences the choice of routes of travellers, giving information about e.g. construction sites ahead, congested road sections and travel times as well as recommendations of alternative routes. The latter exists of free text displays. Variable Message Signs or Dynamic Message Signs combine both types of information signs.			
Reference: Freightvision D3.1, p.25			

ID: **303**	Mode: **Road**	Field: **Infrastructure technologies and intelligent transport systems**	Subfield: **ICT**
Innovation Cluster: **Traffic control - Ramp Metering**			
Besides facilities influencing traffic flow on routes and in a road network (i.e. VMS), there are also facilities that influence traffic flow at intersections. Ramp metering is a facility assigned to the latter. It helps to control the flow of vehicles entering the motorway using traffic signals on motorway ramp meters alternating between red and green signals. Metering rates can be altered based on motorway traffic conditions. Ramp meters assist in dispersing platoons of vehicles that are released from nearby signalized intersections.			
Reference: Freightvision D3.1, p.28			

ID: **304**	Mode: **Road**	Field: **Infrastructure technologies and intelligent transport systems**	Subfield: **ICT**
Innovation Cluster: **Temporary Hard Shoulder Running**			
Hard shoulder running describes an approach where the hard shoulder of motorways, which is usually used for emergency reasons, is free to be used as a supplementary lane by vehicles. Regarding Temporary Hard Shoulder Running, the usage is restricted to times and areas of dense traffic flow in order to increase the capacity of the motorway. The restriction is organised by VMS and optical sensors (video surveillance). VMS show different signals pointing out the beginning or end of the hard shoulder running together with recommended speeds. At times of restriction the VMS show a red cross meaning that the usage is not allowed. Video surveillance is necessary in order to ensure that no emergency or break-down vehicle is located on the hard shoulder during and before its usage. In case of an accident or emergency the video surveillance helps to detect this incident and the VMS can be switched accordingly in order to clear the hard shoulder as quick as possible.			
Reference: Freightvision D3.1, p.31			

ID: **305**	Mode: **Road**	Field: **Infrastructure technologies and intelligent transport systems**	Subfield: **ICT**
Innovation Cluster: **Automated Vehicle Operation - Collision Avoidance Systems**			
Collision avoidances systems help to improve the ability of drivers to avoid collisions e.g. with obstacles or other vehicles. These applications use a variety of sensors to monitor the vehicle's surroundings and alert the driver of conditions that could lead to a collision. Examples include forward collision warning, obstacle detection systems, and lane departure warning systems. Apart from C2C the same technology is needed that was described in chapter 2.2.1.5 Automated Platooning: Adaptive cruise control as well as LDW.			
Reference: Freightvision D3.1, p.37			

ID: **306**	Mode: **Road**	Field: **Infrastructure technologies and intelligent transport systems**	Subfield: **ICT**
Innovation Cluster: **Commercial Vehicle Pre-Clearance – Electronic Screening**			
Electronic screening is a roadway inspection system that allows trucks with good safety records to bypass screening sites, while requiring trucks with poor or questionable safety records to stop for further inspection. It can be individually determined by each country or screening site which criteria will be used to determine whether a truck as to pull off the road for confirmation of its safety compliance.			
Reference: Freightvision D3.1, p.39			

ID: **307**	Mode: **Road**	Field: **Infrastructure technologies and intelligent transport systems**	Subfield: **ICT**
Innovation Cluster: **Commercial Vehicle Fleet Management**			
Commercial Vehicle Fleet Management is an ITS service combining the systems of disposition, en-route guidance and vehicle/freight tracking in order to organise the whole car fleet of a company.			
Reference: Freightvision D3.1, p.41			

ID: **308**	Mode: **Road**	Field: **Infrastructure technologies and intelligent transport systems**	Subfield: **ICT**
Innovation Cluster: **Electronic Financial Transactions – Road pricing**			
Congestion pricing, also known as Road Pricing or Value Pricing, employs the use of technologies to vary the cost of using a transportation facility or network based on demand or the time of day. Pricing strategies interesting for the long-distance freight transport include: variable priced lanes, variable tolls on entire roadways or roadway segments and fast and intertwined regular lanes.			
Reference: Freightvision D3.1, p.43			

ID: **309**	Mode: **Road**	Field: **Infrastructure technologies and intelligent transport systems**	Subfield: **Infrastructure**
Innovation Cluster: **Surface materials – Technologies minimising road abrasion**			
(…) Asphalts consists of sands and bitumen binder in varying proportions. Generally the stone content is around 95% and the bituminous binder around 5%. Asphalt is produced at temperatures of about 200° Celsius in a continuous mixer. Different additives to asphalt or the bituminous binder in particular may help to improve some specific or technical characteristics of asphalt. Bitumen is also used for repairing the surfaces of roads.			
Reference: Freightvision D3.1, p.46			

ID: **310**	Mode: **Road**	Field: **Infrastructure technologies and intelligent transport systems**	Subfield: **Infrastructure**
Innovation Cluster: **Surface materials – Technologies minimising noise**			
Quiet pavements help to reduce noise generated by the friction between tires and the road surface.			
Reference: Freightvision D3.1, p.49			

ID: **311**	Mode: **Road**	Field: **Infrastructure technologies and intelligent transport systems**	Subfield: **Infrastructure**
Innovation Cluster: **Surface materials – Asphalt-heating**			
Black ice on the roads is very dangerous. It can occur very suddenly, is not always noticeable by drivers and thus accidents happen quite easily. Due to lower temperatures black ice is most frequent on bridges. A so called asphalt-heating prevents the appearance of iced patches on roads. It exists of plastic tubes with a diameter of 7 cm that get installed into the asphalt of the road sections that are at risk of the appearance of black ice (such as bridges). The tubes are adjoined to a closed circuit through which warm water is pumped. A temperature of 10 degrees Celsius is enough to hit the required effect.			
Reference: Freightvision D3.1, p.51			

ID: **312**	Mode: **Road**	Field: **Infrastructure technologies and intelligent transport systems**	Subfield: **Infrastructure**
Innovation Cluster: **Noise protection walls**			
Noise protection walls are not a new technology. They help to reduce noise emissions of motorways and thus make adjacent residential areas more liveable. A new technology regarding noise protection walls is its combination with a vehicle restraint system for the safety of middle and marginal strip.			
Reference: Freightvision D3.1, p.52			

ID: **313**	Mode: **Rail**	Field: **Infrastructure technologies and intelligent transport systems**	Subfield: **Intermodal freight transport**
Innovation Cluster: **Rolling highway**			
A very explicit example of intermodal freight transport is the "rolling highway". The trains are provided with a driveable track along the entire train. These rolling highways are mostly used on transit routes through the Alps or from Western to Eastern Europe. The freight forwarder saves money for fuel and tolls, traffic jams are avoided, and restrictions of not being allowed to drive at night or on Sundays can be bypassed.			
Reference: Freightvision D3.1, p.59			

ID: **314**	Mode: **Rail**	Field: **Infrastructure technologies and intelligent transport systems**	Subfield: **Intermodal freight transport**
Innovation Cluster: **Intermodal freight terminals (IFT)**			
Intermodal freight terminals are places where at least two transport modes are connected. They are also referred to as logistic centres or freight villages. Often these terminals are too small and therefore have to struggle with congestion. Especially at ports which lay inside cities where the terminals can not be expanded to surrounding areas.			
Reference: Freightvision D3.1, p.59			

ID: **315**	Mode: **Rail**	Field: **Infrastructure technologies and intelligent transport systems**	Subfield: **Intermodal freight transport**
Innovation Cluster: **Automated guided vehicle devices**			
Automated guided vehicles are mobile robots which are already used in several industry applications. They could be used to load freight ships while reducing waiting time and accelerating the loading process.			
Reference: Freightvision D3.1, p.60			

ID: **316**	Mode: **Rail**	Field: **Infrastructure technologies and intelligent transport systems**	Subfield: **Intermodal freight transport**
Innovation Cluster: **Cargo Speed**			
Cargo Speed rail-wagons can influence the frequency in which trains can be loaded and unloaded. It is based on the Roll-On-Roll-Off concept and insures that trucks do not have to be dispatched one by one but several trucks can be unloaded or loaded at the same time. The trucks roll onto wagons each which each have movable well floors. The trailer is left on the well floor, which lifts the trailer up and is then rotated onto the wagon.			
Reference: Freightvision D3.1, p.60			

ID: **317**	Mode: **Rail**	Field: **Infrastructure technologies and intelligent transport systems**	Subfield: **ITS-Technologies**
Innovation Cluster: **Future ETCS implementation**			
The following activities must be carried out with a view to ensuring the operational interoperability of ERTMS: - Functional requirements of the system should be based on agreed operating principles; - Engineering rules and their impact should be considered in order to limit divergence and to avoid multiplication of different operational situations; - Specifications of the interface between the driver and the system (Driver Machine Interface – DMI) should be harmonised, taking into account possible harmonisation of the trackside 'boards' (fixed panel indications); - Consolidation of the harmonised operational rules and their insertion into the driver's rulebook.			
Reference: Freightvision D3.1, p.65			

ID: **318**	Mode: **Rail**	Field: **Infrastructure technologies and intelligent transport systems**	Subfield:
Innovation Cluster: **National Migration Strategies**			
The analysis in the previous section strongly indicates that the pace of ETCS migration will be driven more by national perspectives and the age and condition of current infrastructure and traction units, than by the attraction of reduced on- board costs of the international fleet. Each network is currently in the process of elaborating their national rollout strategies for ETCS Migration.			
Reference: Freightvision D3.1, p.66			

ID: **319**	Mode: **Rail**	Field: **Infrastructure technologies and intelligent transport systems**	Subfield:
Innovation Cluster: **Present-day ITS analysis**			
Considering the immense complexity of interoperability in the European railway world, it must be stated that huge progress has been made in the past years. The legal system is in place and, although not complete, a large portion of the supporting ITS's have been published. The rapid publication of the remaining ITSs for Conventional Rail must be encouraged. Not only the awareness of the importance of interoperability has increased, but also the first tangible results can be seen on several locations. In this report the progress is eventually measured against the developing interoperability of the TEN network			
Reference: Freightvision D3.1, p.70			

ID: **320**	Mode: **Rail**	Field: **Infrastructure technologies and intelligent transport systems**	Subfield:
Innovation Cluster: **ERTMS**			
Although interoperability encompasses a lot more than ERTMS, the importance of this signalling system is so paramount that, understandably, most attention is focussed on its implementation. We can observe and understand the logical fact that large countries already equipped with sophisticated systems do not take the lead in replacing their systems with ERTMS.			
Reference: Freightvision D3.1, p.70			

ID: **321**	Mode: **Rail**	Field: **Infrastructure technologies and intelligent transport systems**	Subfield:
Innovation Cluster: **Computer Integrated Railroading**			
Computer Integrated Railroading or CIR-ELKE is a system which is able to increase the frequency of trains on high density routes up to 40 %. This is enabled by high performance signal blocks which are partly able to go without permanent signals. The system provides trains with telegrams through a communication system (LZB – linienförmige Zugbeeinflussung), which is similar to ETCS, about upcoming speed-limits and switches right before they reach the danger spot, therefore avoiding unnecessary delays.			
Reference: Freightvision D3.1, p.72			

ID: **322**	Mode: **Rail**	Field: **Infrastructure technologies and intelligent transport systems**	Subfield:
Innovation Cluster: **Cargo Mover**			
Cargo Movers are driverless freight cars that could help to shift traffic from roads to rail networks. Once the data of destination are typed in, the Cargo Mover sets off and reaches it by itself. Multiple sensors that scan the surroundings are installed to prevent possible accidents by hitting obstacles on the track. It is able to carry 60 tonnes of freight volume travelling at 90 km / h while using 30 % less fuel than a truck.			
Reference: Freightvision D3.1, p.72			

ID: **323**	Mode: **Rail**	Field: **Infrastructure technologies and intelligent transport systems**	Subfield:
Innovation Cluster: **Suspension**			
The GIGABOX is a unique system for rail freight transport consisting of a wheel set bearing and hydraulic spring. The new bearing suspension concept for rail vehicles, with integrated rubber spring with hydraulic damping, does what conventional systems cannot do: it reduces noise and pollution while increasing safety at higher travel speeds.			
Reference: Freightvision D3.1, p.73			

ID: **324**	Mode: **Rail**	Field: **Infrastructure technologies and intelligent transport systems**	Subfield:
Innovation Cluster: **K-Blocks / LL-Blocks**			
K-Blocks reduce noise emissions by up to 50 %. They are made of organic composite material and posses different braking characteristics than cast iron blocks, which help reducing the damages to the rail tracks and wheels. Retrofitting therefore requires adjustments to the braking system which leads to costs of up to 10 000 € per wagon while they are cost-neutral for new vehicles. They are able to reduce noise emissions to a degree of 10 dB. LL-Blocks are either made of organic composite material or of sinter metal. Their braking characteristics are quite similar to cast iron blocks; therefore only minor adjustments are necessary for retrofitting. They offer the same amount of noise reduction as K-Blocks.			
Reference: Freightvision D3.1, p.74			

ID: **325**	Mode: **Water**	Field: **Infrastructure technologies and intelligent transport systems**	Subfield:
Innovation Cluster: **X-Gate Vessel Tracking and GPS Repeater**			
The GPS Repeater, Tracking Software, Reporting			
Reference: Freightvision D3.1, p.79			

ID: **326**	Mode: **Water**	Field: **Infrastructure technologies and intelligent transport systems**	Subfield:
Innovation Cluster: **Arrow Program**			
The ARROW program is a software tool to estimate and display the potential conditions of rolling resonances or high wave impacts on ships due to specific wave encounter situations. Only some data input from the user on ship and waves are needed to provide the qualitative results in a way to identify potential problems and tendencies to derive countermeasures.			
Reference: Freightvision D3.1, p.82			

ID: **327**	Mode: **Water**	Field: **Infrastructure technologies and intelligent transport systems**	Subfield:
Innovation Cluster: **Sky Sails**			
The SkySails-System consists of three simple main components: A towing kite with rope, a launch and recovery system, and a control system for automatic operation. Instead of a traditional sail fitted to a mast, SkySails uses large towing kites for the propulsion of the ship. Their shape is comparable to that of a paraglider. The towing kite is made of high-strength and weatherproof textiles.			
Reference: Freightvision D3.1, p.83			

ID: **328**	Mode: **Water**	Field: **Infrastructure technologies and intelligent transport systems**	Subfield:
Innovation Cluster: **Port Feeder Barge**			
The Port Feeder Barge is intended to be deployed as a logistic innovation within the Port of Hamburg in order to ease internal container operation. The innovative vessel is a smart alternative to road trucking. It shall ply between the various terminals in order to shift the in-port container transhipment from road to waterway. It is also usable to tranship containers from seagoing vessels to barges and reverse, without using roads.			
Reference: Freightvision D3.1, p.85			

ID: **329**	Mode: **Water**	Field: **Infrastructure technologies and intelligent transport systems**	Subfield:
Innovation Cluster: **Fuel Cells for Low Emission Ships**			
Combining the continued use of fossil-fuel energy with the growing call for sustainable development poses a global challenge. A shift to gas-based fuels is an important environmental step, allowing independence from oil products, and opens up for the use of fuel cell technology. Compared with conventional power producing machinery, fuel cells offer greatly improved efficiency and massive reductions in atmospheric emissions. The technology has reached a level of maturity that allows for large-scale industrial use.			
Reference: Freightvision D3.1, p.87			

ID: **330**	Mode: **Water**	Field: **Infrastructure technologies and intelligent transport systems**	Subfield:
Innovation Cluster: **Small Waterplane Area Twin Hull**			
The Small Waterplane Area Twin Hull (SWATH) is a twin-hull ship design that minimizes hull volume in the surface area of the sea. By minimizing hull volume in the sea's surface, where wave energy is located, the vessel becomes very stable, even in high seas and at high speeds. The bulk of the displacement necessary to keep the ship afloat is located beneath the waves, where it is less affected by wave action, as wave excitation drops exponentially with depth. Placing the majority of the ship's displacement under the waves is similar in concept to submarines, which are also not affected by wave action.			
Reference: Freightvision D3.1, p.89			

ID: **331**	Mode: **Water**	Field: **Infrastructure technologies and intelligent transport systems**	Subfield: **Inland navigation**
Innovation Cluster: **River Information Services (RIS)**			
Exciting new developments are taking place in navigation that enable all involved parties to have reliable, real time information on the vessels' position and course. Initially elaborated as interactive communication between ship-ship and ship-shore for safe traffic management, River Information Services (RIS) can do a lot more. RIS is to become a great tool and interface for advanced logistics chain management. It can link all parties from river operators to shippers for optimal voyage planning, tracking & tracing, administrative follow-up and exchange with other transport modes.			
Reference: Freightvision D3.1, p.96			

ID: **332**	Mode: **Water**	Field: **Infrastructure technologies and intelligent transport systems**	Subfield: **Inland navigation**
Innovation Cluster: **FUTURA carrier system**			
(…) The Futura Carrier class is currently regarded as the most advanced line of inland waterway vessels in the world. Developed by New Logistics in Kiel, the Futura Carrier design concept is fully modular, making it possible to build bulk carriers, container carriers or tankers. Both the hull and the technical modules allow flexible variation for different sizes and cargo types. The modular design enables shipyards to build ships of this class without additional planning, development and project scheduling overheads. Other benefits compared to conventional inland vessels include significantly lower fuel consumption and very effective exhaust emissions purification systems.			
Reference: Freightvision D3.1, p.99			

ID: **333**	Mode: **Inter**	Field: **Infrastructure technologies and intelligent transport systems**	Subfield:
Innovation Cluster: **CESAR System**			
CESAR is the most important European customer information system for intermodal transport. CESAR stands for "Co-operative European System for Advanced Information Redistribution" between Combined Transport (CT) operators and their customers. As a single access point on Internet, CESAR provides information on services, a common booking interface and updated information on loading units (tracking and tracing). This is the first system functioning in this way at international level. Several operators appear like one virtual company. The most popular function is tracking and tracing: with one single address customers are enabled to receive status information about all their loading units no matter where and with which operators it is actually running.			
Reference: Freightvision D3.1, p.103			

ID: **334**	Mode: **Inter**	Field: **Infrastructure technologies and intelligent transport systems**	Subfield:
Innovation Cluster: **USE IT system**			
In 2002, UIC's Combined Transport Group (CTG), with 22 European railway companies as members, developed a pilot application that made it possible to follow in real time combined transport block trains on three pilot routes. As the system gave satisfaction, CTG decided to extend the project and to design an information system that would make it possible for railway customers to trace trains in real time over the internet or by directly integrating the data into their own IT tracking systems.			
Reference: Freightvision D3.1, p.110			

ID: **335**	Mode: **Inter**	Field: **Infrastructure technologies and intelligent transport systems**	Subfield:
Innovation Cluster: **BRAVO CIS Application**			
In the framework of the BRAVO project (www.bravo-project.com), railways and intermodal operators have developed a pilot application of a train monitoring and customer information system (CIS) which allows monitoring cross border train movements in real time in order to inform customers in case of irregularities.			
Reference: Freightvision D3.1, p.112			

ID: **336**	Mode: **Inter**	Field: **Infrastructure technologies and intelligent transport systems**	Subfield:
Innovation Cluster: **Telematic Regulations**			
The European Commission has published the regulation 62/2005, called TAF-TSI "Technical Specification for Interoperability relating to the Telematic Applications for Freight subsystem of the trans-European conventional rail system." This regulation is referring to the interoperability directive 2001/16 and its objective is to enforce interoperability of the telematics for rail freight.			
Reference: Freightvision D3.1, p.114			

ID: **337**	Mode: **Inter**	Field: **Infrastructure technologies and intelligent transport systems**	Subfield:
Innovation Cluster: **SEDP Plan**			
To achieve the implementation of the TAF TSI, the regulation also required that the "European Rail Representative Bodies" had to deliver a Strategic European Deployment Plan (SEDP) to the European Commission.			
Reference: Freightvision D3.1, p.117			

ID: **338**	Mode: **Inter**	Field: **Infrastructure technologies and intelligent transport systems**	Subfield:
Innovation Cluster: **Europtirails**			
EUROPTIRAILS is managed by RailNetEurope (RNE – 34 European infrastructure managers) and will make real-time, online supervision of European rail traffic possible for the first time. The tool was developed for a given corridor of railway lines running between Rotterdam and Milan and will assist railway operators to follow their trains. The range of the tool has already been extended to further parts of the European railway network.			
Reference: Freightvision D3.1, p.119			

ID: **339**	Mode: **Inter**	Field: **Infrastructure technologies and intelligent transport systems**	Subfield:
Innovation Cluster: **The European Performance Regime (EPR) application**			
A European Performance Regime should be implemented according to the provisions of Article 11 of Directive 2001/14 which states the following: "Infrastructure charging schemes shall through a performance scheme encourage railway undertakings and the infrastructure manager to minimize disruption and improve the performance of the railway network. This may include penalties for actions which disrupt the operation of the network, compensation for undertakings which suffer from disruption and bonuses that reward better than planned performance."			
Reference: Freightvision D3.1, p.121			

ID: **340**	Mode: **Inter**	Field: **Infrastructure technologies and intelligent transport systems**	Subfield:
Innovation Cluster: **InteGRail Project**			
InteGRail aims at creating a holistic, coherent information system, integrating the major railway sub-systems, in order to achieve higher levels of performance of the railway system in terms of capacity, average speed and punctuality, safety and the optimised usage of resources. Building on results achieved by previous projects, InteGRail will propose new intelligent procedures and will contribute to the definition of new standards, in compliance with EC directives and TSI's.			
Reference: Freightvision D3.1, p.123			

ID: **341**	Mode: **Inter**	Field: **Infrastructure technologies and intelligent transport systems**	Subfield:
Innovation Cluster: **FREIGHTWISE Project**			
The overall objective of FREIGHTWISE www.freightwise.eu) is to support the modal shift of cargo flows from road to intermodal transport using road in combination with short sea shipping, inland waterways and rail, as well as to make transport more efficient. It will achieve this objective by means of improved management and facilitation of information access and exchange between large and small, public and private stakeholders across all business sectors and transport modes.			
Reference: Freightvision D3.1, p.124			

ID: **342**	Mode: **Inter**	Field: **Infrastructure technologies and intelligent transport systems**	Subfield:
Innovation Cluster: **IT-based capacity management systems**			
For more than two decades stakeholders in combined rail/road transport services in Europe have felt the need for an information technology (IT) support of the operation of intermodal terminals. Despite strong efforts, which were partly embedded in research and development projects, useable terminal management software applications have only been created in recent years.			
Reference: Freightvision D3.1, p.125			

ID: **343**	Mode: **Inter**	Field: **Infrastructure technologies and intelligent transport systems**	Subfield:
Innovation Cluster: **EDI tools for the check-in/out procedures**			
Before entering a CT terminal, the checker (staff of the terminal) carries out some controls (technical and administrative). In bigger CT terminals (in Verona Q.E. for example), the check-in/out procedures (and also when the freight trains arrive on the terminal) are carried out with the support of an electronic device (like a pocket PC – see picture 17), which is directly connected to the EDI system of the operators.			
Reference: Freightvision D3.1, p.127			

ID: **344**	Mode: **Inter**	Field: **Infrastructure technologies and intelligent transport systems**	Subfield:
Innovation Cluster: **Automated loading unit identification**			
Another potential component of a comprehensive terminal management system is an automated loading unit identification system installed at the road-side or/and rail-side access of a terminal in order to reduce drastically for example the waiting times, one of the main complains of the transport companies on the transhipment yards. These systems already in use at the port-terminals are conceived for sole maritime container traffic. The integration of such an automatic system in a CT environment means huge adaptations to these systems in order to recognize also the loading units like semitrailers, swap-bodies, etc. Therefore, they have to recognise the owner identification consisting of the 'BIC-code' for maritime containers and the owner code on the codification plate, which is in use for the continental loading units (swap bodies and cranable semi-trailers).			
Reference: Freightvision D3.1, p.128			

ID: **345**	Mode: **Inter**	Field: **Infrastructure technologies and intelligent transport systems**	Subfield:
Innovation Cluster: **Technologies for intermodal transport**			
Automatic Identification of damages, Nehts, IUT (Innovatives Umschlag-Terminal), Rolling Trans System (RTS), Automatic stacking Crane System, The MOBILER concept, Roll-off container transport system (ACTS), Steelbro Sidelifters, System Novatrans, System CEMAT, ISU System, Basket Wagon, CargoRoo, Modalohr, CargoSpeed, Flexiwaggon, Automated Guided Vehicles (AGV's), Inter Terminal Transport (ITT), Subtrans, CargoCap (electric driven capsules), CargoMover, CargoBeamer, Compact Intermodal Terminals, WIREOUT, Project FastRCargo, METROCARGO			
Reference: Freightvision D3.1, p.129			

ID: **346**	Mode: **Road**	Field: **Vehicle and Fuel Technology**	Subfield:
Innovation Cluster: **Optimization of conventional Diesel technology**			
The engine specific aspects considered in this section are: alternative combustion systems, downsizing, exhaust heat recovery and electric hybridization.			
Reference: Freightvision D3.1, p.165			

ID: **347**	Mode: **Road**	Field: **Vehicle and Fuel Technology**	Subfield:
Innovation Cluster: **Alternative engine technologies**			
Natural gas engine, Hydrogen internal combustion engines, Electric drive (Fuel cell/battery powered drivetrain)			
Reference: Freightvision D3.1, p.169			

ID: **348**	Mode: **Road**	Field: **Vehicle and Fuel Technology**	Subfield:
Innovation Cluster: **Optimization of operational efficiency**			
Air resistance, Rolling resistance, Giga-liners, Electrification of auxiliary loads, Idling reduction technologies			
Reference: Freightvision D3.1, p.171			

ID: **349**	Mode: **Road**	Field: **Vehicle and Fuel Technology**	Subfield:
Innovation Cluster: **Reduction of pollutants emissions**			
A significant part of the development efforts on diesel technology concerns the exhaust gas aftertreatment to reduce emission of air pollutants (mainly NOX and PM). The main technologies being developed or already on the market for diesel motors are: - Diesel particle filter (DPF): fuel economy penalty due to backpressure, operating costs, thermal management and regeneration requirements - Selective catalytic reduction (SCR): reduction of NOX emissions - Lean NOX trap (LNT) also known as NOX adsorber catalyst: fuel economy penalty for NOX regeneration			
Reference: Freightvision D3.1, p.175			

ID: **350**	Mode: **Rail**	Field: **Vehicle and Fuel Technology**	Subfield:
Innovation Cluster: **Electric locomotive**			
Regenerative Braking, Medium frequency transformer, HTSC transformer, IGBT Inverter, Wheel mounted permanent magnet synchronous motor, Transversal flux motor, Optimisation of traction software, Switch off of traction group			
Reference: Freightvision D3.1, p.177			

ID: **351**	Mode: **Rail**	Field: **Vehicle and Fuel Technology**	Subfield:
Innovation Cluster: **Diesel locomotive**			
Common rail, Upgrade / Replacement of Engines, Diesel mechanic transmission			
Reference: Freightvision D3.1, p.182			

ID: **352**	Mode: **Rail**	Field: **Vehicle and Fuel Technology**	Subfield:
Innovation Cluster: **Alternative engine technologies**			
Gas engine, Gas turbine			
Reference: Freightvision D3.1, p.183			

ID: **353**	Mode: **Rail**	Field: **Vehicle and Fuel Technology**	Subfield:
Innovation Cluster: **Design and Construction**			
Aerodynamic design, Aerodynamic ordering of freight cars, Covers for open freight cars, Friction, Weight reduction, Sandwich structures, Fibre reinforced polymers, Single axle bogies, Mechatronics innovations for future running gear			
Reference: Freightvision D3.1, p.183			

ID: **354**	Mode: **Water**	Field: **Vehicle and Fuel Technology**	Subfield:
Innovation Cluster: **Engines**			
Reciprocating internal combustion engines, Rotational internal combustion engines, Rotational external combustion engines, Integrated electric drive – alternative propulsion and auxiliary systems			
Reference: Freightvision D3.1, p.194			

ID: **355**	Mode: **Water**	Field: **Vehicle and Fuel Technology**	Subfield:
Innovation Cluster: **Efficiency and CO2 emissions optimization**			
Waste heat recovery, Cold ironing, Wind propulsion, Route and speed optimization, Hull design, propellers, Reduction of emissions			
Reference: Freightvision D3.1, p.196			

ID: **356**	Mode: **Fuels**	Field: **Vehicle and Fuel Technology**	Subfield:
Innovation Cluster: **Transport fuels**			
Petrol, diesel, heavy fuel oil (HFO) and marine diesel oil (MDO), Gas-to-Liquid (GTL) fuels and Coal-to-Liquid (CTL) fuels, Methanol and Dimethyl Ether (DME), Conventional and Advanced Ethanol, Straight vegetable oil, conventional biodiesel (FAME) and advanced biodiesels (BTL and HVO), Liquefied petroleum gas (LPG), Compressed Natural Gas (CNG), Liquefied Natural Gas (LNG) and Adsorbed Natural Gas (ANG), Compressed Hydrogen (CGH2) and Liquid Hydrogen (LH2), Fuel Cell and/or Battery-Electric based propulsion,			
Reference: Freightvision D3.1, p.201			

ID: **357**	Mode: **Inter**	Field: **Logistics Technologies**	Subfield:
Innovation Cluster: **Logistics Software Technologies**			
Strategic Network Planning, Master Planning, Distribution and Transport Planning,			
Reference: Freightvision D3.1, p.222			

ID: **358**	Mode: **Inter**	Field: **Logistics Technologies**	Subfield:
Innovation Cluster: **Logistics Hardware Technologies**			
Global Navigation Satellite Systems, Radio Frequency Identification			
Reference: Freightvision D3.1, p.243			

Annex 2 : Questionnaire on assessing the impact of transport innovations

FUture prospects on **TR**ansport evolution and innovation challenges
for the competitiveness of **E**urope

QUESTIONNAIRE ON ASSESSING THE IMPACT OF TRANSPORT INNOVATIONS

FUTRE (FU*ture prospects on* ***TR****ansport evolution and innovation challenges for the competitiveness of* ***E****urope****) Project*** *will highlight which future challenges and demand drivers can have a considerable impact on the global demand patterns in the passenger and the freight transport sectors and how this might affect the competitiveness of related industries and service providers.*

This questionnaire aims at gaining an understanding on emerging transport innovations/technologies, on how these are expected to affect transport system efficiency in Europe and on how these are expected to affect the competitiveness of the European transport sector. It will take about 15-20 minutes to be completed and will be used for research purposes only: data will be coded anonymously in the database and only the FUTRE project research team will have access to the information.

BACKGROUND INFORMATION

rganization	....			Name	....
ountry	....	City	....	Position	....

Ratings

For each Innovation/Technology please indicate how high its anticipated impact is and its likeliness to enter the market on a 1–5 scale considering the following definitions/explanations:

Level of Expertise: is related to a rough estimation of your degree of expertise for each specific question/innovation. : Please fill out the questions also in case that you have a low expertise in a field. **Likeliness:** It is associated with the probability of entering and gaining an important share of the respective market within the next 20-30 years (1- Very Low Likeliness, 5 – Very High Likeliness)

Impact: It is associated with the implications (positive or negative; a "0" encompasses "no impacts" and a neutralization of positive and negative impacts) of the technology in the case of entering and gaining an important share of the respective market within the next 20-30 years.

- **Travel cost*:** This cost refers to the user(s) or shipper(s) cost/time impacts
- **Environment*:** The impact to Environment is considered as the emissions (increase or reduction) resulting from the implementation of the innovation for the same transport 'output', E.g. impact of bio-fuels on Environment: +4
- **Modal split:** Specify the expected modal shift, e.g. Road (Passenger) to Rail (Passenger) or Air to Road (Freight)/Rail (Freight) or even Private Car (Passenger/Freight) to New Public Transport Mode

Beneficial to European transport industry*: It is associated with the potential implications of the innovation/technology to the European transport industry. Transport industry is defined as the manufacturers (automotive industry, civil aeronautics/aviation, waterborne and rail), the constructors of transport infrastructure, the transport service providers and the Intelligent Transport Systems (ITS) companies.

**** Rating Scale:*** *From –5 = very high reduction/negative effect to +5 = very high increase/ positive effect*

Innovation or technology	Level of expertise single choice answer				Likeliness of a significant increase of the market share – rate of usage		Impacts				Beneficial to European transport industry	
	I do research and publish in this field.	I am working in this field / following the professional discourse.	I have only focal or generalized knowledge in this field.	I have no knowledge in this field.	1 = very low likeliness 5 = very high likeliness	Comments	Travel costs/time for users: −5 = very high reduction +5 = very high increase	Environmental impact: −5 = very high damage +5 = very high benefit	Modal shift: Qualitative assessment	Comments	−5 = very high damage +5 = very high benefit	Comments
Innovation Field: Automation of road transport												
Advanced driver assistance systems	○	○	○	○								
Full autonomous driving	○	○	○	○								
Intelligent transport communication systems (e.g. inter- vehicle communication, vehicle-infrastructure communi-cation, intelligent signaling	○	○	○	○								

Innovation or technology	Level of expertise single choice answer				Likeliness of a significant increase of the market share – rate of usage		Impacts				Beneficial to European transport industry	
	I do research and publish in this field.	I am working in this field / following the professional discourse.	I have only focal or generalized knowledge in this field.	I have no knowledge in this field.	1 = very low likeliness 5 = very high likeliness	Comments	Travel costs/time for users: −5 = very high reduction +5 = very high increase	Environmental impact: −5 = very high damage +5 = very high benefit	Modal shift: Qualitative assessment	Comments	−5 = very high damage +5 = very high benefit	Comments
Innovation Field: Fuels and propulsion technologies												
Battery electric vehicles	○	○	○	○								
Hybrid technology (allowing pure electric drive for a certain distance)	○	○	○	○								
Fuel cell Electric Vehicles	○	○	○	○								
Second Generation biofuels	○	○	○	○								

Improvements in conventional internal combustion engines (e.g. downsizing)	○	○	○	○								
Liquid Gas (LNG) for shipping	○	○	○	○								

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Innovation Field: Improving the means of transport												
Lightweight materials (e.g. carbon fibers)	○	○	○	○								
Improved aerodynamics	○	○	○	○								

Innovation or technology	**Level of expertise** single choice answer				**Likeliness** of a significant increase of the market share		**Impacts**				**Beneficial to European transport industry**	
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Innovation Field: Intelligent transportation systems												
Ubiquitous (internet) access to harmonized traveler information (passenger) and tracking information (freight)	○	○	○	○								
Personal Rapid Transport (small automated vehicles operating on a network of specially built guide ways)	○	○	○	○								
RFID (Radio Frequency Identification) /NFC (Near Field Communication) applications for seamless user interfaces	○	○	○	○								
Autonomous supply chain management for more efficient use of logistics services												

Innovation or technology	**Level of expertise** single choice answer				**Likeliness** of a significant increase of the market share		**Impacts**				**Beneficial to European transport industry**	
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Innovation Field: Services /organizational innovations												
Innovative sharing services (car sharing, bike-sharing etc.)	○	○	○	○								
Tele-working, video-conferencing and holographic conferencing	○	○	○	○								
Smart ticketing schemes	○	○	○	○								

Innovation or technology	**Level of expertise** single choice answer				**Likeliness** of a significant increase of the market share		**Impacts**				**Beneficial to European transport industry**	
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Innovation Field: Infrastructures												
Innovative new types of transport infrastructure (e.g. CargoTube, Hyperloop)	○	○	○	○								
Innovative transshipment technologies for seamless intermodal freight transport	○	○	○	○								
Inductive charging infrastructure for electric vehicles	○	○	○	○								

According to your opinion, are there any **other important technologies and/or innovation fields** which are **not included in the questionnaire?** If yes, please also provide a judgement about their impact.

Which of the aforementioned **innovations fields and technologies** will become a **key-issue for competitiveness** for the EU **transport industry**? Please explain.