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Mapping innovation in the European transport sector

An assessment of R&D efforts and priorities, institutional capacities, drivers and barriers to innovation

T. Wiesenthal, G. Leduc, P. Cazzola, W. Schade, J. Köhler

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An assessment of R&D efforts and priorities, institutional capacities, drivers and barriers to innovation

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Glossary of terminology

Transport sub-sectors

The transport sector as defined here comprises the manufacturers of transport equipment and their component suppliers, the providers of transport services, Intelligent Transport Systems and the constructors of transport infrastructure. It does not capture research on e.g. fuels that is carried out by oil companies, or on materials.

Transport comprises highly heterogeneous sub-sectors. The way in which these are defined depends on the nomenclature used in the different primary data sources (see chapter 4, Table 14 - Table 20). In the dominant bottom-up assessment of corporate R&D investments, sub-sectors have been defined as follows (the number in brackets represents the number of companies included in the analysis of corporate R&D investments):

- Automotive industry (66): comprising manufacturers of passenger cars (e.g. Volkswagen, PSA, Fiat), of commercial vehicles (e.g. Volvo, MAN), and component suppliers (e.g. Bosch, Valeo, ZF). Excluded are construction and agricultural machinery as well as road transport service providers, the latter of which are allocated to 'transport service providers'.
- Civil Aeronautics/aviation (20): Manufacturers of aircrafts (e.g. EADS, Finmeccanica) and component suppliers (e.g. Rolls Royce, Safran) for civil purposes, i.e. R&D to defence applications and to space is not included. Excluded are also airlines and other service providers, which appear in the category 'transport service providers' below.
- Waterborne (15): Shipbuilders (e.g. ThyssenKrupp, Fiancantieri, IHC Merwede) and marine equipment manufacturers (e.g. Wärtsilä, MAN) of maritime and inland waterway ships. Excluded is R&D for military purposes, offshore technology and fisheries. Harbours are allocated to the category 'transport service providers'.
- Rail (18): Manufacturers (e.g. Siemens, Alstom, CAF, Talgo) and component suppliers (e.g. Vossloh, Thales, Knorr-Bremse) of the rolling stock, i.e. trams, metro, regional trains, locomotives, high and very high speed trains.
- Infrastructure construction (18): Companies that construct and maintain transport infrastructure (e.g. Bouygues, Skanska, ACS) as well as companies that produce construction equipment (e.g. Atlas Copco, Metso, Demag).
- Transport service providers (20): Logistics and freight transport service providers (e.g. Deutsche Post, TNT, Post Danmark); passenger transport service providers (e.g. Lufthansa, Deutsche Bahn) as well as the providers of infrastructure such as harbours.
- ITS: no clear boundaries can be defined here, in particular also because the other actors mentioned above are likely to dedicate important parts of their R&D to ITS applications. The R&D intensity shown for ITS takes into account only 15 specialised companies (e.g. TomTom, Kapsch TrafficCom, Thales).

Innovation expenditures

Innovation expenditures comprise intramural and extramural R&D, expenditures for the acquisition of innovative machinery, equipment and software, and expenditures for the acquisition of other knowledge.

R&D (Research and Development)

To the extent possible, the definition of R&D follows the Frascati Manual (OECD, 2002). Companies are hold to apply this definition in their financial reporting within the International Accounting Standard 38 ('Intangible Assets'). Regarding the EU public R&D spending only funds within the 7th EU Research Framework Programme have been assessed. While these indeed include some support to demonstration activities, their main focus lies on R&D. Public R&D investments in Member States may contain some funding directed towards demonstration, depending on the primary data source, but this is usually limited.

Industrial R&D investments

The most comprehensive source of information for industrial R&D investments are companies' annual financial reports, whose publication is obligatory for companies listed on the stock market, or those that exceed certain sizes. Companies often report at the group level instead of its subsidiaries (e.g. Volkswagen AG, including Volkswagen Passenger Cars, Audi incl. Lamborghini, Skoda, Seat, Bentley, VW Commercial Vehicles and Scania; see Table 22 in the annex). The regional allocation of companies and their R&D investment is undertaken by their site of registered office, which may differ from the operational or R&D headquarters. Box 1 illustrates the importance of different regional allocation mechanisms. To the extent possible, the publicly funded part of industrial R&D activities is excluded.

Bottom-up assessment

The central bottom-up approach for estimating industrial R&D investments consists of the identification of key companies in a certain sub-sector or for a technology group, the gathering of information on their overall R&D investments (mainly through financial reports collected in the EU Industrial R&D Investment Scoreboard), and the further refinement of the data by removing parts that are not transport-related, and by allocating the remaining investments to different modes or technology groups.

R&D investments for 'reducing GHG emissions'

These comprise R&D investments dedicated to technologies that have the potential to reduce GHG emissions, even though these research efforts may have been motivated by other considerations. This assessment is associated with elevated uncertainties; in particular, for the non-road mode it may contain some R&D investments that are dedicated to environmental technologies other than those that reduce GHG emissions (e.g. noise or air pollution reduction).

R&D intensity

Ratio of R&D investments and net sales.

Electric vehicles

For the purpose of the present study, the generic term 'electric vehicles' will be used to define a group made of battery electric vehicles (BEV), hybrid electric vehicles (HEV) and plug-in hybrid electric vehicles (PHEV). Fuel cell electric vehicles (FCV) will be treated separately and are not subsumed under the header 'electric vehicle' in this study.

Table of acronyms

BERD	Business Enterprise Research and Development
BEV	Battery Electric Vehicle
bn	billion
CARB	California Air Resources Board
CIS	Community Innovation Survey
EII	European Industrial Initiative
ETP	European Technology Platform
EU or EU-27	European Union
EV	Electric Vehicle
FCH	Fuel Cells and Hydrogen
FCV	Fuel Cell Vehicle
FP7	7th EU Research Framework Programme
GBAORD	Government Budget Appropriations or Outlays on R&D
GERD	Gross Domestic Expenditures on R&D
GHG	Greenhouse gas
H2/FC	Hydrogen and Fuel Cells
HDV	Heavy Duty Vehicle
HEV	Hybrid Electric Vehicle
ICB	Industry Classification Benchmark
ICE	Internal Combustion Engine
IEA	International Energy Agency
IPC	International Patent Classification
ITS	Intelligent Transport Systems
JRC	Joint Research Centre
JTI	Joint Technology Initiative
JU	Joint Undertaking
LDV	Light Duty Vehicle
LEV	Low-Emission Vehicle
NABS	Nomenclature for the Analysis and Comparison of Scientific Programmes and Budgets
NACE	European Classification of Economic Activities
PHEV	Plug-in Hybrid Electric Vehicle
PPP	Public-Private Partnership
RD&D	Research, Development and Demonstration
R&D	Research and Development
ZEV	Zero Emission Vehicle

Executive summary and policy conclusions

Context

Transport is a key enabler of economic and social activity, but also the source of environmental concerns and other negative externalities. The efficiency of the transport system affects the costs and environmental impacts of the growing volumes of passengers and freight. The European policy on transport recognizes the importance of the sector and aims at creating a competitive, user-friendly and long-term sustainable transport system. To this end, the 2011 White Paper on Transport set an ambitious objective of reducing greenhouse gas emissions of the transport sector by around 60% compared to its 1990 levels by the year 2050, of strongly reducing oil dependency, and of limiting the growth of congestion (European Commission, 2011a). These objectives are to be achieved without curbing mobility.

Implementing this vision requires the development of new technologies, the availability of suitable infrastructure and the introduction of organisational innovations. Innovative solutions for transportation concerns vehicles (e.g. drive trains, materials and design, energy carriers), infrastructure (e.g. network construction, optimisation of capacity – also including the application of information and communication technologies, network safety), and transport services (e.g. marketing and pricing strategies). Innovation also needs to target different transport modes, promote sustainable behaviour through better mobility planning, improve the access to information, leverage on the opportunities offered by urban environments; and enhance cross-modal transport.

Currently, EU-based manufacturers of transport equipment (e.g. manufacturers and suppliers to automobile, airplanes and trains), infrastructures (e.g. construction companies for roads, railways, ports and airports) and service providers (e.g. airlines, container transport services, express package services), are well positioned in the global market. Being the first to tackle the challenges faced by the transport sector and develop and apply innovative solutions has proven a successful strategy in the growing global market for transport equipment and services, and can strengthen the competitiveness of the European transport industry in the future.

In order to further enhance innovation in the transport sector, the European Commission will devise a research, innovation and deployment strategy for the transport sector in its Communication on a European Transport Technology Strategy.

Scope

The assessment in this report tries to capture the specific innovation activities and systems for many of the different transport sub-sectors, including the manufacturers of transport equipment in various modes as well as transport service providers, infrastructure developers, and developers of Intelligent Transport Systems. It further looks into the existing public R&D efforts that complement industrial innovation.

The analysis addresses transport-related innovation from three different angles that complement each other. Hence, this report includes

- A review of the various innovation incentives across the diverse transport sub-sectors and identification of drivers and barriers to innovation, including policies to overcome them;
- An assessment of quantitative indicators through the detailed analysis of the main industrial R&D investors and public R&D investments in transport for the year 2008[2].
- The sketch of the innovation systems of the various transport sub-sectors through the analysis of key actors and knowledge flows between them.

[2] 2008 has been chosen as the base year of this analysis since the largest sample of data from public and corporate R&D investments is available for this year. An update undertaken for corporate R&D investment in 2010 indicates that the changes between the 2008 figures displayed here and comparable ones for 2010 are very limited.

Even though the combination of three different approaches supports the validity of key conclusions, it may not fully capture the innovation base on which the European transport sector can draw. The two main reasons for this are the difficulty to quantify knowledge spillovers and the little opportunities to effectively overcome data limitations.

- Knowledge spillovers between sectors and across regions:

  Important developments in the transport sector benefit from research activities performed in other sectors, such as on material, informatics or energy. Also military research – which lies outside of the scope of this work – undoubtedly increases the knowledge base of the civil transport sector, in particular in the aviation sector. At the same time, large retail companies and other important transport service consumers are likely to also invest in innovation on supply chain logistics, but this part can hardly be quantified and is therefore not included here. There are also important knowledge spillovers across individual transport modes which may imply that figures provided for the R&D investments by mode do not fully reflect actual research activities.

  Considering the global nature of transport – and of its major players –, knowledge created in one part of the world will rapidly become available globally. Hence, any assessment focusing on a certain region will miss out global knowledge flows by construction. Note also that there is a discrepancy between the funding of research by EU-based companies and the execution of research on the territory of the EU. The present assessment follows the first approach, i.e. concentrates on the R&D investments of companies with their registered offices being placed in one of the EU Member States.

- Data limitations:

  Available data are scarce and there is no single database that provides a comprehensive collection of indicators related to innovation. Instead, several databases exist with diverse scopes, varying in terms of coverage of innovation activities, geographical coverage, allocation schemes and sectoral classifications.

  The limited data availability on innovation indicators implies that the quantitative assessment of the present study largely concentrates on R&D investments, which sometimes may include some funds to demonstration. Yet, the wider scope of innovation cannot be captured by these indicators alone. Also innovative solutions that are being developed 'on the spot' to overcome problems that occur unexpectedly within a project, e.g. in the construction industry, are not captured; in these cases, the tacit knowledge – and the way in which it is managed – is a more important contributor to the success of innovation that R&D.

  In order to obtain data for R&D investments at a higher level of detail, including also important companies in the supply chain, a bottom-up approach based on companies' annual reports has been applied here. This methodology nevertheless introduces some uncertainty and may underestimate the actual level R&D investments since it concentrates on a limited number of actors only, yet covers the most important ones.

  Initiatives such as ERA-WATCH, NET-WATCH, the ERA-NETs and projects like the Transport Research Knowledge Centre and TransNEW are steps towards overcoming the lack of information and have been used for the assessment of R&D programmes and projects in EU Member States. However, they do not consistently contain quantitative information.

Despite the underlying uncertainties and limitations in scope, the complementary nature of the combined approach applied in this work allows a diagnosis of the status quo of the transport innovation system in Europe. Key findings are summarised in the following.

R&D investments in the transport sector

1. In 2008, **corporate R&D investments** amounted to more than € 39 billion[3], making transport the largest industrial R&D investing sector in Europe. After a decline in 2009 due to the economic downturn, available data indicate that R&D investments have been increasing again in 2010.

2. The transport sector comprises highly heterogeneous subsectors (modes, markets, service providers, vehicle manufacturers, cross-modal actors, construction companies building and maintaining infrastructure), all of which are exposed to a different market environment and innovation system. Hence, they vary considerably in terms of drivers, needs and boundary conditions for innovation. As a result, transport sub-sectors are highly diverse in their innovation activities. This is reflected in very different R&D intensities in each sub-sector, but also in the fact that some sectors significantly invest in own research and development activities, while others prefer to buy in innovation through external knowledge. Policies therefore need to be well-tailored to the needs of the diverse sub-sectors.

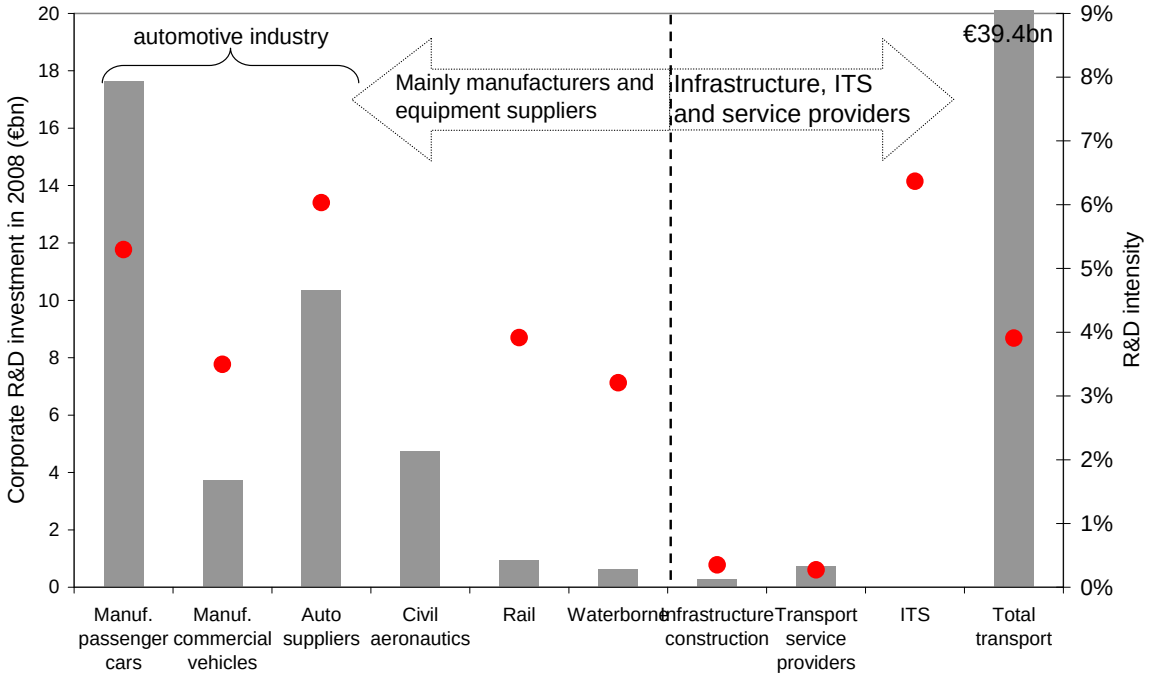

Figure 1: R&D investments and intensities of EU-based transport-related companies in 2008
Source: JRC-IPTS bottom-up assessment using data from EU Industrial R&D Investment Scoreboard, companies' annual reports and other sources. R&D investments from specialised ITS companies have been found to exceed €400 million in 2008; this figure has not been displayed since substantial additional R&D investment from other companies are dedicated to ITS which could not be quantified.

The *automotive industry* is characterised by a strong innovation system with a very strong vertical knowledge flow between component suppliers and car manufacturers. This also becomes evident in the high R&D investments by both the manufacturers of passenger cars (€ 17.6 billion in R&D in 2008) and the automotive suppliers (€ 10.3 billion) as well as the more limited investments from manufacturers of commercial vehicles (€ 3.7 billion). In line with the concentration of vehicle manufacturing, also R&D investments are strongly concentrated in a limited number of major actors, even though the importance of smaller specialised component suppliers needs to be acknowledged. The high levels of R&D investment and in particular the elevated R&D intensities of 5.3% for car manufacturers and 6% for component suppliers are coherent with the idea that these actors have a high interest in product innovation, since innovation is a main marketing

[3] This refers to own-funded R&D investments, hence excludes publicly funded research activities to the extent possible in order to avoid double-counting with public R&D investments.

strategy for new car sales and innovative products contribute considerably to the turnover of the sector. At the same time, the sector invests in process innovations to reduce the costs of manufacturing. In the case of the passenger car manufacturing sector, the nature of the competition environment (oligopolistic competition with strong product and brand differentiation) and the large market size are favourable for innovation. The mature industry and infrastructure create a framework that favours incremental innovations to those of more radical nature that diverge from the current design, since the latter would not benefit from the existing infrastructure (roads; fuels), the large and stable innovation system built up over many decades, and economies of scale due to mass production. With the recent uptake of electric vehicles (as hybrid or pure electric solutions), a considerable change has just been started. It will be important to monitor how EU-based companies catch up to leading companies from other world regions, as there is some indication that they lag behind in these areas whereas they keep stable technology leadership in conventional engine technologies.

Manufacturers of commercial vehicles are operating in a more competitive environment where brands and consumer taste counts less. Transport companies follow a cost-based logic when acquiring new transport equipment and are not easily convinced to use innovative technologies unless they reduce their overall utilisation costs. Innovations performed by manufacturers of commercial vehicles are therefore also more likely to focus on fuel efficiency. The competitive environment of this sub-sector explains why innovation activities are lower than those of the automotive industry, with an R&D intensity of 3.5%.

Manufacturers of civil aeronautic equipment are the second largest R&D investing transport sector and the one having the by far highest R&D intensity (7.8%). This confirms the importance of innovation for the aviation sector, triggered by exceptionally strong safety and security requirements and increasing pressure to reduce its environmental impacts. The aircraft manufacturing industry is dominated by few large players and concentrates largely on EU- and US-based companies. These large airframe and engine manufacturers all compete in a global market, and rely on a large number of smaller suppliers following a pyramidical structure. The aggregated R&D investments to civil aeronautics of the 20 largest EU-based companies including EADS, Finmeccanica, Rolls Royce, Safran amounted to € 4.7 billion in 2008. This figure may underestimate the research base of the sector since a knowledge flow between military and civilian technological developments exists due to many of the industries having both civilian and military products, even though this may be less pronounced for EU-based than for American companies.

Manufacturing of *rail transport equipment* is highly concentrated, the main manufacturers in Europe being Alstom and Siemens, with Bombardier in Canada, GE from the US and now Hitachi from Japan competing. The aggregated R&D investments that covers the 18 largest EU-based rail equipment manufacturers and suppliers leads to an estimate of € 930 million spent in R&D in 2008. The related R&D intensity (3.9%) is comparable to the one characterising commercial vehicle manufacturing. This elevated value can be linked to the high technological knowledge of European companies – e.g. in high-speed trains –, which are amongst the main players on the world scale. At the same time, the R&D intensity in this sector is lower than those characterising the automotive sector and in plane manufacturing. This is because of factors that limit incentives for innovations, such as a relatively small market size, a high capital intensiveness, a limited amount of rail transport operators, the relatively good energy efficiency of electric trains and the long turnover of the rail vehicle stock. In addition, the lock-in aspects associated to the existing rail infrastructure limit the scope of radical innovations, while benefitting incremental ones.

Shipbuilding and manufacturing of related equipment in the EU is focused on specialist commercial products (cruise ships, luxury yachts and offshore) and military production, while the production of low-value vessels is largely undertaken outside the EU. A distinction needs to be made between deep sea and coastal shipping and inland waterways to account for the different operating conditions, which impact on their innovation incentives. The level of R&D investment from major EU-based waterborne transport equipment manufacturing industries was around € 620 million in 2008, with an R&D intensity of 3.2%. This figure results from the analysis of 15 EU

companies active in this sector that have been further classified into shipyards R&D intensity of 1.6%) and marine equipment manufacturers (4.1%).

The category *transport service providers* as defined here includes companies involved in industrial transportation, companies providing passenger transport services, airliners and the providers of infrastructure services like harbours and highway operators. Their aggregated R&D investment amounted to more than € 700 million in 2008. It must be noted that on top of the R&D investments, another important part of the sector's innovation expenditure is directed towards the purchase of innovations from other industrial sub-sector (namely ICT) through the acquisition of advanced machinery, software and other equipment. Notwithstanding the relative heterogeneity of the companies included in this group, a low R&D intensity is a rather uniform feature for all transport service providers (0.3% found here for the total group). This can partially be explained by low innovation incentives caused by the market structure, such as the high competition levels and the limited contribution of innovation to the turnover. Low entry and exit barriers in road freight, as well as a competition that is essentially based on the price of the service offered, result in many small companies and a limited number of rather large firms operating at small margins and allow for a limited capacity to cover fixed costs and finance innovation. Some segments of public passenger transport lie on the other extreme of road freight service providers with respect to competition, since they have a limited exposure to it. In this case it is the organization of the sub-sector that is likely to be detrimental for innovation.

The *construction industry* faces strong competition on the basis of costs, combined with a high level of standardization (ultimately leading to a relative homogeneity to the products delivered to those who commissioned them) for what concerns building and maintaining of transport-related infrastructure. The nature of the competition and the market are therefore unlikely to result in strong budget allocations for R&D. This is especially true for smaller construction companies, where technological developments resulting from R&D activities are integrated at a slower pace. Besides, the project-based nature of the work suggests that the management of tacit knowledge is more important for successful innovative solutions than R&D projects. Hence, in Europe a limited R&D investment and a very low level of R&D intensity (0.3%) have been documented for the whole sector. This is well below the levels characterising the manufacturing industry, but also below the values that characterise the construction sector in Japan. Public authorities, being heavily involved in the technical specifications for construction, have the potential to play a proactive role to drive innovation in this area.

Intelligent Transport Systems (ITS) are solutions based on Information and Communication Technologies (ICTs) and electronic tools that aim to provide innovative services for transport applications. Hence, ITS have become a central enabler of innovation for the manufacturers of transport equipment, foremost all the automotive industry. At the same time, ITS bear an important potential in improving the efficiency of the overall transport system, including the use of existing infrastructure and transport services of both passenger and goods. Due to the cross-cutting nature of ITS applications throughout all transport modes and the fact that many of the underlying ICT and software developments are carried out by companies that lie outside of the transport sector, it is extremely difficult to estimate the total R&D investments of all agents dedicated to this research. The figure provided for the R&D intensity in ITS, reaching 6.4%, refers only to the average R&D intensity of dedicated ITS companies. The same group of only 15 dedicated ITS companies invested more than € 400 million in R&D; yet, this figure neglects the important research activities in ITS of other agents. Despite the difficulties in quantification, this highlights a strong innovation base for ITS.

3. In 2008, **public R&D investments** amounted to roughly one tenth of corporate R&D investment in transport. EU Member States contributed for € 3.6 billion, and the EU funds through FP7[4] allocated to transport-related R&D on an annual basis accounted for € 0.6 billion, approximately.

[4] Other EU funding schemes that go beyond direct support to R&D, such as the Competitiveness and Innovation Programme, the Cohesion funds, Trans-European Networks, Marco Polo have not been included here. Also financing programmes of the European Investment Bank have not been analysed here in detail.

Public R&D expenditures are more evenly distributed across modes than corporate R&D investments. However, about three quarters of the total public (Member States and EU) funds are dedicated towards research on road and air transport modes. EU FP7 funds are of highest importance in the aviation sector, due to a number of European initiatives such as the Clean Sky Joint Technology Initiative and the SESAR Joint Undertaking as well as collaborative research. The importance of public R&D funds is outstanding in research on socio-economic issues and cross-modal questions, and also in the construction sector public funds are high compared to corporate investments.

An in-depth analysis performed for some automotive engine-related research reveals that public R&D efforts become increasingly important and can reach up to 40% of total funds for more radical technologies, compared to less than 5% of the whole automotive R&D investment. This underlines the importance of public funding for fostering research in less mature technologies.

4. The **overall R&D investments dedicated to transport-related research** in the EU from all public funders and industry exceeded € 43 billion in 2008. They are dominated by corporate investments (90.4%), in particular from road transport industries, while public funds from EU Member States account for 8.2% and those from the EU through FP7 for 1.4%.

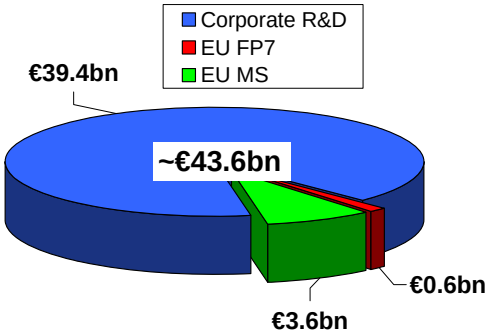

Figure 2: Overall R&D investments in transport by source of funds for the year 2008
Source: JRC-IPTS

Category/Segment	**Corporate R&D** (EU companies)		**Public R&D**		**Total R&D**
	R&D inv. (€bn)	R&D intensity	Public MS (€bn)	EU FP7 (€bn)	(€bn)
ROAD					
Automotive sector (total)	**31.7**	**5.2%**	**1.4**	**0.1**	**33.3**
Automotive manufacturers	21.4	4.9%			
Passenger cars	17.6	5.3%			
Commercial vehicles	3.7	3.5%			
Automotive suppliers	10.3	6.0%			
out of the above:					
R&D to conventional engine technologies	~5-6		~0.13	~0.02	~5-6
R&D to electric vehicles	~1.3-1.6		~0.08	~0.02	~1.4-1.7
R&D to hydrogen fuel cell vehicles	~0.4		~0.17	~0.08	~0.6
AIR					
Civil aeronautics	**4.7**	**7.8%**	**1.3**	**0.3**	**6.3**
RAIL					
Rail	**0.9**	**3.9%**	**0.2**	**0.03**	**1.2**
WATERBORNE					
Waterborne (total)	**0.6**	**3.2%**	**0.3**	**0.1**	**0.9**
Shipbuilders	0.1	1.6%			
Marine equipment manufacturers	0.5	4.1%			
CROSS-MODAL					
Transport infrastructure construction	**0.3**	**0.3%**	**0.4**		**0.6**
Transport service providers	**0.7**	**0.3%**			
Dedicated ITS companies	**0.4**	**6.4%**			
TOTAL TRANSPORT					
Total transport R&D	**39.4**	**3.9%**	**3.6**	**0.6**	**43.6**

Table 1: Summary of results – Approximates for the year 2008 (rounded numbers)
Note: For ITS, only dedicated companies have been considered. Public ITS research investments are allocated to modes as they often clearly focus on one or several modes. A comparison with different approaches (e.g. BERD, Scoreboard data following the ICB classification) is displayed in Table 11.

Drivers and barriers to innovation

An increasingly stringent framework is emerging because of environmental requirements, the economic downturn with the resulting higher price pressure and the growing importance of non-EU transport markets and equipment producers. This raises the need for the European transport sector to develop and apply innovative solutions.

Two main **drivers** are stimulating innovation in transport:

- The ambition to increase the range and improve the quality of transportation equipment and services – and with this to ultimately increase market shares and enter into new markets –, and to simultaneously add flexibility and reduce costs in the production processes. To this end, the transport sector combines product and process innovations.
- Regulatory and fiscal policies, since they are capable to steer innovation efforts by stimulating the rapid adoption of innovative technologies as well as significant market transformations.

Several **barriers**, however, play against these driving forces:

- the high capital intensiveness of innovation, reinforced by problems of financing;
- uncertainties in the volume and structure of market demand, caused by mismatches between consumer demand and innovation supply, as well as a conservative mindset and lack of information and confidence in innovative solutions from consumers;
- the complexity of innovation systems that require coordinated innovation efforts and speeds between several players (e.g. vehicle/fuel/infrastructure/consumer);
- markets that are solidly dominated by established enterprises with very high entry barriers for newcomers;
- knowledge spillovers that become increasingly important due to growing global competition;
- the lack of qualified personnel.

These **barriers become more pronounced for radical or systemic innovations**, i.e. innovations that diverge from the currently predominant design. Incremental innovations remain well within the boundaries of the existing market and technologies/processes of an organisation, benefitting from the accumulated knowledge and innovation systems built up on the existing transport system and the existing infrastructure. They therefore carry lower financial and market-acceptance risk than radical innovations, which imply a break from the currently dominant design. Systemic innovations go one step further as they require changes to the entire system. They require changes that can stretch far into existing systems and markets, production processes and in some cases even business models. In particular, the capital intensiveness of many of the industrial sectors related to transportation implies that radical innovations require high upfront costs, leading to high investment risks. Radical and systemic innovations are further hampered by the need to overcome lock-in phenomena (e.g. concerning knowledge flows, technology, infrastructure and markets). In addition, established companies may have problems in dealing with radical innovations due to organisational inertia, resource dependency in fixed assets, incorrect market appreciation, cannibalization of their own technology etc. As a result, radical innovations are often pushed for by small entrepreneurs or outsiders of the innovation system, i.e. companies that often face problems in financing the transition from the demonstration to the (expensive) commercial phase ('valley of death'). This is particularly relevant in the transport sector due to the capital intensiveness of innovation. Finally, a conservative mindset and missing trust from the consumers, often due to a lack of information on the benefit of the innovation, further hamper the market uptake of radical and systemic innovations.

Policy conclusions

This section focuses on the main policy actions suitable to strengthen the drivers of innovation in transport and to weaken its barriers[5].

1) The emergence of innovative solutions ultimately depends on an appropriate anticipation of consumer preferences. **Technology roadmaps** may be an effective tool to a priori address this need, since they can foster the discussion amongst stakeholders. The common vision shared through a roadmapping exercise has also the potential to reduce investors' uncertainty, in particular when accompanied by an agreed timeline comprising the development of a certain technology, its key components and the related infrastructure. This can speed up agreements on standards, infrastructure needs and technical specifications, and is consistent with the lead-time required by manufacturing industries to plan their product developments and to define their market strategy.

   European Technology Platforms are examples for bringing together stakeholders involved in all stages of innovation and from industry and the public. Their Strategic Research Agendas are an important element in better aligning and focusing the research efforts of key actors since they provide important input to the design of the EU Research Framework programmes, impact on national research policy programmes and also influence corporate research efforts. A much higher degree of collaboration is achieved in the Fuel Cells and Hydrogen JTI, or the SESAR JU and Clean Sky JTI.

2) **Supportive market conditions** due to regulatory and fiscal instruments as well as other measures capable to stimulate market demand can reinforce industrial innovation activities with policy objectives. In the case of transport, such objectives include the decarbonisation of the transport system, the promotion of cost-efficient seamless mobility, consumer protection, security, and safety, increased competitiveness of the transport industry and better territorial and social cohesion.

   Fiscal measures can take the form of taxes, subsidies and marketable permits (or a combination of these). Taxes impose a penalty on economic actors not aligned with policy objectives (typically, this is the case of polluters), while subsidies are essentially incentive programs that reduce the costs of innovations contributing to policy objectives for consumers, also aiming to foster economies of scales and technology learning to achieve lower production costs.

   Regulatory instruments, like pollutant emissions standards, also proved their effectiveness to stimulate the rapid deployment of innovative technologies capable to address environmental concerns (as in the case of tailpipe pollutant emission reduction). For what concerns environmental regulations, standards are best when monitoring costs are very high and when optimal level of emissions is at or near zero. It has been proven that the stringency of the performance standard is a key determinant for the degree of induced technological change.

   Public procurement represents an important market share in particular in the transport sector, and is therefore a powerful tool that can support innovations by helping sales of innovative products to reach a critical mass, but yet remains under-exploited. Directive 2009/33/EC on the promotion of clean and energy efficient road transport vehicles requires public authorities to take into account the energy and environmental impacts of vehicles over their lifetime when purchasing new vehicles. Nevertheless, the potential for innovation through public procurement is currently still under-exploited in the EU. Most public purchases do not put a premium on innovation; besides, the fragmented public procurement markets often remain too small to reach a critical mass for innovation.

[5] The reduction of knowledge spillovers, e.g. through the adequate enforcement of private property rights is another important policy to counteract barriers to innovation. As it is not specific to the transport sector, however, it is not highlighted here. Also efforts to ensure that skilled labour will be available to the transport sector are not dealt with in the executive summary, but are discussed in detail in chapter 3.

Standardisation is an important pre-requisite for a fast market uptake. In particular, the transfer of R&D results into technical standards can largely facilitate the uptake of innovative solutions and is highly relevant in the transport sector due to its complex innovation system; for example, a standardised quality of a novel fuel type is important for vehicle manufacturers to adapt their engines. Standards for interoperability are essential for allowing innovations to complement existing products and services and integrate existing systems, and are crucial e.g. for ITS and cross-modal transport. Standards are also key to integrate fragmented markets that entail high costs and administrative burdens into larger markets.

The transnational transport component implies that a supra-national approach is often favourable for many of the measures above. However, the European internal market of innovative transport vehicles, infrastructures and services currently still suffers from some fragmentation due to differences in public procurement and the existence of subsidies (e.g. for electric vehicles) that are not harmonised or aligned across Member States. Harmonising efforts through a common framework could help achieving collective targets more effectively. A number of initiatives for demand-side innovation policies have been established at the EU-level. Individual Member States have also introduced programmes to support the uptake of innovative solutions beyond the research phase. One relevant example concerns electric vehicles. These public research and scale-up programmes are pointing in the right direction, in particular when considering the risk that EU car manufacturers are not the most competitive in this area.

3) **Stable long-term signals** are vital in reducing innovators' uncertainties. A clear and reliable future-oriented regulatory framework can stimulate investment in innovation while allowing for the necessary time to undertake the required investments. By setting binding limits for the CO_2 emissions of the new vehicle fleet by 2015 and 2020, the EU has set clear indications. Realistic and reliable targets beyond 2020 are desirable for companies in order to better adjust the direction of their strategic long-term research efforts and to bring it in line with EU climate policy. To this end, the 2011 White Paper sets a greenhouse gas emission reduction target of 60% for transport as a whole for the year 2050 compared to 1990 levels. Similarly, the announcement of ambitious and credible policies regarding the handling of vehicles at the end of their useful life, regulations on the recyclability of their components (including batteries) and the recovery of materials whose availability may become scarcer (like, for instance, rare earths), would help manufacturers to better adjust the direction of their strategic long-term research efforts.

4) Radical high-risk, high potential innovations that face the problem of capital intensiveness may further require **direct public support**, which can take place throughout the entire innovation chain in different forms, e.g.

   - R&D support to achieve cost competitiveness for solutions that are not yet close to commercialisation;
   - by contributing to the 'up-front learning investment', i.e. supporting demonstration and early commercialisation;
   - whereas direct grants seems most appropriate in the research phases, the up-scaling and commercialisation phases can be supported by debt financing and risk-sharing guarantees and/or a blend of loans and grants where venture capital cannot be raised from private investors alone;
   - by facilitating knowledge flows that go beyond traditional innovation schemes, i.e. require knowledge from players that are outside existing collaborations on innovations;
   - by supporting the build-up of the necessary steps to allow the development of the required infrastructure.

   Whereas duplication of R&D efforts on the same subject can be positive as it may enhance the probability of breakthroughs and may also open up the variety of solutions to a given problem, the particularities of innovation in the transport sector suggest that joint efforts may be more effective. In particular, a number of transport innovations require very high upfront investments both in

infrastructure and manufacturing equipment. For those, a better harmonisation of the Member States' national and European R&D funds can help in financing these 'minimum costs', which might not be realised by one Member State alone. Currently, however, the EU and its Member States are not exploiting the full power of joint technology-push mechanisms through aligning of R&D efforts. This may to some extent be caused by the heterogeneous institutional set-up of transport policy making and research across Member States, but also by divergent transport research policies, reflecting differences in the countries' industrial, regional, geographic, and historical characteristics. Measures to overcome the fragmentation in R&D, such as European Research Area Networks (ERA-NETs) are considered successful, but transnational research activities still remain a very small fraction of the total national R&D investments except for a few cases such as the Fuel Cells and Hydrogen Joint Technology Initiative. Despite the relatively limited volume of transnational calls (that has been augmented significantly by the recent call Electromobility+), they have an important leverage effect.

5) There is a risk that the important potential of radical, often **cross- or intermodal innovations** will not be fully exploited, since they are particularly affected by the institutional lock-in of the dominant transportation systems. R&D and innovation activities tend to become more fragmented to mode/segment-specific compartments the closer they are to the market. In addition, the agents that have a genuine interest in fostering cross-modal innovative solutions often operate at very low profit margins and have therefore fewer incentives to invest in research. They may thus have a limited capacity to tackle some of the issues that affect the quality of the service they provide, e.g. due to infrastructural and regulatory bottlenecks of the intermodal transport chain, fragmentation of trans-national railway links, or information flows in cross-border or cross-modal freight shipments.

   Current public support to cross-modal innovation may not be able to fully counteract the limited industrial activities. In many cases, transport policies are structured along modes instead of following solution-based approaches. Many Member States have government departments or agencies dedicated to individual transport modes and/or programmes addressing research in certain modes. In a relevant number of cases, intermodal transport has been incorporated as a distributed function (e.g. by expanding the scope of existing modal units or by creating new units within existing modal organisations). Existing knowledge, cooperation and coordination initiatives, such as Technology Platforms and ERA-NETs, are also often organised alongside modes or technologies. Bringing them together through e.g. a joint intermodal working group could draw on the modal expertise of existing Platforms and on that basis identify synergies and potential conflicts can help to move towards a more holistic approach.

1 Introduction

The European transport sector is currently facing new challenges that induce a need for innovation. The economic downturn and with it the lower demand of transport services and equipment increase the price pressure faced by companies. At the same time, it becomes obvious that the currently dominating technological portfolio will be insufficient for reducing the sector's emissions in line with European climate change targets (Schade et al., 2010; Fontaras and Samaras, 2010) or global ambitions to significantly lower transport-related GHG emissions (IEA, 2010). The emerging electric vehicles are one mean to encounter this, but non-European manufacturers have had a head start in this technology. Further challenges and opportunities arise at the overarching levels of transportation system organization and mobility management, especially in urban areas with developed transit systems, since they can catalyze the adoption of innovative solutions. The last dimension is particularly relevant for future developments, since the share of urban population is expected to grow in the next decades. All in all, innovations aiming at developing new products while at the same time improving the cost efficiency and productivity of manufacturing processes and logistics are crucial for the European transport industry's medium- and long-term perspective.

The present scientific assessment provides a snapshot of current (2008 for the comprehensive analysis; more recent when available) innovation capacities in the European transport sector, making use of diverse data and information sources. It addresses transport-related innovation from three different angles that supplement each other. To this end, this study is divided into three parts, aiming at providing an answer to the following key questions:

PART I: *General considerations*
Why do firms innovate?
How can the different innovation activities in transport sub-sectors be explained?
What are the barriers to innovation in the transport sector?
What are the policies to overcome these barriers?

PART II: *How much does the European transport sector innovate?*
How much does industry invest in transport R&D?
How much is being invested in transport R&D by the public sector?
What do complementary indicators tell about other parts of the innovation process?

PART III: *What do the innovation systems of the different transport sub-sectors look alike?*
What are the key characteristics of the sector that influence innovation activities?
Who are the key actors involved?
How are knowledge flows organised?

Each of the chapters is introduced by a summary of key messages and policy conclusions that can be drawn from it. The report is enriched by several annexes that provide more detailed information on the main industrial and public actors involved in transport research.

Figure 3 provides an (incomprehensive) overview of the elements influencing innovation activities. Fields in blue correspond to part I of the present analysis and the orange centre part to part III. Quantitative input indicators are mainly dealt with in part II of this report.

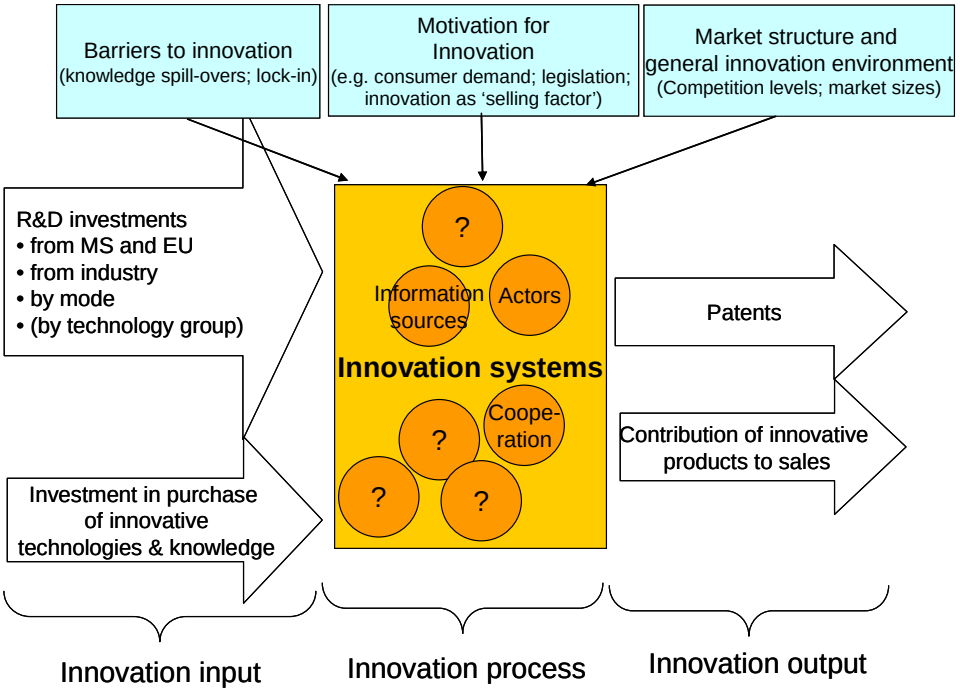

Figure 3: Overview of factors determining innovation dealt with in this report
Source: JRC-IPTS

Throughout the entire analysis, the highly heterogeneous nature of the transport sector has been respected[6]. Transport subsumes very diverse sub-sectors that differ largely in terms of modes, technologies, customers and market environment as well as drivers for and barriers to innovation. Hence, innovation processes are fundamentally different between each of the sub-sectors. The analysis of the innovation capacities is therefore undertaken at a higher degree of detail – for example that of modes, and even if within the modes, a differentiation between the passenger and goods transport may be necessary, and between actors offering transport services and equipment – while not forgetting the connections between them.

[6] In the annex, we define the transport sector according to the different socio-economic classifications that are used in the main databases relevant for this report. These include NACE, NABS, ICB, IPC and the technological classification of the IEA RD&D database. While the analysis of innovation activities according to the different socio-economic classification schemes can provide a reasonable approximation of sectoral activities, a more in-depth assessment of e.g. R&D investments in a certain technology may need to overcome this classification and take into account key companies from other sectors (e.g. electric utilities; manufacturers of electronic equipment, etc.). The various approaches used in the present work are explained in more detail in the relevant sections.

PART I - GENERAL CONSIDERATIONS

2 Drivers for innovation in the transport sector

2.1 Overview

A company invests in innovation in order to improve its positioning vis-à-vis its competitors. This can be done through a new product, for which the company has a near-monopolistic situation for a certain time period and benefits from first-mover advantages, and/or by reducing the costs of the product/service. In the case of environmental innovations, additional motivations include the existing or expected regulations, and current and expected evolution of market demand.

Figure 4 provides an indication of the various drivers for innovation of transport-related manufacturing sectors in the EU, based on data obtained by the Community Innovation Survey. From this, the multitude of drivers for innovations becomes obvious, including both the ambition to improve the quality of products and enhance its ranges, and to reduce the costs of labour per unit of output.

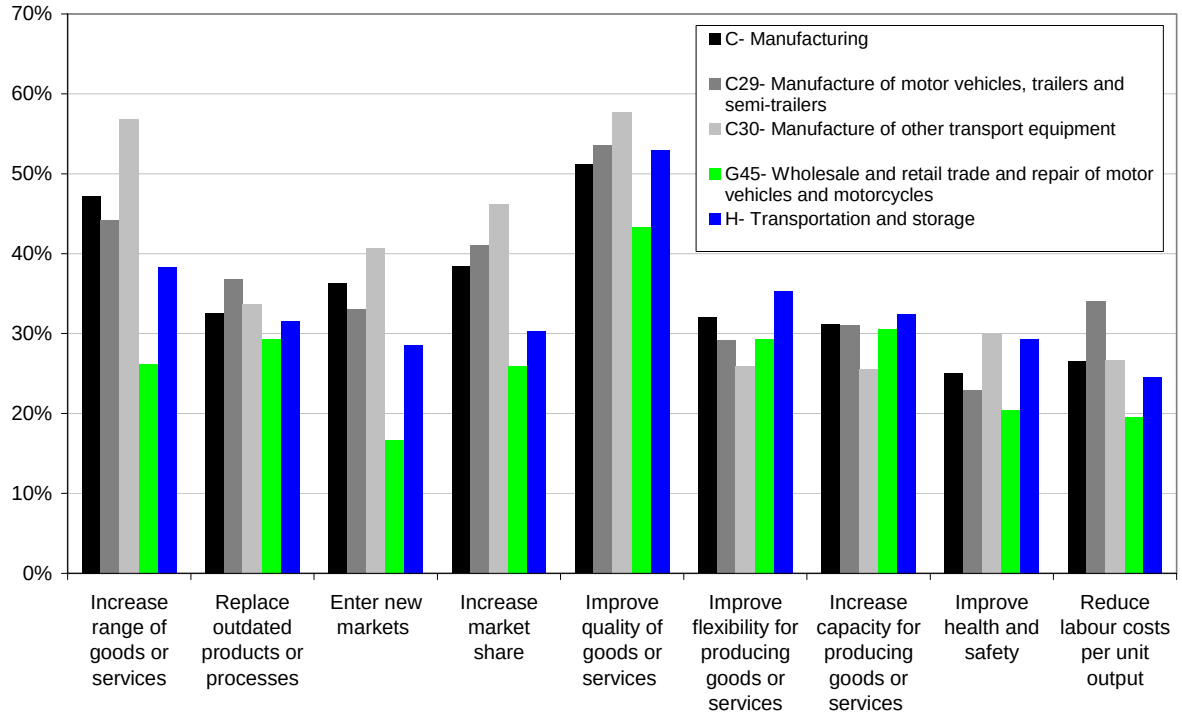

Figure 4: Drivers for innovation in transport
Data source: Eurostat CIS survey 2008 (based on NACE R2 sectors; retrieved in January 2011)
Note: Total EU percentage based on our own calculations, with the following coverage:
C and C29 (no data for MT, GR and UK); C30 (no entries for SL, FI, UK, GR, MT, CY, LU, LT, LV); G45 (data available for ES, DK, FR, CZ, LT, MT and NL); H (no data for MT, UK and GR)

Another clear indication of the importance of innovation for a company is shown in Figure 5. It demonstrates that for the manufacturers of transport equipment innovative products contribute to almost half (car manufacturers) and more than 30% (manufacturers of other transport equipment) to the turnover, whereas this share remains limited for transport service providers.

In the following, we will look into detail into the drivers for innovations in general and more specific for environmental innovations, and will draw some messages for policy-makers on how to support innovations in the transport sector from these theoretical considerations.

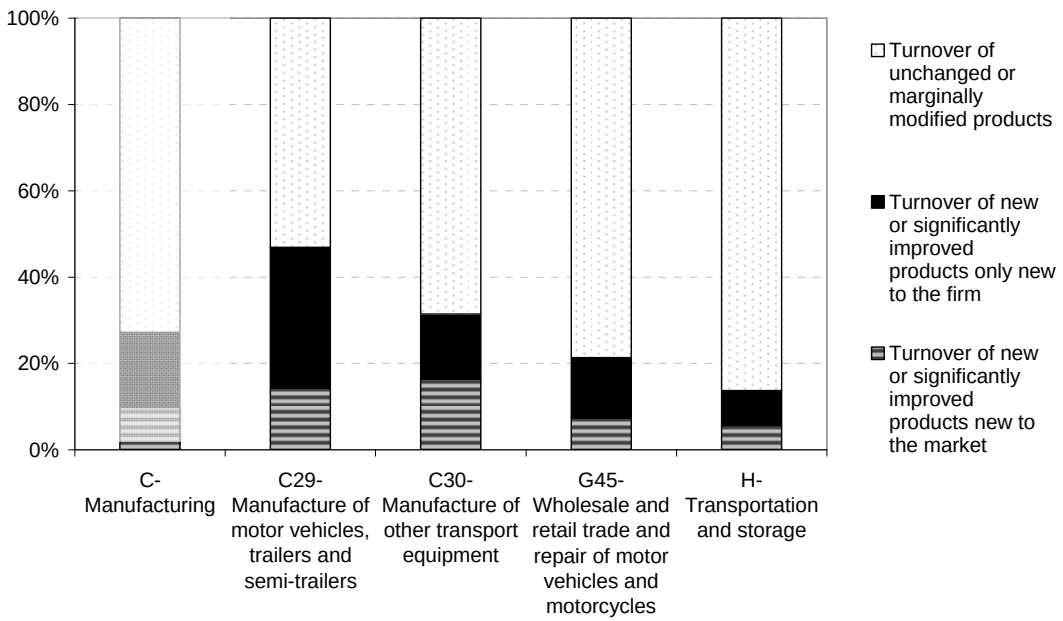

Figure 5: Contribution of innovative products to the turnover of companies in transport-related sectors
Data source: Eurostat CIS survey 2008 (based on NACE R2 sectors; retrieved in January 2011)

2.2 Lead markets, first-mover advantage and technology specialisation

Key findings

- Lead markets can bring substantial benefits to the innovating company, such as high export potentials and a high pool of knowledge.
- The creation of demand is a crucial element for a lead market, complementing the supply of innovations. Missing demand is often claimed to be a factor hampering innovation in the transport sector.
- EU Member States are highly diverse in terms of their lead market potentials for automotive innovations. In general, countries with important automotive industries have a technology leadership role.
- The EU-27 as a total shows a high and stable leadership in innovation in the manufacturing of vehicles but also aviation at a global level.
- While EU-based car manufacturers seem to have a stable technology leadership in conventional engine technologies, there is some indication that they may lie behind with regard to alternative technologies, in particular battery and hybrid electric vehicles. The latter areas are dominated by Japanese car manufacturers, even though Chinese, South Korean and US-based companies gain momentum.

Policy conclusions

- Demand-side innovation policies are important. Demand can be stimulated through a variety of tools, including public procurement and/or legislation that foster certain technologies.
- In particular with regard to alternative engine technologies, there may be some need for EU-based car manufacturers to not miss an opportunity. Public research and scale-up programmes for electric vehicles are pointing in the right direction.

2.2.1 Theory of lead-markets

Lead-markets are countries that first adopt a globally dominant innovation design (Beise and Rennings, 2005). Companies within the lead-market have a first mover advantage. They are at the forefront of diffusion of the innovative technology/product once market demand takes off, following the traditional representation of innovation as an S-shaped diffusion curve (slow take-up; fast diffusion; saturation). They are therefore first to experience the benefits of 'technology learning' and can also register patents and form the market so as to prevent competitors to enter. This has been the case e.g. for Toyota in hybrid electric technologies.

Lead market countries are attractive locations for multinational companies that have to become insiders in this market. Furthermore, a research intensive economy creates a pool of knowledge that would benefit not only the industries active in the 'lead area' but also industries from other fields[7].

In general, policy has realised the advantages that a lead market can bring to its industry (see European Commission, 2007a, 2007b for a general assessment of the potential of lead markets for Europe; Jacob et al., 2005 for examples). For example, the 'Lead Markets Initiative for Europe' aims at supporting the creation of lead markets in six important fields (European Commission, 2007a). Also the 'European strategy on clean and energy efficient vehicles' (European Commission, 2010b) eventually aims at keeping and expanding the EU's lead market position on clean vehicles. Other initiatives, like the commitment of cities to reduce GHG emissions beyond EU targets by 2020 through the Covenant of Mayors, can also contribute to foster lead markets, leveraging on the dynamic nature of urban agglomerations with respect to innovations.

However, for the competitive advantages to be exploited, some pre-conditions for lead-markets need to be fulfilled (see e.g. Walz, 2006). Firstly, a demand for the innovative product needs to be created in other markets as a lead market is not only characterised by the supply side, but also by the demand side (Porter, 1990). Particularly in the transport sector, market demand is a key factor that has the potential to either drive or hamper innovations (ITF, 2010b; Sofka et al., 2008[8]). The results of the Community Innovation Survey strongly point to the importance of the current and expected consumer demand as a driver for (environmental) innovations (see Figure 9).

Secondly, within a lead market competition should be driven not only by prices, but also by quality and performance. This is given for some transport sub-sectors and modes, especially the manufacturers of transport equipments for which innovation constitutes one selling factor, but less so for other transport services as explained in more detail in section 2.4. Finally, high potential learning effects also underline the potential lead market advantages. These would need to be assessed on the basis of individual transport technologies, which falls outside of the scope of the present study.

Policy can (and has) support(ed) the creation of lead markets through various means. It can create a market demand for innovative technologies either through dedicated subsidies or a favourable legislation[9]. The way in which this is tackled by some EU Member States is illustrated for electric vehicles in section 3.4. Another way of creating a niche market demand may be through public procurement, which is discussed in more detail in section 3.4.

Complementing this, the diffusion of innovation also relies on the absorptive capacities of the players acting on the demand side, and the easy access to information on novel products (Suriñach et al., 2009). Moreover, an innovation-friendly regulation that reduces market failures such as innovation spillovers through e.g. Intellectual Property Rights (Walz, 2006) is another important condition for a lead-market.

[7] See European Commission (2006b) for a list of the potential competitive advantages of a lead market.
[8] Henderson and Newell (2010) demonstrate the importance of market demand for innovations in a number of other sectors.
[9] Note, however, that in some cases, regulations have produced extra costs but no extra sales; moreover, a domestic market demand may be created, but export remains limited (see Sofka et al., 2008 with reference to Heneric et al., 2005).

2.2.2 Lead-market and technology specialization assessment: the case of the automotive sector

Sofka et al. (2008) have undertaken a systematic lead market analysis for the European automotive sector, assessing the advantages of different Member States in terms of demand, price, export, transfer and market structure. Even though data did not allow to construct some indicators for a number of countries, the analysis suggest that only some Member States have a very high lead market potential in the automotive industry. These include France and Germany, and with ranking positive for at least three of the five criteria, also the Czech Republic, Italy, Luxembourg, Sweden and the UK. As said, data problems impede a reliable assessment for some Member States, suggesting that the above list may not be comprehensive.

Already today, these are the countries that have accumulated high knowledge in the manufacturing of motor vehicles and other transport equipment. This accumulation of technological knowledge (or specialisation) can be approximated through the Revealed Technological Advantage Index (RTA) developed by Soete (1987). For either a company or a country, the RTA is calculated as the ratio of the number of patents in technology k in the total patents of country l over the same share for all countries:

$$RTA = \frac{(Patents_{kl} / \sum_k Patents_{kl})}{(\sum_l Patents_{kl} / \sum_{kl} Patents_{kl})}$$

In the present work, the share of patents related to the NACE R1 sector DM34 'Manufacture of motor vehicles, trailers and semi-trailers' to the patents in total manufacturing has been compared at a global level. In order to avoid a regional bias when using either the EPO database or the USPTO database, the analysis has been undertaken for both. We find that results are broadly in line between the two databases, and therefore restrict the presentation to the EPO-based results. Following the approach of Sofka et al. (2008), the RTA has been calculated for two different time periods of eight years in order to also show the dynamics. By displaying them on a 2-dimensional chart with the RTA in 1992-1999 along the x-axis and the RTA of 2000-2007 on the y-axis, the chart indicates which countries are keeping the leadership, lag behind, loose or increase momentum.

The strong specialisation role of EU becomes obvious, in particular when compared to the USA. At the same time, the high diversity across EU Member States is evident. Not surprisingly, those Member States with an important automotive industry, many of which also have an elevated public R&D spending on automotive research (see chapter 6), are those that have kept their leadership in car manufacturing: France, Germany, Austria, Luxembourg, Spain, Sweden, Italy, Poland and the Czech Republic. In most of the cases these countries correspond to the candidates for lead-markets found by Sofka et al. (2008) and mentioned above.

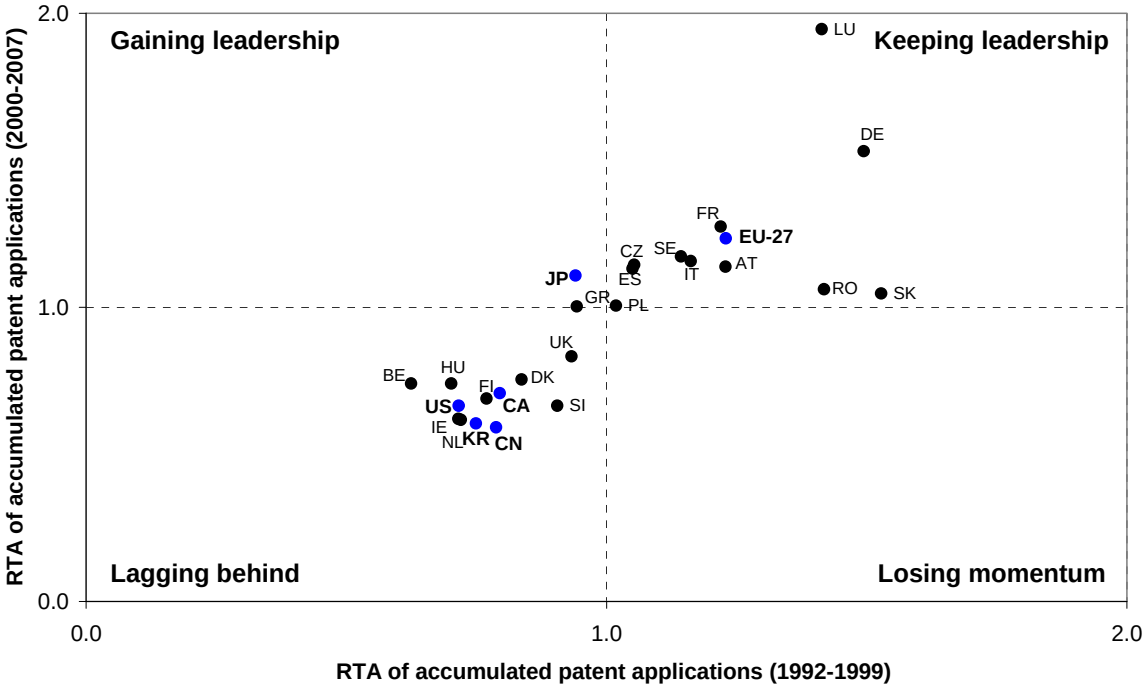

Figure 6: The dynamics of the Revealed Technological Advantage Index in the manufacturing of motor vehicles by country

Source: JRC-IPTS based on Eurostat EPO-data using the NACE R1 classification DM34 'Manufacture of motor vehicles, trailers and semi-trailers'; updating Figure 3.3.1 of Sofka et al. (2008). Note that the number of patent counts in DM34 is too limited for a number of countries to produce representative results (e.g. BG, CY, EE, LT, LV, MT).

Unfortunately, a comprehensive assessment of the RTA for individual technologies, which would have required a search of the EPO worldwide statistical database PATSTAT by selected IPC classes, could not be undertaken in the scope of this analysis. Instead, a simplified keyword-based research has been performed, using the EPO-esp@cenet database. This search strategy follows published articles, in particular Oltra and Saint Jean (2009a); nevertheless, it has a number of methodological limitations, which are described further in chapter 7.3 and the refereed literature.

To this end, patent applications registered in EPO-esp@cenet from 21 car manufacturers have been analysed, using the following keywords (from Oltra and Saint Jean, 2009a): ICEV: 'internal combustion engine vehicle'; DE: 'diesel engine', BEV: 'battery electric vehicle'; HEV: 'hybrid vehicle' and FCV: 'fuel cell vehicle'; hydrogen ICE has been added for Ford, Mazda and BMW under the keywords 'hydrogen engine vehicle'. The results are shown below in Figure 7. Note that they cannot directly be compared to the ones depicted in Figure 6 due to the methodological differences.

EU-based car manufacturers seem to keep the leadership in specialisation on conventional engine technologies, while Japan, driven mainly by Toyota, holds the lead in hybrid and battery electric vehicles. At the same time, there is some indication that EU-based companies lag behind in alternative drive technologies, in particular with regard to hybrid and battery electric vehicles, whereas they are more or less average for fuel cell vehicles despite loosing momentum. In particular Chinese car manufacturers, but also South Korean and Japanese as well as some US-based companies have increased their (patenting) activities on alternative powertrains.

Despite methodological constraints and the fact that suppliers are not included in the search strategy, this analysis provides an interesting indication of the positioning of EU-car manufacturers at a global level in terms of specialisation in different technologies. However, in order to (at least partially) compensate for the comparably low level in battery electric vehicles, many of the principal EU-based car manufacturers are part of strategic alliances that include battery manufacturers and electric utilities (see Figure 50 in section 9.4.1; Barthel et al., 2010). Moreover, an assessment of patent applications derived from the OECD statistics shows a significant increase in patenting activities on electric and hybrid vehicles in the EU in very recent years, which further indicates that European car

manufacturers are catching up, yet with some delay (see Figure 41 in section 7.3.2).

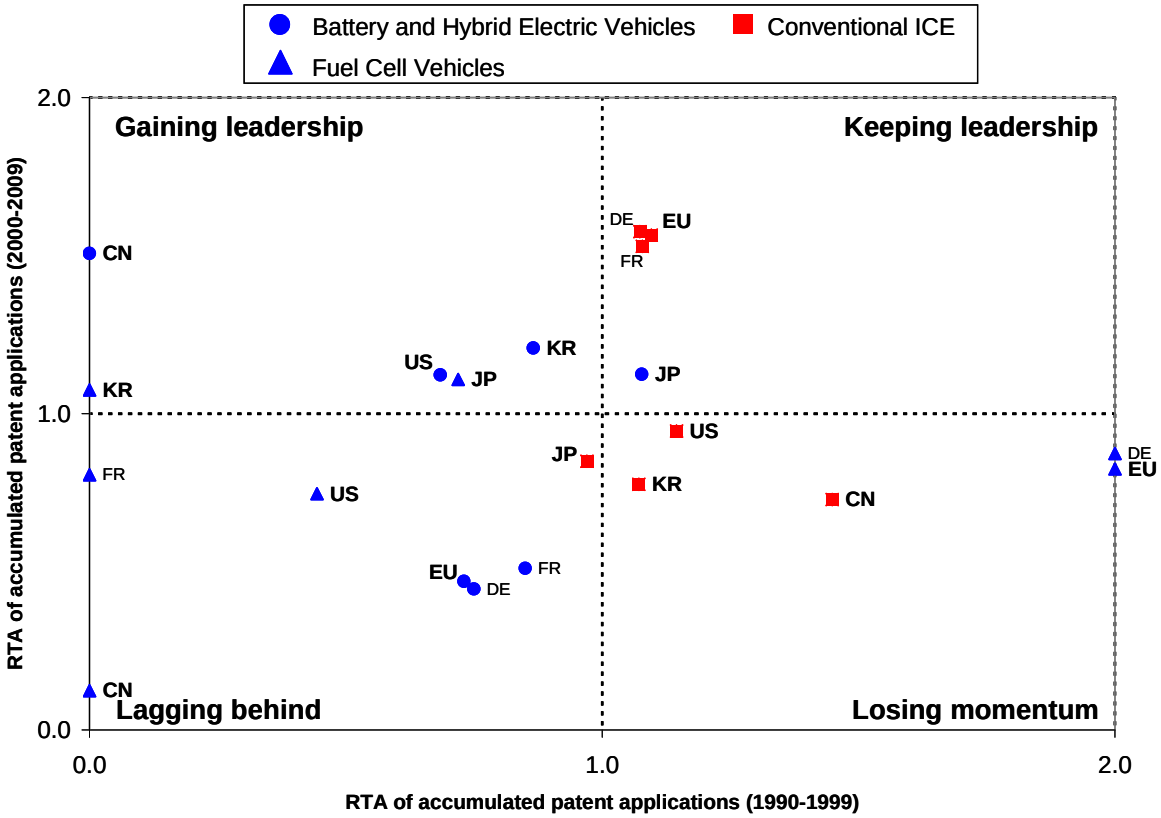

Figure 7: The dynamics of the Revealed Technological Advantage Index for different technologies for selected car manufacturers

Source: JRC-IPTS based on the EPO-esp@cenet database for 21 world car manufacturers using a keyword-based search strategy developed by Oltra and Saint Jean (2009).

2.2.3 Technology specialization assessment for other transport equipment manufacturers

Following the analysis undertaken for the automotive industry above, an RTA can also be calculated for the other manufacturing of non-automotive transport equipments. As shown in Figure 8, the results indicate that most of the European Members, and in particular Austria, Italy, Spain, Germany, France Poland and Sweden, and the EU as a whole have a technological leadership in this area, while countries such as the USA and Japan are lagging behind. Note that the total number of patents has been too limited for a number of countries to present a reasonable base for the assessment.

Although those data are based on the NACE R1 DM35 sector that goes well beyond the aviation manufacturing sector and also includes manufacture of railways, motorcycles, building and repairing of ships, etc., the results are well in line with the trend observed by Hollanders et al. (2008) for the aerospace sector. Unfortunately, that latter analysis covers patents from 1987-1990 and 1997-2000 only, and therefore leaves out more recent developments.

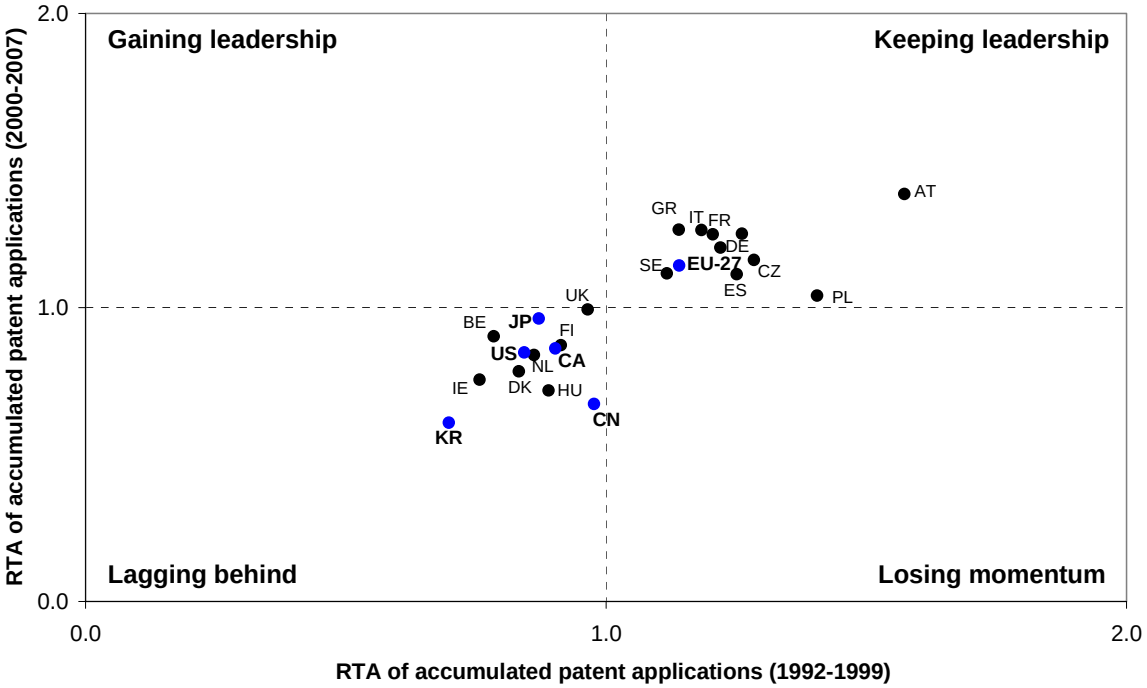

Figure 8: The dynamics of the Revealed Technological Advantage Index in the manufacturing of other transport equipment by country

Source: JRC-IPTS based on Eurostat EPO-data using the NACE R1 classification DM35 'Manufacture of other transport equipment'; following the concept of Figure 3.3.1 in Sofka et al. (2008); Note that the number of patent counts in DM35 is too limited for a number of countries to produce representative results (e.g. BG, CY, EE, LT, LV, MT, SL, SK, RO).

2.3 Environmental innovation: steering research by regulation

Key findings

- Long term binding targets and regulation (e.g. performance standards) are key drivers for environmental innovation in the transport sector. Together with fuel prices, they foster innovation into environmentally friendly vehicles to a much stronger extent than public R&D.
- Stringency of the performance standards is a key determinant of the degree of the induced technological change.
- Another key driver for inducing innovation is the stimulation of consumer demand.

Policy conclusions

- By setting binding limits for the CO_2 emissions of the new vehicle fleet by 2015 and 2020, the EU has set clear signals. For companies to better adjust the direction of their strategic long-term research efforts and to bring it in line with EU climate policy, clear and reliable targets beyond 2020 are desirable.
- Similarly, clear and reliable targets on the handling of vehicles at the end of their useful life, regulations on the recyclability of their components (including batteries) and the recovery of materials whose availability may become scarcer (like, for instance, rare earths), would help manufacturers to better adjust the direction of their strategic long-term research efforts.
- Moreover, similar target-setting for other transport modes and/or technology groups may provide further incentives to innovations in the respective fields.
- Energy- and environment-related target setting taking place at the city level (e.g. through voluntary commitments) also has the potential to stimulate environment-related innovation in transport, since transport is responsible for a consistent share of pollutant and GHG emissions in urban areas.
- Policies that influence consumer demand into environmental technologies can be complementary, considering the importance of the demand side. Energy and eco-labelling are important policy instruments in this respect. Energy labelling, in particular, proved to be very effective in the transformation of the characteristics of white goods and has the potential to play a similar role on transport-related products and services.

Current and expected future legislation are vital factors for environmental innovations in the transport sector. According to the CIS-6 survey, legislation is a key driver for environmental innovation for manufacturers of road vehicles and of other transport equipment (Figure 9). Of equal importance are voluntary codes for environmental good practice, followed by the current or expected evolution of demand for environmental innovations from customers.

Past experience indicates that environmental innovation within the automotive industry has largely been in response to government regulation of industry (see e.g. Gerard and Lave, 2005; Dyerson and Pilkington, 2000; Weber and Hoogma, 1998; US EPA, 2010). The impact of government intervention for environmental purposes was first evident in the US when California initiated legislation for automobile emissions in 1960, and subsequently the 1970 federal Clean Air Act was introduced. This demanded 90% emissions reductions from new automobiles over a four- to five-year period (Gerard and Lave, 2005). In response, GM and Ford invested heavily in R&D and equipment installation for technologies to reduce emissions of hydrocarbons, carbon monoxide and nitrogen oxides, eventually leading to production of the automotive catalytic converter in 1975 and the three-way catalyst in 1981 (coupled with a rapid shift to electronic fuel injection, as shown in US EPA, 2010). Important in this respect, however, is regulator credibility, without which environmental legislation is unlikely to be effective (Mohr, 2006). For example, Gerard and Lave (2005) suggest that Chrysler may not have responded to the Clean Air Act by investing in R&D due to their belief that regulators would not enforce the Act (since Congress had constrained the Environmental Protection Agency's

administrative options). On the other hand, the company's financial distress was also a probable factor in its lack of investment in emissions control technologies.

The impact of the above-mentioned case of the introduction of the American Clean Air Acts has been further analysed on the basis of patents by Lee et al. (2011). They proved that a regulation based on performance standards can induce innovation. Moreover, the stringency of the regulation is a key determinant of technological change. They conclude that more stringent regulations can force companies to overcome easier incremental innovations, and invest in more radical changes.

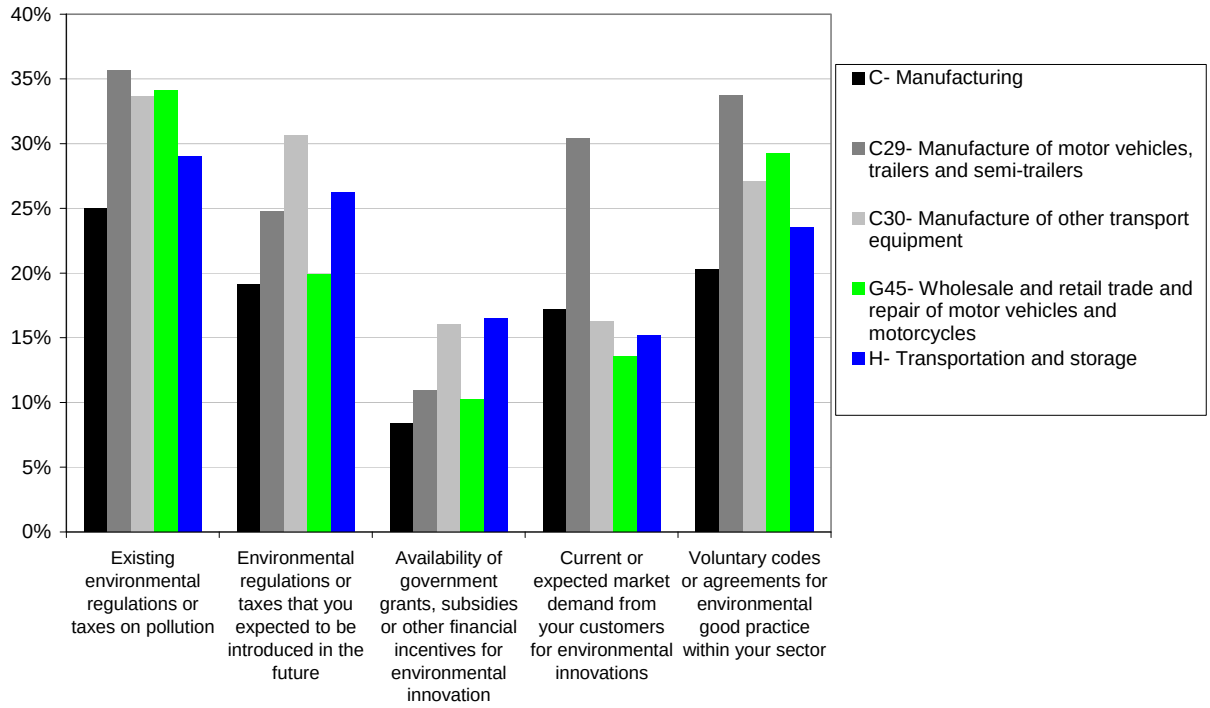

Figure 9: Drivers for environmental innovation
Data source: Eurostat CIS survey 2008 (based on NACE R2 sectors; retrieved in January 2011)
Note: Total EU percentage based on our own calculations, with the following coverage:
C (data for 21 EU MS out of 27, no figures for UK, GR, AT, DK, ES and SL); C29 (no data for UK, GR, AT, DK, ES, SL, BG, CY, LT and MT); C30 (no entries UK, GR, AT, DK, ES, SL, BG, IE, CY, LT, LU, MT and FI); G45 (data only for FR, NL, NT, LT and NL); H (no data for UK, GR, AT, DK, ES, SL and CY).

Similar considerations can be extended to regulatory action targeting fuel consumption (and therefore also CO_2 emissions). In the case of the United States, the introduction of Corporate Average Fuel Economy (CAFE) standards in the late 1970s and their tightening until the early 1980s (Figure 10) resulted in a rapid shift of the average vehicle weight towards lighter classes and in the increasing deployment of technological innovations capable to reduce fuel consumption. In the two decades after the early 1980s, the absence of any tightening of the standards resulted in a slower introduction of innovative technologies and led to a progressive switch to larger and heavier vehicles (including "light trucks").

Another relevant regulatory case that demonstrated high effectiveness with respect to the reduction of the vehicle fuel consumption and CO_2 emissions is the case of the bonus-malus purchase tax system (or feebate) in France, which was introduced since the beginning of 2008. During the first year after its introduction, CO_2 emissions from new vehicles fell from 149 g CO_2/km in 2007 to 140 g CO_2/km in 2008 and 131 g CO_2/km in 2009 (Carballes, 2010). The main market transformations that took place include a remarkable tendency towards downsizing in the vehicle segment mix, downsizing in power and a move to diesel in certain segments (Bastard, 2010).

In 1990, the California Air Resources Board (CARB) announced its Zero Emission Vehicle (ZEV) programme which would require automobile manufacturers to produce and sell an increasing proportion of zero emission vehicles from their new car sales – 2 per cent in 1998, rising to 10 per cent by 2003. After fierce lobbying from auto firms, this legislation was postponed to 2005 and

revised to include a new category (the partial-ZEV) which would include fuel-efficient internal combustion engines (ICEs), for example, hybrids, methanol/gasoline fuel cell vehicles (FCVs), and natural gas vehicles (Hekkert and van den Hoed, 2004). Similar mandates are in force elsewhere (e.g., Switzerland). This has prompted major public and private investment in electric and subsequently hybrid and fuel cell vehicles, not only amongst US car producers but also by Japanese and European firms (Dyerson and Pilkington, 2000). Dijk and Yarime (2010) show for the case of Toyota that the number of patent applications of electric vehicles has reacted to revisions of the ZEV regulation and its revisions. Other US policies, such as the 1992 Energy Policy Act and the current Bioenergy Program, which promote bio-ethanol production and use have encouraged major manufacturers, such as Toyota, to invest in flexible-fuel vehicles (Toyota, 2006).

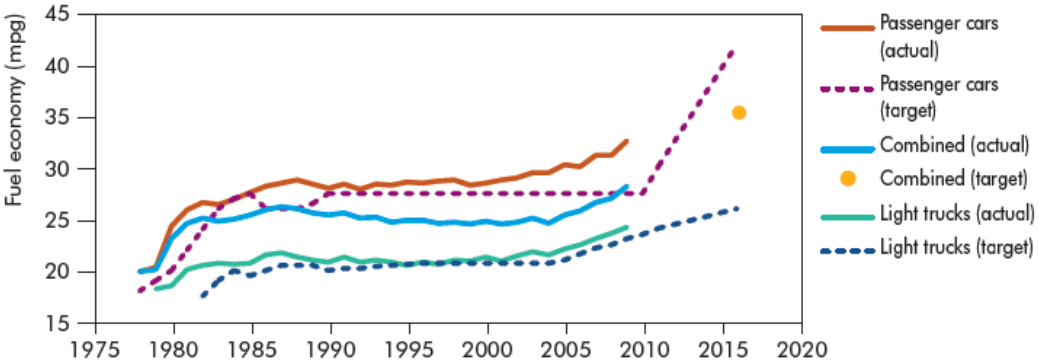

Figure 10: Corporate Average Fuel Economy standards and actual average fuel consumption (United States)
Source: IEA (2009c)
Note: fuel economy is expressed in miles per gallon.

Also in Japan, government policy has similarly stimulated environmental innovation within the automotive sector. The application of the "top-runner" policy to motor vehicles resulted in a significant improvement of their fuel efficiency. The approach adopted in Japan required setting fuel efficiency standards at a level that is dictated by the performance of the best vehicles available in the market. In particular, it requires evaluating vehicle efficiencies for 16 different weight classes and to use the performance of the best vehicles as the target fuel efficiency level that must be met by all vehicles after a number of years. Following the introduction of the "top-runner", in 1999, and considering the 2015 target in place, the average fuel efficiency (expressed in L/100 km) of new gasoline vehicles in Japan has already improved (and is deemed to keep improving) by nearly 2% per year (IEA, 2009). In addition, MITI has created technological 'visions' through collective foresight exercises as part of its programme to develop and promote clean vehicle technologies, established intercompany knowledge networks, sponsored R&D, leasing and purchasing incentive programmes, subsidies for electric vehicle manufacturers, public procurement (e.g., electric Toyota 'Rav4's sold to some Japanese authorities) and facilitated market entry through legislation and standards (Åhman, 2006). This programme, along with the CARB zero-emission vehicles mandate, has been a key determinant of Toyota's investment in, and ultimate commercial success with, hybrid electric-ICE vehicles (Åhman, 2006).

In a recent publication (OECD, 2011), correlations between various policies and patenting activities in different technologies have been quantified. Confirming the considerations above, this econometric analysis found a strong influence of environmental standards on innovation on electric vehicles, while for hybrid vehicles the effect of fuel pricing is elevated, always compared to the effect of public R&D (Figure 11).

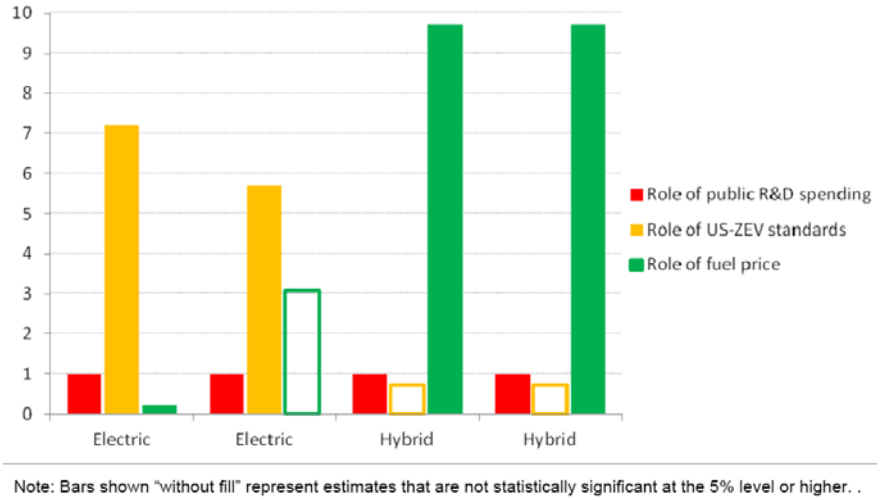

Figure 11: Effect of technology standards and fuel prices on patenting activity relative to the effect of public R&D (normalised to R&D=1)
Source: OECD (2011)

New EU legislation Regulation (EC 443/2009) setting CO_2 emissions limits on cars of 130g CO_2/km, which will be phased in from 2012 onwards until it applies to all new cars by 2015, requires rapid action from manufacturers. Together with the California ZEV standards, adapted in 2009 to allow for hybrids (CEPA-ARB, 2010), it has provided a decisive push towards the development of battery electric hybrids by all the auto majors. Moreover, EU legislation has set a further more stringent limit of 95g CO_2/km as average emissions for the new car fleet for the year 2020.

With this setting of binding and reliable targets, EU legislation can be expected to induce (further) innovations into low-carbon vehicles. For companies to better adjust the direction of their strategic long-term research efforts and to bring it in line with EU climate policy, clear and reliable targets beyond 2020 may be desirable. Moreover, similar target-setting for other transport modes and/or technology groups may provide further incentives to low-carbon innovations in other sectors.

2.4 Market structure and innovation: explaining differences between actors

Key findings

- The market structure can help in understanding different levels, speeds and types of innovation across the diverse sub-sectors of transport. This heterogeneity is a key barrier to innovation in the transport sector as it creates complexity for innovations that require collaboration between different players (e.g. vehicle/fuel/infrastructure).
- The level of competition can be linked to the propensity to innovate. Very high competition levels act as a disincentive to innovations. This is particularly true when the service provided is homogenous across the competitors and price is therefore the main criterion, while the costs of innovation are high. Also monopoly rights may imply that companies are not motivated to invest in innovations. Medium competition levels and products that differ also through their features and not only through the price create a framework that is beneficial to innovations.
- The market size is another important element in understanding which modes are most likely to be leading innovation, since larger markets (e.g. passenger cars) allow for a more widespread amortization of the investments required for innovation in comparison with smaller ones (e.g. ships).
- Linked to this, the turnover of assets and the costs of innovation also influence the propensity to innovate. In general, capital-intensive innovation in assets with a long product cycle may act as a disincentive to innovation as the return on investment stretch over a very long period.
- Among all transport sectors, the automotive sector – and here within particularly the manufacturers of passenger cars and associated suppliers – has an elevated genuine incentive to innovate due to their market structure and the heterogeneous nature of the product. In line with this, more than 60% of all companies active in this sector are considered active in innovation.
- In aviation, R&D intensities are very elevated due to the importance of safety and security requirements. Moreover, civil and military aeronautics are strongly interlinked, enabling the civil industry to benefit from defence-funded research.
- Providers of transport services are exposed to a high price pressure and limited market entry barriers. They sell homogenous goods, for which the price and not innovation is the key selling factor. Hence, the turnover created by the sale of new product remains small. This explains the comparable low number of innovative companies in this segment when compared to the manufacturers of transport equipment.
- The theoretical considerations are supported by the R&D intensities of the different actors. Moreover, the share of innovative products in the total turnover of the various transport sub-sectors clearly underlines the importance of innovation output to the manufacturing industries, whereas innovation contributes little to the turnover of transport service providers.

Policy conclusions

- There may be less need to stimulate additional corporate R&D in the transport manufacturing sectors in general, and in particular the automotive and aviation sector, and ITS compared to other sub-sectors of transport.
- On the contrary, actors offering transport services and constructing and maintaining the transport infrastructure have little incentive to innovate. They may therefore require direct R&D support and more incentives to innovate, in particular when considering that they may push forwards systemic, cross-modal innovations.

Innovation can lead to a competitive advantage, but with increasing competition, the expected future profits decrease until the firm innovates further. Hence, neither perfect competition nor monopolies are optimal in terms of delivering innovation. Aghion et al. (2005) found that the relationship between product market competition and innovation takes the shape of an inverted U (see Figure 12). Following (ITF, 2010b), this relationship can help in better understanding the incentives for innovation of the various, heterogeneous subsectors subsumed under transport.

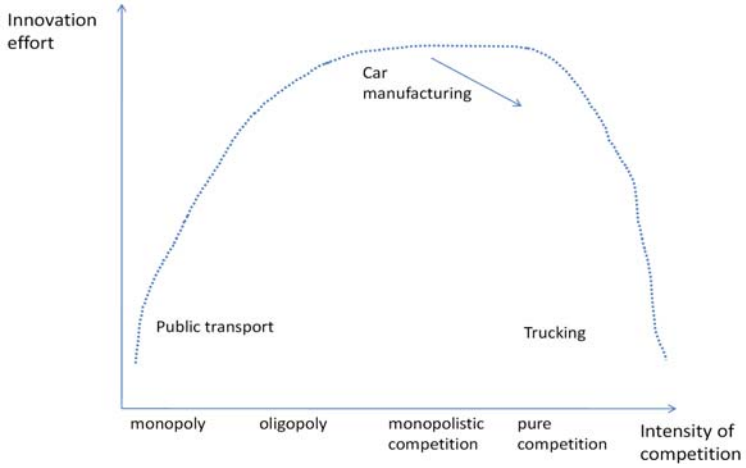

Figure 12: Market structure and innovation effort
Source: ITF (2010b)

Besides the competition level, other factors that influence the propensity to innovate are the nature of the good, the turnover time and the market sizes. In particular, heterogenous goods in which innovation may be a 'selling factor' will trigger more innovation efforts than goods that compete merely over the price, even though process innovations are also important in the latter case in order to reduce production costs. Long turnover times and a small market size tend to be adverse to innovation as they result in a lower demand for (novel) products and hence potentially longer payback times for the innovators. Finally, the capital intensiveness of the innovation is likely to affect the innovation propensity.

In general, these market conditions can help in explaining the incentive of the various transport modes in innovating. At the same time, however, particularities of some sectors, in particular the interlinkage with defence-driven innovation efforts, need to be taken into account. Other relevant factors are the technological opportunities faced by firms acting in different sub-sectors and the technological capability of firms that are embedded in their labour force, since skilled employees are a key asset for an innovative firm.

For most of the **providers of transport services**, and here in particular for goods (trucking, postal service, etc.), competition levels are very high. Low entry and exit barriers result in many small firms operating at small margins, resulting in limited capacity to cover fixed costs and finance innovation (ITF, 2010b). Moreover, transport service providers sell a homogenous good that differs mainly through price, implying that innovative products contributing only very limited to the total turnover of the sector (less than 15%; see Figure 5). The resulting price pressure, high levels of competition and the homogenous nature of the product means that transport companies focus largely on reducing their costs, and act as a disincentive to invest in innovations. This is confirmed by the fact that less than 40% of the companies active in the sector 'Transportation and storage' are considered to be innovative firms (Figure 13). In line with this are the very low levels of R&D investments and of the R&D intensity (0.3%) found in the quantitative analysis for the ICB class ' Industrial transportation' (section 5.2). Some segments of **public transport** lie on the other extreme and are exposed to rather limited competition (ITF, 2010b). Also this near-monopolistic situation acts as a disincentive to innovation. Hence, most of the actors that could push for cross-modal innovations have low research activities.

The **automotive sector**, on the contrary, may be described as a monopolistically competitive industry. Unlike other transport sectors that offer a mainly homogenous service, the automotive industry aims to differentiate their products between competitors. Innovative products serve as one criterion for this branding and may ultimately be one of the 'selling factors' of vehicles, as users are not only price sensitive but also performance sensitive. In consequence, innovative products contribute significantly

to the turnover of the industry, accounting for almost half of the total as shown in Figure 5. At the same time, however, the automotive industry needs to reduce costs and increase productivity. If appropriate, it may also decide to opt for a fast introduction of innovations while leveraging on larger markets to recover costs. Process innovations are crucial for aligning these counteracting objectives one with another. The idea of a platform strategy to be used by many different models and the development of engine families to be used by different brands of the same group illustrate this point. All in all, innovation in the automotive sector is characterised by a strong focus on the core competencies and the constant interplay of product and process innovation (Rhys, 2005; quoted in Sofka et al., 2008). This is confirmed by the results of the Community Innovation Survey (CIS 2008), which demonstrates that for manufacturers of motor vehicles and of other transport equipment, innovation is driven both by the motivation to increase the range and quality of goods and by reducing the labour costs per unit of output.

Thus, the automotive sector has a high incentive for innovating. This is supported by the findings of the quantitative assessment undertaken within the present study, according to which car manufacturers had an R&D intensity of more than 5% in 2008[10]. Considering that major parts of the innovation take place in large tier-1 suppliers (but also smaller tier 2 to tier 4 providers, see chapter 9.4), it is not surprising that the automotive suppliers show an R&D intensity that lies even above this (6%; see Figure 19). In line with this, the results of the CIS-survey indicate that of all transport-related sectors, the share of innovative companies is most elevated for manufacture of motor vehicles, trailers and semi-trailers (more than 60%; Figure 13).

However, the high competition pressures in some countries (e.g. the UK and Germany) may mean that the incentives for innovation already create a disincentive (Sofka et al., 2008). It is difficult to estimate which effect the economic downturn will ultimately have on innovation. On the one hand, it further reduces profit margins and lowers demand of cars, hence increasing competition levels. Moreover, with the advent of novel technologies such as electric vehicles, newcomers beyond traditional manufacturers have entered the market. On the other, the consolidation process has been accelerated with significant M&A activities and cooperation agreements between car manufacturers.

Manufacturer of **commercial vehicles** are exposed to a higher level of competition than car manufacturers as transport companies will follow a strict economic calculus when buying new equipment and are not ready to pay for 'innovative technologies' as such. In parallel, they are also exposed to a smaller and more volatile market base (the commercial vehicle market is especially sensitive to changes of the economic growth rate). Innovations performed by manufacturers of commercial vehicle are also likely to largely focus on fuel efficiency in order to bring down the total operating cost for commercial vehicles. This explains why innovation activities are lower than those of the automotive industry, with an R&D intensity of 3.5%.

Competition levels in the **aviation industry** are elevated (Hollanders et al., 2008), even if the number of major players worldwide is limited and concentrates largely on EU and US-based companies. Considering the outstanding safety and security requirements of this sector as well as the extreme relevance of fuel cost reductions for the airline revenues (resulting in a strong incentive for increased efficiency), it can be considered as research intensive. In principle similar to the automotive industry, yet probably to a lesser extent, innovation constitutes a selling factor for the aviation production industry. The high interlinkage and mutual knowledge flows between civil and military aircraft developments is another important characteristic of this sector. Figure 5 shows that innovative products deliver almost one third of the total turnover of the manufacturers of other transport equipments, which include aviation. These factors explain the elevated R&D intensity of the EU aviation industry, reaching 7.8% in civil aeronautics (see Figure 19).

In the **rail supply industry**, competition is elevated despite the rather limited number of players and the relatively small market size, in comparison with road modes. The European rail supply industry is amongst the main players on the world scale (European Commission, 2009c) with an R&D intensity

[10] Note that R&D expenditures or activities are often used as a proxy for innovation, which is not necessarily the case. Furthermore, a reduction in R&D expenditures may also include an abolishment of inefficiently high or ill-directed expenditures (European Commission, 2006b).

estimated to be 3.9%. It is worth mentioning that the actual innovation in the rail industry may to be more intense than reflected by the figures, as the sector partly benefits from research in other areas.

The **waterborne sector** in the EU is limited to specialist products and military production mainly; production of low-value vessels is often undertaken outside of the EU. Its R&D intensity is found to be 3.2% (1.6% for shipyards and 4.1% for manufacturers of equipment). This may be influenced by the relatively limited opportunities for the recovery of investments targeting innovations due to a relatively small market base, in comparison with other modes. Especially for the EU-based ship-building industry, which is world leader in the export of military vessels (European Commission, 2009c), the knowledge transfer from military innovations may be considered an important driver for innovations. Compared to maritime shipping, inland waterways works under different operating conditions (e.g. vessel dimensions are determined by the fairway), and vessels have longer lifetimes.

The **construction sector** is exposed to a high level of competition, in particular for small contractors. In parallel, competition among large general contractors and among specialty firms has been identified as oligopolistic (OECD, 2008), and anecdotic evidence from discussions with multinational construction companies illustrate that they not often compete for the same projects among each other, even if the lack of a strong competitive environment is less pronounced in Europe and the United States (Girmscheid and Brockmann, 2006). The limited degree of competition seems to be especially important in the case of large and capital intensive applications, typically characterising the large transport-related infrastructures. Albeit different, these indications concur in the identification of a rather poor performance of the construction with respect to innovation, as confirmed by its low R&D intensity (0.3%).

The **ITS** sector cannot directly be compared to other transport sectors, in particular as it is strongly interlinked with other transport sub-sectors (e.g. car manufacturers dedicate significant parts of their R&D investments to ITS and other infotainment) and therefore exposed to their market conditions, and because important parts of the ITS developments take place outside of the core transport sector. Despite this, ITS can be characterised as a technological area that combines very fast turnover times with relatively low capital intensiveness of the product, and for which innovative features constitute one selling factor. These are strong indications of the sector being research-intense, which is fully in line with the elevated R&D intensity observed (6.4%).

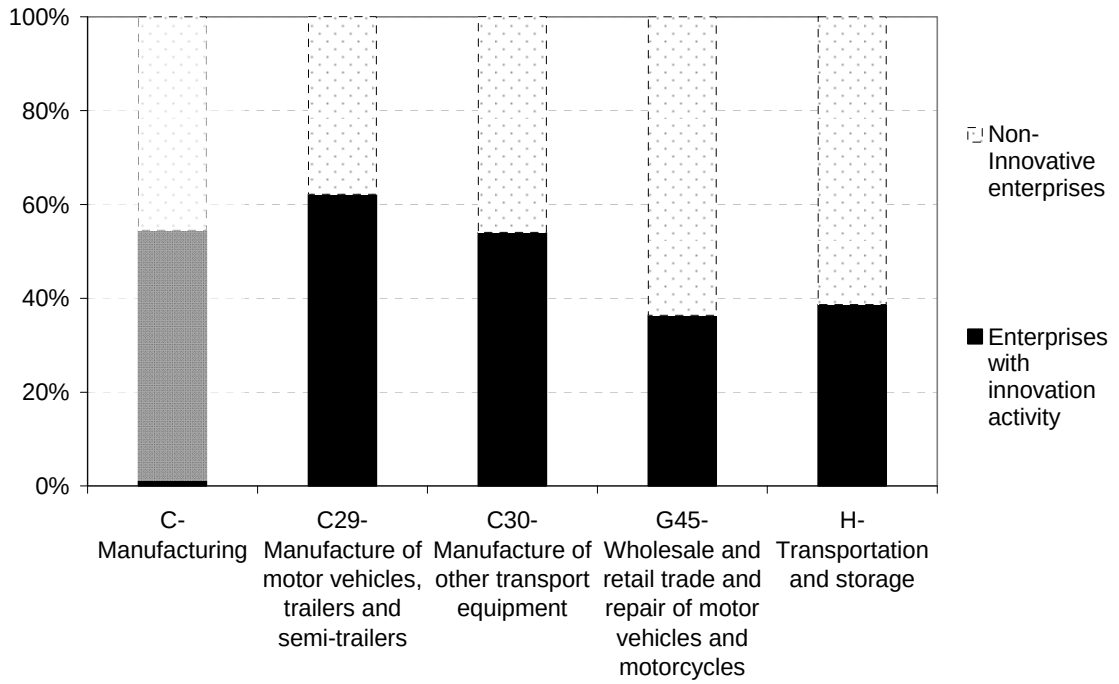

Figure 13: Share of innovative companies in various transport-related sectors
Data source: Eurostat CIS survey 2008 (based on NACE R2 sectors; retrieved in January 2011)

3 Barriers to innovation in the transport sector and ways of overcoming them

3.1 Overview

From the viewpoint of the private investor, innovators bear the risk that their up-front investments will not amortize. In the transport sector, these risks are particularly pronounced due to the following reasons:

a) high capital intensiveness of innovation, reinforced by problems of financing;
b) uncertainty in market demand and therefore little incentive to innovate. This is caused by a mismatch between consumers preferences and innovation supply, by a conservative, myopic consumer profile and missing trust for innovative solutions, often due to a lack of information on the benefit of the innovation, and by uncertainty about potential regulatory changes;
c) complex innovation systems that require coordinated innovation efforts and innovation speeds between all players (e.g. vehicle/fuel/infrastructure/consumer), including industry, academia and governments;
d) markets that are dominated by established enterprises and therefore make it difficult for newcomers to enter;
e) the lack of qualified personnel ('human capital');
f) knowledge spillovers that become increasingly important due to growing global competition.

These key problems are the results of the outcome of companies' replies in the 5th Community Innovation Survey[11] on factors for hampered innovation activities (see Figure 14), ITF (2010c) and sectoral in-depth analysis such as Sofka et al. (2008) and Hollanders et al. (2008).

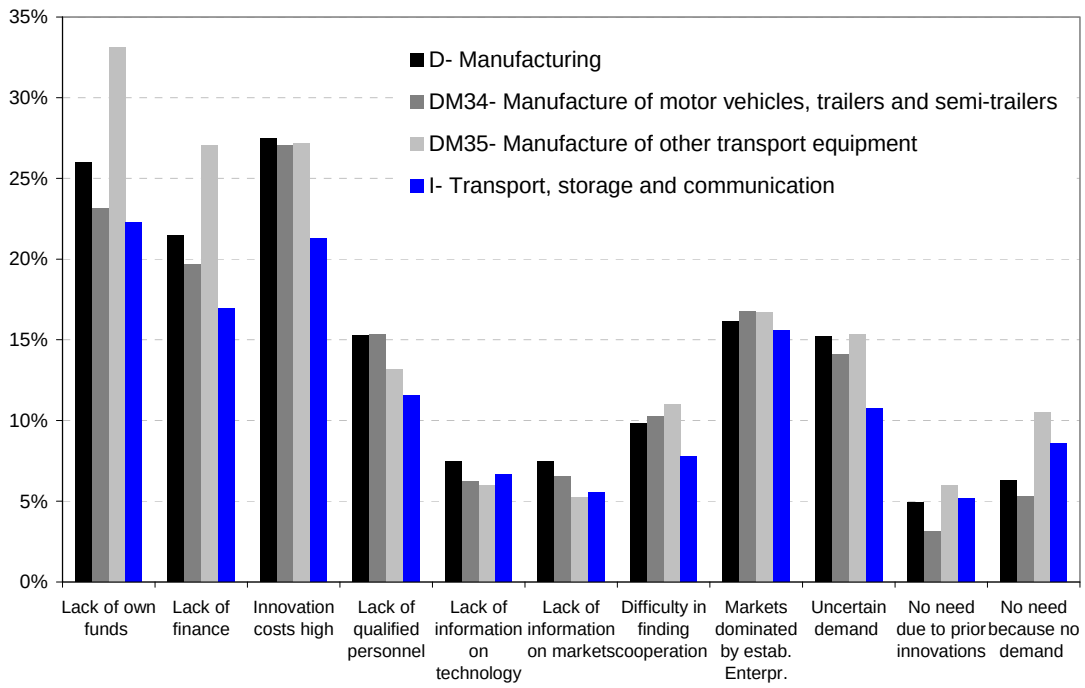

Figure 14: Reasons given for hampered innovation activities
Data source: Eurostat CIS survey 2006 (based on NACE R1 sectors; retrieved in January 2011)
Note: Total EU percentage based on our own calculations, with the following coverage:
D (no figures for UK, FI, DK, SL, BE, IT and DE); DM34 and DM35 (no data for UK, FI, DK, SL, BE, IT, DE, GR except for DM35, CY, MT, LT, LU, SE); I (no entries for UK, FI, DK, SL, BE, IT, DE, FR, MT and SE)

From the perspective of public bodies, additional barriers to innovation in transport include (see ITF, 2010a for a complete list):

[11] The CIS-6 survey has not addressed this topic.

g) the mismatch between operational R&D with its short-term objectives (a greater priority for industry and markets), and longer-term (transformative) R&D that often better matches societal needs;

h) a perception of innovation that is biased towards RD&D, and results in the inability to move innovations from lab to market;

i) an insufficient level of awareness about the importance of innovation among public and private stakeholders;

j) an insufficient coordination of transport policy and transport innovation policies;

k) a lack of institutional coordination, within governmental bodies as well as between industry, governments and academia, and at international level.

l) market failures for environmental innovations as externalities are only partly internalised in the prices e.g. through standards or taxes. Nevertheless, this situation has been gradually changing and EU legislation now sets ambitious limits for emissions of air pollutants, greenhouse gases etc. (see section 2.3).

In the following, the drivers underlying these main barriers to innovation are analysed in more detail. To this end, it is helpful to distinguish between different types of innovation, according to the level of changes needed. In particular, a distinction between incremental innovations and those of more radical or even systemic nature is adequate as they face very different barriers, involve different actors, and have different potentials.

We classify innovations as follows (based on Freeman and Perez, 1988; Freeman, 1992; Dosi, 1982):

- Incremental innovation, i.e. improvements of existing technologies
- Radical (or disruptive) innovations, i.e. innovative designs replace traditional ones
- Systemic changes; i.e. a cluster of innovations requires changes to the conventional system
- Regime changes or 'technological revolutions', i.e. systemic changes that impact other branches of the economy.

Whereas incremental innovations remain well within the boundaries of the existing market and technologies/processes of an organisation, and therefore carry lower financial and market-acceptance risk (Assink, 2006), radical innovations imply a break from the currently dominant design. Systemic and regime changes go one step further; they do not relate to single innovative technologies but clusters of them and require changes to the overall system. These can either be restricted to the concerned system, or involve other sectors of the economy. Examples are the introduction of synthetic materials or the development a centralised power supply system (Freeman and Perez, 1988; Hughes, 1983). Geels et al. (2004) extend this concept from a technology-oriented focus to a societal approach. Eventually, radical and systemic innovations have the power to change the market structure and create new business practices and/or markets (Assink, 2006).

There are divergent beliefs in whether radical or incremental innovations are more important. Fagerberg (2006) summarises that even though Schumpeter believed that radical innovations are more important, there is a widely held view that the cumulative impact of incremental is as great (or even greater), and that the realisation of benefits from radical innovations often requires a series of incremental improvements.

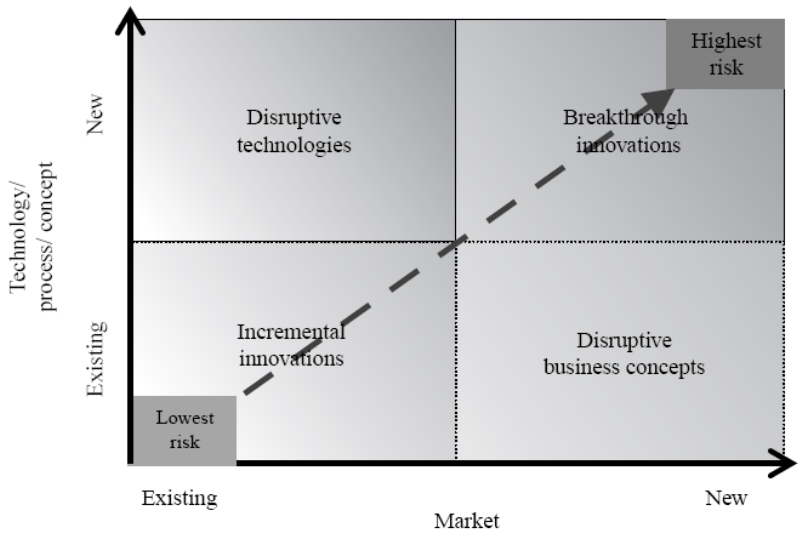

Figure 15: Innovation application space
Source: Assink, 2006

In order to better understand the barriers to innovation in the transport sector, especially the barriers a) to d), g) and h) above, we will introduce the concept of technological lock-in (section 3.2) that applies particularly to innovations of more radical nature. From the micro-economic viewpoint of individual companies, the so-called 'valley of death' provides a complementary, instrumental explanation of these barriers, and is therefore introduced in section 3.3. Section 3.4 gives some indication on the human resource factor, and section 3.5 describes the spillover effects that are faced by innovators in all sectors, not only transport. Section 0 finally discusses a number of policies to overcome these barriers. The topic of institutional coordination (barriers j and k) is being dealt with in part III when introducing the innovation systems in transport; the specific case of environmental innovations (barrier l) was discussed in detail in section 2.3.

3.2 Lock-in effect

Key findings

- Technological and institutional lock-in hampers radical innovations that lie outside of the currently dominant design; this is particularly relevant in the transport sector due to high costs of production equipment and infrastructure. It affects both modal shares (e.g. leading to a dominant role of cars where favourable taxation has been enforced over time, together with significant infrastructure developments) and specific technological choices within modes (e.g. petroleum-based vehicles vs. vehicles using alternative fuels, like natural gas or electricity).
- The high upfront investments and elevated risk levels act as a disincentive to industrial research into radically new technologies. In line with this, companies state that the lack of funds is a prime barrier to innovation in the transport sector.
- Established innovation systems and company business models, and mindset barriers, often mean that incumbent players are not effective in pursuing radical innovations. Hence, these are often introduced by new entrants, or by new coalitions going beyond the traditional knowledge flows.
- Eventually, a lack of trust by consumers vis-à-vis radical solutions, and in some cases the need for changes in behaviour, further enhance the lock-in to existing technologies.

Policy conclusions

- Especially for high risk, high potential technologies public support to research is needed in different forms:
    - by contributing to the 'up-front learning investment', e.g. through grants or risk financing;

- by facilitating knowledge flows that go beyond traditional innovation schemes, i.e. require knowledge from players that are outside existing collaborations on innovations;
- by supporting the build-up of the necessary steps to allow the development of the required infrastructure (e.g. through standardisation).

- The public sector should foster the research on the development of the built environment that minimises lock-in effects. This is particularly relevant for the expansion and evolution of urban areas, where transportation shall be tackled at the planning stage, promoting mixed use, transit-oriented solutions also enabling a larger reliance on non motorised transport modes for passenger mobility.
- The public sector should promote the deployment of promising technologies that are close to the commercialisation stage by finalising all the necessary standardisation procedures, by supporting the build-up of the necessary infrastructure with financial instruments capable to reduce risks for private investors and by promoting the market uptake of innovative solutions capable to reduce environmental and other externalities.
- Supported by EU activities such as the Technology Platforms, the institutional lock-in may have been (partially) overcome for some technologies. For other technologies, the option of additional initiatives facilitating this boundary-spanning knowledge flow may need to be considered, even though companies have reacted to the need of widened knowledge flows by ensuring wide cooperation agreements beyond the sector.

3.2.1 Technological and infrastructure lock-in

The lock-in effect describes a concept that creates path dependency in widely deployed, mature technologies and therefore constitutes a prime barrier to the uptake of competing innovative technologies.

In general, established technologies combine high reliability with low financial costs. Once a technology is chosen, it will increase its market share due to learning effects and economies of scale, both leading to lower unit production costs as production volumes increase. When the related industry has then been built up to a competitive level, it is very difficult to leave this technology aside and substitute it with a new technology.

This is particularly true for sectors with huge sunk costs, and transportation is certainly one of them. A major technology path dependence is created by the high investments required for the construction of roads, motorways, railways and airports (also affecting, in some cases, the whole development of the built environment, e.g. through the promotion of urban sprawls vs. denser suburbs), as well as the relevant vehicle production facilities[12], which create the need for mass production of products.

Under these circumstances, the existing infrastructure ends up being adapted to match the needs of the currently dominating technologies, limiting the opportunities for innovations to emerge. One of the most striking examples is given by the development of a transportation system that is particularly centred on the individual car use, since this is ultimately leading to the dependency on technical change in internal combustion engine technologies for the delivery of environmentally-relevant innovations, while imposing relevant barriers to the development of solutions for mobility that are less dependent on the use of individual motor vehicles (Kopp, 2010). Examples of technological lock-in exist also within the category of motorized road vehicles, since the fuel distribution and retail infrastructure has been optimized for (fossil-based) gasoline and diesel demand, and is less suited for electric vehicles or hydrogen-powered cars. For rail, high speed trains give another good illustration of the importance of path dependency, since one of the success factors of high speed trains is the possibility to use existing railways (at low speed) to access city centres, while the uptake of magnetic levitation trains has been hampered by their need for an entirely new infrastructure (Crozet, 2010).

[12] The costs of a modern vehicle assembly plant is estimated to be around £390-665 million (Andrews et al., 2006, quoted in Christensen, 2011), hence requiring an utilisation rate of above 80% in order to reach the typical profitability zone (IHS Global Insight, 2009, quoted in Christensen, 2011).

Innovative, presently uncompetitive technologies may therefore not enter the market and stay cost-intensive as they do not benefit from the learning effect and economies of scale (del Río González, 2008), even if they have a lower cost in the long run. This leads to a vicious circle, creating a 'lock-out' for new technologies. The situation is even worse for solutions that could be cost competitive on an even basis (i.e. starting from scratch), but remain marginalized because they require the modification of existing infrastructures that compromise their cost competitiveness in the short to medium term. Public support is likely to be vital in breaking this vicious cycle for innovations that lie outside of the currently dominant path.

3.2.2 Institutional lock-in

The lock-in effect is not restricted to technologies as such and their relative prices, but also comprises the related complex scientific and economic framework (e.g. Unruh, 2000). This approach is often referred to as 'technological regime', the latter being defined as "the grammar or rule set comprised in the complex of scientific knowledge, engineering practices, production process technologies, product characteristics, skills and procedures, and institutions and infrastructures that make up the totality of a technology ... or a mode of organization" (Kemp et al., 2000).

This broader concept of lock-in illustrates that barriers to new technologies go far beyond their technological maturity or costs (Sanden and Azar, 2005), but reaches out to the innovation system as such. This institutional lock-in effect hampers in particular those innovations that are not incremental changes that fit within the prevalent technology regime, but constitute systemic innovation in the sense of requiring an alternative technology regime. Established companies have a tendency to invest more in incremental than in radical innovations as the opportunities created by radical innovation often lie outside of an established company's technology base and market (van den Hoed, 2007; Assink, 2006; Henderson, 1993). Hence, radical innovations are often pursued by newcomers to the market.

For example, radical innovations on electric battery and fuel cell vehicles necessitate knowledge that goes beyond the automotive sector (see e.g. Sofka et al., 2008) and may involve a wide variety of changes in the way mobility is conceived. Hence, the sector needs to overcome the institutional lock-in effect and create novel cooperation with sectors that lie outside of the scope of traditional networks. The rail sector provides another example that is somewhere in the middle between technological, infrastructure and institutional lock-in: the strong and complex interfacing of all parts of the existing rail system (infrastructure, control-command, electrification, vehicles, and even country-based standards) results in extreme difficulties, even for major suppliers, to propose breakthrough innovation that is really impacting the efficiency and competitiveness of the whole system.

In the case of road transport, the examples of innovation clusters for electric vehicles and biofuels (see section 9.4) indicate that the sector has undertaken important steps in this direction. For some technologies, such as biofuels and hydrogen, this boundary-spanning approach is supported by EU-level activities such as the European Industrial Initiative Bioenergy and the Fuel Cells and Hydrogen Joint Technology Initiative.

Eventually, not only conservatism of companies and the research structure hamper radical innovations, but also lack of trust by consumers constitutes a barrier to their deployment. This is further enhanced by the lack of information leading to consumers not valuing sufficiently the benefit of innovation against their costs (ITF, 2010a,c).

To summarise, apart from the financial lock-in due to the capital intensiveness of the transport sector, radical and systemic innovations are further obstructed by an institutional and market lock-in (including costumers) and factors internal to the company (e.g. business models built around traditional products and services).

3.3 Valley of death

Key findings

- The transition from the research to the deployment phase is a crucial and risky step in the process. As many technologies fail to take this step, it is often called the 'valley of death'.
- Firstly, the valley of death represents a lack of structure, resources and expertise between the companies/institutions on the research side of innovation and those on the commercialization side.
- In some cases, organisational innovations need to accompany the technological innovations in order to bridge the valley of death.
- Secondly, the valley of death describes the challenge of bringing the technology-focus of public R&D support together with the financial focus of industrial R&D efforts.
- Hence, there is often a deadlock between transport providers and the manufacturing industry, with the former blaming the latter for the lack of innovations, while the manufacturing industry waits for clear signals from the customer.
- In particular small companies, that often can pursue radical innovations, experience a lack in financing when bringing their innovations from the research to the market phase.

Policy conclusions

- Policy-makers need to address innovation in a broader context, instead of focusing on one part of it (e.g. R&D) only.
- The development of technologies needs to respect insights from the market/customer perspective. Technology roadmaps may be a tool for agreeing on innovation steps between key stakeholders on the demand side, manufacturers and relevant innovators on the supply side.
- Also within public policy making, there may be a need to better align the expectations of different departments involved in transport innovation policy.
- A reliable, long-term legal framework can largely reduce the regulatory risks to which the innovator is exposed.
- Public procurement and other instruments to stimulate market demand, as well as specific financial instruments, could reduce the risks faced by investors and venture capitalists, being instrumental to strengthen the flow of capital aimed at the deployment of innovative technologies.
- For electric vehicles, a number of EU Member States and other countries have taken decisive actions to overcome the valley of death.

In the previous sections, we have shown how knowledge spillovers and technological lock-in create disincentives for innovation in the transport sector, leading to societal sub-optimal level of innovation. In the following, the critical point in the innovation process will be assessed from the micro-economic viewpoint of individual investors from private sector or capital markets.

The innovation process is often broken down into various distinct steps. Schumpeter (1942) distinguishes three phases in the innovation process: invention of a scientifically or technically new product or process; innovation seen as the first commercial application; diffusion means the deployment of the new technology (or market uptake).

The transition form the research to the deployment phase (or: invention to innovation, following the nomenclature above) is found to be a crucial and risky step in the process. As many technologies fail to take this step, it is often called the 'valley of death'. Markham (2002) defines the valley of death as "the gap between the technical invention or market recognition of an idea and the efforts to

commercialize it". This gap represents a lack of structure, resources and expertise between the companies/institutions on the research side of innovation and those on the commercialization side. This is caused by e.g. a misunderstandings or different value norms between technical and commercialization personnel.

In some cases, technological innovations need to be accompanied by organisational innovations in order to become commercially successful (e.g. for aviation see Hollanders et al., 2008; p 54). An econometric study undertaken by Suriñach et al. (2009) confirms cooperation to be the main determinant of innovation adoption. A key role for this is played by the level of trust, the improvement of communications, and by high educational levels.

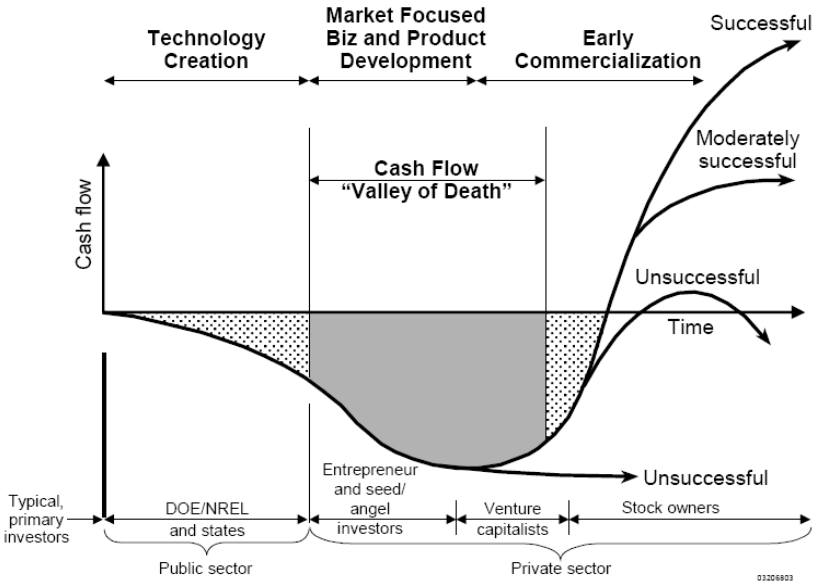

Figure 16: The cash flow valley of death as a function of development stage
Source: Murphy and Edwards (2003)

Murphy and Edwards (2003) extend the concept of a valley of death to a financial viewpoint. A financial valley of death exists between the often publicly funded R&D part of the innovation cycle and the commercialization part, which is generally seen as the responsibility of the private sector. This transition phase between public and private support faces a multitude of challenges as two different viewpoints/needs come together, the technology focus versus financial focus.

Hence, there is often a gap in the financing of small innovative companies in the pre-commercial stage, where they are no longer eligible for public start-up assistance, but the product development process is still too risky to receive sufficient private investments (COWI, 2009). Private sector investors focus on making profit and are thus not genuinely interested in pushing innovative technologies with elevated market and regulatory risks (Foxon et al., 2005; Wiser et al., 2004). The market risks comprise uncertainties of the prices of inputs (e.g. capital costs; labour) and the performance of an innovative technology. Also the price development of the technology that is to be substituted can be summarised under market risks. Regulatory risks arise from uncertainties about the policy environment such as direct subsidies or the legal framework such emission limits that strongly influence the relative competitiveness of innovative technologies.

The risk level rises with the volumes of the investments needed to scale-up the novel technology. In transport, it is generally more limited when considering incremental innovation (e.g. efficiency improvement of conventional engines), but certainly at the higher end when focusing on the promotion of radical innovations such as a more environmentally sustainable growth of cities (e.g. through by fostering co-modality and those IT innovation tools that would be instrumental for it, or through the deployment of the alternative fuel distribution infrastructure due to long time scales involved in this sector and the large scales of investments).

The problem of high costs of innovations and the related lack of financing is particularly pronounced for small enterprises with less than 50 employees[13] as shown in the 5th Community Innovation Survey 2006 (see Figure 14), followed by those with 50-249 employees. This is particularly innovation averse as radical innovations are often pushed for by small entrepreneurs or outsiders of the market because established companies may have problems in dealing with radical innovations due to organisational inertia, resource dependency in fixed assets, incorrect market appreciation, cannibalization of their own technology or sheer conservatism (summarised in van den Hoed, 2007 with further references; Assink, 2006).

3.4 Knowledge, skilled labour and human capital

Key findings

- Skilled labour will become increasingly important in the European transport sector to 1) develop innovations; 2) increase the absorptive capacity of companies with regard to innovative solutions; and 3) manage the complexity of innovations.
- Even though the European knowledge basis is considered good for most of the transport equipment manufacturing sectors, there is already today a shortage of highly skilled labour.
- Demographic changes may further reinforce this problem, in particular when coupled with the decreasing share of graduates in relevant studies. Also limitations of national labour markets with regard to international workers are detrimental.

Policy conclusions

- A strong European skills base is a key factor in maintaining global competitiveness of the European transport sector. Hence, transport needs to be included in training and skills-development initiatives.
- Mobility across European labour markets should be increased, and markets opened to international high-skilled workers.

Lack of skills and knowledge is mentioned as one important barrier to transport innovation from both industry (see Figure 14) and public bodies (see e.g. ITF, 2010a,c). High-skilled employees will become increasingly important in a sector that needs a high pace of innovation in order to keep its global competitiveness and to comply with stricter environmental and safety regulations. A skilled labour force is not only indispensable for research and development of innovations, but also for the absorptive capacity of a company with regard to innovative solutions, and for managing the increasing complexity of innovative technologies (e.g. electronics, chemicals, nanotechnology; Sofka et al., 2008). The transition towards a low-carbon European economy will further enhance the need for skilled labour. Within transport, in particular the automobile sector and road freight sectors that are strongly affected by the decarbonisation would need to have a lead on clean high-value technologies in order to keep their employment levels stable (Dupressoir, 2009).

Hollanders et al. (2008) stress the importance of the human capital for meeting the innovation challenges of the European aerospace sector. In their foresight study, Brandes and Poel (2010) characterise the European knowledge in aeronautics as excellent, but too distributed in the case of space. Nevertheless, the cyclical nature of the aerospace sector, which is caused by large projects, can lead to temporary shortage or surplus of engineering capacity, and therefore poses a problem to keeping the knowledge base in this sector. Engineers that are not needed in times of surplus are often not available anymore in times of shortage as they have found employment in other parts of the world (Brandes and Poel, 2010).

[13] The CIS data do not allow to assess the barriers according to the size for transport manufacturing industries, but only for manufacturing industries in general.

Already today, there is some indication of shortage of highly skilled workforce in the European transport sector. The German Association of engineers reports a lack of 68700 engineers in Germany in April 2011, out of which 29200 are missing in the automotive and machinery manufacturing sectors (VDI, 2011). In the European aerospace industry, growing production levels have led to an estimated shortage of 25000 engineers per year (Ecorys et al., 2009b quoting Wall, 2009), and demand is also growing at the level of component suppliers. Also in transport services, a shortage of qualified personnel can be observed; for example, a lack of 75000 truck drivers has been estimated at EU-27 level in 2008 (European Parliament, 2009).

This effect may be reinforced by the demographic changes, leading to more engineers retiring than young engineers entering the industry (Ecorys et al., 2009b; European Commission, 2009c). At the same time, the on-going trend of industry to outsource their logistics services leads to a knowledge gap on transport and freight operations (ITF, 2010c).

Concerns about a shortage in young engineers growing into the European transport industries cannot be directly verified (Ecorys et al., 2009b). However, Eurostat data indicate that the share of graduates (ISCED 5-6) in Maths, Science and Technology fields in total graduates has been continuously decreasing over the past decade, dropping from 25.1% in 1998 to 22% in 2009. Furthermore, there is a decrease in transport-specific expertise at the university level in disciplines such as civil engineering, economics, operations research (ITF, 2010a). For example, Brandes and Poel (2010) talk of a disinterest of Europeans doing a PhD in engineering and aerospace more specifically. Another example are problems in recruiting skilled worked in the shipbuilding industry due to an image problem of the industry as being 'an old industry' (European Commission, 2009c; see also Platina, 2011).

To partially remedy this, the high number of foreign PhD students in relevant areas could be used as a source of talent for European companies to exploit, which in some international organisations (e.g. ESA) is not foreseen, and also some national labour markets are less open to international experts (Brandes and Poel, 2010). In line with this, the EU research market in general is found to be less attractive than that of the US (European Commission, 2010d).

All in all, this can negatively impact the availability of skilled labour that is required for innovation in the transport sector. ITF (2010c, p6) further argues that on top, linkages between universities and the application of knowledge in government and industry are often insufficient.

3.5 Spillover effects

Key findings

- Spillover effects act as a disincentive to the innovator. Hence, corporate R&D efforts may stay below the societal optimum levels.
- The gap between social and private rates of return ('the spillover gap') is largest for research projects that imply high risks, which is often the case for radical innovations that have a high societal value.

Policy conclusions

- The enforcement of private property rights through e.g. patenting is a way of limiting spillovers for the innovator. While this ensures more benefits to the innovator, however, it shall not completely limit the sharing of knowledge that leads to overall improvements of the sector.
- Direct public support to R&D should concentrate on projects for which the spillover gap is large.

In general, innovation efforts from the private sector are often limited due to risk aversion, freerider concerns and the need for making short-term profits. Three relevant distinct flows of spillovers can be distinguished: Firstly, spillovers occur because the workings of the market for an innovative good create benefits for consumers and non-innovating firms ('market spillovers'[14]). Secondly, spillovers occur because knowledge created by one firm is typically not contained within that firm, and thereby creates value for other firms and other firms' customers ('knowledge spillovers')[15]. Thirdly, because the performance of interrelated technologies may depend on each other, each firm improving one of these related technologies creates economic benefits for other firms and their customers ('network spillovers'; see also Wiesenthal and Saveyn, 2009).

Due to positive spillovers (or positive externalities), the overall economic value to society of a research effort often exceeds the economic benefits enjoyed by the innovating firm. This implies that corporate R&D efforts may stay below the societal optimum levels. This dilemma is further strengthened by the fact that companies tend to focus on technologies that are closer to maturity and therefore bear less risks, while the achievement of long-term visions of a sustainable transport requires also innovations of more radical nature that would bear fruits only on the longer-term horizons.

Bringing innovation to societal optimal levels is a justification of public intervention in research. This can take place by directly complementing private R&D through public R&D; governments should invest in projects that have a high social rate of return, but that would be underfunded, delayed or otherwise inadequately pursued in the absence of government support. This objective can be furthered by pursuing projects for which the gap between the social and private rates of return ('the spillover gap') is large (Jaffe, 1996).

In the transport sector, it is important to consider spillover effects between and within modes. For example, the rail industry benefits from truck engine research. In other modes, knowledge inflows from research funded by military funds are important.

3.6 Policies to overcome key barriers

A wide portfolio of policy options to overcome key barriers to innovation in transport is available and implemented to different extents at the EU and Member States level. They address different types of innovation, and act on distinct parts of the innovation process, thereby creating an innovation-friendly environment that reduces the risk to the innovators. Key elements necessary to the creation of such an environment include:

1. Stable long-term signals, illustrated by a common vision of key actors highlighting objectives that are stringent enough to stimulate investment in innovation while allowing for the necessary time to undertake the required investments. Clear and reliable future-oriented policy targets should accompany this vision.
2. Market demand stimulation, balancing short-term and long-term objectives and leveraging on the most promising environments for the adoption of innovation (in the case of transport, this is often likely to include urban areas and the main intercity and international corridors).
3. Direct financial support to innovation and risk mitigation for innovators. This includes R&D support to achieve cost competitiveness for solutions that are not yet close to commercialisation and financial instruments promoting risk mitigation (also involving the setup of new partnerships and networks, e.g. between public and private actors) to foster investments in innovation.
4. Policies to ensure a skilled workforce, i.e. education and training.
5. Adequate enforcement of private property rights, e.g. by ensuring that patenting is protected while ensuring a balance between incentives for innovation and competition.

[14] One may argue that market spillovers are already priced in by the market.
[15] However, knowledge spillovers are often technology-specific and may thus be restricted to companies that work in the same sector (Dosi, 1988).

Policy instruments are not the same for all innovative solutions. In particular, they need to adapt to the different nature of the radical and incremental innovations (as highlighted in Figure 17).

Incremental innovations	**Systemic/radical innovations**
Well-established (modal) innovation systems Market demand often exists Significant R&I activities on-going Use of existing (mass) production facilities Use of existing infrastructures No need to change consumer behaviour	Lock-in effect is a key barrier for systemic innovations due to: • Capital-intensive infrastructure • High fixed costs in mass production facilities • Institutional lock-in with established knowledge flows; limited power of actors pushing for systemic innovations. Especially for manufacturers, the market is dominated by few players, and it is difficult to enter for newcomers. • Financial lock-in; i.e. limited access to risk financing for bridging the transition from research to commercialisation phase Development of market demand is unclear Uptake may imply changes to consumer behaviour.

Table 2: Characteristics of incremental versus radical innovations

Being pursued by several industrial actors, incremental innovations are relying on consistent capacity. Public intervention should acknowledge and leverage on this capacity, focusing mainly on guiding this innovation in order for it to best match societal policy objectives. Strengthening market demand for the best performing options is crucial to achieve short- and medium-term targets, while the provision of stable long-term signals has a fundamental importance to meet long-term targets.

Stable long term policy signals and market demand stimulations are also necessary pre-requisites for the diffusion of radical innovations. Nevertheless, they are unlikely to be sufficient. Considering the high risks faced by radical innovators throughout the entire innovation chain, target public intervention is needed in all phases of radically innovative processes, especially if they can lead to relevant systemic changes.

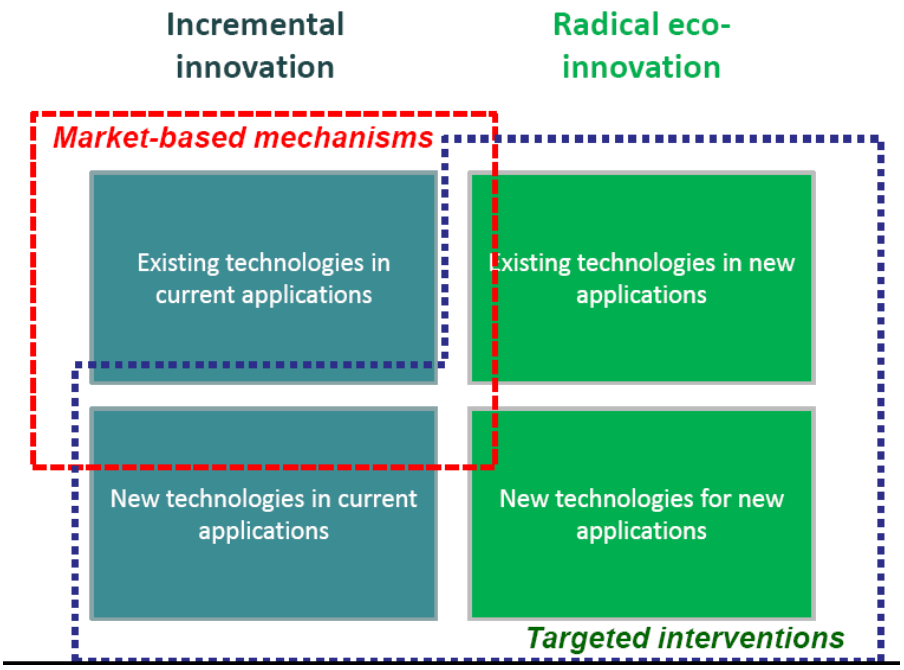

Figure 17: Different policies for different types of innovations
Source: Machiba (2010)

3.6.1 Long-term signals

Stable long-term policy targets provide all actors with regulatory certainty that creates a favourable environment for investments on innovations that are coherent with the societal needs spelled out by policy targets. On the contrary, uncertain policy conditions add to the risk which investors face in the market, and in doing so serve as a brake on innovation (Johnstone et al., 2010)[16]. Long-term policy stability is also consistent with the lead-time required by manufacturing industries to plan their product developments and to define their market strategy.

In the context of EU, the White Papers set out the transport-relevant policy objectives and the measures to be taken in order to achieve these objectives:

- the first White Paper on 'The future development of the common transport policy' (European Commission, 1992), issued in 1992 and focusing on the opening and integration of the EU transport market;
- a second White paper – 'European transport policy for 2010: time to decide' (European Commission, 2001) – that was issued in 2001 and stressed the importance of rebalancing transport modes, eliminating bottlenecks, placing users at the heart of transport policy and managing the effects of globalisation.
- a Mid-Term Review of the 2001 White Paper, 'Keep Europe moving – sustainable mobility for our continent' (European Commission, 2006c), underlining the changes that took place since 2001 (including the EU enlargement, issues related to security and terrorism, the trend towards globalisation, as well as the calls for international commitments to fighting global warming and rising energy prices).
- The 2011 Transport White Paper (European Commission, 2011a) sets the objective of reducing transport GHG emissions by 60% by 2050 compared to 1990 levels.

Broader EU policy targets on the European energy and climate policy[17], such as the setting of greenhouse gas reduction targets (see European Commission, 2007e), also have direct impact on the transport sector, and resulted for example in CO_2 emissions limits for new cars (Regulation EC 443/2009). Other relevant policy documents include broad schemes, as the seven European flagship initiatives of 2010. More narrowly focused transport-specific policies include the green papers on urban mobility (European Commission, 2007c), the TEN-T (European Commission, 2009a), and the action plans on freight and logistics (European Commission, 2007d), urban mobility (European Commission, 2009b) and deployment of Intelligent Transport Systems (European Commission, 2008a).

Complementing the regulatory framework, **a common vision shared by key stakeholders** can further reduce innovators' uncertainty, in particular when it is accompanied by a **roadmap** that provides an agreed timeline for the development of a certain technology, its key components and the related infrastructure. Roadmaps can be good instruments to support structured exchanges between the manifold innovation actors and initiatives in the transport sector, setting up a framework that could speed up agreements on standards, infrastructure needs and technical specifications, while also setting appropriate timelines. Moreover, they can highlight possible transition impacts and therefore contribute constructively preparing suppliers, consumers and regulators to face them ahead of time. Eventually, consensual roadmaps can lead to the adoption of policy instruments characterised by a higher predictability for the relevant stakeholders.

This structured, reliable agreement is particularly important when considering cross-modal innovations, or more radical innovations within a certain mode that needs to consider the whole chain of vehicles, fuels, tanking/charging infrastructure and consumer preferences instead of focusing on e.g. the vehicle engine technologies alone. To this complexity adds a broadening portfolio of technologies.

[16] In some cases policy instability can arise from the acquisition of information: in such cases, there is an inevitable trade-off between changing policy objectives to reflect the new information and keeping incentives constant in order to reduce uncertainty (Johnstone et al., 2010).

[17] See Soria and Saveyn (2011) for a comprehensive overview of the European energy and climate policies.

A survey to its member countries undertaken by ITF (2010a) underlines that currently, a mismatch in expectations between the providers of transport services and the respective manufacturing industry creates a deadlock situation for innovation: while transport providers are often reluctant to introduce innovative solutions and blame industry for lack of adequate supply, the industry is usually waiting for clear market signals to take certain investment decisions and lacks of orientation of the needs of the real customers. The problem of sharing priorities between different stakeholders involved in transport innovations can be extended to the allocation of responsibilities to different ministries and/or department, some of which deal with transport policy as such, others with innovations, while others again may be involved in a certain technological area. The use of roadmaps is likely to be helpful to exit from this sort of impasses.

In the EU, initiatives such as the Fuel Cells and Hydrogen JTI or the European Industrial Initiative Bioenergy are examples for bringing together stakeholders involved in all stages of innovation and are therefore considered a good step in the right direction. Another example to enable communication across stakeholders is the roadmap on electrification of road transport proposed by three European Technology Platforms together, namely ERTRAC, EPOSS and Smart Grids (ERTRAC et al., 2009).

The main drawback of technology roadmaps is the risk to limit the necessary flexibility and technology neutrality of policies encouraging innovations. This is further enhanced by the often modal set-up of existing Technology Platforms, which are key players in contributing to the development of roadmaps, are organised along modes. This observation is reinforced by recent analyses indicating that, in the field of environmental policies, flexible policy regimes tend to be associated to more innovations (Johnstone et al., 2010). The best policy solutions suggested by these observations are therefore those that link support to the policy objectives and hence follow a solution-based approach, avoiding being technology-prescriptive. Given the difficulty to foresee trajectories of technological change and the contextual need to promote promising technologies, it is important to conceive roadmaps in a broader context beyond single technologies and modes, striking a balance that give innovators the incentive to search across a wide range of solutions to comply with policy regulations that are coherently set according to short- and long-term objectives. In this context it is important to ensure that existing coordination and collaboration networks do not focus on R&D only, but also consider the early commercialisation phase.

Another tool to enhance the predictability and trust of heterogeneous actors in new products is the setting of technical standards. The transfer of R&D results into standards helps to validate and ultimately exploit innovative solutions and therefore constitutes an important element for a succesful transfer of research results into the market (Expert Panel on Standardisation, 2010). Technical standard setting becomes increasingly important in sectors with a highly complex innovation system such as transport. Standards for interoperability are essential for allowing innovations to complement existing products and services and integrate existing systems (European Commission, 2007f), and are crucial e.g. for ITS and cross-modal transport (Link Forum, 2010). An outstanding example is the success stories of containers for freight transport, which were originally developed for military purposes and then rapidly gained market shares when ISO standards were introduced in 1961. The definition of quality standards enhances the trust in an innovative product and creates the basis of collaboration between e.g. fuel producers, providers of the fuelling infrastructure and car manufacturers. For example, Member States with a successful penetration of transport biofuels had introduced standards at an early stage: biodiesel standards were introduced as early as 1991 in Austria, followed in 1992 and 1994 by France and Germany. Inversely, the lack of clear biofuel standards has had a detrimental effect on consumer's confidence into biofuels in Poland (Wiesenthal et al., 2009b). At the same time, however, standards that are technology-prescriptive may also hamper innovation.

As standards are usually most effective when applied to larger markets in order to avoid fragmentation, their role in fostering innovation shall be increased in the EU (European Commission, 2008c; see also European Commission, 2011c). To this end, a dedicated joint working group on Standardisation, Innovation and Research has been created to advice two of the European Standards Organisations (CEN and CENELEC, 2010) on this topic. Among their recommendations are that standardisation aspects are included in research projects, and that standardisation needs emerging from research activities are identified.

3.6.2 Stimulating market demand

Demand-side impulses have proven powerful in determining the direction of incremental innovations that are close to market entry. The creation of market demand takes place through various forms, such as by setting a favourable market environment due to standards or taxes. This can be realised both by dedicated technology-specific pull-instruments such as purchase subsidies, (fuel) tax incentives or preferential taxation of efficient/innovative business cars, and by internalising the external costs for environmental innovations, either directly through pricing of pollutants or through the setting of performance standards. For example, the impact of the French 'bonus-malus' system that provides an incentive to purchase vehicles with low CO_2 emissions illustrates that consumer behaviour reacts rapidly to the economic framework (Bastard, 2010; official data until 2008 can be found in Friez, 2009). It has been demonstrated that the American Clean Air Act has triggered innovations; and that more stringent performance standards have induced more technological change (Lee et al., 2011). Other regulatory actions (e.g. focused on granting access to restricted areas to specific types of vehicles that fulfilling a number of environmental requirements, like EVs or Flexi-Fuel Vehicles) can also be effective instruments in this respect.

The impact of regulatory policies, such as technical specifications, can also trigger innovation in sectors that usually are considered as little research-intensive. For example, ambitious technical specifications can foster innovation in the construction sector, considering that public sector funding often focuses on building and improving roads, bridges, railways, waterways, and airports. For example, demand for the use of new technologies in the construction and upgrading of transport infrastructures may help create new sourcing partnerships between contractors and solution providers (OECD, 2009).

Another way of creating a niche market demand is through public procurement that forms a considerable share of total demand in Europe (around 17% of GDP; European Commission, 2010c), and has proven to be an efficient instrument in promoting innovation (Geroski, 1990). PwC (2005) estimates that at the EU-25 level, public bodies purchase around 110000 passenger cars, 110000 LDVs, 35000 HDVs and 17000 buses. To this end, directive 2009/33/EC on the promotion of clean and energy efficient road transport vehicles requires public authorities to take into account the energy and environmental impacts of vehicles over their lifetime when purchasing new vehicles. Nevertheless, the potential for innovation through public procurement is currently still under-exploited in the EU. Most public purchases do not put a premium on innovation; besides, the fragmented public procurement markets often remain too small to reach a critical mass for innovation (European Commission, 2010c).

A number of initiatives for demand-side innovation policies have been established at the EU-level, such as the 'Lead Markets Initiative for Europe' (European Commission, 2007a). This is being tackled also at the level of individual Member States. For example, the IEA pointed out that at least 8 EU Member States have introduced programmes to support the uptake of electric vehicle beyond the research phase (IEA, 2009d).

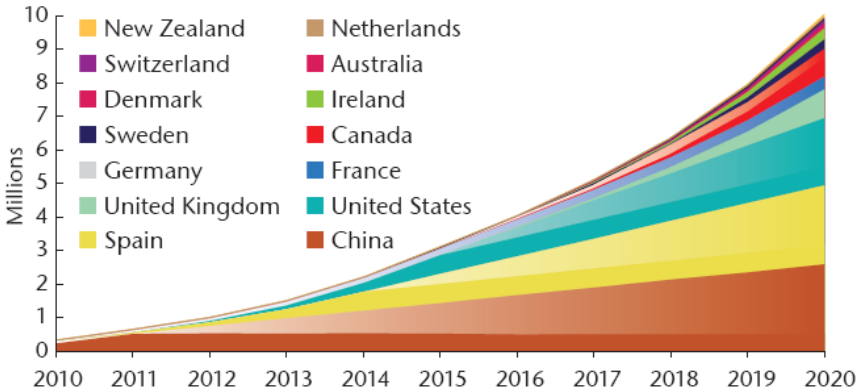

Figure 18: Projected electric and plug-in hybrid vehicle sales through 2020, based on national targets (if national target year growth rates extend to 2020)
Source: IEA (2009d)

Notes: Figures based on announced national sales and stock targets, with assumed 20% annual sales growth after target is met, if target is before 2020 (e.g. China's target is for end of 2011).

Another instrument that can create demand for innovation in the construction of transport infrastructures is the definition of ambitious technical criteria. This can be particularly effective in this sector considering the importance of the public sector in the project definition and financing. The transnational nature of transport also implies that supra-national approaches are also relevant in this respect. This element, as well as the advantages given by a concerted action for the increment of the potential market size, are good arguments to justify efforts that aim at aligning the procedures and the targets that should be adopted by local authorities, as well as the rationalisation of the objectives that should be pursued by local polices.

3.6.3 Bridging the valley of death: grants, loans and risk mitigation

In order to bridge the valley of death, a wide portfolio of instruments is necessary to tackle different phases of the innovation chain. The decision about whether a grant, a loan or other instruments are the most appropriate form of public support depends on the stage of the technology development process and the size of the valley of death (see chapter 2.2 in CEPS, 2011). Whereas direct grants seems most appropriate in the research phases, the up-scaling and commercialisation phases can be supported by debt financing and risk-sharing guarantees and/or a blend of loans and grants where venture capital cannot be raised from private investors alone. Hence, improving the access to financing is a fundamental element fostering the mitigation of risks for innovators. This is also one of the objectives stated in the Communication on the Innovation Union (European Commission, 2010c).

Direct research grants are usually best suited for solutions that still need research efforts to achieve cost reductions. This applies to technologies that are not profitable in the short term (e.g. fundamental research) and carry a high level of risk (CEPS, 2011). As technology development is inherently unpredictable and as bottom-up approaches tend to be more effective in the research field than top-down guidance, direct support for fundamental R&D should maintain technology neutrality to the greatest extent possible. Once the research activity is applied to areas that are closer to the commercial dimension, direct support is likely to be best conceived when it is periodically evaluated on the basis of the potential societal benefits that can be expected by the deployment of the different technology options. In this phase, however, other instruments are likely to become more effective for the provision of R&D support.

When entering the commercialisation phase, innovators must shift their focus from a technology to a market focus, taking into account the financial risk perspective of the private sector. They need to raise capital for the more costly commercialisation phase of the innovative product. Obtaining a bank loan or raising capital in the markets is, however, often difficult for new companies as they are considered risky and have limited cash flows that make interest payments feasible (European Commission, 2010f).

A financial intermediation that is particularly well suited to support the creation and growth of innovative, entrepreneurial companies is venture capital. It specializes in financing and nurturing companies at an early stage of development (start-ups) that operate in high-tech industries. For these companies the expertise of the venture capitalist, its knowledge of markets and of the entrepreneurial process, and its network of contacts are most useful to help unfold their growth potential. However, in its recent communication on the Innovation Union (European Commission, 2010c, 2010f), the European Commission took stock of the current Venture Capital activities in the EU and found that the EU invests about € 15 billion a year less in venture capital than in the US. Moreover, the 10-year return on venture capital investment is substantially lower in the EU than in the US. Together with the fragmentation of EU Venture Capital market into 27 national markets with different regulations and fiscal conditions, this renders the European venture capital market less attractive than its US equivalent. To remedy this, the European Commission (2010c) commits to ensure that venture capital funds established in any Member State can function and invest freely in the EU.

The promotion of financial instruments capable to reduce the investment risk associated to innovative technologies for transportation is another area where European coordination may be particularly

effective. The European Commission therefore made the increase of the supply of risk capital one priority of its policy towards innovation and capital markets (European Commission, 1998, 2003).

Instruments to support access to (risk) financing include the High Growth and Innovative SME Facility that makes risk capital available, and the SME Guarantee Facility that provides EU guarantees. Both instruments are funded by the European Union under the Competitiveness and Innovation Framework Programme with a total budget of more than € 1.1 billion (2007-2013), and are implemented by the European Investment Fund (EIF).

The European Investment Bank together with the European Commission established in 2007 the Risk Sharing Financing Facility (RSFF) with the aim of providing loans and guarantees for research, technological development and innovation activities for companies or public institutions. To this end, the EIB and the European Commission through FP7 each contribute € 1 billion to the RSFF to cover the risk associated with debt financing, thereby creating a loan financing capacity of around € 10 billion. According to a first evaluation of the RSFF which covers the period 2007-2009 (Schmidt et al., 2010), the RSFF has been successful with an important leverage effect. During this period, a total of € 6.3 billion has been approved, out of which 21% are directed to ' transport-related projects'.

Transport-related research is further supported by the EIB through its 'European Clean Transport Facility' programme with a volume of € 4 billion per year. This programme specifically supports the transport sector in carrying out research, development and innovation on emission reduction and energy efficiency. To this end, it provides several debt financing solutions that will increase the investment capacity of corporate borrowers.

Eventually, also structural funds can help regions to build research and innovation capacities corresponding to their situation and priorities. JEREMIE (Joint European Resources for Micro to Medium Enterprises) allows Member States to use part of their structural funds to finance small and medium-sized enterprises (SMEs) by means of equity, loans or guarantees, through a revolving Holding Fund acting as an umbrella fund.

European financial support for low-carbon transport-related innovations may also be linked to the existing initiatives undertaken by urban areas that are willing to be leading the European GHG emission mitigation (like those that committed to reduce their GHG emissions beyond the EU average target through the Covenant of Mayors). Other advantages are also associated to such initiatives since they may act as a catalyzer to promote common action from different local authorities (like for instance joint procurement) and can help reaching a critical size for the market of innovative products and services.

Still, Europe continues to underperform in terms of financing the growth of young innovative SMEs (European Commission, 2010f).

3.6.4 Education and training

Section 3.4 points out the importance of a skilled workforce for the European transport sector. It concludes that already today, some shortages can be observed, which may become more severe considering demographic changes and the decreasing interest in transport-related university studies. Hence, action is required to increase the attractiveness of studies in areas relevant for transport, e.g. by informing about future employment perspectives in this sector. In this respect, a closer cooperation between public and private actors is beneficial. Better pan-European accreditation schemes are important considering the European (or even global) character of many of the major transport industries.

Also on the side of consumers, the absorptive capacities for transport innovation needs to be strengthened, as the diffusion of innovation does not only depend on their ability to match consumer preferences, but also on the awareness of the consumers of new technologies, products and processes, as well as the consumers' willingness to accept and trust them (see for an overview and assessment e.g. Suriñach et al., 2009). Hence, policies addressing education and information often need to accompany those policies that improve the profitability of innovative products.

3.6.5 Enforcing intellectual property rights

Section 3.5 concludes that knowledge spillovers create a disincentive for innovators as other firms also profit from the knowledge created by the innovator. Hence, the reduction of knowledge spillovers through the enforcement of private property rights is an important prerequisite for creating an innovation-friendly environment. This can be realised, for example, by means of patenting. In this context, the proposed single European patent that is applicable in all subscribing countries could be an important step forward, reducing both costs and the time for patenting. Under this (proposed) scheme, applicants will be able to file patents to a central patenting authority and patent court; if accepted, the patent will be enforced across most of the EU.

Despite the importance of patenting as a way of enforcing intellectual property rights, a balance between incentives for innovation and competition needs to be sought; the modern view reported in ITF (2010b) argues that even though innovators need to be rewarded, a too strong protection can easily carry high costs through second-order effects[18].

[18] Lévêque and Ménière (2006) find that the 'effects of patent on innovation are small but significant and the patent system suffers from critical imperfections'. They therefore do not question whether patenting is needed, but advise to reform the patent system.

PART II – QUANTITATIVE ANALYSIS OF R&D INVESTMENTS[19]

[19] The analysis of R&D investments is adapted from the research work being carried out in the context of the FP7 project GHG-TransPoRD (www.ghg-transpord.eu). It presents the key outcomes of the quantitative analysis undertaken in Deliverable 1 (Leduc et al., 2010), which have been further updated, validated and complemented by additional sectors.

4 Scope and data sets

Key findings

- There is no comprehensive database that allows to systematically analyse the industrial and public efforts along the entire innovation chain. But even when focusing on R&D investments, existing databases vary in scope, regional allocation and detail provided.
- There is also no comprehensive database that collects all information, including budgets, for all transport-related innovation projects in the EU and its Member States.
- Recent initiatives such as work undertaken by the ERA-NETs, ERA-WATCH or the projects Transport Research Knowledge Centre and TransNEW have started to tackle this problem.

Policy messages

- Data scarcity impedes the exact definition of the status quo of innovation efforts in the European transport sector.
- Also the monitoring of progress towards policy targets is difficult with current data sources.
- Lack of information may result in the under-exploitation of international collaboration.

This part aims at quantifying indicators related to the innovation process. Unfortunately, there is no single database that provides a comprehensive collection of indicators related to innovation. Instead, several databases exist with diverse scope, regional coverage, allocation of companies to a certain region (either by site of headquarters or by site of activity) and (technological) level of detail, each of which addressing a certain point in the innovation process. Table 3 provides an overview of the most important databases that are used in the present assessment.

Database	Private/public	Main subject covered	Classification
EU Industrial R&D Investment Scoreboard	Private	R&D investments	ICB
BERD (Business Enterprise Research and Development)	Private	R&D expenditures	NACE_R1
GBAORD (Government Budget Appropriations or Outlays on R&D)	Public	R&D appropriations	NABS92 NABS07
IEA RD&D statistics	Public	RD&D budget	Energy technologies
European Patent Office (EPO) United States Patent and Trademark Office (USPTO)	Public	Patent applications (for EPO) Patents granted (for USPTO)	IPC NACE_R1
Eurostat	Private	R&D personnel and researchers	NACE_R1
Eurostat GERD (Gross Domestic Expenditure on R&D)	Private and public	Total intramural R&D expenditure	NABS92 NABS07
Community Innovation Survey (CIS)	Private mainly	Innovation-related topics	NACE_R2 (for CIS 2008) NACE_R1 (for CIS 2006)

Table 3: Overview of key data sources and their main characteristics

The **EU Industrial R&D Investment Scoreboard** is prepared from companies' annual audited reports and accounts and collects data on R&D investment for 1000 EU-based and 1000 non-EU based companies that are grouped according to the ICB classification. Companies are allocated to the country of their registered office, which may differ from the operational or R&D headquarters in some cases. The way in which data from the Scoreboard is further treated in the present report is described later.

GBAORD (Government Budget Appropriations or Outlays on R&D) are all appropriations allocated to R&D in central government or federal budgets. It is also recommended that provincial or state government should be included when its contribution is significant, while local government funds

should be excluded (OECD, 2002). Data are collected from government R&D funders and maintained by Eurostat and the OECD. GBAORD are broken down into socio-economic objectives following the NABS[20] classification. Unfortunately, at the time of this study the data provided by the GBAORD in transport-related NABS sectors presented major limitations in term of geographical coverage (only data are provided for seven Member States in 2006 and for three Member States in 2007) and time horizon. Moreover, transport-related investments often rank as a sub-category for which data are not explicitly collected.

The **International Energy Agency (IEA)** hosts a publicly accessible database on energy RD&D budgets from the IEA member countries. Data is collected from government RD&D funders. The latest available data are for the year 2009. As only 19 of the 27 EU Member States are IEA members, the database systematically contains no data for the other countries. Unfortunately, the breakdown of the IEA R&D database does not cover all RD&D efforts of the transport sector at the level of detail required in the present study (e.g. no distinction between each transport mode). However, the RD&D budgets allocated by Member States to different vehicle technologies (IEA, 2009b) can be of high interest. In the present study, data from the categories I.3 'Transportation' and VI.3 'Energy Storage' have been used to have an estimate of the public R&D investments in new engines and electric vehicles (including hybrids). Furthermore, public R&D investments on biofuels and hydrogen and fuel cells will be derived from the categories V.1 'Total hydrogen' and V.2 'Total Fuel Cells' (following IEA, 2009a).

The Eurostat/OECD **BERD** (Business enterprise sector's R&D expenditure) database contains data on the business enterprise sector's expenditure in R&D for different socio-economic objectives following the NACE[21] classification. Furthermore, the expenditures are given by sources of funds, disaggregated into business enterprise sector (BES), government sector (GOV), higher education sector (HES), private non-profit sector (PNO) and abroad (ABR). We assess transport-related BERD data for funds from all sources and those funds that stem from the business enterprise sector BES. The latter is more comparable to the central bottom-up approach of this report that looks into the R&D investments that stem from the companies' funds.

The **GERD** (Gross Domestic Expenditure on R&D) database is maintained by Eurostat/OECD on the basis of data collected from all R&D performers. It has a sectoral breakdown (BES: business and enterprise, GOV: government, HES: higher education; PNP: private non-profit).

The **Community Innovation Survey** (CIS) is a survey on innovation activities in enterprises covering the EU Member States, EU Candidate Countries, Iceland and Norway. Data is collected by Eurostat on a four-yearly basis. The innovation concept applied follows the Oslo Manual (OECD, 2005), the classification scheme followed is NACE.

Several **patent databases** are available that differ in geographical coverage, breakdown etc. Two different approaches on analysing patent (applications) have been used in parallel so as to overcome the specific shortcomings of each of them. On the one hand, a keyword-based research of the European Patent Office's database Esp@cenet, on the other a search by category of the PATSTAT database. PATSTAT is the Worldwide Patent Statistical Database maintained by the European Patent Office (EPO). Esp@cenet contains data on 60 million patent applications and patents, currently from 76 countries.

Other information sources, which focus on qualitative information on (transport) research programmes and/or institutions are ERA-WATCH, the Transport Research Knowledge Centre and the on-going FP7 project TransNEW with a focus on New Member and Associated States.

Unfortunately, quantitative information extracted from these databases cannot easily be compared one another mainly due to:

- Divergent coverage of innovation activities: of course, patent statistics, CIS and R&D databases cannot be compared. Yet, even among databases on similar type of indicators the scope of

[20] Nomenclature for the Analysis and Comparison of Scientific Programmes and Budgets
[21] European statistical classification of economic sectors

research activities differ. While BERD and GBAORD focus on R&D, the IEA database covers demonstration activities on top of pure research and development activities. 'Demonstration projects' are of large scale, but are not expected to operate on a commercial basis (IEA, 2008). In practice, however, most IEA member countries do either not provide data on funds directed towards demonstration, or do not display them separately[22]. For estimating industrial R&D investments, companies' annual reports are the starting point of our main assessment, processed in the EU Industrial R&D Investment Scoreboard. They follow the accounting definitions of R&D, such as within the International Accounting Standard 38 ('Intangible Assets'), which uses the definition of R&D of the Frascati Manual (OECD, 2002). In general, technology demonstration mostly incurs engineering costs and is thus recommended to not be included under R&D investment. However, this can be expected to strongly depend on the type of sector/activity, influenced e.g. by the maturity of the technology and/or the policy support to its deployment.

- Different geographical coverage and time horizon: While the databases hosted by Eurostat comprise all EU Member States, the IEA database covers IEA Member States. This means that 8 EU Member States are not included in the IEA database, i.e. Bulgaria, Cyprus, Estonia, Latvia, Lithuania, Malta, Romania, and Slovenia.
- Different approaches: While EUROSTAT collects budget data in its GBAORD statistics and expenditure data in GERD, the IEA assembles both budget and expenditure data in its energy R&D questionnaire. The EU Scoreboard uses data from companies' annual audited reports.
- Different sectoral classifications[23]: The BERD follows an institutional nomenclature (NACE), while the Scoreboard classifies companies' economic sectors according to the ICB classification. GBAORD and GERD follow the classification NABS. The IEA energy R&D statistics use a scientific/technological structure.
- Different geographical allocation: The Scoreboard refers to all R&D financed by a particular company from its own funds, regardless of where that R&D activity is performed (Azagra Caro and Grablowitz, 2008). BERD refers to all R&D activities performed by businesses within a particular sector and territory, regardless of the location of the business's headquarters, and regardless of the sources of finances (Box 1).
- Lack of coordination in data collection: Some countries collect data on budgets, others on expenditure; demonstration projects may be accounted for in different ways; some countries attribute the whole budget of a program or project to the first year, whereas others indicate actual yearly expenditures, etc. (European Commission, 2005).

Box 1 - Importance of geographical allocation

Major differences between BERD and Scoreboard data in the transport field are likely to be influenced by the regional allocation. For the Netherlands BERD provides 14 times lower R&D expenditures in transport-related NACE sectors than the Scoreboard. This can to some extent be explained by EADS, for which the Scoreboard allocates all R&D investments to the Netherlands as it is registered there. The opposite phenomenon can be observed for e.g. Spain, which BERD figures are well above those of the Scoreboard. This becomes understandable by the fact that Spain is an important production country for many brands with headquarters abroad. Furthermore, the important Spanish automotive company Seat is allocated to the Volkswagen AG with headquarters in Germany following the reporting rules. Another counter-intuitive example is Magna-Steyr. Due to Magna Steyr being subsidiary of the Canadian company Magna International, its R&D investments are allocated to Canada instead of Austria (see Leduc et al., 2010).

[22] Data on aggregated public national funds of EU Member States dedicated to demonstration amount to some 9% of the total energy R&D budget, only (Wiesenthal et al., 2009).
[23] Some data sources allow for a categorisation of their data according to a secondary socio-economic classification .

5 Corporate R&D investments

The present chapter assesses corporate R&D investments mainly based on the EU Industrial R&D Investment Scoreboard, and compares results to findings from other publications to the extent possible. The most straight-forward way for doing so, is to assess R&D investment of the companies allocated to the ICB classes relevant for transport. This is done in section 5.2 below, both for the year 2008 (following Leduc et al., 2010) and updated for the year 2009.

Unfortunately, this approach has a number of shortcomings. Firstly, there is no ICB sector for the rail and waterborne mode, transport service providers, transport construction companies and ITS. Secondly, several important component suppliers are not included in the transport-related ICB sectors, but are allocated to other socio-economic sectors (e.g. industrial machinery). Thirdly, some companies included in a transport-related ICB sector have significant activities outside of the transport sector or of a certain transport mode. To remedy this, a 'bottom-up' approach has been applied that analyses R&D investments on the basis of individual companies including also players from outside the transport-related ICB classes. This approach also allows some substantiated estimations on the part of R&D investments that are dedicated towards specific objectives (e.g. reduction of GHG emissions) and/or technologies. This is the basis for the assessment in section 5.3. Note, however, that the quantitative assessment performed here is associated with some uncertainties. Moreover, its results are likely to represent an underestimation of the actual transport-related innovation activities, due to knowledge inflows from other sectors (see Box 2 below).

Box 2 - Knowledge spillovers into the transport sector

In addition to the significant innovation activities carried out by transport companies of various kinds, the knowledge base of the sector benefits from research activities carried out by companies that are not primarily allocated to transport. This includes, for example, progress in research on materials (e.g. light-weight composite materials), informatics (Intelligent Transport Systems) or within the energy sector. In particular, research undertaken into transport fuels by e.g. oil companies, is not considered in the present study. At the same time, there are important knowledge inflows from research funded by military funds, in particular in aeronautics but also the waterborne sector.

Also major consumers of transport services, in particular large retail companies are likely to spend a part of their R&D investments for the improvement of the supply chain logistics. The total R&D investment of EU-based companies – such as Tesco, Metro, Delhaize and Marks&Spencer – included in the ICB classes 'food retailers' and 'general retailers' in the EU Industrial R&D Investment Scoreboard amounted to € 830 million in 2008, even though one can assume that the majority of this is dedicated towards improvements of their products or processes and only limited parts are relevant for transport research.

The present quantitative assessment captures transport-related R&D investment not only from manufacturers but also companies in the supply chain. Moreover, it explicitly addresses a wide variety of companies offering transport services and construction companies involved in the building and maintenance of transport infrastructures. However, it cannot fully capture all knowledge inflows mentioned above.

There are also important spillover effects between and within modes. This does not change the overall figures provided here for transport R&D investments, but need to be considered when interpreting the results by mode.

5.1 Synthesis

Key findings

- A detailed analysis of 172 EU-based companies active in transport research found a total corporate investment in transport R&D of more than € 39 billion in 2008, making it the largest industrial R&D investor in the EU. This result is confirmed by a more coarse estimation following the ICB classification scheme, according to which the EU transport industry invested € 40.8 billion in R&D in 2008. Actual investments may even lie above these figures since it forms the aggregate of a limited number of actors only, yet includes the major R&D investors.
- EU-based transport companies hold a large share in global transport-related R&D investment, followed by companies with headquarters in Japan and the USA. Considering the global nature of the transport industry with many of its players acting at world level, this geographical allocation is, however, of limited significance.
- The economic downturn had a significant impact on the R&D investment of EU-based transport industries, which were reduced by more than 6%. However, R&D investments decreased less rapidly than overall net sales. Figures for 2010 indicate that R&D investments have recovered and even exceed their 2008 levels in the year 2010.
- Transport R&D investments (and net sales) were reduced most drastically in US-based companies, whereas only Chinese and Korean saw an increase in both sales and R&D investments.
- Corporate R&D investments are highly concentrated in few companies. In 2008, only 32 companies accounted for around 80% of the world R&D investment in transport. This is even stronger for the EU where 80% of the R&D investment is due to the contribution of only 15 companies.
- Research efforts of the automotive industry – and herewithin in particular those of the car manufacturers – are clearly dominating, followed by those of the aviation sector. R&D investments in rail and waterborne are more limited, comparing the absolute values with road and air.
- R&D intensities in sectors involved in the manufacturing of transport equipment are relatively elevated. In particular, the civil aviation manufacturing industry shows a high R&D intensity (7.8%), followed by the manufacturers of passenger cars (5.3%) and automotive suppliers (6%). R&D intensities are less elevated for manufacturers of commercial vehicles (3.5%), the rail (3.9%) and the waterborne (3.2%) manufacturing industries.
- Actors involved in offering transport services as well as construction companies show a low R&D intensity (0.3%), confirming the theoretical assessment that they have low incentives to innovate. At the same time, these are the actors that often foster non-technological and cross-modal innovative solutions.
- Companies active in the development of ITS solutions show a very high R&D intensity of 6.4%, reflecting the fact that innovation is a key selling factor.
- All modes dedicate an important part of their R&D efforts to technologies that can reduce emissions of GHG. For the road and civil aviation sector, this part has been estimated to be at least one third, and around 45% and 20% for waterborne and rail transport, respectively.

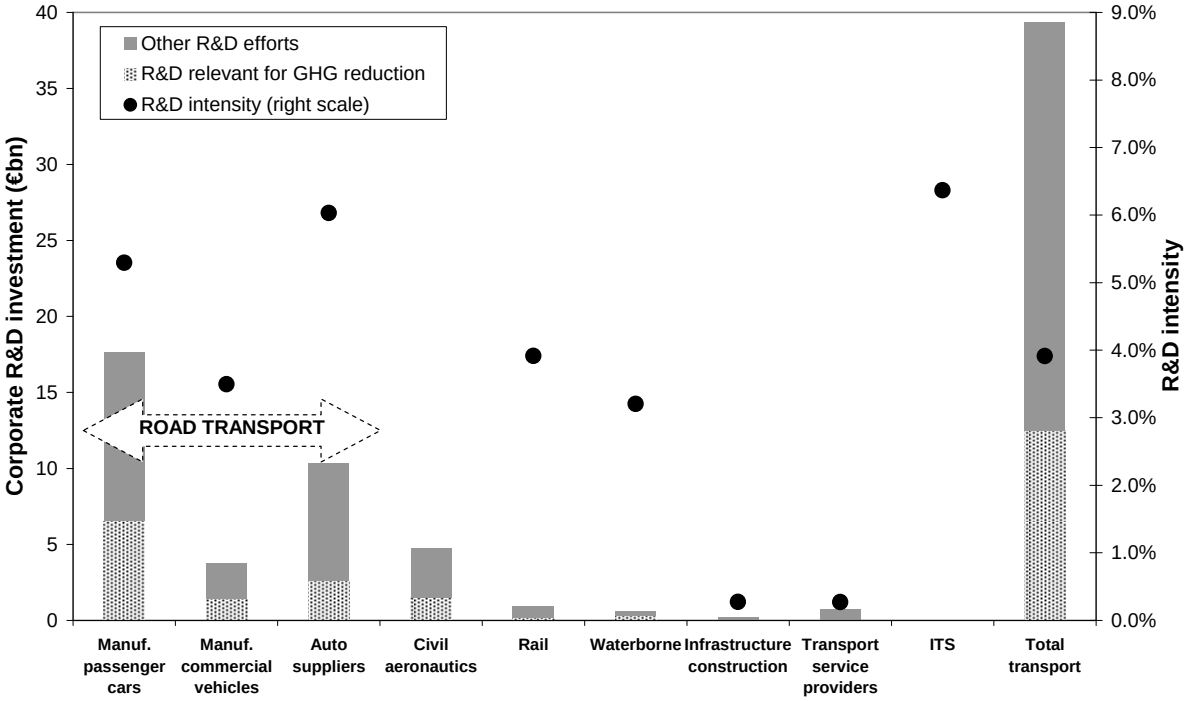

Figure 19: Total R&D investments (and the parts dedicated to GHG emission reduction) and R&D intensities from EU-based companies in different transport sub-sectors (estimates for 2008)
Source: JRC-IPTS bottom-up assessment using data from EU Industrial R&D Investment Scoreboard
Note: no estimates of the share of R&D relevant to GHG emissions reduction have been assessed for the manufacturers of passenger cars and commercial vehicles, for which we assume the same ratio as for automotive manufacturers. R&D intensity for civil aeronautics refers to own-funded research.

Policy conclusions

- The very distinct levels of R&D investments and of R&D intensities across modes underline the heterogeneous nature of the transport sector. Policy measures need to take into consideration this diversity and be adapted to the specific needs of each mode and sub-categories therein (e.g. differentiation between freight and passenger transport).
- The very elevated R&D investments of the automotive and aviation sector indicate that there is limited need for public policy to stimulate innovation in these industries in general (which does not imply that there is not a need for public action for pushing R&D in selected technologies).
- The lower R&D intensities in the providers of transport services and construction companies may imply a need for stimulating innovation in these sectors, in particular considering their role in fostering more systemic innovations, such as intermodality applications and advanced logistics.
- Already today, environmental innovations receive a large part of the overall corporate R&D investments, in particular those into technologies that can reduce GHG emissions. This can be seen as a response to tightened policy standards and changes in consumer preferences, but it is unclear whether this is sufficient for developing those technologies that are in line with EU climate change mitigation targets.

5.2 Corporate transport R&D investments in 2008 and 2009 (by ICB class)

The objective of this section is to provide a first estimate of the R&D investments allocated to the transport sector at world and regional level (EU-27, USA, Japan and Rest of the World RoW). The EU Industrial R&D Investment Scoreboard is used as a central dataset for this exercise. In this section (unlike in the ones following) the ICB classification has been respected. For the transport sector, the most relevant ICB industry sectors are 'Automobiles & parts', 'Commercial vehicles & trucks[24]', 'Aerospace & defence' and 'Industrial transportation', which are the categories analysed in the present chapter. For a more thorough analysis, we have split the 'Automobiles & parts' sector into two subsectors namely 'Automotive manufacturers' and 'Automotive suppliers'[25]. In the following, we will thus assume the 'transport' sector as the grouping of the above-mentioned ICB categories. It is important to bear in mind three important points:

- The figures are derived from a limited number of companies only. The transport sector as defined here contains 104 EU-based companies and 101 non-EU-based companies for the year 2008 (respectively 104 and 108 in 2009). Even though these are the largest R&D investors, the limited number of actors considered means that the actual figure would be even higher.
- Even if the ICB categories considered here cover a wide number of key companies active in transport-related research, other ICB categories can include important firms playing a key innovation role into one or several transport modes. It is the case for instance of Alstom (cat. 'Industrial machinery'), Siemens (cat. 'Electric components & equipment') and all energy suppliers (e.g. biofuels, hydrogen, battery producers).
- By definition, the regional (country) figures relate to the companies with their headquarters in this region (country).

R&D investment (€ bn)	World		EU		Japan		USA		RoW	
	2009	2008	2009	2008	2009	2008	2009	2008	2009	2008
Automotive manufacturers	46.2	53.1	18.9	20.9	17.3	19.3	7.7	11.1	2.3	1.7
Automotive suppliers	16.6	19.6	8.5	9.5	5.5	6.1	2.2	3.6	0.4	0.3
Commercial vehicles & trucks	6.7	6.8	2.3	2.4	0.9	0.9	2.7	3.0	0.7	0.6
Aerospace & defence	15.0	15.6	8.0	7.5	0.1	0.1	6.4	7.4	0.6	0.6
Industrial transportation			0.4	0.4						
Transport (sum of the above)	85.0	95.5	38.2	40.8	23.8	26.4	19.1	25.1	4.0	3.2
All industries	409.3	430.8	130.0	130.4	88.6	93.9	137.9	159.2	52.7	47.5
Share of 'Transport'	*20.8%*	*22.2%*	*29.4%*	*31.3%*	*26.8%*	*28.1%*	*13.8%*	*15.8%*	*7.6%*	*6.8%*

Table 4: Corporate R&D investments related to the ICB transport-related categories (2008 and 2009)
Data source: EU Industrial R&D Investment Scoreboard (JRC-DG RTD, 2009, 2010)

Table 4 summarises the level of R&D investments of the relevant transport-related ICB sectors for the years 2008 and 2009. In 2008, the 205 transport-related companies considered at the global level invested almost € 96 billion (i.e. € 10 billion more than in 2009; see sections 5.3.2.4 and 5.4 for a more detailed analysis of the impact of the crisis) thus accounting for 22% of the total industrial R&D investment, which makes it one of the largest R&D investor worldwide[26]. Within this total, EU-based

[24] The ICB category 'commercial vehicles and trucks' is not exactly the same as the category 'manufacturers of commercial vehicles' in our bottom-up assessment since the latter only focuses on road, whereas the ICB category also includes manufacturers of rail cars, non-military ships and heavy agricultural and construction machinery (see Table 14). However, actual data show that manufacturers of road commercial vehicles are dominant in that category in the EU Industrial R&D Investment Scoreboard.

[25] Note that in the ICB classification 'Automobiles & parts' is generally divided into 'Automobiles', 'Auto parts' and 'Tires'. In this chapter, tyre manufacturers are assumed to be part of 'Auto parts'. This is mainly motivated by the fact that key companies such as Continental cannot be simply classified as 'tyre manufacturers' since their R&D efforts go well beyond tyre manufacturing.

[26] This ranking depends on the sector or group of sectors forming part of a given activity. For instance in 2009, the ICB sector 'Automobiles & parts' was the second largest investor worldwide (15.4% of the total, just behind 'Pharmaceuticals' with 16.4%), the largest in Europe (21.1%) and Japan (25.7%) but only the fifth in the US (7.2%) and sixth for the rest of world (5.1%).

firms show the highest contribution with an aggregated R&D investment accounting for 43% of the total (45% in 2009, see Figure 20) followed by Japanese and US-based companies with 28% and 26% respectively. Note that the share of other regions of the world (essentially South Korean and Chinese companies) in the total R&D investment has increased from 3% in 2008 to 5% in 2009.

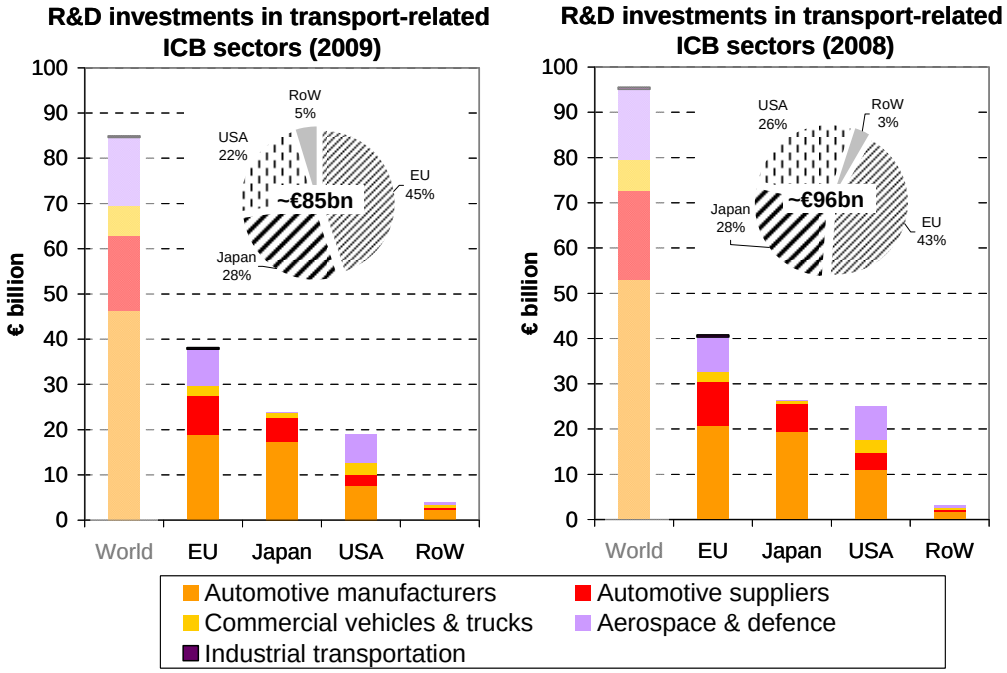

Figure 20: Corporate R&D investments of different transport-related ICB categories in 2008 and 2009
Data source: EU Industrial R&D Investment Scoreboard (JRC-DG RTD, 2009, 2010)

In Europe, the 104 companies listed in the EU Industrial R&D Investment Scoreboard active in transport invested around € 41 billion in 2008 . European-based automotive manufacturers invested approximately € 21 billion followed by automotive suppliers with some € 9.5 billion and the aerospace and defence industries (€ 8 billion). Hence, the EU transport sector represented 31% of the total EU industrial research in 2008 (29% in 2009), with some differences between Member States (e.g. transport-related companies account for around half of the total industrial R&D in Germany according to the EU Scoreboard). This makes the sector the largest R&D investor in Europe, largely due to the automotive industry. For comparison, the transport sector accounted in 2008 for 28% of the total industrial R&D investment in Japan, 16% in the US and around 7% for the rest of the world.

The recent economic downturn has certainly had an impact on the R&D investment of EU-based transport industries, which reduced their R&D investments by more than 6% between 2008 and 2009 (see section 5.4). Nevertheless, R&D investments have decreased less rapidly than overall activity volumes and sales. Transport R&D investments (and net sales) were reduced most drastically in US-based companies, whereas only Chinese and Korean saw an increase in both sales and R&D investments. According to more recent data, R&D investments from EU-based automotive industries have been rising again in the year 2010 are back to the year-2008-levels.

Figure 21 displays the cumulative 2008 R&D investments realised by the 205 worldwide companies that form part of the above-mentioned 'transport' sector. The top ten companies[27] accounted for around half of the total of R&D investment of this sector. When expanding this list by another eleven companies[28], it would cover 70% of the total R&D investment and 80% if we add another eleven. This concentration is more remarkable in the EU, where 15 EU-based companies invested more than 80%

[27] Toyota, Volkswagen, GM, Ford, Honda, Daimler, Robert Bosch, Nissan, BMW, EADS
[28] Boeing, Denso, PSA Peugeot Citroen, Renault, Fiat, Finmeccanica, Continental, Volvo, Delphi, United Technologies, Hyundai Motor

of the total industrial transport R&D investments. are due to the contribution of only . Many of these large transport R&D investors have their registered headquarter in Germany, France, or Italy.

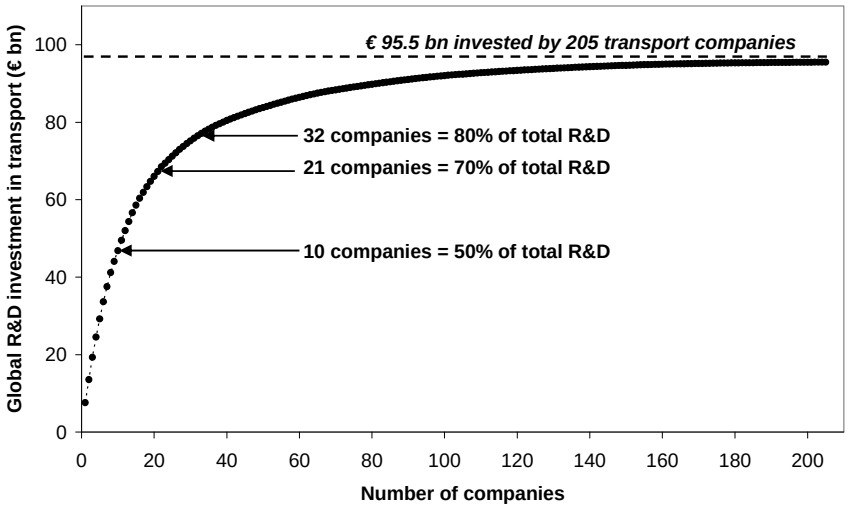

Figure 21: Cumulative R&D investments of transport-related companies worldwide (2008)
Data source: EU Industrial R&D Investment Scoreboard (JRC-DG RTD, 2009)

Automotive manufacturers invested € 53 billion in R&D in 2008, derived from the assessment of 30 companies worldwide. Almost 40% (i.e. € 21 billion) were due to companies with their headquarters in the EU (mainly Germany; France and Italy), 36% from Japan and 21% from US-based firms (reduced to 17% in 2009). At world level, twelve groups namely Toyota, Volkswagen, General Motors, Ford, Honda, Daimler, Nissan, BMW, PSA Peugeot Citroën, Renault, Fiat, and Hyundai accounted for 90% of the total R&D investment. In the EU, six car manufacturers accounted for 95% of the total R&D expenses, namely Volkswagen, Daimler, BMW, PSA, Renault and Fiat.

In 2008, worldwide automotive suppliers invested almost € 20 billion, stemming from the R&D efforts of 80 companies. The largest investors for this year were Robert Bosch, Denso, Continental, Delphi, Aisin Selki, Valeo, Bridgestone, ZF, etc. At EU level, Robert Bosch, Continental, Valeo and ZF are the EU automotive suppliers that invested the most in 2008[29], with Robert Bosch accounting for 41% of the total R&D investment in 2008.

The R&D investment of the ICB sector Commercial vehicles and trucks reached some € 7 billion in 2008, based on the assessment of 32 firms amongst which Volvo, Caterpillar, Deere, Isuzu Motors, MAN and Komatsu were the largest investors. In Europe, 80% of the total R&D investment of this sector was due to Volvo (62%) and MAN (18%).

The Aerospace and defence sector spent € 15.6 billion in R&D in 2008. This figure is based on the assessment of 53 world firms amongst which EADS, Boeing and Finmeccanica are the largest investors accounting for almost half (46%) of the total R&D investment. In Europe, 60% of the 2008 R&D investment stems from EADS and Finmeccanica. It is worth mentioning that the 'Aerospace & defence' ICB sector is the only transport sector for which R&D investments have increased between 2008 and 2009 (from € 7.5 billion in 2008 to € 8 billion in 2009).

The R&D investment of the ICB sector Industrial transportation reached some € 430 million in 2008, based on the data from 12 firms with headquarters in the EU. Note that at the non-EU level, this ICB class does not contain any companies. The companies with the most elevated R&D investments in 2008 were Deutsche Post (DHL), SNCF, Poste Italiane and TNT. The average R&D intensity if this sector amounted to 0.3% in 2008 and 2009.

[29] Note that R&D expenses of Faurecia and Magneti Marelli (key EU automotive suppliers, part of the PSA Group and Fiat Group respectively) are included within the 'Automotive manufacturers' category. This will no longer be the case with the bottom-up approach described in section 5.3.

5.3 Corporate R&D investments by transport sub-sector (bottom-up approach)

5.3.1 Methodology

The following analysis of corporate R&D investments builds on a bottom-up approach at the level of individual companies. This approach (documented and discussed in Wiesenthal et al., 2011) consists of the following five steps:

Step 1: Identification of key industrial players by sub-sector and/or technology group.

Key industrial players and innovators in the transport sector and by technology (group) were identified. Identifying them one by one instead of relying on the classification by sector allows companies from ICB sectors that are not necessarily transport-related to be considered, such as industries that act in the supply chain. In total, more than 250 relevant companies have been identified. Note, however, that since the lists of key companies are not exhaustive, neglecting minor players that might, in sum, provide a far greater R&D commitment, they tend to underestimate the total R&D efforts dedicated to transport technologies.

Step 2: Gathering of information on R&D investments

The overall R&D investments in the year 2008 had to be identified for the companies selected. The most important data input are the companies' financial statements that are published in their annual reports. This information is collected in the EU Industrial R&D Investment Scoreboard, which is therefore used as the most important single data source. To the extent possible, gaps in the information of the EU Industrial R&D Investment Scoreboard have been filled through a systematic research of annual reports or other information for those companies that are not obliged to publish their financial reports. For 172 of the companies identified in step 1 – including almost all large ones – the R&D investments in the year 2008 could be identified.

Step 3: Estimation of non transport related R&D activities and breakdown by sub-sector.

Even though many of the companies identified are exclusively active in the transport sector, a number of large companies also have substantial activities in non-transport sectors. This is the case in particular for large supranational companies such as Bosch, Siemens, Alstom, etc. For those players, assumptions had to be made on the parts of their overall R&D activity that are directed towards transport. In a number of cases, this figure can directly be derived from official sources. In other cases, it was approximated by e.g. the turnover of the various branches, thus including some uncertainty to the results. Furthermore, for companies active in more than one transport mode an allocation of the R&D investments by mode were performed.

Step 4: Estimation of R&D investments for GHG emission reduction and single technologies.

A further breakdown to activities that aim are reducing GHG emissions and those that rather aim at enhancing safety or comfort has been introduced. Note that an intermediate 'instrumental' step often had to be performed, focusing on R&D investments into 'environmental technologies', as for this sub-group, more information was available than for 'GHG emission reduction technologies'. In a final step, an even further breakdown of the research efforts to distinct technology groups and individual technologies has been aimed at in the road transport sector.

This allocation requires additional information as there is no data available at this level of detail. To this end, companies' annual reports and corporate sustainability reports were systematically searched for indications on the breakdown of R&D investments. Moreover, the websites of individual companies and associations were screened for further information, enhanced by free searches that delivered additional information in the form of e.g. presentations and speeches from company key actors or press releases.

In the easiest cases, this additional information revealed the allocation of the R&D investment to the different technologies. For most companies, however, the R&D expenditures could be narrowed down

to a particular field (e.g. 'GHG emission reduction') with certain accuracy but then needed to be further split between the various technologies based on qualitative information. In those cases, some substantiated estimates based on expert knowledge had to be performed in order to allocate their R&D investment to single technologies.

These estimates build on a number of indirect indications, such as the number of researchers by field that allowed a rough estimation of the R&D investments by applying an average R&D investment per research employee. An average investment of € 120-160k per research employee was found to be a suitable proxy based on information from 67 companies or research centres (Leduc et al., 2010). This range was then used for further estimates, unless more precise figures could be obtained for the specific company. Other companies announced future R&D investment plans, which were subsequently 'extrapolated' to the 2008 data. In other cases, figures on the net sales of various business units could be identified and helped to narrow down relevant R&D investments.

The use of patents (or patent applications) proved to be one of the most important tools in approximating the R&D investments by technology group. Based on the assumption that patents may reflect a company's research effort, the distribution of patents across the relevant technologies was used as a proxy for the distribution of its R&D expenditures. Linking input indicators such as R&D spending to output indicators (such as patents) entails a number of problems as the transport sector' includes a broad variety of technologies and industries with different characteristics regarding the research intensity needed for a patent and the propensity to patent. As a consequence, the average R&D intensity per patent may differ considerably between technologies. Companies may also decide to classify or label patents in a way that makes it difficult to detect them with the patent search scheme applied here. Despite these general constraints regarding the use of patents, they may nevertheless be used as a rough indicator within the scope of this analysis, taking into account that studies show a strong correlation between the number of patents granted and the R&D investments (Popp, 2005; Kemp and Pearson, 2007, Griliches, 1990)[30]. In general, there is the consideration that patents are a good indicator of the direction of research and of the technological competencies of firms (Oltra et al., 2008). Furthermore, with regard to the special sector in question, patents are much more accessible than any information of research efforts by technology, as the automotive industry is the industry which protects the most its innovation with patents[31].

Certainly, one needs to keep in mind the time delay between R&D inputs and outputs. Investments in research need some years before it materializes in the form of patents or patent applications. Hence, using patent data from the latest available years (2007/2009) as a proxy for the R&D investments in the year 2008 leads to a systematic error. Despite the uncertainties resulting from this procedure, it is still considered a valuable input to the assumption-based allocation process when having in mind that its outcome will not be able to deliver more than an estimation of the order of magnitude.

Two distinct patent analyses have been used in the present work, as described in the following section when giving detailed information on the search of patent applications. Not only the patent search, but also its application as a proxy for the R&D investment breakdown follows a two-track approach. Firstly, we determine the share of patents on a certain technology in relation to the overall patents of a company as an indication of their share of research efforts in this technology. Alternatively, we use the relative distribution of patents across the different low-carbon technologies as an indication for the relation of the R&D efforts among them. This latter approach makes sense in those cases where – from other approaches or literature – the R&D investment in one technology had been determined before with a reasonable degree of uncertainty, stemming e.g. directly from company sources.

To the extent possible, several of the above mentioned approaches have been combined for individual companies in order to reduce the uncertainty of the estimates. Nevertheless, the allocation process proves to be the greatest source of uncertainty in the present work.

Step 5: The summing up of the individual companies' R&D investments by mode, technology group and single technology.

[30] Popp (2005) shows that patents are a suitable mean for obtaining R&D activity in highly disaggregated forms.
[31] 42.5% of firms of the industrial sector 'Motor vehicles' protect their innovation with patents (Oltra et al., 2008).

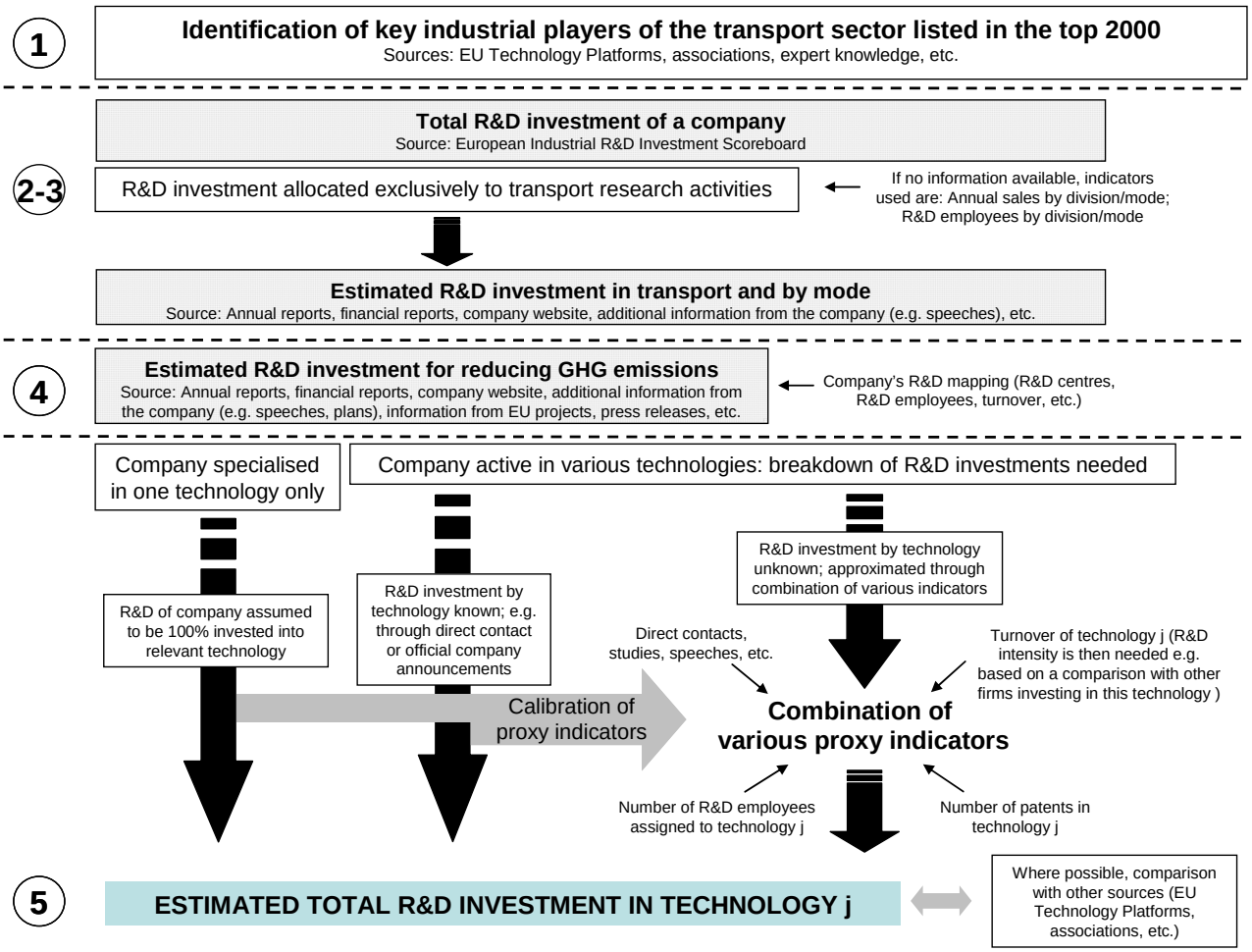

Figure 22: Schematic overview of the methodology

5.3.2 Automotive industry

5.3.2.1 Overall R&D investments

The corporate R&D investments of the EU automotive industry reached € 31.7 billion in 2008. This is the result from the analysis of 66 EU-based companies that are key players in this sector. Their aggregated net sales were around € 610 billion in 2008[32]. This leads to a R&D intensity of 5.2% for this sector.

It does not come as a surprise that the EU automotive manufacturers are by far the most important investors with almost € 21.5 billion spent in 2008 associated with net sales of approximately € 440 billion. These figures indicate that the R&D intensity of the EU automotive manufacturers has been around 4.9% in 2008. In order to account for the systematic differences between road freight and road passenger transport, we further disaggregated the research efforts of EU manufacturers into those related to passenger cars[33] and to commercial vehicles (trucks, buses and vans). This distinction required to examine the R&D investments allocated to the different divisions of a parent company (e.g. Iveco for Fiat, Scania and vans for Volkswagen, Daimler trucks, etc.). The following results have been found:

- Out of the € 21.4 billion spent by the EU automotive manufacturers in 2008, we estimated that € 3.7 billion (i.e. 17% of the total) was invested in R&D in commercial vehicles with a turnover of around € 107 billion[34] in 2008. The R&D intensity of this segment has then reached 3.5% in 2008. The R&D investments of the passenger cars segment represent the highest share with € 17.6 billion invested in 2008, along with a turnover of approximately € 330 billion (R&D intensity of 5.3%). The substantially higher levels of R&D investment volumes together with the higher R&D intensity of car manufacturers compared to manufacturers of commercial vehicles can be explained by the very distinct nature of road passenger and road freight transport (see Part I).
- The EU automotive suppliers invested at least € 10.3 billion in 2008 with a turnover of almost € 172 billion. It should be noted that this figure is an underestimate since not all EU automotive suppliers have been included in the present analysis[35]. This sector presents the highest R&D intensity within the automotive industry with 6%.

5.3.2.2 How much is spent for reducing GHG emissions?

The automotive industry devotes a large share of its R&D investments on R&D activities directly or indirectly targeted at reducing the energy consumption/GHG emissions of road vehicles[36]. This share has been assessed for the major EU-based companies of this sector, based on information or indication from a wide range of sources (companies' annual and sustainability reports, speeches, direct contacts, reports, etc.). Unfortunately, although there is consensus among the actors to claim that 'most' of their R&D investments is dedicated to reduce the 'environmental impact' or to develop 'green' or

[32] This represents a very large fraction of the total turnover for the manufacture of motor vehicles, trailers and semi-trailers, which was close to € 800 billion according to Eurostat (2011), even though methodological differences impede a direct comparison.

[33] R&D investments on two-wheelers are included in this category (we estimated this contribution to be in the order of € 250 million in 2008, see Leduc et al., 2010).

[34] Analysis based on annual figures from Daimler Trucks (Mercedes), Daimler vans and buses, Fiat (Iveco), Volvo (Volvo Trucks and Buses, incl. Renault Trucks), Volkswagen (Scania and VW commercial vehicles), MAN (commercial vehicles).

[35] R&D investments of Faurecia (PSA Group) and Magneti Marelli (Fiat group) have been assigned to the automotive suppliers segment here.

[36] Some research efforts that results in enhanced fuel efficiency or decreased weight etc. may have been motivated by other than environmental considerations, e.g. to increase the 'joy of driving', and may be (partly) outweighed by more performing cars etc. Nevertheless, the technology can save GHG emissions and is therefore allocated to this group for the purpose of the present exercise.

'environmentally-friendly' technologies, there are very limited available information about a precise level of investments in this domain.

According to our research, it has been estimated (as a proxy) that around 43% of the total R&D investment of the private sector in 2008 was spent to reduce the environmental impact of this sector, i.e. including research on GHG emissions reduction and air quality. When differentiated between automotive manufacturers and suppliers, this share reaches 45% and 38% respectively. These findings are supported by the collection of official statements from companies (web-based research; see Box 3). Moreover, the French Patent Office (INPI, 2007) reports that 40% of the patent applications of the automobile industry relates to environmental issues (the rest being allocated to safety and comfort issues with 35% and 25% respectively).

In a second step, R&D efforts for reducing GHG emissions have been estimated. They amounted to some € 10-11 billion, i.e. approximately 32-35% of the total R&D investments in 2008. Different 'low-carbon' technology areas in which these investments are directed to, will be analysed in more detail in section 7.2.

5.3.2.3 Comparison with literature

Figure 23 below summarises private R&D investments reported by recent sources or studies with regard to the **automotive industry**. Despite the discrepancies in the approaches across the different datasets (methodology, geographical coverage or classification used), which render a direct comparison difficult, Figure 23 proves that our results are well supported by other studies.

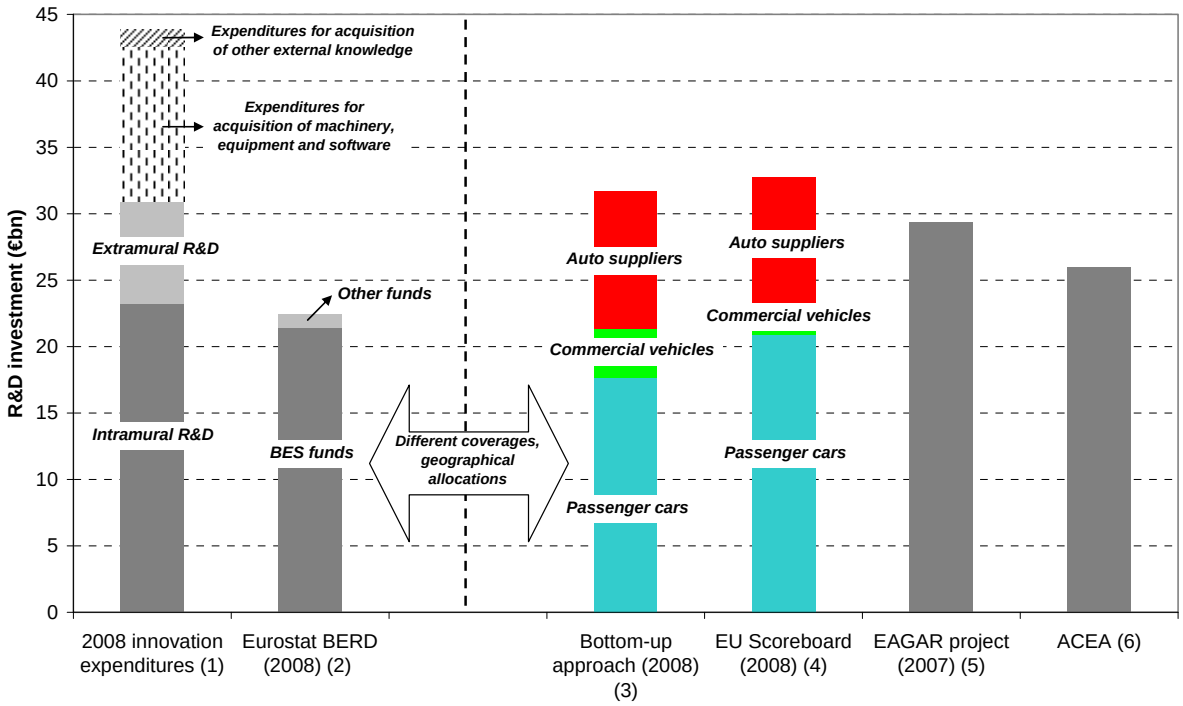

Figure 23: Innovation and R&D expenditures of the EU automotive industry

Source: JRC-IPTS derived from:

(1) Eurostat CIS survey 2008 (EU27 without MT, UK and GR). Missing data for GR and UK have been completed with BERD figures (intramural R&D only). Data retrieved in January 2011.

(2) Eurostat BERD (EU27 minus LU and FI) for the NACE R1 DM34 sector 'Manufacture of motor vehicles, trailers and semi-trailers'. Gap-filling has been applied from previous years.

(3) Results from our bottom-up analysis.

(4) EU Industrial R&D Investment Scoreboard (JRC-DG RTD, 2010) for the ICB sectors 'Automobiles & parts' (further split into auto manufacturers and suppliers) and 'Commercial vehicles & trucks' (see section 5.2).

(5) It relates to the automotive industry (EAGAR, 2010).

(6) See e.g. ACEA website, EUCAR (2010). It refers to the annual R&D investment of the 15 ACEA members in Europe.

- As shown on the left side of the chart, the innovation expenditures provided by the Community Innovation Survey have been analysed. These include not only intra- and extra-mural R&D, but also expenditures for the acquisition of innovative machinery and of external knowledge, etc. R&D expenditures nevertheless account for a large part (70%) of the total innovation expenditures. Intramural R&D expenditures (more than half of the total innovation expenditures) are well in line with the BERD results presenting an overall R&D expenditure (all funds) of € 22.4 billion in 2008.
- The Eurostat/OECD BERD (Business enterprise sector's R&D expenditure) database has been consulted to assess the R&D expenditures of the automotive sector in the EU. BERD contains data on the business enterprise sector's expenditure in R&D for different socio-economic objectives following the NACE R1 DM34 sector 'Manufacture of motor vehicles, trailers and semi-trailers'. The R&D expenditures are given by sources of funds, disaggregated into business enterprise sector (BES), government sector (GOV), higher education sector (HES), private non-profit sector (PNO) and abroad (ABR). The business enterprise sector BES is more comparable to the central bottom-up approach of this report that looks into the R&D investments that stem from the companies' funds. Note that data from the Eurostat BERD database have been manipulated in order to fill data gaps in the latest available year 2008 with data from previous years where available.
- As somewhat expected, the results from the present bottom-up approach are in the same order of magnitude of those that are directly extracted from the EU Scoreboard (ICB-based classification), even though the ICB category 'commercial vehicles and trucks' as used in the EU Scoreboard shows lower R&D investments than those estimated by the present assessment.
- Recently, an assessment of R&D expenditures in the automotive sector has been carried out in the context of the EU FP7 project EAGAR (EAGAR, 2010). Even if the emphasis is put on public automotive R&D for the year 2007, the level of private automotive R&D spending has been estimated for 13 Member States[37], showing an aggregated R&D investment of almost € 30 billion for the EU in 2007 (intramural expenditures). Having in mind the methodological differences between both approaches, this figure is very close to the € 31.7 billion estimated in the present work.
- Finally, key EU organisations have assessed the level of R&D investment of the automotive sector. Both the European Automobile Manufacturers' Association (ACEA) and the European Council for Automotive R&D (EUCAR) recently reported that 'the fifteen ACEA members together spend over € 26 billion every year on R&D, or about 5% of their turnover'[38]. Considering that additional R&D investments from non-EU based companies are included in their assessment, this figure is somewhat in line with the results found in the present study. Furthermore, the European Association of Automotive Suppliers (CLEPA) reported that automotive suppliers in Europe present an annual R&D spending of € 12 billion (CLEPA, 2009), which is also in the same order of magnitude of the present analysis.

[37] Germany, France, Spain, Austria, the Netherlands, Belgium, Sweden, Poland, Italy, Czech Republic, UK, Slovenia, Greece.

[38] From the ACEA website and EUCAR (2010). See also EUCAR (2009, 2008) and ACEA (2009) for further information on automotive R&D.

Box 3 - What can be found from a web-based research?

As shown previously, the automotive industry is the largest investor in R&D in Europe with almost € 32 billion spent in 2008. This huge investment is essentially targeted to develop safer, more intelligent, more comfortable and of course 'greener' vehicles. The last objective is doubtless the most important challenge the automotive industry is currently facing. Most of the actors in this area, namely automotive manufacturers and suppliers, agree to say that a '*large share*' or '*most of*' the corporate R&D investment is allocated for improving the vehicle energy efficiency and then reducing greenhouse gas emissions. For instance, the ACEA[39] reported that 'A large part of the R&D investments is spent on technologies to reduce emissions of greenhouse gases such as carbon dioxide (CO_2)'. But how much exactly? What about the evolution of this share in the near future?

Except in a few cases, no accurate figure is disclosed about the real share of R&D investment going to GHG emissions reduction and its (supposedly) growth over the last years. Assessing the precise share of the total R&D allocated to GHG emissions reduction is very difficult; instead, only rough estimates can be obtained. In those cases where we obtained more precise information, this shall be shown in the following.

Thomas Weber (Daimler) reported that Daimler spent € 4 billion in R&D of which half going to green technologies, CO_2 emission reduction and Euro 6 standard[40]. In September 2008, a similar press release confirmed this information saying that 'Daimler has raised the share of its investments in more economical vehicles from 25 percent to 60 percent. At Volkswagen and BMW, one in every two euros goes into environmentally friendly technologies'[41]. At the same date, C. Ghosn (Renault) claimed that the Alliance Renault-Nissan allocated one third of its R&D expenditures to clean vehicles, with the priority going to zero emission vehicles[42]. In November 2009, G. Faury (PSA Peugeot Citroën) declared that the PSA group will allocate more than half of its R&D expenses over the period 2010-2012 towards new technologies for reducing CO_2 emissions and pollutants[43]. In its last annual report (2009), PSA Peugeot Citroën indeed reported that half of its R&D efforts is devoted to 'clean technologies' aiming at reducing the carbon footprint of vehicles. On their website, Bosch reports that 'in 2009, some 45 percent of Bosch's research and development budget again went into products that conserve resources and protect the environment' (see Bosch's annual report 2009).

At global level, a recent study from the consulting group Oliver Wyman reported that 'today, automakers are already investing about one-third of their worldwide research and development expenditure of some Euro 75 billion on this goal on these efforts, which include both further optimizing traditional combustion drives and developing alternative drive technologies for serial production. In the next ten years, investments in reducing carbon dioxide worldwide will total around Euro 300 billion – of which Euro 50 billion will be spent on alternative drive systems like hybrid or electric'[44].

With regard to patent applications of the automotive sector, the German Association of the Automotive Industry (VDA) stated that 'On average, the German automotive industry applies for ten patents daily, a good half of which are in the field of environmental engineering'[45].

Based on all these various 'official' announcements, there is evidence that the share of R&D spending allocated to GHG emission reduction is high, probably ranging from one third to more than half of the total R&D budget depending on the car manufacturer and the year considered. This gives an indication about the order of magnitude where our results should range.

[39] European Automobile Manufacturers' Association

[40] Interview of T. Weber (07/10/2008) available at: http://www.usinenouvelle.com/article/l-interview-thomas-weber-responsable-rd-daimler-et-mercedes-benz.148420

[41] http://www.atlantic-times.com/archive_detail.php?recordID=1460

[42] Interview of C. Ghosn, Le Parisien (02/10/2008) http://www.leparisien.fr/automobile/mondial-auto-2008/voiture-propre/renault-presente-sa-voiture-electrique-02-10-2008-263108.php

[43] Interview of G. Faury (27/11/2009) about the PSA vision about CO2 emissions reduction, originally released by the Financial Times. http://www.ccfa.fr/article87729,87729.html

[44] Oliver Wyman study 'E-Mobility 2025' (September 2009) http://www.oliverwyman.com/ow/pdf_files/ManSum_E-Mobility_2025_e.pdf

[45] VDA, Annual Report 2009 available at http://www.vda.de

5.3.2.4 Trend over the period 2003-2010

The evolution of both R&D investments and net sales of major EU-based automotive manufacturers is presented below for the period 2003-2010, split into the manufacturers of passenger cars and of commercial vehicles.

For the manufacturers of passenger cars, a stagnation of R&D investment levels (net of inflation) becomes apparent. When concentrating on more recent years, the annual fluctuations are obvious, mainly caused by the economic downturn in 2009 with a recovery thereafter. In total, however, annual fluctuations in R&D investment levels are significantly less pronounced than changes in net sales. This can be explained by some inertia as R&D investments are often planned for some time ahead, but also by the importance allocated to research in times of crisis.

Unlike the more or less stable trends observed for passenger cars, the manufacturers of commercial vehicles increased their R&D investments by 55% between 2003 and 2010, with some important annual variations. Fluctuations in R&D investment nevertheless remain small when compared to the significant changes in the net sales of the sector, which has been strongly affected by the economic downturn in 2009.

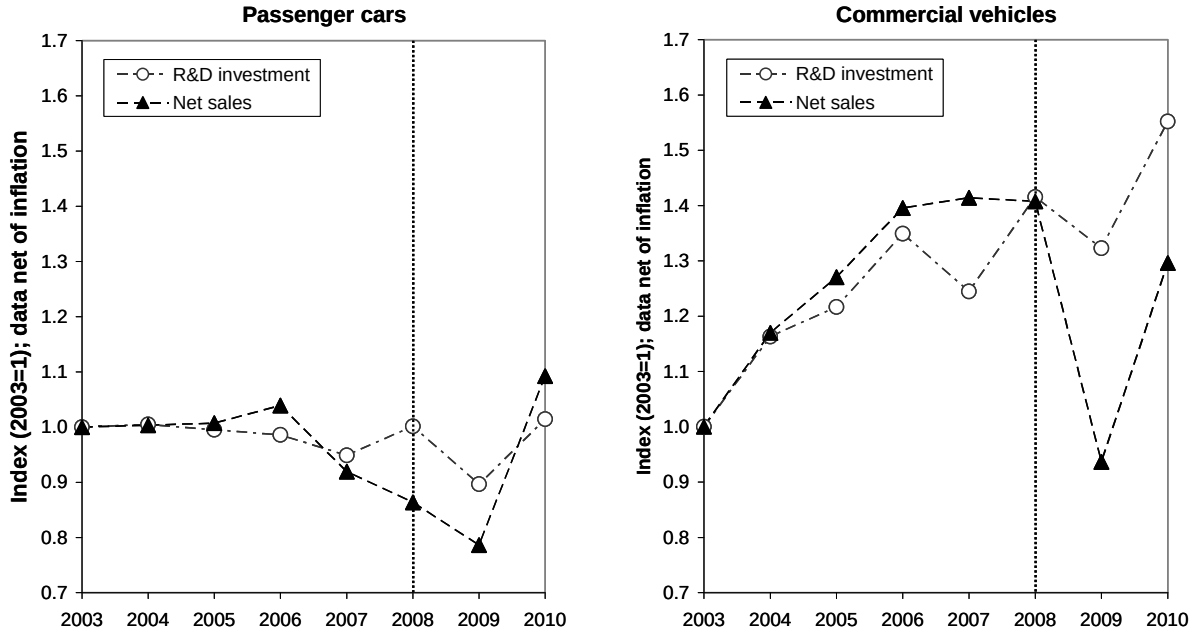

Figure 24: Variation of R&D investment and net sales of major EU automotive manufacturers (2003 = 1)
Data source: Companies' annual reports and EU Industrial R&D Investment Scoreboard for various years; data gathered at division level (see annexes) over the period 2003-2010.
Sample of manufacturers: Daimler, Volkswagen, Porsche, BMW, PSA Peugeot Citroen, Renault, Fiat, MAN, Volvo.

5.3.3 Civil aviation equipment manufacturing industry

5.3.3.1 Overall R&D investments

The analysis undertaken above in section 5.2 follows the ICB classification scheme. The related ICB category 'Aerospace and defence' includes research activities into aerospace (aeronautics and space) and defence segment; companies allocated under this category were found to invest € 7.5 billion in R&D in 2008.

In this section, we focus to the extent possible on the R&D investments of EU-based companies allocated to *civil aeronautics,* hence excluding military and space-related R&D activities. We focus on 20 EU-based companies that are key players of the civil aviation equipment manufacturing industry. Their net sales in 2008 exceeded € 61 billion and are well in line with the € 58.5 billion reported by the Aerospace and Defence Industries Association of Europe for the same year (ASD, 2009; Figure 25). Even though discrepancies in the geographical allocation schemes prevent a direct comparison, the net sales represent a large fraction of the total turnover of the € 86 billion characterising the sector classified in the Eurostat statistics as 'manufacture of air and spacecraft and related machinery' (Eurostat, 2011).

Companies' R&D investments into civil aeronautics reached around € 4.7 billion in 2008[46]. This compares reasonably well to figures derived from the ASD (2009) according to which company-funded investment on civil R&D reached some € 5.5 billion. Differences may to some extent by caused by the slight disparity in the regional coverage between the present study and ASD[47]. The R&D intensity of the civil aeronautics sector accounted to 7.8% in our analysis.

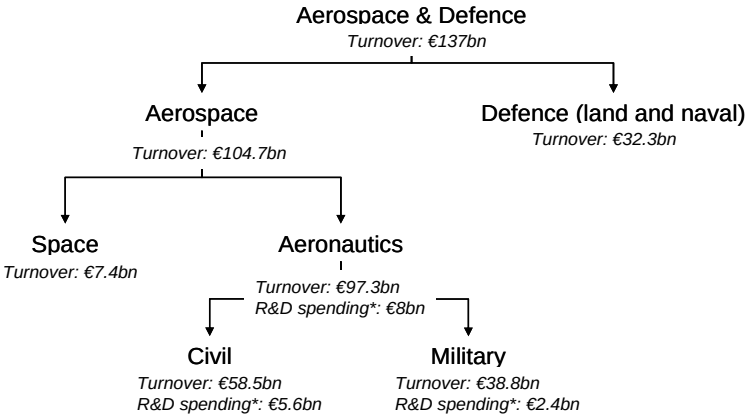

Figure 25: Overall turnover and R&D spending flows of the aerospace and defence sector in 2008
Source: adapted from ASD (2009)
** Company-funded R&D*

5.3.3.2 How much is spent for reducing GHG emissions?

At least one third of the € 4.7 billion is estimated to be directly invested for reducing GHG emissions. This significant amount highlights the increasing R&D efforts of the aeronautic industry to develop 'green' technologies. This is mainly driven by economic considerations linked to the importance of fuel costs in civil aviation, to the increasing importance of reducing GHG emissions in the aviation sector after its inclusion in the European Emission Trading Scheme, and to other environmental concerns, spanning from resource efficiency to local air pollution. The development of technologies that enhance energy efficiency and GHG reduction is now involving important R&D programmes of the main

[46] In line with other sectors, this figure comprises only company-funded sources (i.e. not taking into account government funding), which typically accounts for more than two thirds of the total R&D expenditure of the EU aeronautic industry and up to 82% for civil aeronautics (ASD, 2009).
[47] ASD covers 20 countries (EU15 minus Luxembourg, plus Bulgaria, Turkey, Czech Republic, Poland, Norway and Switzerland).

actors of the sector (e.g. EADS, Finmeccanica, Rolls-Royce, Safran). It links also with the commitment of the aeronautic industry to achieve the ambitious ACARE target of a 50% CO_2 reduction per passenger-kilometre in 2020 compared to a benchmark large civil aircraft from 2000 (with sub-targets assigned to different technology areas; see Annex IV). The technologies developed by the aircraft manufacturing industry to meet this objective (alongside safety improvements), relate to R&D activities on[48]:

- Advanced engines: engine manufacturers have been developing more fuel efficient and low-emission propulsion technologies. It is the case for instance of Rolls-Royce with the TRENT 1000 and future TRENT XWB, as well as Safran with the LEAP-X[49]. An important objective in this area is to achieve the ACARE engine target consisting of a 15-20% reduction in fuel consumption by 2020 compared to 2000 levels.
- Improved aerodynamics, weight reduction (e.g. composite materials), increased use of electrical energy, etc.
- Increased use of alternative jet fuels: second generation biofuels suited to the aviation sector (especially Hydrotreated Vegetable Oils and Biomass-To-Liquids) are likely to play a role in the reduction of CO_2 emissions of this sector in the medium term (see e.g. Akkermans et al., 2010). According to Airbus, aviation biofuels could power 30% of commercial aviation by 2030[50].
- Increased air traffic management efficiency (see e.g. the SESAR programme)

There is no doubt that significant fuel consumption reduction will be achieved by new commercial aircrafts (e.g. A380 and A350 XWB), as well as in other areas (see e.g. the Bluecopter technology developed by Eurocopter, part of EADS, that can significantly reduce the environmental impact[51]).

5.3.3.3 Comparison with other sources

For the air transport sector, the present analysis estimates the total R&D investment in civil aeronautics to have reached € 4.7 billion in 2008. The ICB category 'Aerospace and defence' of the EU Scoreboard shows a corporate R&D investment of € 7.5 billion in 2008 (and € 8 billion in 2009) out of which we estimated that around € 2.5 billion are directed to 'defence' research activities. The Eurostat BERD (BES funds) under the NACE R1 category DM353 'Manufacture of aircraft and spacecraft' indicates a total of € 4.4 billion for the same year (with gap-filling from previous years), while the figures derived from the ASD are in the order of € 5.5 billion for civil aeronautics and € 2.4 billion for military applications in 2008. The R&D intensities related to civil aeronautics research are high, ranging from 7.8% (bottom-up analysis) to more than 9% (based on ASD, 2009). The results are summarised in Figure 26 below.

A similar estimate (€ 4.5 billion), but for the year 2003, is also suggested in an article published by the American Institute of Aeronautics and Astronautics (AIAA), relying on information provided by an expert of the European aerospace industry (Butterworth-Hayes, 2005).

[48] See e.g. Hazeldine et al. (2009) and Hill et al. (2009) for a description of key options to reduce GHG emissions of this sector.

[49] The LEAP-X is actually developed by CFM International (50% Safran and 50% General Electric owned company).

[50] http://www.airbus.com/en/corporate/ethics/environment/alternative-fuels/

[51] www.bluecopter.com

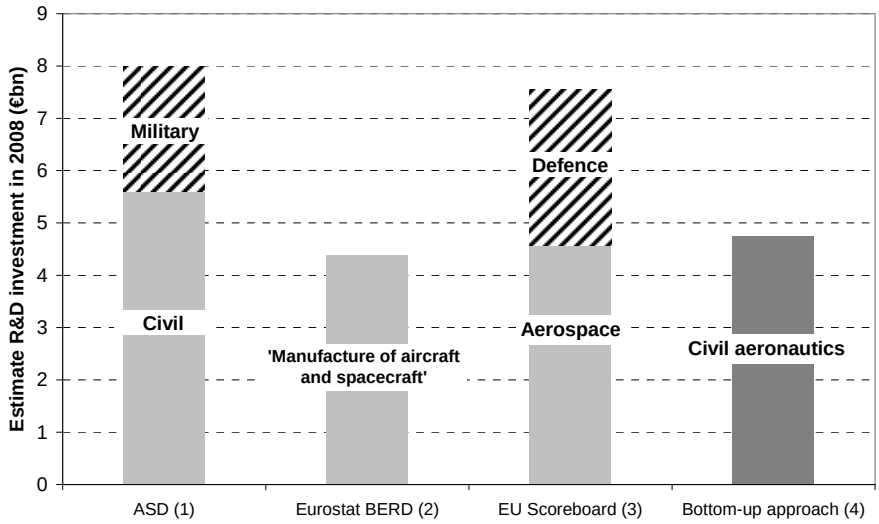

Figure 26: R&D investments of the EU air transport industry according to different studies (2008)
Source: JRC-IPTS, derived from:
(1) Aerospace and Defence Industries Association of Europe (ASD, 2009). It refers to the EU aeronautic industry (civil and military). ASD covers 20 countries namely EU-15 minus LU + BU, TR, CZ, PL, NO and CH.
(2) Eurostat BERD (BES funds only) related to the NACE R1 DM353 category 'Manufacture of aircraft and spacecraft'. Data have been gap-filled with previous years; figures are available for 16 EU MS (missing data for BE, DK, IE, GR, LT, LV, LU, HU, NL, FI and SE).
(3) Industrial R&D Investment Scoreboard (JRC-DG RTD, 2010) for the ICB sector 'Aerospace and defence'.
(4) Results from the current bottom-up analysis (civil aeronautics only).

5.3.4 Rail transport equipment manufacturing industry

5.3.4.1 Overall results

In Europe, rail-related research activities carried out by Siemens and Alstom represent by far the largest R&D contribution to the rail transport equipment manufacturing industry. The analysis undertaken here takes into account the corporate R&D expenditure from these two companies, together with 16 other EU-based companies that include several EU rail suppliers.

In 2008, the net sales of all these companies exceeded € 23 billion, a value that closely matches the Eurostat figure for the manufacture of railway locomotives and rolling stock (€ 23 billion) (Eurostat, 2011), provided that the missing figures for France and Italy are estimated using the net sales of the railway section of companies like Alstom, Thales and Finmeccanica.

The analysis carried out leads to an estimate of € 930 million spent in R&D in 2008, implying an R&D intensity of 3.9%.

5.3.4.2 How much is spent for reducing GHG emissions?

Out of the € 930 million, it was roughly estimated that € 170 million (almost 20%) were targeted at reducing GHG emissions. This is mainly resulting from important R&D programmes undertaken by Alstom and Siemens, which are the largest EU investors of this sector.

The relatively low share of R&D spending for GHG emission the rail sector can be partly explained by the fact that most of the European train operations are electrified, something that links the GHG emission reduction for the majority of rail links in the European Union to the decarbonisation of the electricity generation mix, rather than rail-specific R&D investments.

Despite the rail electrification and the fact that rail transport is already a very efficient mode, the improvement of energy efficiency (electric or diesel trains) remains an important issue to be tackles in this sector.

Besides projects aimed at the reduction of GHG emissions, the attention for a better environmental

performance and improved energy efficiency in rail is also demonstrated by some of the aims pursued by R&D activities on new generation of very high speed trains (e.g. AGV for Alstom based on articulated carriages and a distributed drive system; Velaro for Siemens, AVRIL for Talgo with wide body and low floor).

R&D programmes are also related to new generation of tramways (e.g. Citadis for Alstom, URBOS for CAF), regional trains (e.g. Coradia diesel or electric from Alstom), locomotives, signalling, etc.

More generally, the main research domains in which the EU rail transport manufacturing industry has been invested for reducing the GHG emissions are[52]:

- The development of braking systems allowing energy regeneration: these technologies can save important amounts of energy (see e.g. the HESOP project with Alstom or the electricity returned to the grid by high speed trains in Spain).
- The development of hybrid or dual mode (ability to function on both electrified and non-electrified rail tracks) technologies.
- Weight reduction, improved aerodynamics (e.g. shape optimisation via CFD[53] and wind tunnel).
- The improvement of the energy efficiency of auxiliaries e.g. heating, air conditioning, lighting.
- The improvement of the energy efficiency of diesel locomotives (passenger and freight services) and diesel railcars (passenger service only). Research is often derived from R&D in other areas that can be transferred to the rail sector (see e.g. the GREEN project[54]).

5.3.4.3 Comparison with other sources

Based on the Eurostat BERD database (BES funds), the aggregated R&D investments of the NACE R1 DM352 category 'Manufacture of railway, tramway locomotives, rolling stock' reached € 393 million in 2008, which is far below our estimate since figures for only 15 EU MS were available at the time of this study (no data for UK, SE, RO, NL, LU, LT, LV, IT, IE, HU, GR, FI, DK and BE). A recent publication by the European Commission (2010e) reports an R&D investment of € 1 billion of the rail supply industry, which is relatively well in line with the present assessment. On top of this, European railway operators and infrastructure managers would invest another € 250 million in R&D, which in the present report is considered under transport service providers.

5.3.5 Waterborne transport equipment manufacturing industry

5.3.5.1 Overall results

Overall, the level of R&D investment stemming from major EU-based waterborne transport equipment manufacturing industries was around € 620 million in 2008, with an R&D intensity of around 3.2%. This figure results from the analysis of 15 EU companies active in this sector that have been further classified into shipyards (€ 110 million invested; R&D intensity of 1.6% due to e.g. Fincantieri and ThyssenKrupp) and marine equipment manufacturers (€ 510 million invested; R&D intensity of 4.1% due to e.g. MAN Diesel & Turbo, Wärtsilä, Rolls-Royce Marine).

Even though the main EU-based firms of this domain have been analysed, this figure is probably an underestimation of the real picture, since a number of smaller companies has not been included in the present analysis.

[52] See e.g. Hazeldine et al. (2009) and Hill et al. (2009) for a description of key options to reduce GHG emissions in this sector.
[53] Computational Fluid Dynamics
[54] GREen heavy duty ENgine http://green.uic.asso.fr/

5.3.5.2 How much is spent for reducing GHG emissions?

Our analysis shows that almost half of the total R&D spending in 2008 has been allocated to improve the energy efficiency of ships and then reduce their GHG emissions (CO_2 emissions but also important reduction in NO_x and SO_x emissions have been achieved, notably for meeting future regulation on ship emissions). This elevated amount stems from the increasing R&D activities of this sector in key research areas such as[52]:

- Improvement of the energy efficiency of conventional diesel engines for commercial marine propulsion, which still power most of the fleet (i.e. two-stroke and four-stroke diesel engines). European manufacturers such as MAN Diesel & Turbo (e.g. for large-bore diesel engines) and Wärtsilä (e.g. for common-rail technology) are examples in this domain.
- The use of gas turbines (running on LPG) is a promising option to significantly reduce CO_2 and air pollutant emissions in the longer term (e.g. with combined cycle gas turbine systems), compared to conventional diesel engines. For instance, according to Rolls-Royce, the Bergen K gas engine running on LPG produces up to 90% less NO_x and 20% less CO_2 than an equivalent diesel engine (it also offers weight and space advantages).
- Further significant CO_2 emissions reduction can also be achieved through the development of biofuels (bio-oil), multifuel engines (gas/bio-oil), waste heat recovery, electrification, fuel cells (see e.g. Wärtsilä), etc.

5.3.5.3 Comparison with other sources

Based on the Eurostat BERD database (BES funds only), the aggregated R&D investments of the NACE R1 DM351 sector 'Building and repairing of ships and boats' was at least € 215 million in 2008. Unfortunately, this latter figure constitutes an underestimation owing to the fact that only 13 EU MS are covered (no data available for SE, RO, NL, LU, LT, LV, IE, HU, FI, DK, BE and AT). Furthermore, the important differences in the approaches between BERD and the bottom-up methodology need to be considered.

According to Waterborne TP (2007) implementation plan € 1.5 billion are spent on basic and industrial research of the European maritime industry, which has a turnover of more than € 200 billion. This figure cannot directly be compared to the result of the present assessment, as the European maritime industry includes not only the equipment manufacturers for civil purposes but also maritime transport service providers (that are allocated to 'service providers' here), offshore industries etc. It is therefore more relevant to compare the R&D intensities. According to the Waterborne TP "an estimated 1 to 2 percent is spent on the “R” (basic and industrial research), involving the maritime universities and research institutes as well. In the offshore industry this part is likely to be higher, as well as in major parts of the marine equipment sector and the naval sector". This confirms the order of magnitude of our findings, in particular when considering the more narrow focus on the marine equipment sector.

The R&D intensities found in the present assessment related to EU shipbuilders (1.6%) and equipment manufacturers (4.1%) are also supported by the analysis undertaken by Ecorys et al. (2009a; p.132).

5.3.6 Transport service providers

A combination of different categories of companies is included in the category of transport service providers. This comprises companies included in the ICB sector 'Industrial transportation', as it is defined in the EU Scoreboard (this concerns mainly shipping companies such as Deutsche Post and TNT; see section 5.2) as well as other companies involved in the provision of passenger transport services (including railway operators like Deutsche Bahn, public transport operators like Veolia Transport and RATP, and airliners such as Lufthansa), adding up to a total of 20 companies assessed. The providers of infrastructure services (like harbours and highway operators) are also captured within this group.

The methodology of the analysis disregards smaller companies, which are of particular relevance in this sector and in sum may add a significant R&D investment. For example, the R&D investments of the European railway operators and infrastructure managers have been estimated to reach € 250 million (European Commission, 2010e), whereas our bottom-up approach would sum to less than € 150 million. Hence, the higher, officially reported figures have been used here for railway operators. Figures for the Dutch marine service providers have been taken from Webers et al. (2010).

The aggregate R&D investments of the sector 'transport service providers' amounted to more then € 700 million in 2008. The related R&D intensity is 0.3%.

Notwithstanding the relative heterogeneity of the companies included in this group, a low R&D intensity is a rather uniform feature for all transport service providers: most freight shipping companies (e.g. Deutsche Post, Poste Italiane, TNT) taken into account are characterised by R&D intensities included between 0.2% and 0.4% (but some, like Post Danmark, reach 1.2%); the R&D intensity is close to 0.1% for airliners like Lufthansa; passenger transport operators also invest a small share of their net sales in R&D (e.g. 0.15% for Veolia transport); the expenditures of railway operators lie in a range between 0.05% (as in the case of Deutsche Bahn) and 0.4% (for SNCF); highway operators like Atlantia, in Italy, invest about 0.1% of their revenue in research; and port authorities like Havenbedrijf Rotterdam and Hamburger Hafen und Logistik about 1%.

Amongst the companies considered, the main exception to the low R&D intensity is represented by NATS, a provider of air traffic control services for aircraft flying in the UK airspace and the eastern part of the North Atlantic. In this case, R&D investments account for 3.5% of the net sales.

5.3.6.1 Comparison with other sources

Broadly speaking, the R&D intensities identified here fit well with the information collected by other analyses that looked at similar indicators, like for instance the OECD Science, Technology and Industry Scoreboard (OECD, 2007). These studies highlighted the service sector as typically characterised by a lower R&D intensity with respect to the manufacturing sector. This gap may be partly due to difficulties associated with the methodological differences in classifying firms' R&D expenditure, partly to the fact that the service sector is more likely to innovate in areas that may fall outside those captured by R&D expenditure as indicated in Figure 29, and partly because of specific characteristics of the service sector with respect to the manufacturing sector.

5.3.7 Infrastructure construction

In order to extend the scope of this bottom-up approach to also include research on transport infrastructure, the level of R&D investments stemming from key infrastructure construction companies has been assessed. The collection of information focused on the R&D investments of 14 EU-based firms that are considered as key players in this domain (e.g. Bouygues, Balfour Beatty, Skanska), and form part of the Europe's 100 construction companies listed in Deloitte (2009). Their R&D investments and turnover have been taken from the EU Industrial R&D Investment Scoreboard database. On top of this, some companies that produce construction equipment (e.g. Atlas Copco, Metso, Demag) have been considered. To the extent possible, only the R&D investments and net sales related to transport infrastructure, and to the manufacturing of equipment for infrastructure construction, have been taken into account. .

The transport-related parts of the R&D investment of these companies amounted to almost € 300 million in 2008. In total, the R&D intensity of this group is rather limited (0.3%), even though importance differences can be observed between construction companies with very low R&D intensities well below 1%, and the manufacturers of transport infrastructure construction equipment with R&D intensities in the order of 1% to 3%.

In particular in the construction industry, however, a R&D-related indicator does only very partially capture innovation activities. Even though Gambatese and Hallowell (2011) found a strong positive correlation between R&D and innovation in the results of a survey to construction companies, they point out the difficulties in realising research in a project-based industry such as construction. Hence,

the level of R&D support is only one of the indicators measuring innovation in construction. As the construction industry is dominated by heuristics, in which past experiences and tacit knowledge are important in project executions (Maqsood, 2006), knowledge management, the organisational structure and human resources are other factors that strongly impact on the success of innovation (Gambatese and Hallowell, 2011 with further references).

5.3.7.1 Comparison with other sources

The findings of the present analysis are confirmed by other studies, either carried out for specific countries like the UK (NESTA, 2007), or looking at the sector in more general terms (OECD, 2009).

5.3.8 Intelligent Transport Systems

Intelligent Transport Systems (ITS) are solutions based on Information and Communication Technologies (ICTs) and electronic tools that aim to provide innovative services for transport applications. A wide variety of very different actors are pursuing research on Intelligent Transport Systems (ITS). These comprise non-transport companies involved in the general production of ICT hard- and software, many manufacturers and component suppliers of transport equipment and a number of companies dedicated specifically to ITS. Given the significant overlap of application of ICTs and the difficulty to allocate expenditures to end-uses, it is very difficult to identify with a sufficient precision the transport-related parts of the high total R&D investments of the ICT sector. In addition, the research activities of the European transport industry that concentrate on ITS solutions are also difficult to single out from the total R&D investments by mode assessed above, even though there are some indications that these are rather elevated[55].

For these reasons, the analysis carried out in this report cannot provide comprehensive figures on investment levels directed towards R&D on ITS. Instead, it gathered (with the support of ERTICO) information from 15 dedicated ITS companies that are particularly involved in the development of ITS such as TomTom, Tieto, Kapsch Traficcom, Invensys, Indra Systems, Elektrobit and Trafficmaster. Their overall R&D investments reached € 415 million, and an average R&D intensity of 6.4% for those companies for which information on both R&D investments and net sales could be obtained. This is, however, a strong underestimation of the total ITS research activities considering the above.

Notwithstanding the limited understanding of the weight of ITS in the total R&D investment, the above indications suggest that the ITS-related industries are characterised by a rather good performance with respect to R&D. In addition, the low investments that are typically characterising the application of ICT-based applications (namely in a capital intensive sector like transport) further strengthens the identification of a strong innovation potential in the application of ICT to the transportation sector.

5.3.8.1 Comparison with other sources

The R&D intensity identified here for ITS is well in line with typical R&D intensities in the IT sector, which range between 3% and 15% (OECD, 2010).

Looking at OECD countries, it is possible to observe that companies involved in telecommunications, IT equipment, IT services and electronic components manufacturers tend to be at the lower end of this range. On the other hand, companies dealing primarily with IT related to the internet, communications equipment, and software, as well as semiconductors firms, tend to be characterised by R&D intensities that are at the high end of the range (OECD, 2010). The EU Industrial R&D Investment Scoreboard shows also that the considerations relative to OECD as a whole also apply to EU-based companies. Within EU-based companies, the R&D intensity of firms active in electronic equipment and computer hardware is close to 6-7% in 2009. This value increases to nearly 14% for the EU-based software industry.

[55] Juliussen and Robinson (2010) estimate that the 'in-house' software R&D performed by car manufacturers could reach some 15-20% of their total R&D investments, not including research on embedded hardware.

5.4 Evolution of corporate transport R&D investments over time

This section describes the development of industrial R&D investments in the EU. Section 5.4.1 will highlight the impact of the economic downturn on the net sales and R&D investments of companies based in the EU, the USA, Japan and other world regions, based on the EU Industrial R&D Investment Scoreboard. Section 5.4.2 will then look at longer time horizons, i.e. the period 1999-2008, based on data from BERD. Note that the datasets used in the two sections cannot be compared one with another due to the differences in regional allocations, and some discrepancies in the definition of sectors.

5.4.1 The impact of the economic downturn

Caused by the economic downturn, the R&D investment associated to transport-related ICB companies dropped by 9% in 2009 compared to the previous year, along with a net sales reduction of 13%. R&D investment of US-based companies have been the most affected by the crisis (-20.5%) followed by EU (-6.2%) and Japanese companies (-4.6%), although these reductions are different across transport subsectors.

As reported in the EU Scoreboard 2010 (JRC-DG RTD, 2010), companies included in the ICB sector 'Automobiles & parts' presents the largest negative one-year R&D growth, in front of 'Technology Hardware & Equipment' and 'Leisure Goods'. The automotive industry (sum of 'Automobiles & parts' and 'Commercial vehicles & trucks' ICB sectors) was significantly hit by the crisis where R&D investments dropped by 11% in 2009. Most of the main car manufacturers worldwide reduced their R&D investment in 2009. Ford (-33%), Renault (-26.5%) and General Motors (-24%) are those presenting the most important declines, while Asian manufacturers such as Suzuki (+6%), Mitsubishi (+3.5%) and Hyundai (+2%) have slightly increased their R&D investment. Likewise, the R&D investments of the 'Industrial transportation' ICB sector have been reduced by 14% between 2008 and 2009. On the other hand, the 'Aerospace & defence' sector was much less affected by the crisis than the automotive industry. The R&D investments have been reduced by only 1% in 2009 with differences across world regions (+5% for EU companies and -7% for US companies). The two main aircraft manufacturers EADS and Boeing present slight increase in their R&D investment (4.4% and 0.9% respectively).

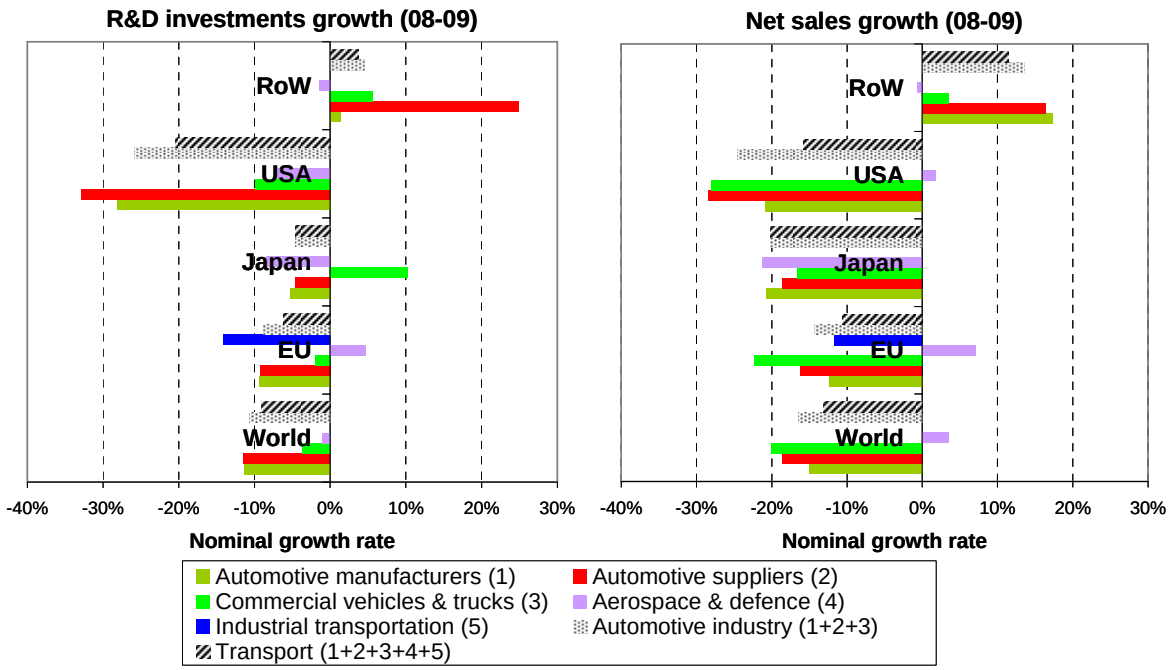

Figure 27: Nominal variation of R&D investments and sales between 2008 and 2009
Data source: EU Industrial R&D Investment Scoreboard (JRC-DG RTD, 2009, 2010)
Note: figures are based on the same number of companies between 2008 and 2009. The ICB class Industrial Transportation does not contain any company outside of the EU.

Since the decrease of R&D investments is globally less pronounced than for the fall of sales, the R&D intensity of the transport sector increased in 2009. The R&D intensities of the automotive industry in 2009 have reached 4.5% at world level and 5.4% for EU companies (5.1% for car manufacturers, 6.7% for automotive suppliers and 4.6% for commercial vehicles & trucks). On the other hand, the R&D intensity of the aerospace and defence sector has slightly decreased in 2009, while that of the industrial transportation sector has remained constant at 0.3% (see table below).

R&D intensity	World		EU		Japan		USA		RoW	
	2009	2008	2009	2008	2009	2008	2009	2008	2009	2008
Automotive manufacturers (1)	4.5%	4.4%	5.1%	4.9%	4.6%	3.8%	4.7%	5.1%	2.3%	2.6%
Automotive suppliers (2)	5.0%	4.5%	6.7%	6.1%	5.1%	4.3%	2.9%	3.0%	1.7%	1.5%
Commercial vehicles & trucks (3)	3.4%	2.9%	4.6%	3.6%	3.5%	2.6%	3.5%	2.8%	1.8%	2.1%
Aerospace & defence (4)	3.9%	4.1%	5.7%	5.9%	6.3%	5.4%	3.0%	3.3%	2.3%	2.2%
Industrial transportation (5)			0.3%	0.3%						
Automotive industry (1+2+3)	4.5%	4.2%	5.4%	5.1%	4.6%	3.9%	3.9%	4.0%	2.1%	2.3%
Transport (1+2+3+4+5)	4.1%	4.0%	4.7%	4.5%	4.6%	3.9%	3.5%	3.8%	2.1%	2.3%
All industries	3.3%	3.1%	2.4%	2.3%	3.8%	3.4%	4.8%	4.5%	2.7%	2.5%

Table 5: R&D intensities of the different transport-related ICB sectors for the years 2008 and 2009
Data source: EU Industrial R&D Investment Scoreboard (JRC-DG RTD, 2009, 2010)
Note: The ICB class 'Industrial Transportation' does not contain any company outside of the EU

5.4.2 Longer-term trends in industrial R&D

The Eurostat BERD database contains data on business investments in R&D. As mentioned above in chapter 4, the methodology of BERD (expenditure), its geographical allocation of the R&D investments to the country of execution of research instead of the country that hosts the funder, the socio-economic classification scheme (NACE for BERD) and data gaps at a high level of detail impede a direct comparison to the central bottom-up approach of the present study.

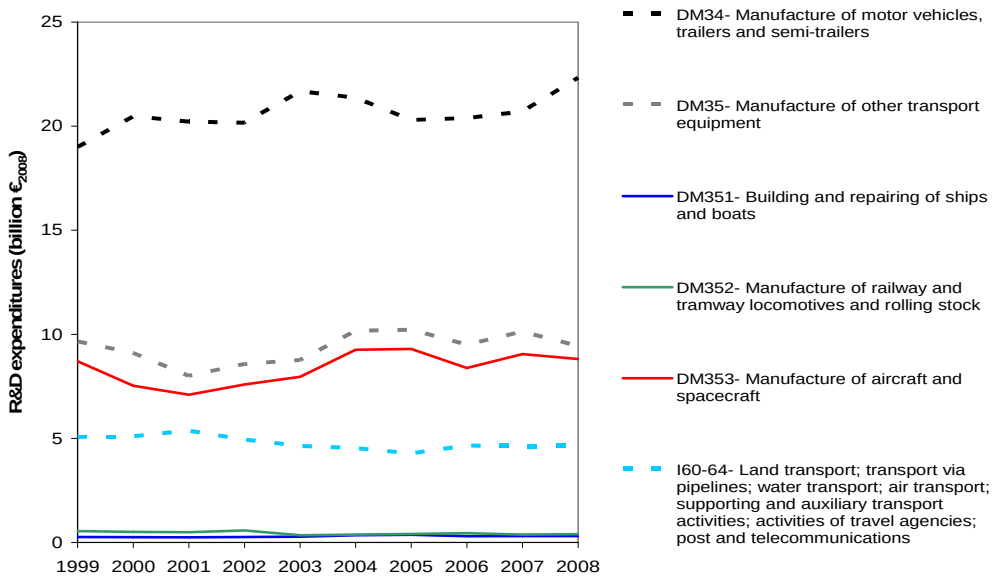

Figure 28: Industrial R&D investments between 1999 and 2008 (BERD figures)
Data source: Eurostat BERD

Despite this, the longer timelines covered by BERD data allow for the analysis of trends in industrial R&D expenditures in the transport sectors between 1999 and 2008, net of inflation expressed in $€_{2008}$. Figure 28 shows a more or less stable trendin R&D expenditures of the automotive sector (DM34) despite annual fluctuations, with some slight increase over the entire period. R&D expenditures in the manufacturing of air- and spacecrafts have been rising slightly after the year 2001, whereas the research expenditures into rail and land transport services remained constant or even declined slightly.

Except for the case of railway manufacturing, which experienced a declining R&D intensity, the research expenditures have grown broadly in line with the turnover (automotive and shipbuilding industries) or even faster, leading to an increase in the R&D intensities (aircraft manufacturing).

5.5 Level of innovation expenditures

Innovation is not necessarily restricted to in-house R&D activities. Besides R&D expenditures, innovation expenditures can be used for the acquisition of innovative machinery, equipment or software, and also other knowledge. The results of the Community innovation survey show that the latter expenditures are pre-dominant especially for those transport sub-sectors that have a low genuine incentive to undertake research, i.e. transport service providers. On the contrary, manufacturing industries spend the majority of their innovation expenditures on R&D (see Figure 29). Figure 29 also shows the very low R&D expenditures of the wholesale and repair of motor vehicles, which justifies that their R&D efforts have not been analysed in detail in the present report.

These results are well in line with the theoretical considerations on the varying incentives to innovate across the diverse transport sub-sectors (see section 2.4). An example illustrating the importance of purchasing innovative products for the low-R&D investing sectors are ITS applications in logistics (see section 9.10).

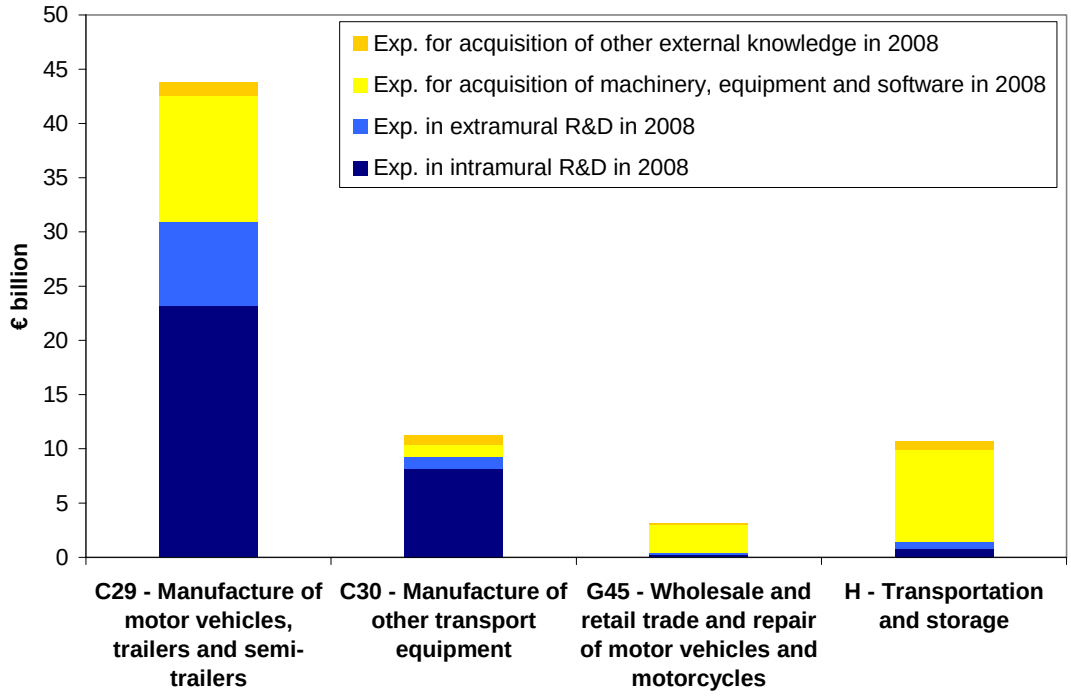

Figure 29: Breakdown of innovation expenditures in 2008
Data source: Eurostat CIS survey 2008, based on NACE R2 classification
Note: C29 (no data for MT); C30 (no data for LU and DK); H (no data for UK, GR and DK). When available, intramural R&D for UK, CY, GR and SL has been filled with figures from the Eurostat BERD database. Data for G45 have been available only for CZ, ESP, FR, IT, LT, NL and have been approximated based on the turnover for other countries.

6 Public R&D investments

6.1 Synthesis

Key findings

- Public R&D investments from EU Member States have been in the order of € 3.6 billion in 2008. However, the presence of important data gaps mean that the actual amount of funds dedicated to public R&D investments from EU Member States is likely to lie above this figure.
- Public R&D investments are largely concentrated in seven Member States, namely Germany, France, Sweden, the UK, Spain, Italy and the Netherlands.
- Public R&D is more equally distributed across modes than corporate R&D investments. Nevertheless, about three quarter of the total public (Member States and EU) funds are dedicated towards research on road and air transport modes.
- The EU funds through FP7 add another around € 0.6 billion per year (once the budget is spread across the full duration of FP7) to transport-related R&D. Within the FP7 funds, the aviation sector is the most prominent because of a number of European initiatives, including the Clean Sky JTI and the SESAR JU.

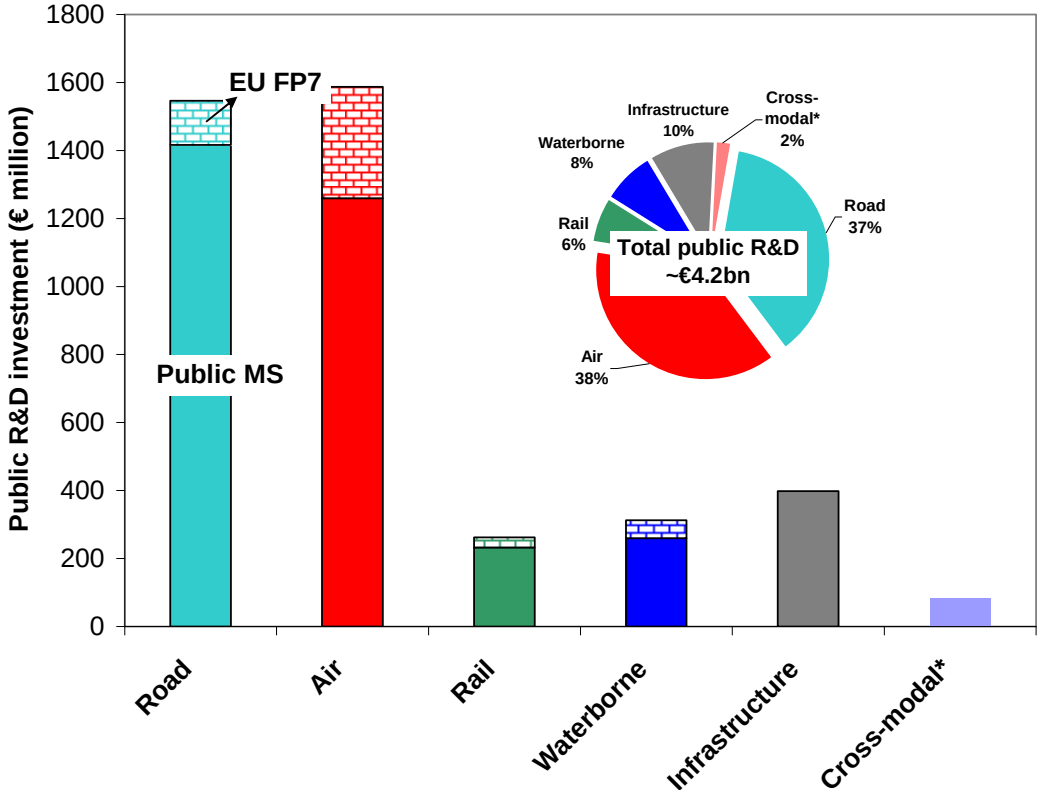

Figure 30: Estimate of public R&D investments (annualised)
Source: JRC-IPTS
Data source: EAGAR (2010) for road; AirTN (2009) and ASD (2009) for air; ERRAC (2008) for rail; MARTEC (2007) and Waterborne TP (2007) for waterborne. Moreover, data have been completed by figures collected directly from MS (AT, CZ, FI, FR and PT) and by own assumptions derived from other sources (e.g. NET-WATCH)
Note: R&D investments have been annualised. Due to limited data availability, the figures displayed are likely to constitute an underestimation.
** Public MS R&D investments directed to 'cross-modal' is generally spread over the different modes and could not be fully captured in the present assessment. The actual R&D investments are likely to lie well above the figure shown here.*

Policy implications

- Public R&D investments have an important share in non-road modes, making up around one quarter of the overall research investments in rail and aviation, and more than one third for the waterborne sector.
- Public funding to research in social, economic and regulatory issues is crucial as these topics usually attract little industrial research efforts.
- Research in transport infrastructure is financed through public funds by two thirds, clearly demonstrating the important of public action in this area.
- The case of vehicle engine research demonstrates that publicly funded research becomes more important for less mature technologies, which are not in the focus of commercial research interest. Public funding complements industrial research that is often exposed to the expectation of short-term results.
- Beyond the direct financial support to R&D, publicly financed research has a key role in bringing together public and private actors from various sectors, and thereby coordinating, multiplying and leveraging research efforts.

6.2 Public R&D investment from EU Member States

The most straightforward way to collect data on public transport-related R&D investments in Member States is to rely on figures extracted from available supranational datasets such as the Eurostat GBAORD. This approach has been followed for the total public R&D budgets (section 6.2.1). Unfortunately, the socio-economic classification scheme followed (NABS 2007 for recent data) and the fact that for relevant classes a further breakdown is not available means that R&D budgets allocated to transport cannot be clearly identified, but only approximated (see also chapter 4).

Section 6.2.1 concentrates on the NABS 07 category 04 'Transport, telecommunication and other infrastructures', which nevertheless includes some spending on non-transport-related R&D such as telecommunications and water supply. At the same time, funds allocated for transport equipment manufacturers are not included here as they could not be separated from the broader category 06 'Industrial production and technology'. For data up to the year 2007, GBAORD also provides data in the classification NABS 92 that contains more details on transport-related sectors, but data are scarce.

The limitations deriving from methodological issues and concerning completeness and accuracy are such that the GBAORD database cannot be used systematically for the analysis of R&D funds allocated to single modes (sections 6.2.2.1 to 6.2.2.4) or specific sub-sectors. Hence, other sources containing information about national R&D programmes and funding have been consulted for the analysis illustrated here. These sources include, in particular, the ERA-NET projects, the reference documents published by the European Technology Platforms (e.g. strategic research agenda, implementation plan) and the outcomes from different EU FP projects on related topics (including e.g. data from the Transport Research Knowledge Centre).

In this study, two ERANET projects have been of particular relevance for collecting data on national R&D programmes and funds: Air Transport Net (AirTN) for aeronautical research and MARTEC (Maritime Technologies) for the maritime transport. Figures from ASD (2009) on aeronautical research miss the level of detail on the Member State basis, but provide a reasonable estimate for them as a whole. For the road sector, the EAGAR FP7 project[56] has been used as a relevant source of information for providing estimates on the level of R&D investments in automotive research at EU and Member State level (note that the scope of EAGAR goes beyond EU countries). In addition, the database of the Transport Research Knowledge Centre (TRKC, FP6 project) has been widely used to get a comprehensive overview of transport-related research activities carried out at European and national level in all transport modes. In 2009, the TRKC released an updated review of the different transport research programmes and projects undertaken at EU and national level (TRKC, 2009).

[56] European Assessment of Global Publicly Funded Automotive Research

Finally, the assessment of public R&D investments of EU Member States into individual technologies of the automotive sector – biofuels, hydrogen/fuel cells and electric vehicles (see chapter 7) takes the IEA RD&D statistics as a starting point, even though not all Member States are covered by this database (see chapter 4).

6.2.1 Total transport R&D investments - GBAORD

As explained before, the NABS 04 category 'Transport, telecommunication and other infrastructures' has been used here as the closest proxy to the transport sector even though it also includes R&D to other topics. At the same time, public R&D to the manufacturing of vehicles and other transport equipment, which is part of the much broader category industry, has been disregarded in the following. Aggregated public budgets and appropriations of EU Member States to this category were € 2.3 bn in 2008, rising to almost € 2.5 bn in the year 2009. About 90% of this aggregate comes from only ten Member States, namely Spain, Germany, Italy, the Netherlands, the UK, France, Sweden, Portugal, Romania and Belgium.

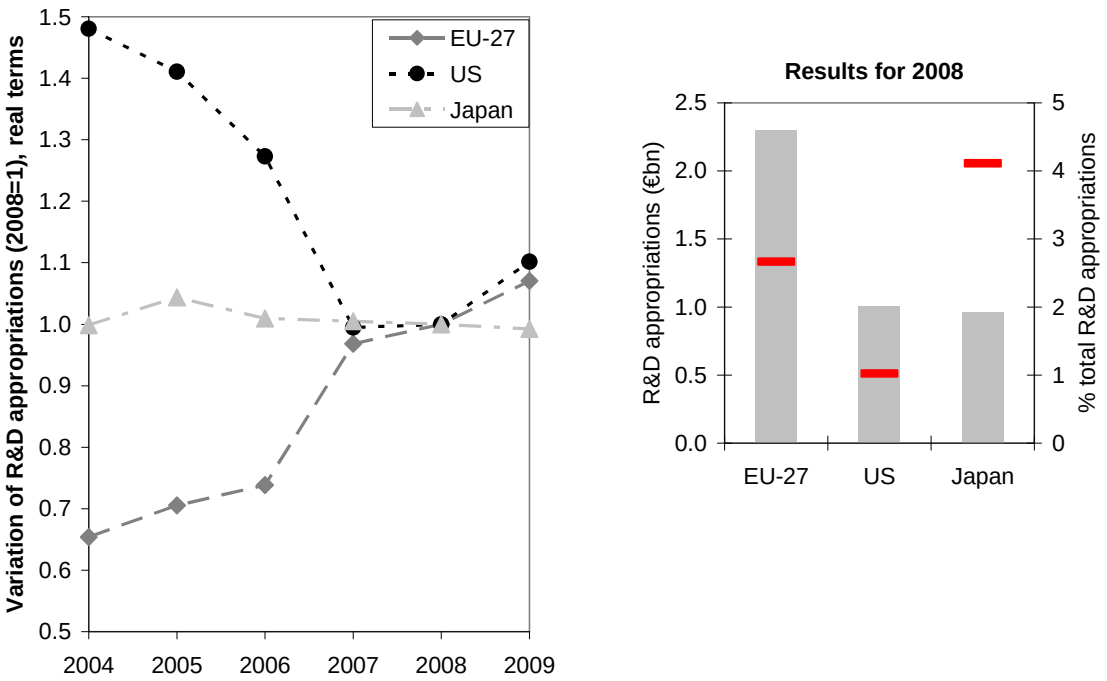

Figure 31: Trend in R&D appropriations (left chart) and 2008 figures (right chart) of the NABS 07 04 class 'Transport, telecommunication and other infrastructures'
Data source: Eurostat GBAORD (data retrieved in August 2011) completed with OECD data
Note: Original data of the left-hand chart are in national currencies in real terms.

Figure 31 clearly shows that the aggregated public R&D budgets to the transport-related category NABS04 of EU Member States have been rising continuously between 2004 and 2009 (net of inflation), whereas comparable budgets in Japan are more or less stable throughout this time period and the US-budget experienced a sharp decrease until 2007, followed by an increase thereafter. These trends mean that by 2008, the level of EU Member States' aggregated R&D budgets dedicated to the NABS04 category was more than twice those of comparable efforts in the USA and Japan; this would be even more pronounced if on top of EU Member States budgets the EU support through FP7 (see section 6.3) were added. However, a direct comparison at the basis of R&D budgets may be misleading considering the important differences in the set-up of public research across these regions/countries (see e.g. TRB-ECTRI, 2009).

Among these three countries/regions, Japan shows the highest share (4.1%) of total R&D appropriations allocated to the category 'Transport, telecommunication and other infrastructures'. It is

followed by the EU as a group (2.7%), for which the differences its Member States must be noted, reaching from as little as 0.1% to more than 11% (Table 6). Member States that combine elevated total R&D budgets in this category NABS 04 with a high importance of transport research within total research and GDP include Romania, Spain, Portugal, Sweden and the Netherlands.

	R&D appropriations of NABS 04 'Transport, telecommunication and other infrastructures' (€m)	% of NABS 04 in total R&D appropriations
Austria	20.9	1.1
Belgium	44.0	1.9
Bulgaria	1.1	1.0
Cyprus	0.7	0.9
Czech Republic	30.6	3.7
Denmark	15.5	0.8
Estonia	7.4	7.1
Finland	40.9	2.3
France	138.6	1.0
Germany	328.8	1.7
Greece	10.9	1.6
Hungary	25.2	5.6
Ireland	14.3	1.5
Italy	189.8	1.9
Latvia	4.6	6.8
Lithuania	0.1	0.1
Luxembourg	7.5	4.3
Malta	0.1	0.9
Netherlands	177.2	4.3
Poland	38.4	3.5
Portugal	97.6	6.6
Romania	64.0	11.5
Slovakia	3.9	2.2
Slovenia	n.a.	n.a.
Spain	756.6	9.0
Sweden	115.8	4.3
UK	156.9	1.3
EU27	**2297.0**	**2.7**
USA	**1002.9**	**1.0**
Japan	**962.7**	**4.1**

Table 6: R&D appropriations of the NABS 04 sector 'Transport, telecommunication and other infrastructures' and its percentage on total R&D appropriations for the year 2008
Data source: Eurostat GBAORD (data retrieved in August 2011)
Note: no data for Slovenia; 2007 figure for Greece; OECD data for France

GBAORD also makes available data on R&D budgets following the NABS 92 classification, but only up to the year 2007. This includes a further breakdown of transport-related sectors; however, at the higher level of detail, data are available only for a few Member States. These figures are summarised in Table 7. The table illustrates that consistent and comprehensive data for R&D investment by mode cannot be derived from this source only, in particular when considering that, in some cases, the most recent data available refer to the year 2000. Hence, a bottom-up approach combining various data sources has been applied in the following.

	NBS02-Infrastructure and general planning of land-use	Year	NBS0204-Transport systems	Year	NBS0705-Manufacture of motor vehicles and other means of transport	Year	NBS07051-Aerospace equipment manufacturing and repairing	Year	NBS07052-Manufacture of motor vehicles and parts	Year	NBS07053-Manufacture of all other transport equipment	Year
EU	**1874.5**		**275.0**		**442.8**		**158.5**		**20.6**		**56.7**	
Belgium	17.5	2007	n.a.		n.a.		n.a.		n.a.		n.a.	
Bulgaria	2.1	2007	n.a.		n.a.		n.a.		n.a.		n.a.	
Czech Rep.	27.9	2007	4.5	2006	16.3	2008	10.47	2008	2.14	2008	3.66	2008
Denmark	10.4	2007	n.a.		n.a.		n.a.		n.a.		n.a.	
Germany	305.5	2007	89.2	2006	184.5	2006	130.43	2006	14.45	2006	39.57	2006
Estonia	7.3	2007	n.a.		n.a.		n.a.		n.a.		n.a.	
Ireland	4.7	2006	10.6	2002	0.8	2001	n.a.		n.a.		n.a.	
Greece	10.9	2007	3.2	2007	0.1	2007	0.00	2007	0.10	2007	0.00	2007
Spain	719.2	2007	21.4	2006	205.2	2006	n.a.		n.a.		n.a.	
France	86.0	2007	n.a.		n.a.		n.a.		n.a.		n.a.	
Italy	93.7	2006	1.8	2000	11.1	2000	10.33	2000	0.68	2000	10.33	2000
Cyprus	0.6	2007	n.a.		n.a.		n.a.		n.a.		n.a.	
Latvia	3.6	2007	n.a.		n.a.		n.a.		n.a.		n.a.	
Lithuania	3.6	2007	n.a.		n.a.		n.a.		n.a.		n.a.	
Luxembourg	3.2	2007	n.a.		n.a.		n.a.		n.a.		n.a.	
Hungary	6.9	2005	n.a.		n.a.		n.a.		n.a.		n.a.	
Malta	0.0	2007	0.0	2007	0.0	2007	0.00	2007	0.00	2007	0.00	2007
Netherlands	162.8	2007	61.1	2007	11.4	2007	n.a.		n.a.		n.a.	
Austria	28.7	2007	24.0	2001	n.a.		n.a.		n.a.		n.a.	
Poland	11.9	2007	n.a.		n.a.		n.a.		n.a.		n.a.	
Portugal	78.2	2006	n.a.		n.a.		n.a.		n.a.		n.a.	
Romania	15.6	2007	7.1	2007	13.5	2007	7.25	2007	3.11	2007	3.11	2007
Slovenia	2.6	2007	0.2	2004	0.1	2004	0.00	2004	0.07	2004	0.00	2004
Slovakia	6.0	2007	n.a.		n.a.		n.a.		n.a.		n.a.	
Finland	28.5	2007	n.a.		n.a.		n.a.		n.a.		n.a.	
Sweden	107.1	2007	n.a.		n.a.		n.a.		n.a.		n.a.	
UK	130.0	2006	51.8	2006	n.a.	n.a.	n.a.	n.a.	n.a.		n.a.	

Table 7: R&D appropriations of NABS 92 transport-related sectors
Source: Eurostat GBAORD (data retrieved in March 2011) completed by other sources

6.2.2 Bottom-up estimation of R&D investments by mode and research area

The bottom-up estimation of public transport R&D finds that EU Member States as a group invested at least € 3.6 billion to transport-related R&D in 2008. This figure is the result of an assessment by transport sub-sector, following a classification similar to the one used for corporate R&D funding.

Within each sub-sector, a further differentiation between vehicles, the network and the provision of transport services has been aimed at. The first area concerns vehicles. It comprises topics like vehicle manufacturing, vehicle technologies affecting fuel consumption, emissions of greenhouse gases and air pollutants, safety and noise. This is analysed here looking at each transport mode separately and building to the largest possible extent on specific datasets and studies that provide relevant information. A second area is the transportation network. This includes research fields like infrastructure construction, network safety, and network efficiency through planning. The importance of R&D investments on these issues is addressed by a number of qualitative considerations in the discussion on the different transport modes. In addition, a quantitative assessment based on GBAORD looks at the relevance of public R&D investments for what concerns the transport network as a single entity. A third area concerns the operation and maintenance of vehicles and networks for the provision of mobility services for passengers and freight. This dimension includes R&D that targets the logistics sector and public passenger transport. Due to the limited availability of data, it is only addressed with qualitative considerations in the discussion concerning each mode. Similarly, ITS-related research is also analysed in relation with the different dimensions where it finds applications within each mode.

Finally, research activities that target specifically economic, regulatory and social issues (including for instance pricing and charging schemes), typically characterising the public sector and, in particular, the policymaking activities, have been grouped together for all modes and have been considered separately in a single category.

6.2.2.1 Road transport

In the case of road transport, the vehicle dimension of transport R&D is best represented by the automotive sector (including commercial vehicles). Public funds originating from EU Members States in this field reached around € 1.4 billion and they account for 4% of the total R&D investment (both corporate and public) in the automotive sector. This figure is essentially based on the outcomes of the EAGAR FP7 project (EAGAR, 2010) that provides an assessment of the overall public (and also private) automotive R&D expenditures for some EU countries (and other non-EU ones) for the year 2007. However, since not all Member States that are also important road vehicle producers are covered[57] by that analysis, it should be considered as a lower bound assessment of the actual R&D efforts.

Out of this total for the automotive sector, around € 470 million have been estimated as investments dedicated to technologies suitable for reducing GHG emissions. Despite the high uncertainties associated with the latter figure due to the fact that R&D activities focusing exclusively on GHG emissions reduction are not easily identifiable within national research programmes, this means that about 30% of the public Member State funding in road transport is thought to be targeting GHG-related issues and fuel efficiency. Examples include the funding provided by important national research programmes launched in France (e.g. PREDIT programme), Germany, UK, Italy and Austria.

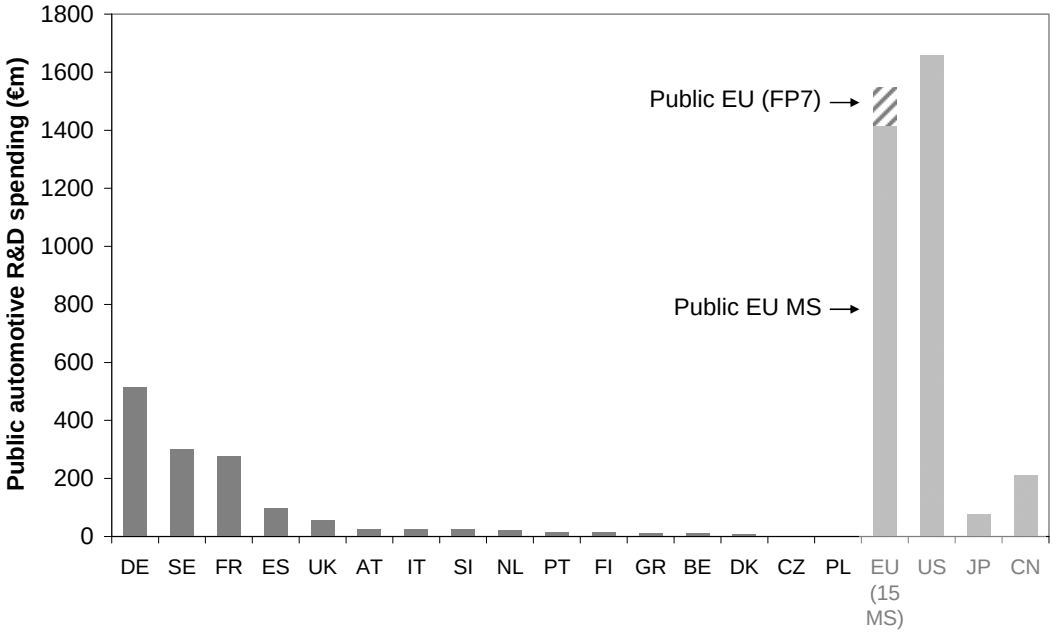

Figure 32: Public automotive R&D funding

Source: JRC-IPTS

Note: Data based on EAGAR (2010) for the year 2007 and completed by other sources. Figures for PT refer to the average of the years 2008-2011. EU funds through FP7 are taken from the present analysis, representing annualised figures and respecting the European Green Cars Initiative.

For road transport, the network dimension of R&D concerns infrastructures for motorcycles, cars, buses and trucks like roads, bridges, tunnels, and parking areas, as well as the infrastructure needed for non-motorised modes like walking and cycling, like, for instance, footways and bicycle lanes.

Funds used for network research are likely to be primarily allocated to research centres focused on road construction and road safety. Examples of such centres include those that participate in the activities of the Forum of European National Highway Research Laboratories (FEHRL). Other funds, targeting intelligent transport systems (ITS), are likely to be allocated to laboratories and research centres looking more specifically at ICTs. A detailed evaluation of public funds originating from EU Members States for road network research is challenging because of the limited availability of detailed

[57] Data have been found for only 15 Member States: Germany, France, Austria, Belgium, UK, the Netherlands, Sweden, Finland, Denmark, Spain, Italy, Slovenia, Poland, Czech Republic, Greece.

information. Nevertheless, estimates on the aggregated value for the whole transport network, discussed in detail in section 6.2.2.5, confirm that the entity of public R&D budget on network-related research is well below the budget allocated to vehicle-related research.

Even though no literature is available on national research budgets allocated to road transport services, universities and transport research centres like the members of the European Conference of Transport Research Institutes (ECTRI) are likely to benefit from them, at least to some extent. Service-oriented public research funds may also be destined to support the activities of passenger transport operators, shippers, and operators of the road network infrastructure. Nevertheless, qualitative indications suggest that the fraction of national research funds that are allocated to road transport services remains is well below the research budget targeting vehicles.

6.2.2.2 Civil aviation

The evaluation of EU Member States funding in civil aeronautic research programmes in 2008 is difficult to assess. Data collected from national aeronautical research programmes (AirTN, 2009), complemented by other specific sources (including GBOARD) and by information received during Member State consultations suggest an estimation of the total EU Member States funding in civil aeronautic research programmes in 2008 that exceeds € 900 million.

According to ASD (2009), R&D investments of the aeronautic sector accounted for 12% of the turnover (for 17 EU Member States and 3 non-EU countries). Within this, the parts financed by governments have been estimated to be 1.3% for civil aeronautics and 2.5% for military applications of the turnover in 2008. This would mean that about € 1.26 billion have been spent by the ASD governments[58] for civil aeronautics research in 2008. This figure is the value that has been retained in the remainder of this document, following an in-depth discussion and exchange with ASD.

A similar estimate (€ 1.2 billion) is also suggested (for the year 2003) in an article published by the American Institute of Aeronautics and Astronautics (AIAA), relying on information provided by an expert of the European aerospace industry (Butterworth-Hayes, 2005).

The EREA (Association of European Research Establishments in Aeronautics, including members from 11 Member States: Austria, Czech Republic, Finland, France, Italy, Germany, the Netherlands, Poland, Romania, Spain and Sweden) issued a booklet on fifteen years of European Cooperation in Aeronautics that contains an estimation of the total revenues of its members, as well as the share derived from public grants and governmental contracts. According to these figures, public grants and contracts contributed for roughly € 700 million to the € 1.1 billion total revenues of EREA members in 2008. Roughly € 400 million were spent for research on aeronautics in the same year, while space accounted for about € 300 million (EREA, 2009).

The EREA, AIAA and ASD values have the same order of magnitude of the estimate derived from our bottom-up approach, albeit being, respectively, lower (which in the case of EREA can be explained by the more limited coverage of research actors) and higher. The lack of data for a number of EU Member States suggests that the bottom up approach attempted here is likely to be an underestimation. To remedy this, we use the figures published by ASD (2009) as an estimate of the EU Member States' aggregated R&D investment in civil aeronautics, and we refer to the results of the bottom-up analysis only to have an indication of the shares at the level of individual countries.

In the case of civil aviation, the available information did not allow assessing the share of the R&D investment that is targeted to reduce GHG emissions, nor the separation amongst the vehicle-related (aircraft) and the network-related (airports, land-based infrastructure) dimensions of research.

Some qualitative considerations, however, can help understanding that research activities that are related to GHG mitigation in air transport are likely to be very relevant. The main reason for this lies in the high importance of fuel (directly linked to CO_2 emissions) in terms of cost for civil aviation, since fuel accounts for up to 35% of the total costs (UK CCC, 2009). A second reason is the fact that

[58] These are the countries of the EU 15 apart from Luxembourg, plus Bulgaria, the Czech Republic, Poland, Norway, Switzerland and Turkey.

research is the most effective instrument capable to tackle fuel consumption and GHG emissions without cuts to the air travel. The technical instruments it offers address fields like aircraft design, structure, materials, aerodynamics, propulsion and a wide range of systems, as well as the optimisation of the air traffic control, the synthesis of advanced fuel options. All these domains have no reasons to be excluded from publicly funded research (i.e. from research carried out by laboratories and other similar facilities), even if the primary contribution to these research areas is likely to come from the private sector.

Avionics and, more generally, applied research building on ICTs (including safety-related applications) are extremely relevant for the optimisation of air traffic control, i.e. what can be interpreted as one of the main elements of ITS-related research in the field of aviation. Avionics include applications that need to be on board of aircrafts, as well as the development of technologically advanced land-based instruments. Even if the information available on public R&D funding does not allow assessing the share of the R&D investment that is targeted to aviation infrastructures, these considerations suggest that avionics and ICT-based technologies with implications for air traffic management are likely to be the main area of research concerning airports and other ground infrastructures of the air transport sector. Given the importance of the air traffic management activities at the EU level, there is no reason to think that publicly funded research centres are not contributing to scientific investigation in this area.

The total public budget dedicated to research in civil aviation infrastructures is likely to depend on national circumstances (e.g. like the presence of a strong specialization of industries in the avionics and ICT fields). On the European scale, however, the Member States' contribution given to research on land-based infrastructures is also likely to be in balance with the relative importance of this sector in the total turnover of the aviation industry, provided that other funds (e.g. stemming from military research) and other public budgetary allocations (as the EU-funded research) do not lead to strong distortions. Qualitatively, it is conceivable to expect that the total national public funding of research applied to airport infrastructures and the land-based part of air traffic management is lower than the funding dedicated to the development of technologically advanced aircrafts, since the latter does not only include the avionic applications for on-board systems, but also a wide spectrum of other research activities concerning aircraft design, structure, materials, aerodynamics, propulsion, as well as other aircraft systems and advanced fuel options.

Another area of research is more specifically related to the provision of transport services in aviation. This is a field that concerns primarily airliners and is likely to see a lower involvement of public research actors. Considering the relatively low R&D intensities registered in this area (see part III for more details), as well as the fact that the service sector is more affected by innovations that are not easily measurable and that are not characterising the activities of publicly funded research centres (like, for instance, innovations concerning marketing and organisational strategies), the national research budget allocated to this area is expected to be significantly lower than the public expenditure concerning vehicle- and network-related research.

6.2.2.3 Rail transport

Overall, the assessment of the total level of public funding in 2008 in rail research suffers from a lack of available data at the time of the present analysis. According to our estimates, the level of public Member State R&D investments has reached some € 230 million in 2008.

This amount is mainly derived from the survey carried out by the ERRAC platform on national rail research programmes (ERRAC, 2008) and complemented by further sources, like the information received following the consultation with Member States. The ERRAC work contains quantitative information on eleven Member States, and relying on it is likely to result in an underestimation of the actual situation. Nevertheless, it is the most complete assessment available on the topic. The main actors involved in rail-related research funded by Member States level include Ministries, railway authorities, infrastructure managers, research institutes, urban passenger transport operators and rail operators, the manufacturing and construction industries, and companies involved in ICT activities.

As in the case of road transport and aviation, rail-related research can be classified amongst activities

focusing primarily on rail vehicles (trains), the rail network (railways) and services (rail passenger and freight transport). However, no detailed information exist on the share of the total rail research budget that is allocated to these categories, nor on the share of R&D investments going specifically to GHG emissions reduction. The manufacturing industry, public research institutes, laboratories and universities targeting vehicle technologies (like motor and brakes technologies for, rolling stock technologies, noise-abatement solutions, maintenance technologies and on-board information and communication technology) are the most likely references for publicly funded research projects aimed at the development of vehicles. On the other hand, construction companies, infrastructure managers and research institutes focusing on civil engineering activities are expected to be associated to projects targeting the nationally funded research on the rail network (including optimisation of capacity, safety-related issues, noise-abatement, advanced track and maintenance technologies), together with companies, research institutes and laboratories involved in investigation activities applied to ITS for intercity and urban rail. The ITS component is also likely to be shared by service-oriented companies like urban passenger transport operators, rail operators, logistics and ICT companies, e.g. for the development of journey planners to facilitate co-mobility in cities.

Research activities typically characterising the service sector in rail include areas that are not addressed by public research funds because of their strong commercial connotations (like for instance marketing strategies and reservation or ticketing services, or the development of software aimed at the optimisation of logistics), as well as topics that link to the development and implementation of public policies (e.g. impacts of fiscal reforms and pricing schemes). Notwithstanding the public focus that is inevitably coupled with research and innovation in the development and implementation of public policies, the national research budget allocated to the service sector in rail is expected to be lower than the public expenditure concerning vehicle-related research. This expectation is due to the relatively low R&D intensity of the transport services sector in comparison with the other research areas, and to its strong commercial focus.

6.2.2.4 Waterborne transport

Main information sources are the national R&D programmes analysed in the frame of the MARTEC project (MARTEC, 2007), and the Waterborne TP Implementation Plan that provides en estimation of the total public funding by EU Member States (Waterborne TP, 2007). Unfortunately, these two sources are not fully consistent: the figure from Waterborne TP is higher than the total obtained from the MARTEC study, but the MARTEC study is the only one providing data for single Member States. The estimate retained considers the figure suggested by the Waterborne TP for the EU aggregate: € 260 million per year, on average.

Key research topics indicated in the Waterborne TP analysis include vessel technologies (e.g. for emission reduction, safety, manufacturing technologies, new and extended marine operations, and on-board ICT for ITS), many of which are relevant for transportation (the main exceptions are related to those technologies focusing on the extraction of natural resources from the sea bed). The same analysis also looks at network-related technologies, including those that aim to enhance port efficiency, to accelerate the development of infrastructures, to facilitate interoperability and intermodality in port facilities, to increase the safety of operations and to improve the understanding of the environmental impact of infrastructure building and dredging. Network-related research also includes the land-based component of intelligent transportation technologies and integrated ICT solutions. Other applications of ICTs are relevant for research in the sector of logistics and passenger transport services, as already highlighted in the case of rail transport.

Unfortunately, the allocation of national research funds to different research categories cannot be estimated for waterborne transport because of the very poor quantitative details found in relevant analysed and published data. Qualitative analyses could build on analogies with the corporate R&D intensity. If national research funds reflected research investments from industry (e.g. because of the allocation of research budgets in projects that require a matching effort in the private sector), vessel-related research would be the sub-sector receiving most of the public research funds of Member States, while lower budgets would concern the network development (best represented, for the waterborne sector, by port facilities) and the service sector (navigation companies).

The lack of information also hampers the estimation of the research budgets that are actually allocated for GHG emissions reduction. The research on the estimation emissions of GHG and local pollutants from ships, considered as an essential step for the implementation of regulations, is still requiring more investigation. The 'Green Ship of the Future'[59] programme, launched in 2008 in Denmark (25 Danish companies are involved) and aiming to significantly reduce the environmental impact of shipping through innovation, constitutes one example of a national initiative that is specifically addressing this topic. Even if it helps understanding that specific budget allocations aiming at the mitigation of GHG emissions in shipping exist, it is not sufficient for an assessment on the entity of these resources.

6.2.2.5 Transport network infrastructures

Total public R&D investments from Member States targeting the transport network infrastructure can be estimated using the GBAORD data allocated according to the NABS 92 classification (more detailed on transport sub-sectors), since this GBAORD version includes pubic R&D funding provided by Member States for infrastructure and general planning of land-use. Since the detailed data are only available for 2007, estimates based on this figure shall only be taken as an indicative value of the order of magnitude of these expenditures.

The total public R&D investment for infrastructures reported in GBAORD for 2007 is close to € 1.9 billion, while the available data concerning transport systems lead to a total of € 275 million. In most cases the share of R&D investments in the total budget allocated to R&D infrastructure ranges between 15% and 45%. Assuming that transport systems account for about 30% in those Member States where detailed data are not reported leads to an estimate close to € 400 million: this corresponds to roughly one fifth of the total investment for infrastructure and general planning of land-use and is the value taken as a reference in this analysis.

In addition, GBAORD also provides data on the public R&D funds provided for the general planning of land-use. Using the information available for 2007 leads to an estimation of roughly € 50 million spent for this purpose. The share of land-use planning R&D investments in the total public funding for infrastructure and planning is in the range of 5% to 12% for most of the Member States that reported detailed data in GBAORD. Assuming that the share of land use planning is about 9% of the total public R&D allocated to infrastructure and planning also in Member States for which a detailed assessment is not available leads to a final estimation of public R&D funding in land-se planning close to €90 million. If one fifth of this is allocated to transport (on the basis of the share of public R&D investments in transport systems in the total infrastructure and planning budget), the total public expenditure for network-related R&D in transport should be close to €0.43 billion, a value that corresponds to 13% of the total public funding provided for R&D on vehicles.

This estimate, combined with the one concerning corporate R&D investments in transport infrastructure, highlights an important difference between the construction sector and the automotive and other vehicle equipment manufacturing sectors, ultimately pointing out that the share of public R&D investments in construction is much higher than in the transport vehicle manufacturing industry. This is consistent with the importance of the public sector in the field of construction of transport infrastructure, since its role in this field is way more relevant than in the vehicle manufacturing industry. In addition, this conclusion would also be maintained by a possible underestimation of the total public R&D investments in the construction sector due to the lack of data reported in the GBAORD dataset for the infrastructure sector.

6.2.2.6 Economic, regulatory and social issues

Activities in this area include the research focusing on the relationships between the economic system, the transport system, human health and the natural environment. This encompasses issues like an improved assessment of the links between mobility and economic development, as well as those between the transportation sector and employment. Other examples of relevant activities include the

[59] http://www.greenship.org/

understanding of the consequences that the transport system have on human health (e.g. because of the emission of local pollutants), its impacts on the environment (like those due to climate change), and its effect on the availability of natural resources (including non-renewable energy sources). Research in this area also includes specific analyses on the effects of new taxation schemes or subsidies, analyses aimed to understand the effect of changing governance structures, studies aiming at the development of a fairer and more efficient way to pay for the use of transport infrastructure, or investigation targeting the implementation an efficient internalisation of transport externalities. Policy suggestions are typical outcomes of all these research activities, and innovations in this area are most likely to materialise through the approval and the implementation of policy proposals, including pilot projects.

Academic institutions, consultancies and public research institutes are amongst the main players in this area. Other stakeholders include public institutions like local or regional governments and industry. Public institutions are mostly involved in the approval and the funding of innovative policies (as well as in ensuring their enforcement). Industry is mostly involved through the provision of innovative solutions that address the needs emerging from the theoretical debate (e.g. by the development of ICT-based detection, tracking or payment systems for road usage or congestion charging). In addition, industry is also contributing with contributions to the policy debate, participation in research activities and its involvement in standardisation processes.

A quantitative assessment of the public expenditure on economic, regulatory and social issues related to transportation is not easy to carry out, since all these areas are not considered in any of the databases taken into account and since little information exist in literature. Qualitative considerations, essentially based on evidence drawn from literature, indicate that the specific budget dedicated to research that targets the societal dimension of mobility is significantly smaller than the one directed towards the development of transport vehicle and network technologies (TRB-ECTRI, 2009). This is the case even if the socio-economic dimension of mobility is always present in the vision underlying research programs.

A significant fraction of the research funding concerning the themes included in the area of economic, regulatory and social issues in transportation is also likely to be covered by funds dedicated to economic research activities that encompass transportation issues as one of the elements of a broader context. This means that a larger amount of public funds from member States (e.g. contributing to the financing of academic research in economics, health and environmental sciences) dedicated to this theme should also be taken into account. However, similar considerations also hold for technical research (mechanical, aerospace, and civil engineering, electronic, informatics) for vehicle- and network-related research. In any case, the available information on public research funds are not detailed enough to identify the expenditures allocated for these purposes to any of these specific research areas.

6.3 EU FP7 funding

6.3.1 Overall picture

European funds complement the Member States' public R&D support. The Research Framework Programme is a key source of R&D financing on new transport technologies. Launched in 2007, the Seventh Framework Programme (FP7) has a total budget of € 50.5 billion[60] over the period 2007-2013, broken down into four main programmes (Cooperation, Ideas, Capacities, People) as well as JRC contribution. Under the Cooperation Programme (€ 32.4 billion), the 'Transport' theme (including all transport modes and aeronautics) has been allocated around € 4.2 billion and the 'Energy' theme some € 2.3 billion (Figure 33).

Transport research projects under FP7 cover all modes of transport (people and goods). They reflect the objectives and research priorities defined by the strategic research agendas of relevant technology platforms (e.g. ERTRAC for road, ERRAC for rail, WATERBORNE TP for waterborne transport and ACARE for air transport; as well as the contribution of EIRAC for intermodal, etc., see Part III).

[60] Plus € 2.75 billion for nuclear research through Euratom.

Priorities are divided into the following sub-themes (European Commission, 2006a):

- Aeronautics and air transport AAT (excluding military aeronautics research) covers emissions reduction, new engines and alternative fuels, air traffic management, safety and environmentally efficient aviation. Research priorities and goals build on the ACARE platform (see section 9.5.3). Research projects are launched through 1) Collaborative research complemented by two key EU initiatives namely 2) Clean Sky JTI and 3) SESAR JU (European Commission, 2010a).

  Overall, a total EC budget of € 960 million (2007-2013) is dedicated to collaborative research in order to reduce the environmental impact of aviation and improve the efficiency, competitiveness and safety of this mode. Additionally, € 800 million has been allocated by the EC to the Clean Sky JTI focusing also on environmental aspects and another € 350 million has been contributed by the EC towards financing the SESAR JU on new air traffic management system. All in all, the annualised FP7 budget allocated to air transport lies in the order of € 300-350 million that represents a sharp increase compared to the previous FP6 budget (Figure 35).

- Sustainable surface transport SST (rail, road, waterborne) focuses on six areas namely (1) The greening of surface transport; (2) Encouraging modal shift and decongesting transport corridors; (3) Ensuring sustainable urban mobility; (4) Improving safety and security; (5) Strengthening competitiveness and (6) Cross-cutting activities. Additionally to the EC budget on collaborative research, another around € 220 million should be added coming from the EC contribution to the EGCI (note that in our bottom-up approach the total EC contribution to the EGCI i.e. € 500 million is assigned to road transport research[61]).

- Support to the European global satellite navigation system Galileo and the European Geostationary Navigation Overlay Service (EGNOS): The share provided from the FP7 budget in the total contribution amounts to € 400 millions (European Commission, 2008b). Nevertheless, for the period 2007-2013, the total support granted by the European Commission to them amounts to € 3.4 billion. This budget has been split across the three main activities: the completion of the Galileo development phase (accounting for around € 600 million), the Galileo deployment phase (€ 2.4 billion), and the operation of EGNOS (around € 400 million) (European Commission, 2011b). Further information on Galileo and EGNOS are given in the Box 4.

- Horizontal activities for the implementation of the transport programme.

Aeronautics and air transport
Reduction of emissions, work on engines and alternative fuels
Air traffic management, safety aspects of air transport
Environmentally efficient aviation
Sustainable surface transport (rail, road and waterborne)
Development of clean and efficient engines and power trains
Reducing the impact of transport on climate change
Inter-modal regional and national transport
Clean and safe vehicles
Infrastructure construction and maintenance, integrative architectures

Table 8: Research priorities of the different transport modes under FP7
Source: CORDIS website[62]

[61] The European Green Car Initiative has three main lines of action, out of which R&D is only one. The overall budget of the total initiative is € 5 billion. Out of this, € 1 billion go to R&D activities, equally distributed through funds from the EU, and from industry and Member States. See page 218 for more details and references.

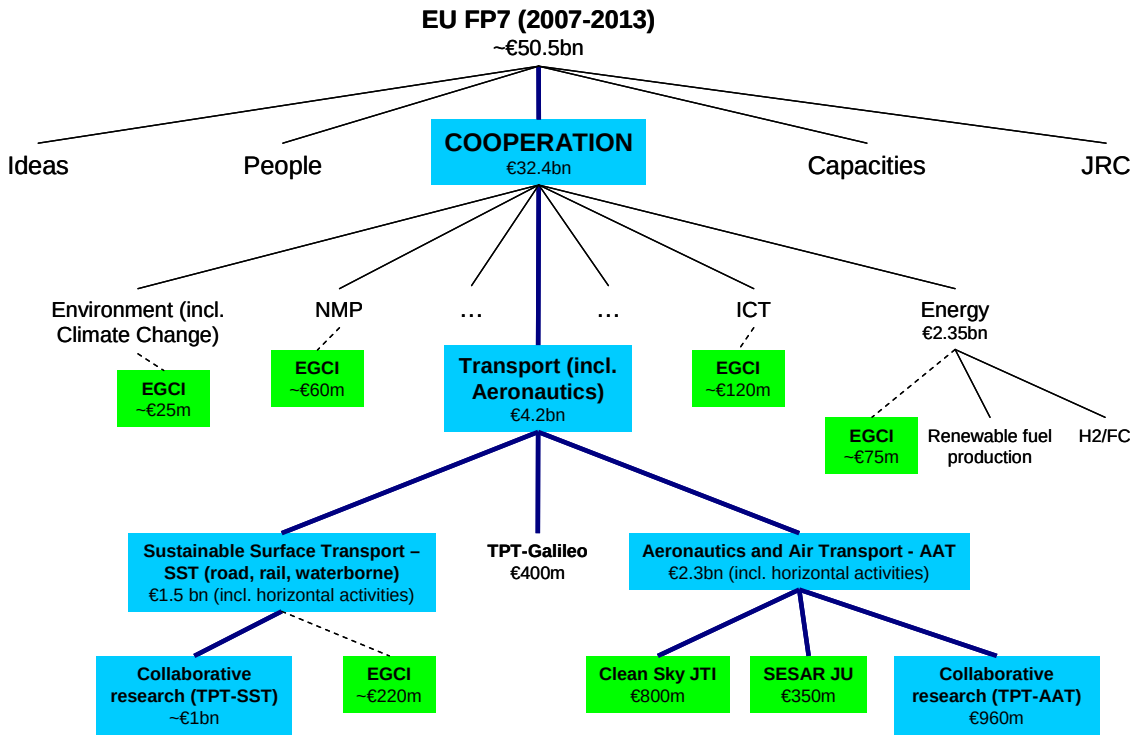

Figure 33: Transport research under FP7 – indicative budgets (simplified)
Source: JRC-IPTS, based on several sources (CORDIS website[62]; European Commission, 2010a; 2010d; Breslin, 2007; EGCI website[63], Regulation No 683/2008 on EGNOS and Galileo)
Note: EU research initiatives (PPP, JTI, JU) are highlighted in green. Note that the European Green Cars Initiative EGCI[61]; with a total EC contribution of € 500m on the R&D activities, runs only over the period 2010-2013. EGCI is a cross-thematic cooperation between five themes: transport SST (44%), ICT (24%), NMP (12%), Energy (15%) and Environment (5%). The FP7 budget allocated to the Hydrogen and Fuel Cells Joint Technology Initiative is €470 million. Although from 2008 onwards most of the hydrogen and fuel cell projects are implemented by the FCH JU, some other FCH-related projects were launched across several themes (e.g. 'Energy' and 'NMP').

Furthermore, alongside the transport theme, other transport-related R&D projects are funded under the themes 'Energy' including research projects on biofuels and hydrogen and fuel cells (the latter being implemented through the Fuel Cell and Hydrogen Joint Technology Initiative with € 470 million funded by the EC, see Annex IV) and, to a lesser extent, under 'Environment', 'ICT' and 'NMP' that are other themes of the cooperation programme.

6.3.2 Estimation of the annualised EC funding under FP7

The assessment of the FP7 R&D investments undertaken here relies on a combination of different approaches. To the extent possible, the official budgets – also including the recent European Green Cars Initiative from 2010 onwards – have been used, and then annualised. The interim evaluation of EU Transport research within FP7 (Technopolis, 2011) has been used as another important source for comparing and updating our results.

When going at a higher level of detail, e.g. for obtaining a breakdown of the R&D investments by transport mode or technologies, information on budgets does not provide the required level of detail. In these cases, FP7 commitments during the first three years of its duration to single projects have been analysed. This track of assessment systematically includes all projects funded within the core budget line used for transport-R&D projects ('Transport' thematic priority); to the extent possible it has been complemented by other transport-relevant projects that are funded through other budget lines (e.g. 'Energy' or 'Environment').

[62] http://cordis.europa.eu/fp7/transport/
[63] http://www.green-cars-initiative.eu/

As the EU Research Framework Programmes are of multiannual nature, while the present report aims at presenting the EU R&D investments for the year 2008, they had to be broken down further in order to determine the specific budgets available for one single year. In order to level out annual fluctuations in the budget that are due to the project cycles, an even allocation of the total expenses to every year of the FP7 duration was assumed. Despite some uncertainties associated with this approach, the figures obtained here are consistent with official figures at the more aggregated level. More concretely, the following approach has been used for assessing the various FP7 R&D support:

- For road, the European Green Cars Initiative has been used as one basis, assuming an annual spread of the budget over the period 2007-2013, even though it has been launched at a latter stage only. On top of this, projects launched under TPT-SST that relate to road transport R&D other than EGCI are taken into account.
- For rail and waterborne as well as multimodal research, an analysis of the projects launched during the first three years has been used as estimate. The same applies to the analysis of biofuels-related R&D.
- For hydrogen and fuel cells, the EC FP7 budget to the FCH JTI has been annualised.
- In the case of air transport, the annualised budget of the Clean Sky JTI and the SESAR JU is taken as a basis. This is complemented by the commitments to aviation-related projects under Collaborative Research TPT-AAT.

Other EU funding schemes such as the Competitiveness and Innovation Programme with its pillar Intelligent Energy Europe, the Cohesion funds, Trans-European Networks, Marco Polo etc. could either not be assessed quantitatively on the level of detail needed for this report, or were considered less relevant for research as they mainly focus on deployment. Their importance in supporting the uptake of innovative transport technologies must nevertheless be duly noted! Also financing programmes of the European Investment Bank (e.g. the European Clean Transport Facility and the Risk Sharing Financing Facility) have not been taken into account (see section 3.6.3 for more information on these instruments). They are important instruments in providing access to financing for innovative companies, and can therefore help in bridging the technology 'valley of death' between the technological feasibility and commercial implantation.

Figure 34 presents the overall breakdown of FP7 funding (annualised) towards the different transport modes. Under FP7, the average EC funding to transport research (excluding here energy-related research such as biofuels and hydrogen and fuel cells) amounts to some € 600 million per year, out of which more than half (54%) is dedicated to aeronautics research and 22% to road research. On the other hand, waterborne and rail research account for only 9% and 5% of the total EC funding towards transport respectively, which may already include some cross-modal research. Finally, around 10% of the EC funding is directed to research activities non-specifically related to one transport mode e.g. urban mobility, transport policies, Galileo, cross-cutting research. The above figures refer to collaborative research projects as well as the Clean Sky JTI, SESAR JU and the European Green Car Initiative. If only collaborative research projects had been analysed, the dominance of aviation and road research would be less pronounced, and the distribution be relatively well in line with the results obtained when analysing the Technopolis (2011) database.

When compared to previous Research Framework Programmes, the increase in the overall annualised EC budget to transport-related research is remarkable (Figure 35). However, some differences in budget occur between modes. While the EC FP7 budget on aeronautics research represents an increase of almost 70% compared to FP6 (and more than 80% in nominal terms), EC budgets directed to waterborne and surface transport show a more limited increase, and the limited data included here show no increase for rail-related research so far.

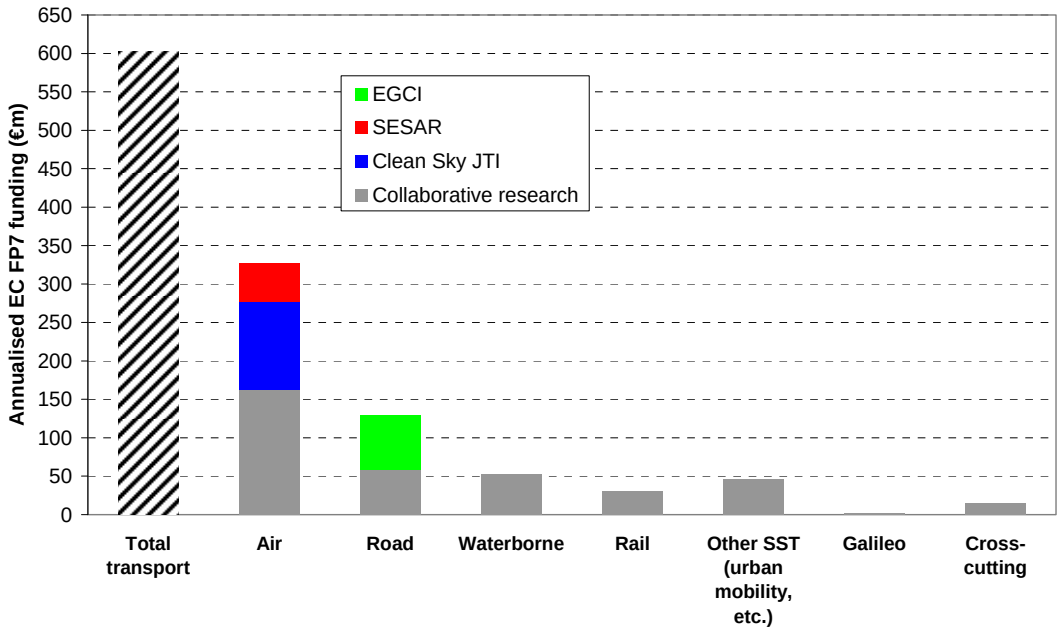

Figure 34: Repartition of the EC FP7 funds (annualised)

Source: JRC-IPTS

Note: Collaborative research estimated from commitments made during the 3 first years of FP7. EC contribution from EGCI, Clean Sky JTI and SESAR JU have been annualised (in the case of EGCI we annualised over seven years even though formally, EGCI runs only since 2010). Although EGCI funds are spread over several themes, we allocate the total amount to road transport. The figures for R&D by mode are associated with some uncertainty as in some cases an allocation to one single mode has been problematic.

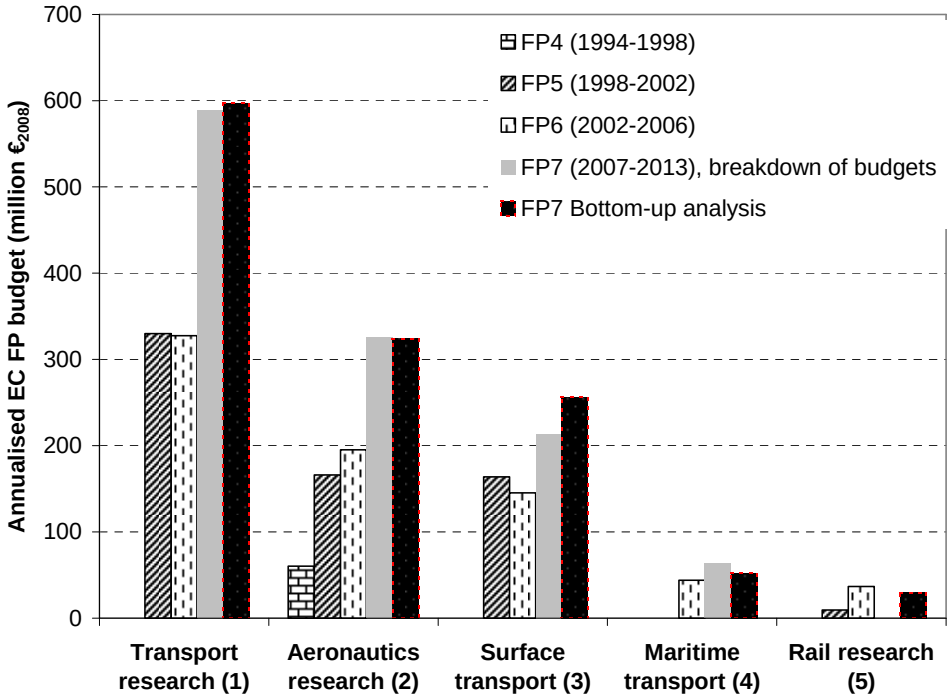

Figure 35: Annualised FP budgets in different transport-related research areas

Source: JRC-IPTS, based on EU sources and results from our bottom-up analysis (for FP7 only)

Notes: Figures are given in $€_{2008}$. They have been deflated using a GDP deflator for the middle year of the programme duration. Funding to hydrogen and fuel cells and biofuels are not displayed.

(1) Total research funding on transport

(2) See e.g. European Commission (2010a); MEFISTO (2010)

(3) Surface transport under FP5 is an overestimation since it includes the thematics 'Sustainable mobility and intermodality' (i.e. incl. some air transport research) and 'Land transport and marine technologies'. Also, note that FP7 funding obtained through our bottom-up approach includes the total EGCI funds.
(4) See European Commission (2006a)
(5) See e.g. http://ec.europa.eu/research/transport/news/article_3171_en.html. No reliable data have been found for the FP7 budget on rail research. Note however that in 2004 ERRAC asked for a total budget of € 400m (i.e. € 57m per year) to be spent on railway research (see http://www.errac.org/IMG/pdf/positionpaper_fp7_errac_240105.pdf)

Funding allocated to **air transport** research represents the largest part within EC FP7 transport funds with a total of almost € 330 million spent per year (excluding some cross-cutting research), out of which € 163 million are due to collaborative research (TPT-AAT), € 114 million financed through the Clean Sky JTI and € 50 million stemming from the SESAR JU. The share of the total EC funding aiming at reducing GHG emissions of this sector has been estimated to be in the order of € 160 million (i.e. 48% of the total[64]), although this figure includes environmental aspects such as NO_x and noise reduction. Along with collaborative research (under the priority 'the greening of air transport'[65]), this significant investment is notably due to the launch in 2008 of the above-mentioned EU aeronautic research programme Clean Sky JTI (see Annex IV), which strives at fulfilling the objectives fixed by the ACARE SRA (see Annex IV). Both the reduction of GHG emissions (e.g. via new engines, airframe) and the environmental impacts of aircrafts and helicopters (e.g. eco-design, noise reduction) are actively covered by this initiative. Note that GHG and pollutant emissions reduction are also addressed through projects of the SESAR JU for improving the air traffic management system[66].

Resulting from our bottom-up analysis, the EC research support to **road transport** under FP7 reached some € 130 million on an annual basis. This figure takes into account the EC budget allocated to collaborative research on road transport (TPT-SST) but also includes the total budget of the EGCI of around € 70 million per year on average, even if the latter is spread over several cooperation themes (see Figure 33) and runs over the period 2010-2013 (we assume the same duration as for FP7 i.e. seven years). In a second step, it has been estimated that almost 40% (€ 48 million per year on average) of the EC funds to road transport is directly devoted to reduce GHG emissions, especially due to research projects launched under the collaborative research thematic 'The greening of surface transport'[67] and the EGCI[68].

With regard to **waterborne** transport (maritime and inland waterways), EU FP7 annualised funds have been estimated to reach some € 53 million[69], out of which roughly € 21 million are directed to reduce GHG and air pollutant emissions. As an example of key FP7 project, the HERCULES ß project (€ 26 million over 3 years with an EC contribution of € 15 million) was launched in 2008 as a follow-up of the former HERCULES (High Efficiency Engine R&D on Combustion with Ultra Low Emissions for Ships)[70] project. One of the main objectives of this project is to reduce fuel consumption of marine diesel engines by 10% by the year 2020 and move towards ultra low exhaust emissions (70% NO_x and 50% PM emissions reduction) from marine engines by the year 2020 (compared to 2000 level). Another important FP7 projects in this area are the POSE²DON project (Power Optimized Ship for Environment with Electric Innovative Designs Onboard; total budget of € 21.46 million over four years)[71] regrouping 30 partners under the 'electric ship' concept as well as the STREAMLINE project (Strategic Research For Innovative Marine Propulsion Concepts; total budget of € 10.9 million over the period 2010-2014) addressing new propulsion concepts that could significantly increase the energy

[64] Note that the share of FP7 activities that contribute to environmental targets estimated here lies above that estimated on the basis of the Technopolis (2011) database. This is due to the wider scope of the present analysis, which includes SESAR, Clean Sky and the EGCI, the latter which aim at reducing environmental impacts. To this add the collaborative research projects allocated under 'greening of transport'.
[65] The on-going FP7 project DREAM (valiDation of Radical Engine Architecture systems http://www.dream-project.eu) is an example of key EU research programme aiming at reducing the CO_2 emissions (among others) of the aviation sector. See also the OPENAIR project for noise reduction.
[66] See e.g. the AIRE initiative http://www.sesarju.eu/environment/aire
[67] See e.g. the FP7 projects INGAS and POWERFUL
[68] The projects launched under the 2010 calls (around € 100 million) focus on transport electrification (electric vehicles, infrastructure, batteries, etc.).
[69] Waterborne TP (2007) estimated an annual average of around € 70 million.
[70] http://www.ip-hercules.com/
[71] http://www.poseidon-ip.eu/

efficiency[72]. Furthermore, the FP7 project BESST (Breakthrough in European Ship and Shipbuilding Technologies) was launched in 2009 for a total budget of € 29 million over 42 months to 'achieve a breakthrough in competitiveness, environmentally friendliness and safety of EU built ships'[73].

The results of our bottom-up approach show that **rail** research projects under FP7 receive an annual EC funding of almost € 30 million, which constitutes the lowest EC contribution towards a transport mode. Around 17% of this amount was found to be targeted to reduce GHG emissions and the environmental impact of this sector. For instance, the FP7 project CleanER-D (Clean European Rail Diesel; total budget of € 13.39 million over 48 months)[74] is an important research initiative in this domain. It was launched in 2009 with the objective to develop emissions reduction technologies for diesel locomotives and rail vehicles (including hybrid technologies).

Finally, several other FP7 research projects are dealing with horizontal activities (e.g. urban mobility, modal shift, socio-economic issues, policy support, etc.) and cannot be assigned to one transport mode in particular. In our analysis, they represent an annualised EC contribution of around € 63 million and also address (directly or indirectly) climate change and environmental issues.

Note that important research activities including ITS that focus on one mode are allocated to the mode, and not to ITS per se. This is somehow in line with the methodology applied for corporate R&D investments, where e.g. the part of automotive research oriented towards ITS has not been singled out.

Box 4 – Galileo and the European Geostationary Navigation Overlay Service (EGNOS)

The creation of a Global Navigation Satellite System (GNSS) started from a very ambitious location intelligence project. Since the opening to civilian use, the primary aim of GNSSs is to provide very precise time, location and velocity information so that receivers anywhere in the world can identify a unique physical address. These characteristics, combined with the mobile nature of transport, make location technologies extremely important in the context of ITS. At present, location technologies are used mostly for navigation – land, maritime and air transport – but they are rapidly merging with information technologies. Location and information technologies are crucial to deliver tailored information for a user (as in car navigation and emergency assistance). They become a necessity to apply the appropriate fee in case of the implementation of an advanced road pricing scheme.

The backbone of the present generation GNSS (or GNSS-1) is two space-based navigation systems: the Navstar Global Positioning System (GPS) owned and operated by the United States and the Russian GLONASS (OECD, 2000). The European Union is now building its own GNSS through its satellite radio navigation programmes, Galileo, and the European Geostationary Navigation Overlay Service (EGNOS). Galileo is essentially an independent European navigation-satellite constellation. EGNOS is the first-generation European GNSS System and constitutes also a first step in the implementation of Galileo (ESA, 2006).

These European satellite radio navigation programmes commenced more than 10 years ago on the basis of a political vision to achieve autonomy with respect to the systems of the USA and Russia and provide satellite navigation services optimised for civil use (European Commission, 2011b). A key governance reform of the programmes took place in 2007, when the European financing and risk management needed for the satellite radio navigation system has been fully based on public action (rather than partly based on a public private partnership). The same reform gave the responsibility for managing the Galileo and EGNOS programmes to the European Commission and entrusted the ownership of the infrastructure resulting from them to the European Union. Today both these programmes are integral parts of the trans-European networks.

The EGNOS open service officially became operational on 1 October 2009. The system has operated since then in accordance with the requisite specifications. It is operated by a service provider under a contract to the Commission whose main subject is the uninterrupted provision of the open service and of the safety-of-life service (European Commission, 2011b).

Galileo's development phase comprises the construction and launch of the first satellites, the establishment of the first ground-based infrastructures and all the work and operations necessary to validate the system in orbit. It will continue, in parallel with the deployment phase, until 2012, when the development phase will be completed. The exploitation phase for the first services will start in 2014, and full operational capability should be achieved in 2019-2020 (European Commission, 2011b).

On funding issues, it is important to notice that the development phase led to additional cost that amount to some € 500 million in total. Similarly, the price of launch services, for example, has entailed an additional cost of more than € 500 million (by comparison with the original budget) in the deployment phase (European Commission, 2011). Other issues are

[72] http://www.streamline-project.eu/
[73] http://www.besst.it/
[74] http://www.cleaner-d.eu/; see also the Railenergy project under FP6 http://www.railenergy.org/

having an impact on the programme's funding needs. Overall, initial cost estimates have not been kept to because some risks, relating primarily to technical issues, security requirements and the situation in the marketplace, have materialised during these very complex phases of the programme. Taking into account the cost overruns arising in the development and deployment phases, the Commission considers that additional funding of € 1.9 billion is needed to complete the infrastructure, even if the budget currently available does not call into question the ultimate objectives because it already encompasses the building and launch of 18 satellites, with the associated ground infrastructure, and the supply of the first services from 2014-2015, and it also covers the initial operation of the EGNOS services (European Commission, 2011b).

6.4 Number of companies receiving public funding

Information about the number of companies that receive public funding in transport can complement the quantitative assessment of public R&D investment. This indicator can be found in some editions of the Community Innovation Survey. On average, more companies active in the manufacturing of both motor vehicles and of other transport equipment receive any kind of public funding than the average manufacturing sector (Figure 36). The sector 'Manufacturing of other transport equipment' contains the highest share of companies that have received public funding, which is very likely due to the aeronautic industry. Figure 37 shows for the example of companies active in the manufacturing of motor vehicles, trailers and semi-trailers the different types of public funding. The importance of funding through the central government becomes obvious, in particular considering the decrease of regional funding over the last years. At the same time, there are significantly more transport companies that receive funding from EU Research Framework Programmes in 2008 than in 2004.

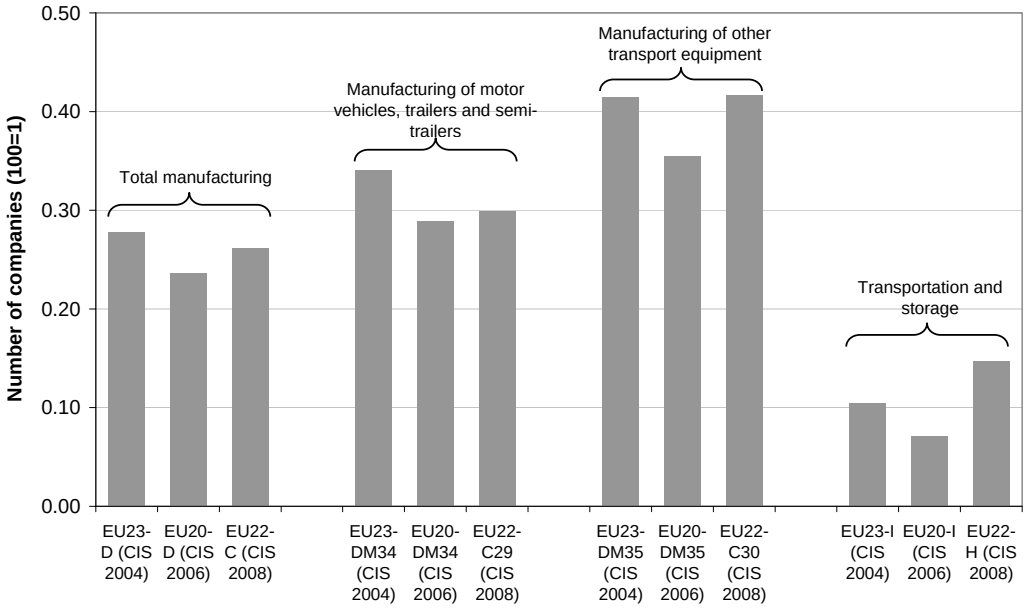

Figure 36: Share of enterprises that receive any kind of public fundings
Data source: Eurostat CIS 2004, 2006, 2008

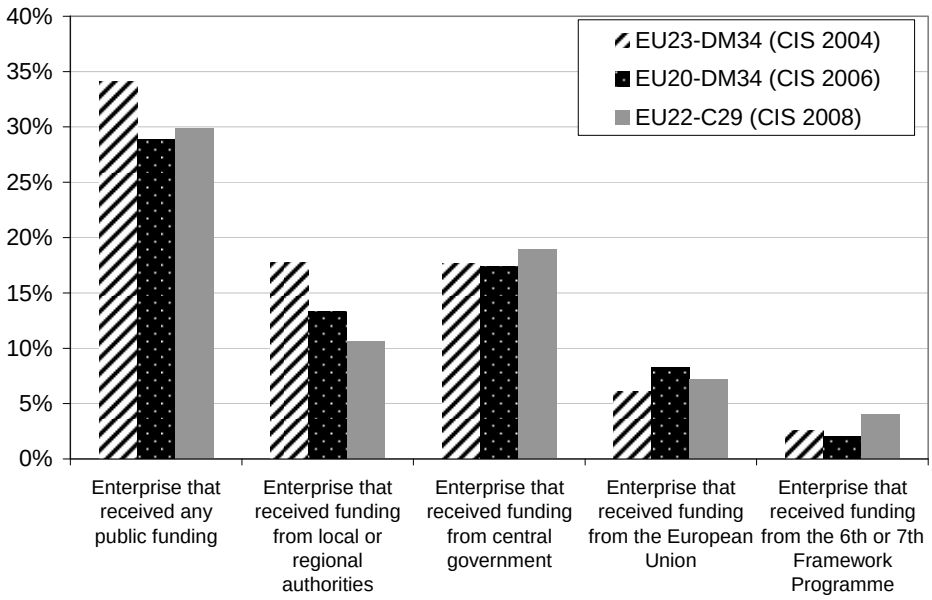

Figure 37: Share of companies active in the manufacturing of motor vehicles, trailers and semi-trailers (NACE R1 DM34 or NACE R2 C29 category) that receive different kinds of public funding
Data source: Eurostat CIS 2004, 2006, 2008

7 Innovation in low-carbon technologies: the case of the automotive sector

7.1 Synthesis

Key findings

- The automotive sector dedicated around one third of its R&D investments to technologies that can contribute to reduce emissions of greenhouse gases, even though this research may not always be primarily driven by environmental concerns, and may often have been outweighed by increases in motor power and/or vehicle weight.
- Within the research efforts towards low-carbon powertrains, more than half is dedicated towards the optimisation of conventional power-trains. Among the alternative power-trains, battery and hybrid electric options receive considerably higher funds than fuel cell vehicles.
- This is confirmed by a patent analysis that clearly demonstrates the fast take up of patenting activity in 1) alternative powertrains, and within these, 2) BEV and HEV. Overall, corporate R&D spending and number of patents directed to fuel cell vehicles are still increasing but at a lower rate than for electric and hybrid vehicles (BEVs, HEVs, PHEVs).
- EU-based companies have a high technological knowledge for conventional engines, and keep the leadership in these technologies. In terms of battery/hybrid electric vehicles, however, they are lagging behind. Partially, this is being tackled by the companies through a number of strategic alliances with battery manufacturers and electric utilities.

Policy conclusions

- Overall, car makers are putting important R&D efforts for developing all type of low carbon technologies in parallel, but with some recent shift in priorities. Nevertheless, fuel cell vehicles are still seen as a long-term strategy for this industry. Public efforts should observe this trend and ensure that research in promising long-term options is not neglected.
- Public R&D investments take more important shares for technologies that have not yet successfully achieved a high market penetration. This is in line with innovation theory according to which corporate innovators prefer lower-risk options, whereas the public sector has a more important role in carrying out long-term research.

7.2 R&D investments in selected low-carbon engine technologies

The bottom-up assessment carried out so far revealed that the EU automotive sector invested more than € 32 billion in R&D in 2008 (public and private funds), out of which more than 40% is dedicated to reduce the environmental impact of vehicles (and around one third for reducing GHG emissions). To go further in the analysis, a question then arises as to know how much of this amount is directed towards (selected) low-carbon technologies.

Figure 38 shows a global picture of technological fields in which R&D efforts are generally undertaken by the automotive sector to reduce the energy consumption and the environmental impact of vehicles. Typically, five key research areas can be distinguished:

- Optimising conventional drive technologies: it refers to the improvement of powertrains (engine and transmission) and still represents one of the best means (at least in the short-to-medium term) to reduce GHG and air emissions in order to fulfil the EU regulations.
- Developing alternative drive technologies: it generally includes R&D in electric vehicles (i.e. battery electric vehicles (BEVs), hybrid electric vehicles (HEVs) and plug-in hybrid electric vehicles (PHEVs)) and fuel cell technologies. Both technologies have not reached the same level of maturity and require different strategies.
- Alternative fuels: the use of alternative fuels in road transport such as biofuels or CNG is an important part of the R&D strategy for this sector, whatever funded by the industry or through public funds. However, the scope of this research topic goes well beyond the automotive sector and should include R&D investments from e.g. energy suppliers.
- Optimising vehicle design: this 'category' focuses on R&D activities related to the car body i.e. for reducing the vehicle weight as well as drag resistances (aerodynamic and rolling resistances).

  - Reducing the vehicle weight by using lightweight materials (e.g. through the displacement of conventional ferrous metals with e.g. high strength steel (HSS), aluminium, magnesium, composites) can lead to significant fuel consumption reduction (as well as improving air quality). However, the equation is quite complex since weight reduction is directly connected to safety and comfort issues meaning that a trade-off is necessary between all these constraints.

  - Drag resistances: important R&D efforts are regularly undertaken by the automotive industry to reduce the aerodynamic drag (depending on the speed, vehicle shape, air density, etc.) and rolling resistance (caused by the tyre deformation, depending on the vehicle speed and weight). For aerodynamics, experimental (wind tunnel testing) and simulation tools (e.g. CFD software) are widely used to optimise the car shape and then reduce, as much as possible depending on the constraints (safety, comfort), the aerodynamic drag coefficient. Regarding the rolling resistance, important fuel savings can be obtained by systematically using low rolling resistance tyres (LRRT) and tyre pressure monitoring systems (TPMS).
- Auxiliaries: R&D efforts are permanently carried out to optimise auxiliaries such as the mobile air conditioning system.

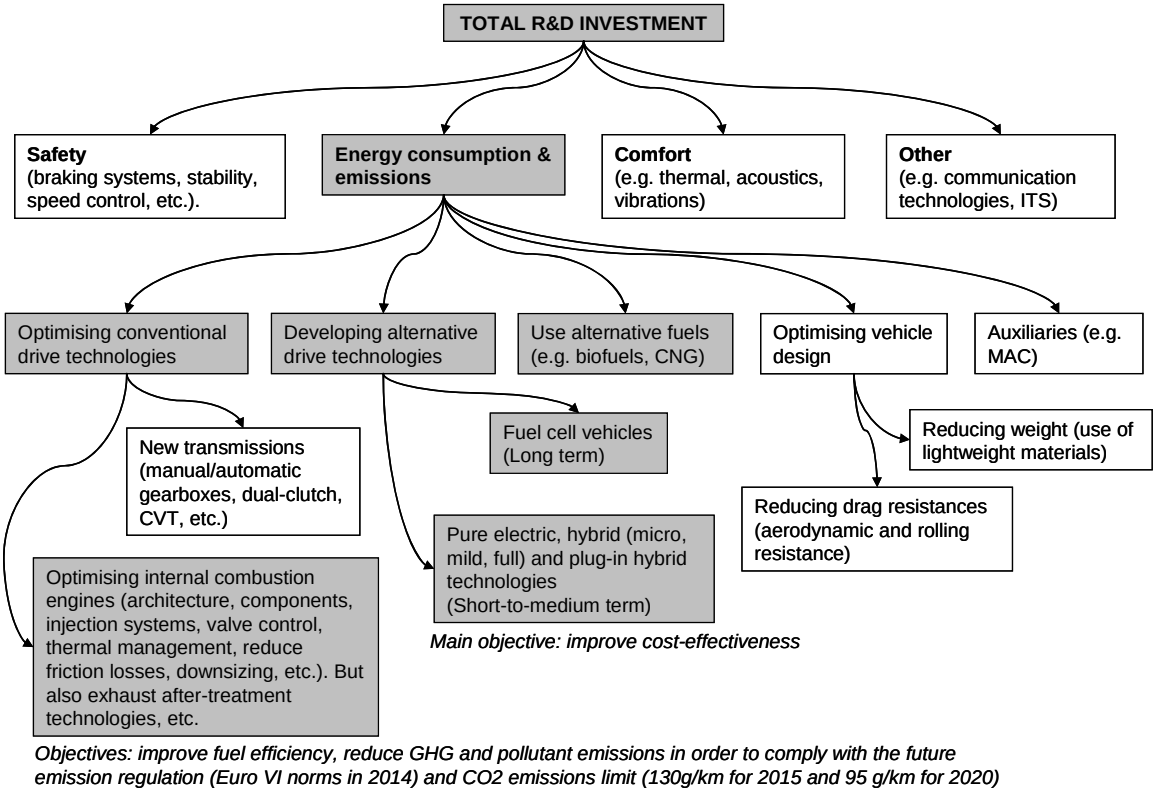

Figure 38: R&D investment flows in road vehicle technologies for reducing GHG emissions
Source: JRC-IPTS
Note: R&D topics coloured in grey are those for which the R&D investment will be estimated

Table 9 provides the estimated ranges of the R&D investments directed to conventional engines, electric vehicles, fuel cells and hydrogen technologies, and biofuels. Corporate figures result from the methodology set up in our bottom-up approach (see section 5.3.1) while public MS figures are derived from the IEA RD&D budget database and EU funds have been annualised over the duration of FP7. Note, however, that unlike in the other parts of the present assessment, some relevant R&D investments from companies outside of the transport sector (i.e. oil companies) have been included here.

	Corporate R&D (€ m)	**EC FP7 (€ m, avg per year)**	**Public MS R&D (€ m)**	**Overall estimate or range (€ m)**
Conventional engines	5000-6000	16	132	5000-6000
Electric vehicles (incl. hybrids)	1300-1600	23	60-100	1400-1700
Fuel cells (out of which H2)	375 (102)	78 (8)	173 (41)	627 (150)
Transport biofuels	269	55	68 (253 for bioenergy)	392

Table 9: Approximate R&D investments in selected vehicle technologies (2008)
Source: JRC-IPTS (rounded numbers)
Note: Corporate R&D for biofuels and hydrogen and fuel cells are based on Wiesenthal et al. (2009) and refers to the year 2007. Estimates for public MS are derived from the IEA RD&D statistics with gap-filling from previous years when appropriate. Public FP7 funds are derived from an analysis of related projects over the first 3 years of FP7, except for H2/FC that corresponds to the EC contribution to the FCH JTI (€ 470 million over 6 years).

7.2.1 Conventional ICEs

According to the present analysis, R&D investment for optimising/developing ICE technologies ranged in the order of € 5-6 billion in 2008, thus accounting for around half of the total R&D spending for reducing GHG emissions of the sector. This figure is mainly based on corporate R&D investment that is by far the largest contributor (only 2.5-3% were found to come from public funds, see Figure

39). Despite important (but unavoidable) uncertainties associated to this figure[75], such a huge investment does not come as a surprise since automotive manufacturers and suppliers have been massively investing in the optimisation of conventional engines (diesel and gasoline, depending on the firm's strategy). As mentioned before, there exist several domains of research, all of them having the potential to reduce, at different degree, the vehicle emissions (GHG and air pollutants).

7.2.2 Hybrid and battery electric vehicles

In 2008, the R&D investment into hybrid, plug-in hybrid and battery electric vehicle technologies (HEV, PHEV, BEV) has been estimated to range in the order of € 1.4-1.7 billion, most of this amount (94%) stemming from the private sector. This elevated investment is the result of a growing interest of the EU automotive industry sector in this field. Today, most of the automotive manufacturers are involved in the 'electrification' race and have set up partnerships (e.g. through joint ventures) with battery manufacturers[76], automotive suppliers and also energy suppliers to develop electric vehicles worldwide (see section 9.4.1). The results of the patent search also clearly underline the importance given to research in electric vehicles in more recent years, therefore supporting the figures found here.

We roughly estimated that between 6% and 7% of the total R&D invested in electric vehicles stems from public funds. Yet note that since 2008, the year of the present assessment, several Member States have launched important research programmes in this area (IA-HEV, 2010) and have set up ambitious sales targets for 2020 (and beyond) as it is the case for Germany and France (IEA, 2010). Under FP7, an annual average of around € 20 million was estimated to be allocated to electric vehicles, mainly through projects launched under the European Green Cars Initiative[77].

7.2.3 Hydrogen and fuel cells

The present analysis estimated that R&D investments in hydrogen and fuel cell technologies attracted around € 630 million by 2008, out of which € 252 million are financed from public funds (i.e. 40% of the total, including Member States and EC FP7 funding. It makes hydrogen and fuel cells the technologies having the largest relative public R&D funding among the technologies analysed in this section, see Figure 39) while € 375 million are due to the private sector (energy suppliers, fuel cell manufacturers, automotive industry, etc.).

The assessment of the corporate R&D investment is taken from the analysis undertaken by Wiesenthal et al. (2009) for the year 2007, which resulted from an analysis of around 70 companies active in this area. This relatively high investment (€ 375 million) is mainly due to the large number of companies active in this research area and their high interest in this technology that is considered as a strategic research field for many of them[78]. Note that a more thorough analysis of the R&D investments in hydrogen and fuel cells and the source of discrepancies with other references is provided by Wiesenthal et al. (2009).

The total public R&D spending (i.e. from EU Member States and annualised EU funds under FP7) amounted to more than € 250 million, with the EU funding under FP7 having accounted for around one third of this.

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[75] There are two main sources of uncertainties. Firstly, it is very complex to systematically isolate R&D investments on conventional engines from R&D investments on transmission. Secondly, it was not feasible to systematically distinguish R&D activities aiming at reducing GHG emissions from those relative to air quality improvements (e.g. exhaust after-treatment technologies).

[76] Most of the battery manufacturers have their headquarters outside the EU (e.g. Japan and the U.S.). Evonik (DE), Saft (FR), BASF (DE) are key EU industries involving in R&D activities in this area.

[77] See e.g. the calls for proposals on the electrification of road transport launched in the frame of the EU Green Cars Initiative in 2009.

[78] For instance Daimler (as well as non-EU based companies such as Ford and Toyota) have confirmed their commitment to this technology and foresee that the technology will be for sale around 2015 (Hybridcars.com, 2009).

7.2.4 Biofuels

The research budget dedicated to transport biofuels amounted to € 390 million in 2008, which reflects the fact that biofuels is a key research area. This figure is not restricted to research into second generation biofuel production pathways but comprises all transport biofuel technologies.

The corporate contribution to this investment amounted to € 270 million based on the analysis carried out by Wiesenthal et al. (2009) for the year 2007. The public share of R&D investments has been greater than 30% in 2008 with EU funds through FP7 amounted to around € 55 million on an annual basis. The limited share of public R&D investments may not only be due to the relatively elevated maturity of biofuels, but may also be explained by data restrictions (Wiesenthal et al., 2009).

Furthermore, the data suggest that some Member States may not explicitly disclose R&D on biofuels, but rather allocate it under the category bioenergy-related research. In 2008, the total R&D investment in bioenergy for the EU Member States reaches some € 253 million out of which only € 68 million was allocated to transport biofuels.

7.2.5 Public funds

The ranking of corporate R&D investments with clear priorities given to the improvement of conventional engine technologies and electric vehicles rather than fuel cell vehicles[79] (and the exactly opposite ranking of public R&D investments, see Figure 39 below) can be explained by innovation theory[80]. In general, technologies that are close-to-market and thus require expensive pilot plants and up-scaling would face larger industrial contribution, while technologies that are further from market are mainly publicly financed as industry would not want to take the risk. Hydrogen fuel cell vehicles are seen as a strategic long term option also over battery vehicles for longer range vehicles (see Thomas, 2009; Campanari et al., 2009; Offer et al., 2010). This explains that industry keeps investing in them, even though their R&D investment is more limited due to the longer time horizon compared to HEVs and BEVs.

Public R&D investments follow a ranking opposite to that of corporate investments. Their share in total investments into activities that optimize the conventional ICE powertrains remains very limited with some 2.5-3%, but increases for technologies that have a lower degree of market-readiness (see Table 9 and Figure 39). This can be explained by industrial research efforts generally preferring more mature technologies, and public efforts concentrating on less mature technologies and research of more basic nature. This fact underlines the more elevated importance of public research in fuel cell related research compared to e.g. electric vehicles.

[79] Data on Figure 39 refer to the public R&D share of hydrogen and fuel cells as a whole i.e. going well beyond fuel cell vehicles. However, based on information about the EC FP7 budget breakdown (FCH JU, 2009) and the R&D investments allocated to the category 'Mobile applications' of fuel cells from the IEA RD&D database, as well as a rough estimate of the corporate R&D investments directed to fuel cell vehicles, we came to the conclusion that at least 35% of the R&D investments on fuel cell vehicles is due to public funding.

[80] Biofuels research is an exception in the sense that most of the R&D efforts are undertaken outside of the automotive industry. Moreover, the results shown above relate to the year 2007; at that time, conventional biofuel production was already mature, but the need for (and R&D in) advanced 2nd generation biofuels has become more pronounced thereafter.

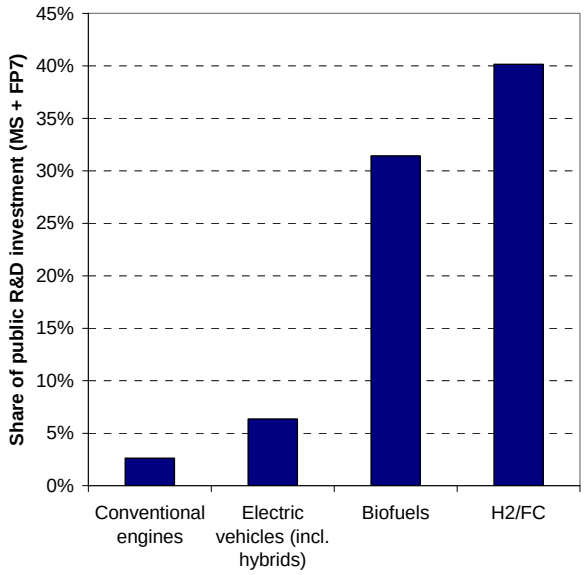


Figure 39: Share of public funds (from Member States and EU FP7) in total R&D investments to selected technologies
Source: JRC-IPTS (average values)

7.3 Patenting activity in low emission vehicle technologies: indicating the dynamics

While the above assessment of R&D investments only provides a snapshot for a certain year, a simplified analysis of patent applications can more easily be done for a time series and can thus help to understand the dynamics of research by technology.

7.3.1 Methodological considerations

Patent statistics, though an imperfect measure, are an established tool in the assessment of the technological capabilities of countries or companies. In order to better understand the current stand of technological development related to reducing greenhouse gas emissions in the transport sector, the patent activity in four selected technology areas is examined (conventional engines; electric vehicles; fuel cell vehicles; biofuels).

The outcome is used for two different purposes in the present report. Firstly, it serves as a rough indicator when estimating corporate R&D investments by technology (group). To this end, the share of a company's number of patents on a certain technology in their overall patenting activity is assumed to be related to their share of R&D investments dedicated to this technology in total R&D investments, despite all the drawbacks related with linking R&D investments and patents. Secondly, as it has not been possible to assess the R&D investments into certain technologies over time, the results of the patent search are used as an indication of the time dynamics of attention given to certain technologies.

Two different approaches on analysing patent (applications) have been used in parallel so as to overcome the specific shortcomings of each of them. On the one hand, a keyword-based research of the European Patent Office's database Esp@cenet, on the other a search by category of the PATSTAT database.

The (straightforward) **keyword-based research** builds on literature and follows the methodology developed by Oltra and Saint Jean (2009a). The yearly number of patent applications delivered worldwide to different technologies can be obtained from the patent database hosted by the European Patent Office (EPO)[81]. The searching process consists of using the three search fields: 'keywords in

[81] http://ep.espacenet.com/

title or abstract', 'publication date' and 'applicant'. However, this keyword-based approach is subject to several drawbacks, as underlined by Oltra and Saint Jean (2009a).

The more in-detail search **using the IPC[82] method** with the October 2009 snapshot of PATSTAT, the Worldwide Patent Statistical Database maintained by the European Patent Office (EPO). We consider here "international patent applications", defined as those applications filed under the Patent Cooperation Treaty (PCT, "world patents") and those filed directly at the EPO[83]. The technologies fields investigated were:

- Hybrid and electric vehicles: this includes electric motors used for traction in vehicles (i.e. small electric motors included for comfort are excluded), their integration into the vehicle, energy recovery from braking, and the pertinent control structures.
- Mobile fuel cells: this includes all aspects of fuel cell manufacture as well as their integration into vehicles.

The IPC method has been used successfully in a number of past studies. Nevertheless, a brief look at its strengths and weaknesses is warranted. The principal strength compared to the keyword method lies in the assessment of relevant technology fields, regardless of whether the patents contain the selected keywords or not. Furthermore, this type of search profits from the expertise of the patent offices when assigning each patent to the relevant field of technology. However, the selection on the basis of IPC still cannot guarantee that all relevant patents are captured in the search (false negatives). On the other hand, it is not possible to exclude the possibility of counting patents that are not directly relevant and that for one reason or another are included in the IPC codes deemed as adequate for the search (false positives).

In order to minimize the error in the search based on IPC codes, the search strategies are extensively tested by performing limited searches (e.g. to a single year, depending on the absolute number of patents) and examining the titles and abstracts of the patents matched by the search. In general, search strategies are initially designed to be broad and are then trimmed according to the detailed information in the patent applications. In the case that a given IPC code contains significant numbers of false positives, this particular IPC code is constrained by using keywords. Despite these precautions, we are compelled to point to the inherent uncertainties in the results presented in this chapter, which make it impossible to provide absolute numbers of relevant patent applications. Moreover, because the respective margins of error are unknown, it is not possible to apply significance testing (in the statistical sense) to small differences between observations. Despite the difficulties outlined above, it is possible to use the data to identify patenting trends and as an indicator of the technological performance of companies, countries or regions in comparison to each other.

[82] IPC stands for International Patent Classification. It provides a hierarchical system of language independent symbols for the classification of patents and utility models according to the different areas of technology to which they pertain. The search is thus performed by specifying relevant IPC codes.

[83] To avoid double counting of patent applications, those patents at the EPO resulting from applications under the PCT are excluded.

7.3.2 Results

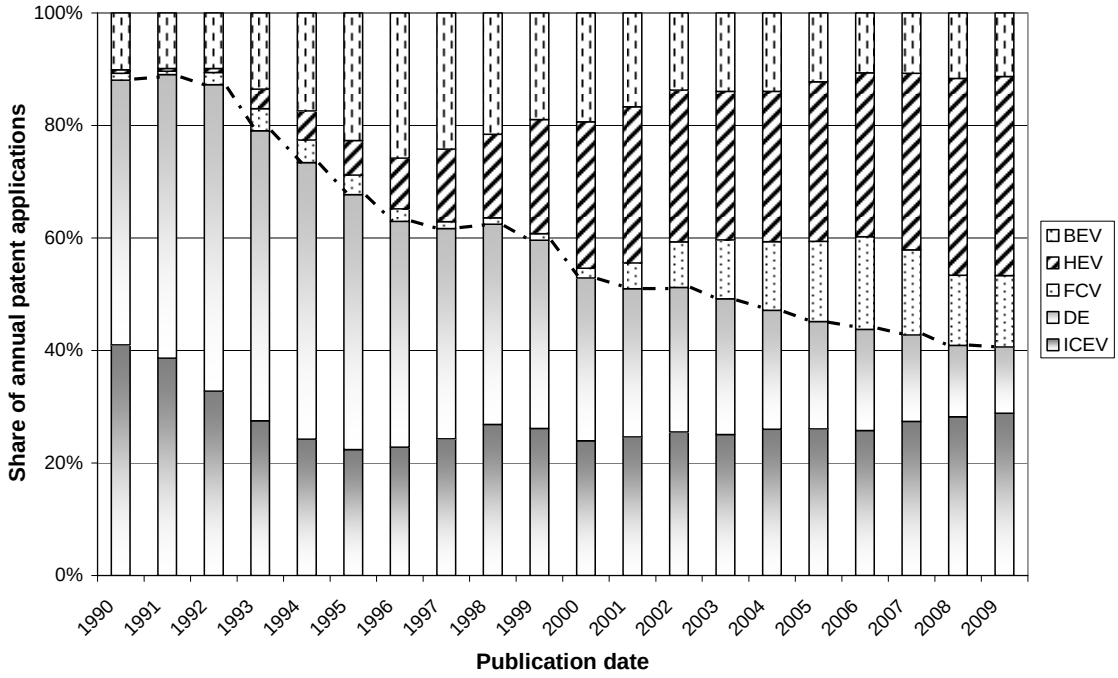


Figure 40: Dynamic of car manufacturers' patent portfolio into conventional and innovative engine technologies; 2-year moving average

Source: IPTS, based on EPO-Esp@cenet database

Note: ICE = Internal Combustion Engine Gasoline Vehicle; DE = Diesel Vehicle; HEV = Hybrid Electric Vehicle; BEV = Battery Electric Vehicle; FCV = Fuel Cell Vehicle. Sample of car manufacturers: Daimler, Volkswagen-Audi, Renault, PSA Peugeot Citroen, BMW, Porsche, Fiat, General Motors, Ford, Toyota, Mitsubishi, Nissan, Mazda, Honda, Suzuki, Hyundai-Kia, Ssangyong, SAIC Motor, Dongfeng, Chery Automobiles, FAW, Tata Motors.

Car makers have considerably increased their patenting activities in low-carbon technologies such as hybrid, battery electric and fuel cell vehicles, in parallel of improvements of conventional powertrains. From less than 20% in the early nineties, around 60% of the patent applications in 2009 are directed to alternative powertrain technologies (i.e. BEV, HEV and FCV; see Figure 40), with the higher share for hybrid electric vehicles. This hints at the rapidly growing importance paid by industry to the development of these technologies in recent years, supporting the conclusion of the technology's importance that was drawn from the assessment of R&D investments above. At the same time, the patent applications on FCV are somewhat less, and rise much less rapidly. This general trend does not mean that hydrogen- and fuel cell related R&D activities have been stopped. It rather indicates that they have become a lower priority for EU-based companies in the sector when compared to electric vehicles.

These findings are in line with some recent developments in fuel cell research as announced by the main car manufacturers (see Akkermans et al., 2010, Annex 6.1 – Table 9). Although most car makers keep on investing, at different level, in R&D programmes to develop new FCV or H2-ICE prototypes, last years have shown growing R&D efforts in favour of battery and hybrid electric vehicles (BEV, HEV and PHEV). A set of innovation indicators (e.g. R&D expenditures, number of patent applications, number of papers) clearly demonstrates that electric vehicles (incl. hybrids) have gained special attention from car makers in the last years; and although car makers are massively investing into them, this does not mean that research on fuel cell vehicles has been abandoned to the great benefit of battery electric and hybrid/plug-in technologies. A recent report from the IEA Hybrid and Electric Vehicle Implementing Agreement[84] further underlines the key role the development of electric vehicle technologies can play in response to the economic downturn, in the sense that

[84] http://www.ieahev.org/

'developing plug-in hybrid electric vehicles (PHEVs) and –for latter- the battery electric vehicle (BEV) can be seen as long-term activities to help the automotive industry out of the current crisis, so governments have recently reinforced and/or expanded their support programmes for electric mobility' (IA-HEV, 2010).

Overall, corporate R&D spending and number of patents directed to fuel cell vehicles are still increasing but at a lower rate than for battery and hybrid electric vehicles. Car makers are putting important R&D efforts for developing all type of low carbon technologies in parallel and fuel cell vehicles are still seen as a long-term strategy for this industry.

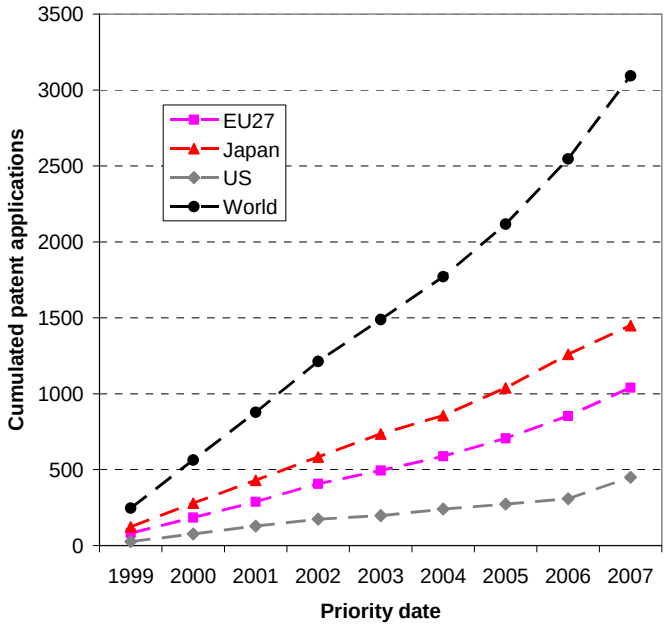


Figure 41: Cumulated patent applications to the EPO in electric and hybrid vehicles
Data source: OECD

Following the same methodology of a keyword-based research, the revealed technological advantage of EU-based car manufacturers in various motor technologies can be calculated. The results are shown in Figure 7 and further discussed in that section 2.2. The assessment indicated that EU-based companies have a high technological knowledge for conventional engines, and keep the leadership in these technologies. In terms of battery/hybrid electric vehicles, however, they are lagging behind. Partially, this is being tackled by the companies through a number of strategic alliances with battery manufacturers and electric utilities (see section 9.4.1; and also Barthel et al., 2010).

This finding is underlined by an assessment of patent applications derived from the OECD statistics (see Figure 41). At the same time, the dynamics depicted below also indicate that EU-based companies have drastically increased their patenting activities on electric and hybrid vehicles.[85]

7.3.3 Literature review

The findings above- though associated with some methodological drawbacks- are well in line with the analyses of many research works that have dealt with the analysis of patent applications, at firm level, of the automotive industry in low-carbon technologies. In the following, we concentrate on those assessments that focus on electric power trains (i.e. hybrid, battery and fuel cell electric vehicles, called hereinafter low-emission vehicles LEVs). These studies analyse the dynamic and diversity of patent portfolio of the main car manufacturers towards these promising technologies.

Their analyses can either focus on all the above mentioned technologies (e.g. Oltra et al., 2009a, 2009b; Frenken et al., 2004; Yarime et al., 2008) or can address only one specific technology such as BEV (Pilkington and Dyerson, 2006; Pilkington et al., 2002), HEV (Berggren et al., 2009; Doll, 2008)

[85] http://stats.oecd.org/

or fuel cell/H2 technologies (Bakker, 2010a; Mock and Schmid, 2009; Pilkington, 2004; van den Hoed, 2005). Generally, the U.S. (USPTO) and/or the European Patent Office (EPO) patent databases have been used for this exercise along with different search strategies (e.g. keyword-based or IPC-based search). A list of recent studies is given in Table 10.

Broadly speaking, and despite methodological differences, results showed that:

- The automotive manufacturers' patenting activities towards LEVs have been increasing over the last decade, at different speed depending on the technology considered (patent counts in HEV technologies are dominant). Patenting activities in conventional ICE technologies (gasoline and diesel engines) are still increasing but alternative drive technologies are closing the gap.
- Competition between LEV technologies and among car manufacturers is growing. For instance, Frenken et al. (2004) analysed the patent portfolio of key organisations in low-emission vehicles (BEV, HEV, FCV) and fuel technology, based on the USPTO patents database over the period 1990-2001. They analysed the cumulative number of patents in these technologies but also their distribution by using entropy statistics. Their results showed an increasing competition between LEV technologies but also among organisations towards LEV (entropy is steadily growing since the early nineties). In other words, it means that there is neither dominant LEV technology (technological diversity) nor dominant organisation in these technologies (organisational variety), thus showing that 'premature lock-in in unlikely to occur' (Frenken et al., 2004). Note that although the results are shown up to the year 2001, this trend has been confirmed by our own analysis.

Reference	Scope	Methodology	Comments
Oltra and Saint-Jean (2009a)	BEV, HEV, FCV, ICEV and DE Car makers (11): GM, Ford, Toyota, Mitsubishi, Nissan, Honda, Hyundai, Renault, PSA, Daimler, VW	Keyword-based from EPO-Esp@cenet database Results shown are cumulative number of patent applications per technology and per firm (accumulation of knowledge).	Analysis of the evolution of patent portfolio of car firms. An index of specialisation (ISPE) is used. Important diversification of patent portfolio, showing an active competition between these technologies.
Oltra and Saint-Jean (2009b)	BEV, HEV, FCV, ICEV and DE French car makers (Renault and PSA Peugeot Citroen) and beyond	Keyword-based from EPO-Esp@cenet database Cumulative number of patents from Renault and PSA (same methodology as above)	Integrated approach. Policy regulation is a key factor for environmental innovation but not only (technological regimes, demand conditions are also important).
van den Hoed (2005)	FCV, BEV, HEV (ATVs) Car makers (16): GM, Ford, Daimler, Chrysler, VW, PSA, BMW, Renault, Honda, Nissan, Mitsubishi, Toyota, Fiat, Mazda, Hyundai, Daewoo	USPTO database (+EPO) Keyword-based search Period: 1990-2000 Results shown are moving average of 2 years and % ATVs of total automotive patents.	Focus on car manufacturer's R&D in fuel cells. See also van den Hoed (2007)
Bakker (2010a)	Hydrogen vehicle technologies (storage, conversion) Car makers (12): GM, Ford, Toyota, Mitsubishi, Nissan, Honda, Hyundai, Renault PSA, Daimler, VW, BMW	Keyword-based from EPO-Esp@cenet database Period: 1990-2009 Results shown are absolute number of patents per year.	Patent portfolio on H2 powered vehicles. Oltra's method applied to hydrogen. Entropy is also measured Increasing entropy in storage patent portfolios, industry has not picked any winner yet, according to their patent behaviour. Commercialisation will not take place in the short term.
Berggren et al. (2009)	HEV and diesel engine Car makers (11): Toyota, Honda, GM, Ford, VW, BMW, Nissan-Renault, PSA, Fiat, Daimler	USPTO and EPO database Keyword-based search For USPTO: 'hybrid' in the abstract and 'vehicle' in the content of the document. For EPO: 'hybrid vehicle' as a search term in titles and abstracts. Period: 1990-2007 Results shown are mostly absolute number of patents.	Results demonstrate active patenting of major manufacturers on both gasoline hybrid and diesel technologies. Gasoline engines are also continuously being refined but with much less patenting activity.
Frenken et al. (2004)	BEV, HEV, FCV (+ fuels) Car makers (7): Honda, Toyota,	USPTO database Period: 1980-2001	Entropy is used as an indicator of technological variety.

	GM, Ford, Mitsubishi, Nissan, Daimler-Chrysler, plus 2 FC manufacturers and one oil company.	Figures shown are cumulated number of patents.	
Pilkington (2004)	Fuel cells (incl. stationary applications)	USPTO database Keyword-based search ('fuel cell' in the full text) up to the year 2000	
Pilkington and Dyerson (2006)	BEV	IPC B60L 11/-	Analysis of regulation vs. technological development
Pilkington et al. (2002)	BEV	IPC B60L 11/- USPTO and EPO are used 1973-2000	Effect of US regulation
Mock and Schmid (2009)	Fuel cells (with the focus on PEMFC)	Number of patent applications derived from Derwent Innovations Index, Scopus, DEPATISnet. A combination of different keywords and IPC-classes was used.	Patents and publications are used as indicators. Research on fuel cells has constantly been increasing since the 1990s
Doll (2008)	HEV and their components	EPO and WIPO IPC is used Results shown in absolute number of patent applications (indexed) and also RPA and RCA 1991-2004 period Analysis by region	The Relative Patent Application (RPA) is used as a measure for the specialisation of the R&D activities of countries in particular technologies. Revealed Comparative Advantage (RCA) is an indicator expressing the relative export power of a country with a given product type compared to the relative export power of all countries worldwide. Increase of patent applications in hybrid vehicles technologies. Japan is the technology leader in the field of HEV.
Yarime et al. (2008)	HEV, BEV, FCV JP car makers: Toyota, Nissan, Honda, Mazda, Mitsubishi, Fuji Heavy Industries (Subaru)	Japanese Patent Office (JPO) Results shown are absolute number of patent applications (1975-2003).	

Table 10: Overview of recent research studies analysing the patents portfolio of car firms in low-carbon technologies

8 Summary of public and corporate R&D investments

1 – Overall R&D investment in transport in 2008

The overall R&D investments dedicated to transport research in the EU from all public funders and industry exceeded € 43.5 billion in 2008. From a modal perspective, road transport takes by far the largest share with more than € 33 billion followed by civil aeronautics (€ 6.3 billion), rail (€ 1.2 billion) and waterborne transport (€ 0.9 billion). This is complemented by R&D investments in transport services, transport infrastructure and ITS. Note that the figures do not necessarily fully reflect the innovation capacities of the different actors as there are significant differences in the level of spillovers, e.g. between civil and military applications and different transport sub-sectors.

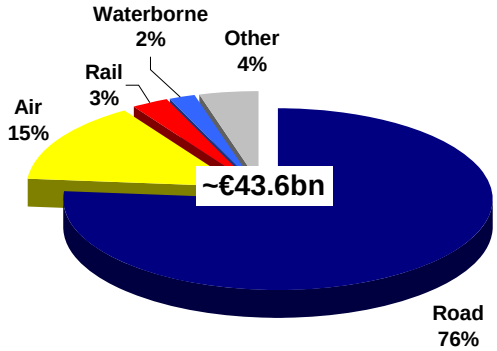


Figure 42: Total transport R&D investment (2008)
Note: the category 'Other' includes infrastructure construction, service providers, ITS as well as some cross-modal research. However, ITS-related research clearly oriented to a mode is allocated within the mode.

2- Funders of transport R&D

Transport research funding is dominated by corporate R&D investments (90.4% of the total), in particular from road transport industries, while public funds from EU Member States account for 8.2% and those from the EU through FP7 for 1.4%.

However, the role of public R&D investments is very heterogeneous between the different transport modes. While it is comparably low in the automotive sector (5% of the total) as a whole, which is also due to the fact that the total investments of this sector are by far most elevated of all modes, its role is much more pronounced in other modes. Public funds account for 25% for aviation, 22% for rail and 34% for waterborne.

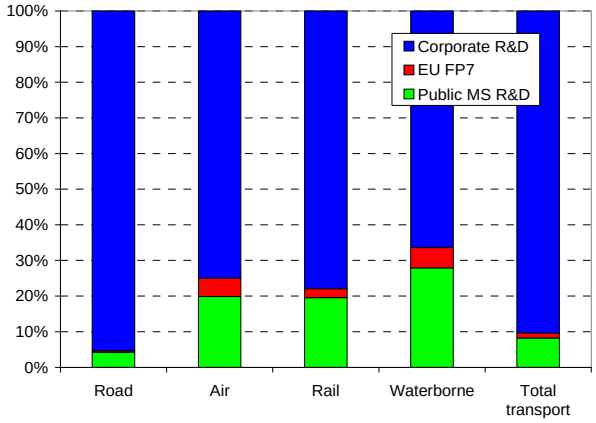


Figure 43: Percentage of public/corporate R&D investments by mode
Note: a breakdown for the category 'Other' has not been displayed as uncertainties are considered too elevated.

3- Distribution of R&D investments

The R&D investment distribution varies widely across modes. While more than 80% of the corporate R&D investment is allocated to the automotive industry, the situation is somewhat different for the public funds. Nevertheless, still around three quarter of total public funds from Member States and EU FP7 are dedicated to road and air transport. The latter mode also receives the largest part of FP7 funds with almost 55% of the total. The importance of public funds in research on cross-modal issues, infrastructure and socio-economic question should be noted.

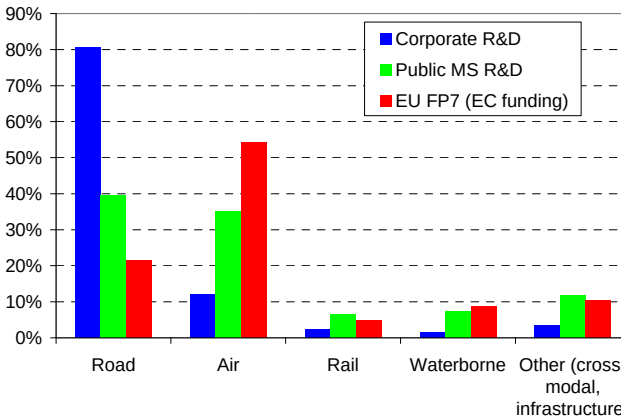


Figure 44: Percentage of R&D investments by source of funds

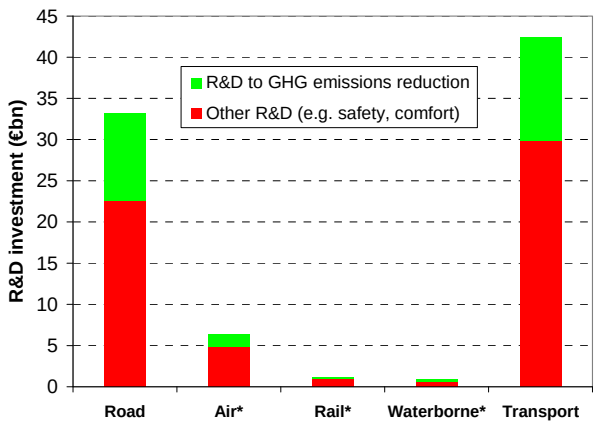
4- R&D efforts for GHG emissions reduction

Despite the uncertainties associated with such an analysis, it was estimated that roughly one third of the total transport R&D investment from industry and public funders is allocated to technologies that can reduce emissions of greenhouse gases (yet in some cases also including some other environmental research).

For the road sector, the part dedicated to R&D focusing on GHG emission reduction technologies is one third, rising to some 40% when also including technologies to reduce the emissions of air pollutants. It is also around one third in aviation, but this figure may already include some R&D focusing on other environmental issues, such as reduction of noise or air pollutant emissions. For rail, this part is more limited with around 20%, whereas it is higher for waterborne transport (47%).

5- R&D in selected low-carbon vehicle technologies

For the automotive sector, a further breakdown of research efforts into three technology groups has been performed. From this it becomes obvious that within the GHG emission reduction R&D efforts, and herewithin focusing on engine technologies, the largest focus of industrial research lies on the optimisation of conventional internal combustion engines. Electric vehicles (including hybrids) are the most relevant field of developing non-conventional engine technologies. Fuel cell vehicles and biofuels show comparably lower industrial R&D investment.



** No estimates of public MS R&D to GHG emissions reduction (40%, 35% and 20% are assumed for air, maritime and rail respectively i.e. ranging between corporate and EU figures)*

Figure 45: R&D investments dedicated to GHG emissions reduction (estimates for 2008)

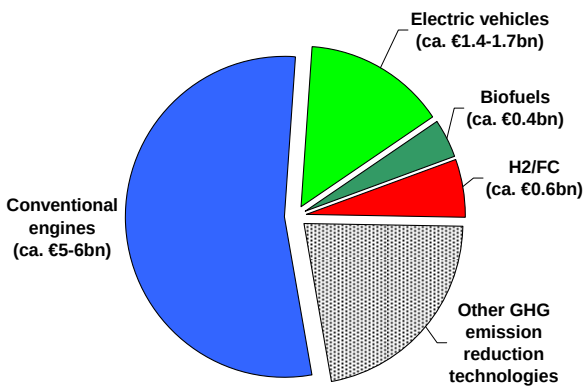


Figure 46: R&D investments in selected low-carbon technologies (automotive sector only; estimates for 2008)

Category/Segment	Corporate R&D		Public R&D		Total R&D
	R&D inv. (€bn)	R&D intensity	Public MS (€bn)	EU FP7 (€bn)	(€bn)
WORLD					
ICB- Automotive manufacturers (1)	53.1	4.4%			
ICB- Automotive suppliers (2)	19.6	4.5%			
ICB- Commercial vehicles & trucks (3)	6.8	2.9%			
ICB- Automotive industry (1+2+3)	79.5	4.2%			
ICB- Aerospace and defence (4)	15.6	4.1%			
ICB- Industrial transportation (5)	0.4	0.3%			
ICB- Transport (1+2+3+4+5)	95.5	4.0%			
EU-27					
ROAD					
ICB- Automotive manufacturers (1)	20.9	4.9%			
ICB- Automotive suppliers (2)	9.5	6.1%			
ICB- Commercial vehicles & trucks (3)	2.4	3.6%			
ICB- Automotive industry (1+2+3)	32.8	5.1%			
BU- Automotive manufacturers	**21.4**	**4.9%**			
Passenger cars	17.6	5.3%			
Commercial vehicles (trucks, buses)	3.7	3.5%			
BU- Automotive suppliers	**10.3**	**6.0%**			
BU- Automotive sector	**31.7**	**5.2%**	**1.4**	**0.1**	**33.3**
Eurostat BERD (BES) DM 34- Manufacture of motor vehicles, trailers and semi-trailers	21.4				
BU- Conventional ICEs	~5-6		~0.13	~0.02	~5-6
BU- Electric vehicles	~1.3-1.6		~0.08	~0.02	~1.4-1.7
BU- H2/FC	~0.4		~0.17	~0.08	~0.6
BU- Biofuels	~0.3		~0.07	~0.05	~0.4
AIR					
ICB- Aerospace and defence	7.5	5.9%			
BU- Civil aeronautics	**4.7**	**7.8%**	**1.3**	**0.3**	**6.3**
Eurostat BERD (BES) DM 353- Manufacture of aircraft and spacecraft	4.4				
RAIL					
BU- Rail total	**0.9**	**3.9%**	**0.2**	**0.03**	**1.2**
Eurostat BERD (BES) DM 352- Manufacture of railway, tramway locomotives, rolling stock	0.4				
WATERBORNE					
BU- Waterborne total	**0.6**	**3.2%**	**0.3**	**0.1**	**0.9**
Shipbuilders	0.1	1.6%			
Marine equipment manufacturers	0.5	4.1%			
Eurostat BERD (BES) DM 351- Building and repairing of ships and boats	0.2				
CROSS-MODAL					
ICB- Industrial transportation	0.4	0.3%			
BU- Infrastructure construction	**0.3**	**0.3%**	0.4		
BU- Transport service providers	**0.7**	**0.3%**			
GBAORD NABS 02 04 - Transport systems			0.3		
BU- Dedicated ITS companies	**0.4**	**6.4%**			
TOTAL TRANSPORT					
ICB- Transport	40.8	4.5%			
BU- Transport	**39.4**	**3.9%**	**3.6**	**0.6**	**43.6**

Table 11: Summary of results – Approximates for the year 2008 (rounded numbers)

Note: BU refers to the results of the bottom-up approach (in bold) – this constitutes the main set of data that has been used in the present report, whereas other information is considered as complementary; ICB follows the classification of the EU Scoreboard. Note that figures from the EU Scoreboard, Eurostat BERD and GBAORD are not comparable due to methodological differences (sectoral definition, allocation method, etc.). For ITS, only dedicated companies have been considered. Public ITS research investments are allocated to modes as they often clearly focus on one or several modes.

** The ICB category 'commercial vehicles and trucks' does not entirely focus on road as it also comprises manufacturers of rail cars, non-military ships and heavy agricultural and construction machinery. However, actual data show that the manufacturers of road commercial vehicles are dominant in that category in the EU Industrial R&D Investment Scoreboard.*

PART III – INNOVATION SYSTEMS TRANSPORT: KEY PUBLIC AND PRIVATE ACTORS AND THEIR INTERACTION

9 Innovation Systems in the Transport Sector

9.1 Synthesis

Automotive

- The automotive industry is dominated by a few large car manufacturers and component suppliers, which are also vital for the sector's innovation on the supply side. They rely on a wide network of smaller, more specialised companies in the supply chain.
- The high costs of mass-production vehicle assembly plants may create a lock-in, and could constitute one obstacle to radical innovations.
- Nevertheless, radical innovations that go beyond the traditional steel bodyshells and internal combustion engine opens up opportunities for new entrants to the market, as could be seen e.g. for electric vehicles.
- Recently, new collaboration schemes have emerged to increase the knowledge base of the automotive industry in areas that go beyond their historical core competencies.
- Standards and regulations directly influence the innovation process. But also social norms are crucial in understanding the innovation system, and may e.g. have slowed down the uptake of some ITS applications.

Aviation

- Aviation is a high technology industry, dominated by few airframe and engine manufacturers. The limited number of system integrators build on a wide network of smaller companies in the component supply chain, following a pyramidical structure.
- The aviation industry has a strong innovation system which is continuing to deliver improvements safety, security and energy efficiency and therefore emissions. Civil and defence applications in aviation are closely interlinked.
- Unlike for road transport, not all Member States allocate public R&D budgets towards aviation. Member States that have major aviation R&D support in place include Austria, Czech Republic, France, Germany, Hungary, Ireland, Italy, Poland, Portugal, Sweden, Spain, Slovakia, and the UK.
- Transnational research activities, such as the Clean Sky JTI and SESAR programme, have a higher importance in aviation than in other transport modes.

Rail

- In contrast to road or aviation transport, rail has a relatively small share of transport volumes, except in some particular markets – medium distance high speed passenger and bulk freight. Therefore, the industry is smaller than aviation or road transport.
- Railway vehicles have a typical lifetime of 30-35 years, impeding a fast uptake of novel technologies. Rail infrastructures have an even longer lifetime.
- R&D is undertaken by locomotive/rolling stock and control systems manufacturers or the national railways. In parallel, R&D is also undertaken at the rail infrastructure development level, including high speed rail lines and issues related to the interoperability of rail networks characterised by different technical specifications.
- A major weakness of the rail innovation system lays in its organisation and its international fragmentation. Because the technology is suitable for long distances, many services cross national boundaries. Since the ownership structure, in particular infrastructure control and operations is almost always national, coordination of long distance services is difficult. In

addition, this is also associated with country-specific technical characteristics that result in increased vehicle costs and time delays.

Waterborne

- A particular feature of shipping is the complex pattern of ownership and insurance. Ships are often not built for a shipping line, but for leasing intermediaries. All ships have to be insured for each voyage and the risk is aggregated through the Lloyds insurance market.
- EU shipyards concentrate on either military or specialist ships (e.g. cruise, luxury yachts) and marine systems. The large shipbuilders have access to an extensive and effective innovation infrastructure, mostly within the companies themselves or through established industry consultancies. Nevertheless, innovation in shipping needs to cope with a relatively limited market size in comparison with other transport modes.
- Inland waterways shipyards and operators are often local firms and small firms. They have limited resources for innovation. Even though they share some parts of the innovation scheme, their different operating conditions and the related impact on innovation needs to be respected.

Cross-modal transport

- Typical actors are service providers, in particular providers of public transport and of goods services. Also harbours or airports bring forward intermodal solutions.
- The agents that have an interest in fostering cross-modal innovative solutions often operate at very low profit margins and have therefore fewer incentives to invest in research. Additionally, they may have a limited capacity to tackle some of the issues that affect the quality of the service they provide (like those due to the international fragmentation of railway links).
- In parallel, lock-in effects hamper some of the possibilities of development of radical cross-modal innovation.
- Whereas many Member States have government departments or agencies dedicated to individual transport modes and/or programmes addressing research in certain modes, only a few have specific intermodal transport units within their specific organisations. In a relevant number of cases, intermodal transport has been incorporated as a distributed function (e.g. by expanding the scope of existing modal units or by creating new units within existing modal organisations).

Construction sector

- The construction sector is mainly consisting of two groups of activities. On one hand, it is characterised by many small local firms that are exposed to high levels of competition. On the other, major international construction companies compete for the development of the largest projects (leveraging also on mid-size SMEs as subcontractors). The markets where such firms compete often bear the typical characteristics of oligopolies. Albeit different, these indications concur in the identification of a rather poor performance of the construction with respect to innovation, as confirmed by its low R&D intensity.
- The construction market for transport infrastructure is to an important extent (co-)financed by public budgets. This opens up possibilities to induce innovations e.g. through a regulatory framework.

ITS

- Intelligent Transport Systems (ITS) are closely linked to innovation because of the ability of ICT to favour the introduction of new products, services, business processes, and applications. In the case of transport, the importance of ICT is confirmed by the large amount of new products penetrating the automotive market, as well as logistics and the service sector.

- ITS build on relatively cheap ICTs and, as such, are less affected than other technologies by financial barriers. This is due to the low capital intensiveness of the industry and the important share of venture capital that continues to flow to the ICT sector.
- Some important barriers exist for ITS applications. They include: the need for a critical level of market penetration before the achievement of effective results, the conflict between standardisation needs and the evolving nature of some technological solutions, high risks of obsolescence and leapfrogging privacy-related issues (e.g. affecting RFID technologies).

Policy messages:

- Agents that could push for cross-modal innovative solutions have low incentives for research, whereas the key R&D investing transport industries are usually focusing on a single mode. At the same time, public transport research policy is often organised alongside transport modes. This may indicate that the important potential of cross-modal innovations is not fully exploited.
- Due to the heterogeneity of the transport sector, its historical development and differences in the emphasis attributed to specific transport-related objectives, there are important discrepancies in capacities and responsibilities for transport R&D across the EU Member States. This heterogeneity may constitute a barrier towards the full exploitation of synergies.
- A number of EU-wide initiatives, such as European Technology Platforms or ERA-NETs, as well as dedicated programmes (such as the European Green Cars Initiative) facilitate knowledge flows between the various private and public actors and across Member States. For example, the Strategic Research Agendas of the Technology Platforms help in better focusing and harmonising European and national public and private research efforts. ERA-NETs are considered to have important leverage effects that go far beyond the relatively limited scale of transnational calls.
- As many of the existing Technology Platforms are organised along modes, a joint intermodal working group could draw on the modal expertise of existing Platforms and on that basis identify synergies and areas of cooperation across stakeholders.
- The verge of alternative power-train technologies and fuels requires expertise from outside of the traditional fields of car manufacturing, including e.g. co-operations with electric utilities, battery suppliers etc. There is some indication that industrial partnerships and joint ventures are already ensuring these cross-sectoral knowledge flows. Yet, it needs to be seen whether more formal ways of collaboration will be required for distinct technologies that also need pan-European action such as electric or fuel cell vehicles.

9.2 Innovation systems in transport sub-sectors

The following sections will sketch out the innovation systems in the transport sectors, following the concept of a sectoral system of innovation as shown in Figure 47. This approach views innovation as arising from a system structure i.e. from components that interact. Demand for a new or improved product is assumed to be met by innovations from industrial firms. However, there is a set of further actors and relationships. The research system may inform both demand and production, while the political system may influence both R&D activities through subsidies, by setting the agenda and by determining the environment or framework conditions within which the innovation system operates. Furthermore, there may be a series of intermediaries: financial, knowledge sharing - such as research institutes, research parks associated with universities (and generating spin-off companies in technologies developed within universities), as well as professional associations or entities providing business support for start-ups in new technologies.

This sectoral innovation system approach has been adapted as a Technological Innovation System (TIS). The idea of a TIS has been used to analyse the dynamics of systems of innovation in particular technology areas, with the objective of understanding the processes which influence the diffusion of a new technology. A TIS has been defined as 'network(s) of agents interacting in a specific technology area under a particular institutional infrastructure to generate, diffuse, and utilize technology' (Carlsson and Stankiewicz, 1991, p. 111). Hence, three elements characterise a TIS: actors, networks and institutions.

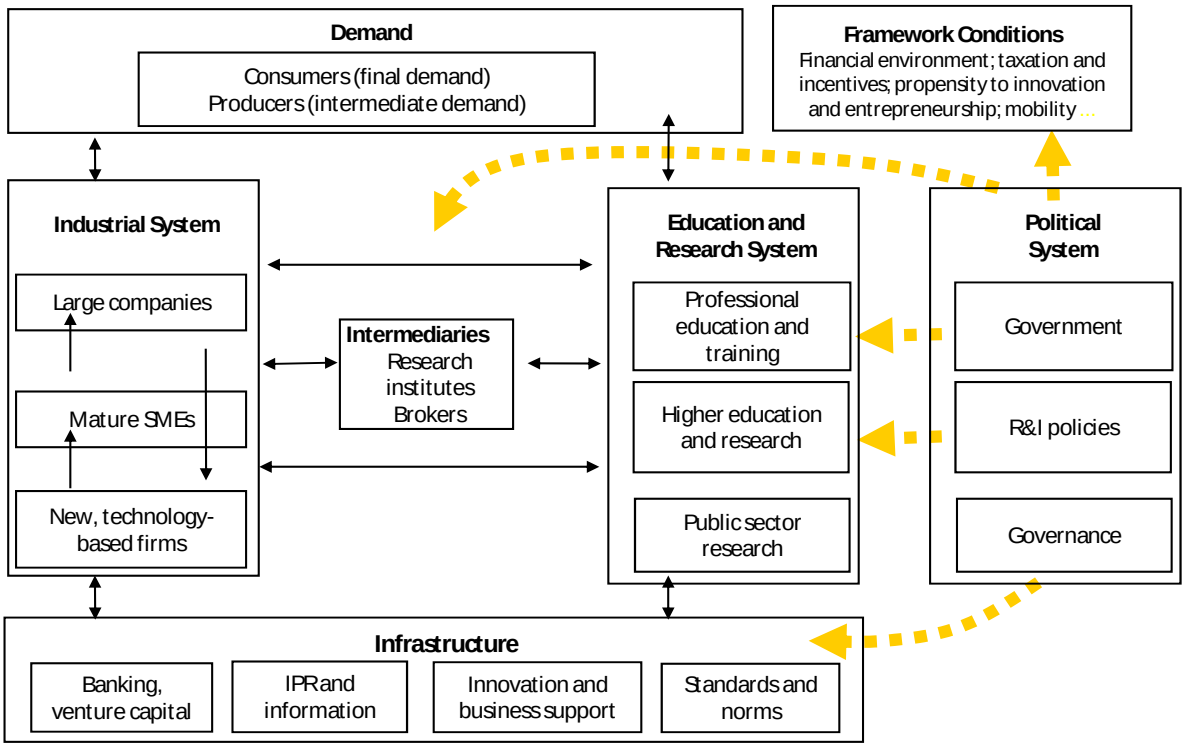


Figure 47: A sectoral system of innovation
Source: Arnold et al., 2001

In order to successfully innovate, it is required that all functions of ISyT can be activated such that they form a reinforcing feedback loop (see Figure 48) that will make the new technology take-off in the market. This links to the theoretical considerations on e.g. the 'valley of death' and the importance of market demand, which is described in more detail in sections 3.2 and 3.3.

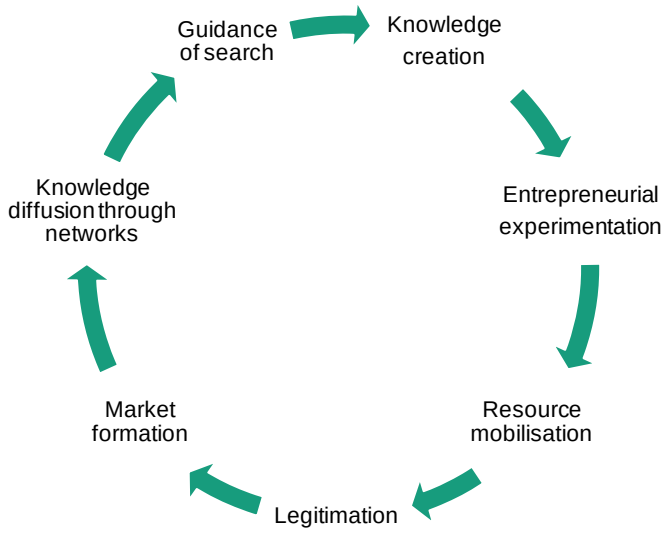


Figure 48: The reinforcing feedback between functions of the Innovation System Transport
Source: GHG-TransPoRD project, published in Leduc et al. (2010)

9.3 Common points

Whereas chapters 9.4 to 9.9 will draw the detailed innovation systems by mode, for cross-modal issues, the construction sector and ITS, this section will provide some general remarks to the institutional set-up of public research at Member States and EU level, which apply to most individual transport innovation systems.

9.3.1 Institutional set-up of transport research in EU Member States

Institutional transport R&D capacities vary among EU Member States at all levels of decision making, implementation and research performance. This variety reflects different historical developments, the overall structure of the public sector and the specific situation in terms of transport of a country. The heterogeneity with regard to actors and responsibilities may constitute a barrier towards the full exploitation of synergies across EU Member States. Recent initiatives such as the ERA-NETs, Technology Platforms, as well as established frameworks like the transport-relevant IEA implementing agreements or other transnational information platforms such as the Transport Research Knowledge Centre (TRKC), are steps towards overcoming these barriers.

The detailed Table 21 in the annexes aims at providing a systematic overview on the key players involved in national public transport research. To the extent possible, it attempts to allocate players to decision making and priority setting, implementing R&D policies and conducting and carrying out of research itself. Nevertheless a clear distinction between these divisions is very often somewhat artificial. For example, public research organisations often act both as a performer of research, but are active also in the policy implementation by allocating funds. Similarly, Research Advisory Councils are sometimes involved both in the policy making and the implementation processes. For an in-depth description of the national transport research processes, appropriate references include the country profiles of the Transport Research Knowledge Centre (TRKC, 2009), the country reports of the EAGAR FP7 project, information collected by the ERA-NET Transport, the on-going project TransNEW and chapter 10 in Leduc et al. (2010).

Table 21 in the annexes lists the key public actors involved in **decision making and priority setting**, implementing transport R&D policies and conducting and carrying out of research itself. Even though the decision making of transport R&D policies primarily lies with ministries, the responsible ministries vary across Member States. Whereas in some Member States, transport R&D seems to be concentrated in few departments focusing either on transport and/or on research, in other Member

States responsibilities for transport-related research seem more decentralised, involving other ministries for specific topics.

In some Member States, inter-ministerial bodies supervise and coordinate sectoral R&D activities in order to develop a unified national R&D strategy, such as CICYT in Spain. Also National councils on e.g. Research or Science and Technology play an important role in the decision process in a number of Member States. There are also significant differences in the importance of the regions in transport research. While this is high in e.g. Belgium, Germany and Spain, it is much more limited in many other Member States.

The importance of a comprehensive transport research programme for coordinating relevant research activities has been realised by EU Member States. To this end, some Member States have introduced a coordination specifically targeting transport R&D programmes (e.g. Austria, Finland, France, Germany, the Netherlands), whereas other include transport R&D within a broader research strategy (e.g. Greece, Spain, Romania and Lithuania) or have specific programmes for special parts of transport research (e.g. the United Kingdom).

National differences also occur in the **implementation of transport-related research policies**. In some countries, the funding of transport research falls directly under the responsibility of the ministry. They are then either directly managed by governmental departments (e.g. Italy), or through specific para-governmental agencies such as the General Secretariat for Research and Technology in Greece or the Danish Agency for Science, Technology and Innovation.

In some occasions broader technology agencies that are not limited to the transport sector (such as ADI and FCT in Portugal; the Danish Agency for Science, Technology and Innovation; ADEME, ANR and OSEO in France or CDTI in Spain) play a key role in the implementation of transport-research, while in others this is realised through dedicated agencies to research in (the different aspects of) transport (e.g. IFSSTAR in France, VTT in Finland, KTI in Hungary and CEDEX in Spain). The UK is an example for a country with several specific agencies for different aspects of transport-related research. The Department for Transport commissions the execution of research to a number of individual executive agencies, most of which have their own research programme. These agencies include the Highways Agency, the Driver and Vehicle Licensing Agency, the Vehicle and Operator Services Agency, the Driving Standards Agency, the Vehicle Certification Agency, and the Maritime and Coastguard Agency (TRKC, 2009). Besides, other government department fund transport related R&D. Specific central policies, such as the Ultra Low Carbon Vehicle Strategy, are then implemented by a cross-government team. In addition, two out of the seven national Research Councils take an active role in the implementation of transport R&D policy in the UK. Also in other Member States Research Councils have an active role in transport policy making and implementation.

Actors that aim at improving the coordination between European, national and industrial research efforts (see in particular section 9.3.2) are the national technology platforms (NTPs). They mirror the European Technology Platforms, and actively interact with the science and innovation system at the national level, but also with their European counterparts. Also the sectoral regional clusters bring the cooperation among actors a step further.

The **performer of public energy research** comprise universities, public research organisations and industry (see Table 21 in the annexes). Even if available data do not allow for an assessment of the importance of each of these organisations in performing transport-related research, latest Eurostat data on the total intramural R&D expenditure (GERD) clearly show the importance of universities in the overall European research system. The higher education system accounted for 24% of the research expenditure in 2009 in the EU, compared to only around 13% in the USA (2008) and Japan (2007). Also the government sector accounts for a higher share of total R&D expenditures in the EU than in the USA and particularly Japan. At the same time, R&D expenditure of EU Member States of the Business and Enterprise sector are lower than in the USA and Japan. Note however, that the in-depth assessment of corporate and public R&D investments for transport (see Part II of this document) indicates the strong role of industry in transport research.

Reference public or semi-public national transport technology laboratories include e.g. VTT in Finland, IFSSTAR and IFP in France, CIRA in Italy or IDIADA, CIDAUT, CTAG, INSIA and TECNALIA in Spain. In Germany, two out of the Helmholtz Research Centres and four out of the Fraunhofer Society are particularly involved in transport. A number of large PROs are active in transport research, but not entirely dedicated to transport. It is important to note that PROs often have strong links to research policy-making, and are sometimes also involved in the general implementation of public transport research policy.

9.3.2 Policy and governance: EU and transnational level

The European Research Area constitutes the research segment of the European triangle between research, innovation and education (TRB-ECTRI, 2008). To this end, the Surface Transport Research Area makes use of three concepts, namely the creation of an internal market in research, the restructuring of the European research fabric, and the development of a European research policy.

In order to accelerate and improve Europe's innovation potential so as to ensure its long term competitiveness and sustainability, innovation is one of the core initiatives of the Europe 2020 strategy[86], and the Innovation Union[87] is a flagship Initiative of this strategy. The Innovation Union introduces a new way of bringing together public and private actors at EU, national and regional level together to tackle the big societal challenges, and which also represent opportunities for new business. These **European Innovation Partnerships** will join up all key players from researchers, businesses to end users and remove bottlenecks so that good ideas can be translated into successful innovative products or services.

They complement existing instruments that shall coordinate research efforts between EU and national public players and industry, namely the European Technology Platforms (ETPs), and the ERA-NETs, and the JTIs, JUs and the collaborative research under the Research Framework Programme. The most relevant FP7 activities for transport include the European Green Cars Initiative, the Clean Sky Joint Technology Initiative, the SESAR (Single European Sky Air Traffic Management Research) Joint Undertaking, the FCH JTI (Fuel Cells and Hydrogen Joint Technology Initiative), and part of the ARTEMIS (Advanced Research & Technology for EMbedded Intelligence and Systems) Joint Technology Initiative. They are complemented by the Networks of Excellence.

Table 12 below provides an overview of the main actors involved in transport research at the European level. While in the following, we will only briefly introduce the general concept of some of the institutions, they will be set in context in the sections on different modes; additional details can then be found in Annex IV.

The **European Technology Platforms** (ETPs) aim at providing 'a framework for stakeholders, led by industry, to define research and development priorities, timeframes and action plans on a number of strategically important issues where achieving Europe's future growth, competitiveness and sustainability objectives is dependent upon major research and technological advances in the medium to long term'[88]. In other words, the core activity of an ETP is to bring together private and public stakeholders to develop a medium to long term RD&D strategy and action plan in the field concerned. A main outcome of an ETP is the elaboration of a Strategic Research Agenda (SRA) that identifies the key R&D needs for the next decades in order to achieve the objectives defined in a 'Vision' (2020 or 2030) document. As far as the transport sector is concerned, four ETPsconcern directly one specific transport mode namely ERTRAC for road, ERRAC for rail, ACARE for air and WATERBORNE-TP for waterborne transport. Following the concept of the Technology Platforms, but not officially being one[89], the European Intermodal Research Advisory Council (EIRAC) shall guide research on intermodal transport, and to this end developed a first Strategic Research Agenda until 2020 and a second for the period until 2030. Other European Technology Platforms are not directly focused on

[86] Conclusions of the European Council from 17 June 2010.
[87] COM(2010) 546 final
[88] http://cordis.europa.eu/technology-platforms/
[89] EIRAC is not an official ETP (see http://cordis.europa.eu/technology-platforms/individual_en.html)

transport, but relevant for some of its sub-sectors (namely for intelligent transport systems and system integration), or relate to fuels or infrastructure. This is the case for the Biofuels Technology Platform, the Construction TP (ECTP), EPOSS (European Technology Platform on Smart Systems Integration), Net!Works (former eMobility), NESSI (Networked European Software and Services Initiative), NEM (Networked and Electronic Media) and SmartGrid (ETP for the Electricity Networks of the Future).

The concept of the European Technology Platforms has proven to have an important, positive impact on transport research at different levels. ETPs with their Strategic Research Agenda provide important input to the EU FP7 work programme design. At the same time, they impact on national research policy programmes, fostered e.g. by national platforms that mirror the European Technology Platforms (Technopolis, 2011; IDEA consult, 2008; AGAPE, 2010 for the case of ACARE). Moreover, even though the SRAs are naturally influenced by the research programme of large companies who take an active role in the ETPs, they also influence these corporate research efforts in return (Technopolis, 2011).

Despite the very positive role of the ETPs, a (slightly outdated) evaluation (IDEA consult, 2008) provided some recommendation on how to further improve them. In particular, as the ETPs are bottom-up initiatives, and in the transport area often follow modal lines, there is a risk of overlaps and a potential under-exploitation of synergies. In addition to EIRAC and ECTP, there may be a need to further exploit synergies across existing Platforms. An intermodal working group might be an appropriate approach there (also recommended by the LINK forum, 2010).

The **European Research Area Networks (ERA-NETs)** have been introduced in order to improve the coordination of national and regional research programmes among EU Member States. To this end, the scope of ERA-NET activities ranges from networking and the systemic exchange of information to the launch of joint transnational research activities, e.g. with joint calls that are financed together by a group of Member States interested in the topic (and with an EU contribution in the case of ERA-NET plus actions). There are currently four active ERA-NETs on transport under FP7 (ERA-NET Transport, ERA-NET Road, AirTN and MARTEC; ERA-STAR regions has been funded under FP6; see details in the relevant sections in Part III). In addition, there have been ERA-NETs on topics that are relevant for transport, such as those dealing with bioenergy and hydrogen and fuel cells.

The ERA-Net Transport (ENT)[90] is the network/platform in charge of national transport research programmes in Europe with the aim of structuring the European Research Area (ERA) for transport as a whole, while the other ERA-NETs focus on different modes or technologies. Several studies have been carried out that provide, among others, a mapping of the different R&D actors and national transport research programmes in EU countries. Note that within ENT, research funding cooperation is organised in 19 action groups (such as electric mobility, freight transport, alternative fuels, etc.).

When looking into the already started joint calls of ERA-NETs under FP6 and FP7 (i.e. disregarding those that have only very been recently launched or are planned), around one out of ten ERA-NET joint calls relates to transport, but the budget of these calls only amounts to some 3% of the total budget of joint calls, indicating the financial volume of transport-related joint calls is below the average. Up to now, transnational calls have been launched from transport ERA-NETs with a total volume of some € 45 million (incl. some funding from non-EU Member States), with the number of participating countries varying between two and ten (NETWATCH data; enTnews Transport, 2011). When compared to the total public transport R&D investment of EU Member States, this remains very limited. This figure further rises with the large ERA-NET+ call 'Electromobility+' of € 30 million (incl. EU-contribution) that has been launched in early 2011.

Even though the absolute funding level of transnational calls organised through transport ERA-NETs has remained limited, their leverage effect needs to be acknowledged. Moreover, Matrix Insight and Ramboll (2009) found that 'factors such as the participation in joint calls had a positive influence on the impact of ERA-NETs on national programmes by providing practical evidence of benefits'.

[90] http://www.transport-era.net/

Moreover, instruments such as the ERA-NETS, the Technology Platforms and the Joint Technology Initiatives are considered as major vehicles for implementing transnational science and research coordination by Member States (ERAWATCH Network, 2009).

However, TRB-ECTRI (2009) indicates that despite on-going efforts there was still some double-funding between individual Member States national research and European programs. They illustrate this with a figure from the ITS area, according to which there were some 100 national programs running in parallel with EU-funded ones in 2008 (TRB-ECTRI, 2009, p.10).

The European **Research Framework Programmes** have also played an important role in supporting the sharing of knowledge about the new technologies and developing plans/roadmaps for technology development that contribute to developing common expectations for the new technologies.

The **European Conference of Transport Research Institutes** (ECTRI)[91] is an international non-profit association that was founded in April 2003. It is the first attempt to unite the forces of the foremost multimodal transport research centres across Europe and to thereby promote the excellence of European transport research. Today, its members are 28 major transport research institutes or universities from 20 European countries. Together, they account for more than 4000 European scientific and research staff in the field of transport. ECTRI's vision is to have 'an efficient, integral European transport system that provides completely safe, secure and sustainable mobility for people and goods'. To this end, ECTRI provides the scientifically based competence, knowledge and advice necessary to move towards its vision.

[91] www.ectri.org; description taken from this website

Actor	Acronym
European Technology Platforms	
European Road Transport Research Advisory Council	ERTRAC
European Rail Research Advisory Council	ERRAC
European Technology Platform Waterborne	WATERBORNE-TP
Advisory Council for Aeronautics Research in Europe	ACARE
European Biofuels Technology Platform	EBTP
European Construction Technology Platform	ECTP
ERA-NETs	
ERA-NET Transport	ENT
Road	ERA-NET ROAD
Air Transport	AirTN
Waterborne Technologies	MARTEC
Bioenergy	ERA-NET Bioenergy
Hydrogen and Fuel Cell	HY-CO
Road	
European Association of Automotive Suppliers	CLEPA
European Automotive Research Partners Association	EARPA
The European Council for Automotive Research and Development	EUCAR
European Automobile Manufacturers Association	ACEA
European Conference of Transport Research Institutes	ECTRI
Association for European Transport	AET
European Union Road Federation	ERF
The Motorcycle Industry in Europe	ACEM
European public/private partnership for the implementation of Intelligent Transport Systems and Services	ERTICO
Oil companies' European organisation	CONCAWE
Forum of European Road Safety Research Institutes	FERSI
European Asphalt Pavement Association	EAPA
Forum of European National Highway Research Laboratories	FEHRL
Air transport	
Aerospace and Defence Industries Association of Europe	ASD
Association of European Research Establishments in Aeronautics	EREA
International Air Transport Association	IATA
International Civil Aviation Organization	ICAO
European Aeronautics Science Network	EASN
Waterborne	
Community of European Shipyards' Associations (see Working Group on R&D – COREDES)	CESA
European Marine Equipment Council	EMEC
European Council for Maritime Applied R&D	ECMAR
Confederation of European Maritime Technology Societies	CEMT
European Barge Union	EBU
European Association of Universities in Marine Technologies and related sciences	WEGEMT
European Community Shipowners' Association	ECSA
Rail	
International Union of Railways	UIC
The European Railway Industry (formerly Union of European Railway Industries)	UNIFE
Community of European Railway and Infrastructure Companies	CER
European Rail Infrastructure Managers	EIM
European Rail Freight Association	ERFA
The International Union of Private Wagons	UIP
European Network of Excellence for Railway Research	EURNEX
Inter- and cross-modal	
European Intermodal Research Advisory Council	EIRAC

European Intermodal Association	EIA
European Cities and Regions Networking for Innovative transport solutions	POLIS
International Association of Public Transport	UITP
The Network of Major European Cities	Eurocities
European Metropolitan Transport Authorities	EMTA
Others	
European Platform of Transport Sciences	EPTS
European Petroleum Industry Association	EUROPIA
European Network of Construction Companies for Research and Development	ENCORD
Key EU research initiatives	**Acronym**
European Green Cars Initiative	EGCI
Clean Sky JTI	Clean Sky JTI
SESAR JU	SESAR JU
Fuel Cells and Hydrogen JTI	FCH JTI
Intelligent Car Initiative (under i2010)	
Joint Programming Initiative Urban Europe	JPI Urban Europe

Table 12: List of key EU actors and programmes

9.4 The innovation system of the automotive sector

The European automotive industry is considered a 'cornerstorne' of Europe's economy (Sofka et al., 2008), and has been successful in positioning itself in the international market. It is characterised by a strong innovation system with a very strong 'vertical' knowledge flow between component suppliers and car manufacturers, both of which are involved in R&D activities that complement each other (see part II). The tier1- component suppliers take over responsibility for developing, producers and refining complete modules of the car (Sofka et al., 2008; European Commission, 2009c), and are therefore important drivers for innovation. But even though large parts of the sector's R&D investments concentrate in the limited number of car manufacturers and very large primary (tier1) component suppliers (see Figure 21), also the large number of smaller (tier 2-4) component suppliers have a very important role in innovation that is needed to comply with the stringent quality and technical requirements demanded by the tier-1 suppliers. Many of these tier 2 to tier 4 suppliers are SMEs; more than 80% of the companies in the automotive sector have less than 50 employees (in 2008; Eurostat SBS indicators).

Besides vehicle and component manufacturers, service operators – like logistics companies and hire companies – play a significant role in forming market demand, which is crucial for the diffusion of innovative technologies as pointed out in sections 3.2, 3.3 and 3.4. The very extensive network of retail outlets does not have much influence on innovation (see Figure 29 in part II of the report), even if it does play a role with respect to the provision of information to customers.

Technological development in the industry has been mainly driven by suppliers' perceptions of consumers' requirements like required size, performance and safety, with fuel consumption having a relatively low priority for many consumers. To this end, also social norms influence the innovation process, such as the norm that the driver of a vehicle should have complete direct control of the vehicle, which explains why innovations on the supply side such as ITS have not been fully diffused yet. This autonomy is only very slowly being eroded through automatic braking systems and driver information systems such as navigation systems. The other main social norm is that the car has been one of the defining elements of social status (Sheller, 2004) although this seems to be weakening (Bratzel, 2010).

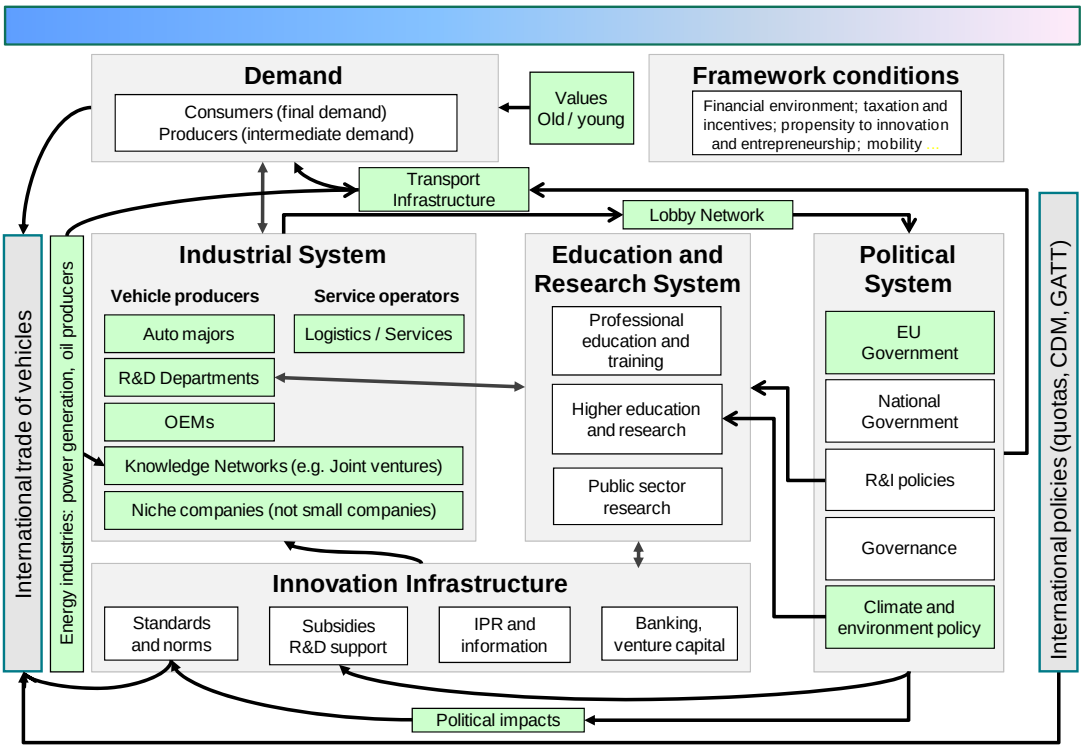


Figure 49: The innovation system for automobiles
Source: GHG-TransPoRD, published in Leduc et al. (2010)

The stable innovation system of the automotive sector (Figure 49) has constantly generated innovations to meet consumers' demand and to reply to tightening environmental regulations (see section 2.3 for further details). However, there is some indication that much of the product innovations carried out so far has been incremental in nature, thus making use of the existing road and fuelling infrastructure. In parallel, innovations in the manufacturing process take place to reduce costs and improve the quality (Sofka et al., 2008; see Figure 4).

With growing worldwide competition on the one hand, and the advent of more radical innovations such as electric vehicles, the innovation system is also changing. The drive to low carbon innovation has led to opportunities for new entrants, both in the manufacture of low carbon cars (e.g. Tesla in the US (WSJ, 2009), Loremo in Germany), and in particular in battery, fuel cell and energy storage technologies such as the application of Carbon Nanotubes to enable ultracapacitors to be practicable for vehicle power systems (PopularMechanics, 2008).

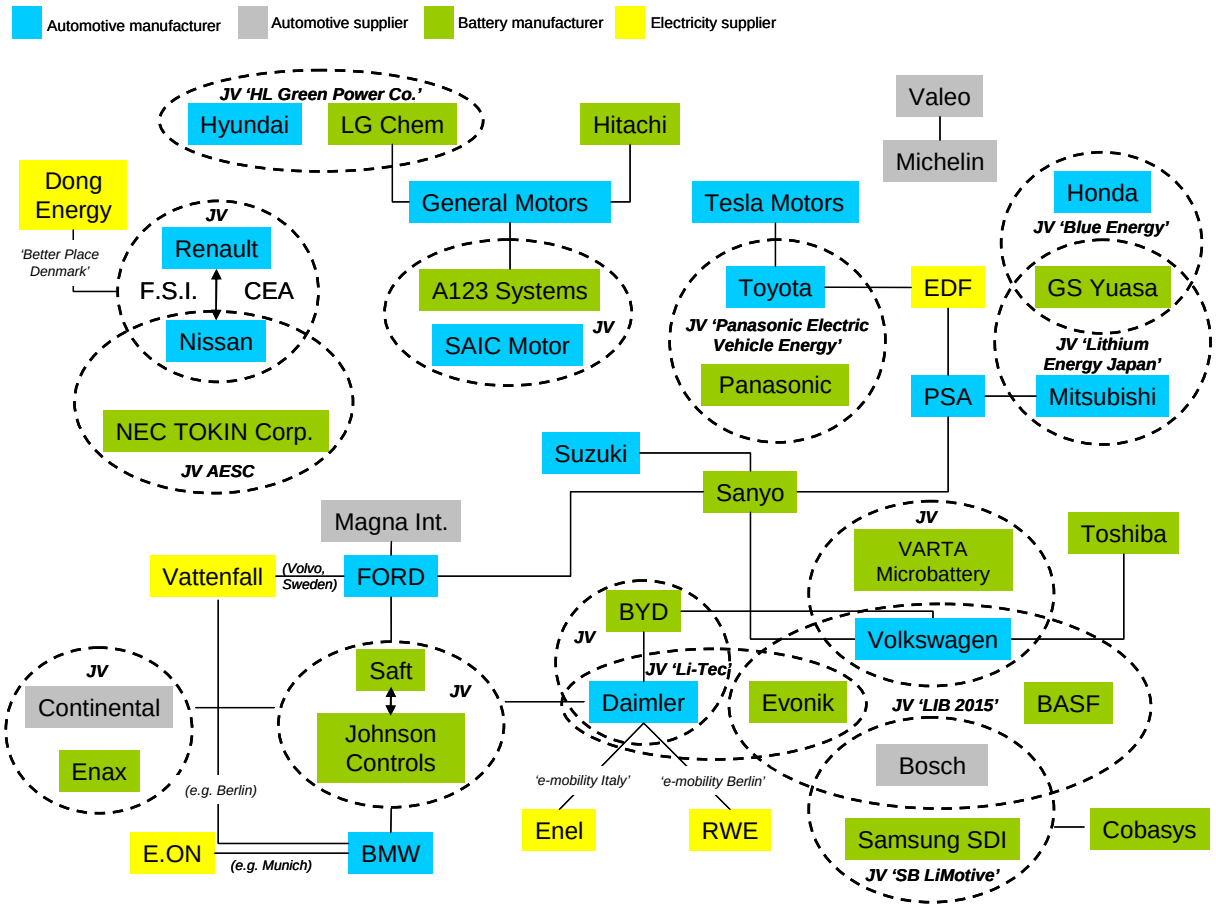


Figure 50: Examples of partnerships worldwide for developing electric vehicles (incl. hybrids)
Source: Leduc et al. (2010)
Note: Snapshot prepared by mid-2010.

Electric drive trains are common in other industries, so the basic knowledge for the construction of vehicles with electric power trains is also common. In contrast, advanced Li-ion battery and fuel cell technologies are specialised activities and need to be made available to the automotive industry (or incorporated by it). Therefore, it has been necessary for car manufacturers to enter into agreements with battery and fuel cell specialists. Because of the concentration of car manufacturing and the consequent strong competition between established companies, knowledge sharing happens mainly through limited, explicit alliances – e.g. Renault-Nissan-NEC, Toyota-Matsushita. Figure 50 illustrates the structure of alliances for electric vehicles. Several small scale networks combining car manufacturers, battery producers and energy firms can be seen.

In a similar manner, major oil companies, chemical industry, specialised (start-up) companies together with research institutes have build up synergies to bring forward advanced biofuel technologies. This is illustrated in Figure 51.

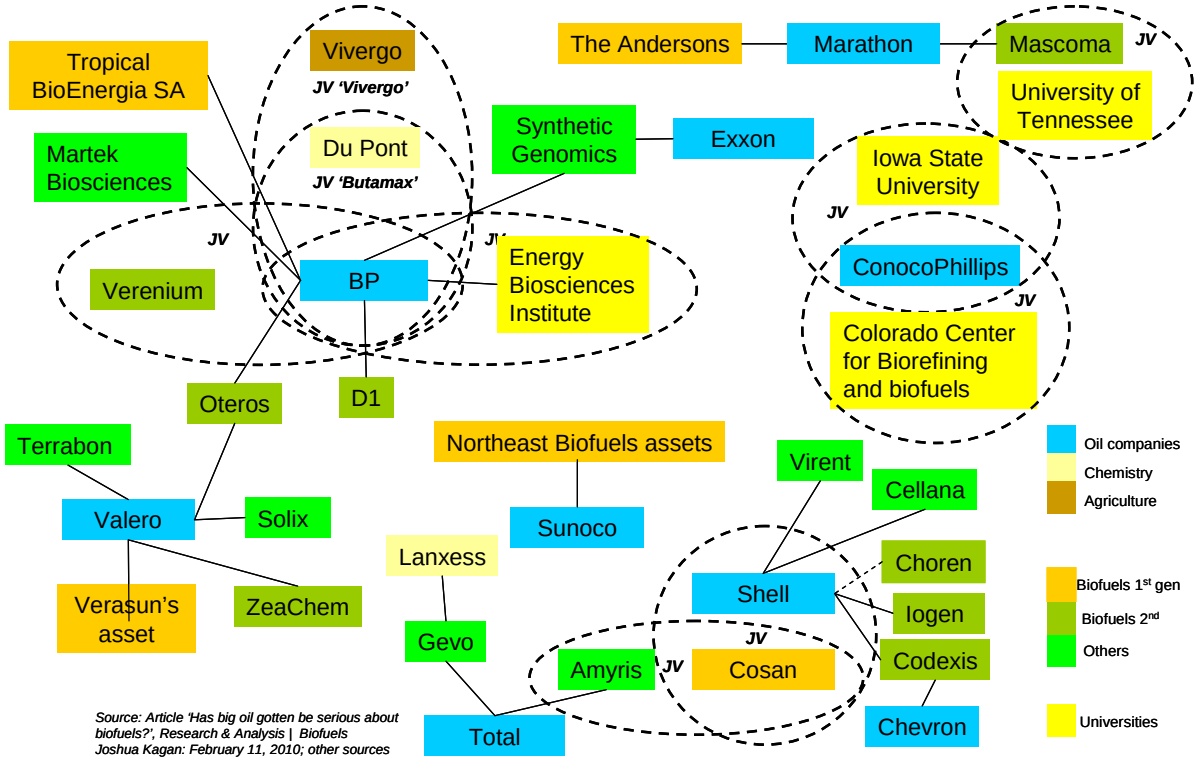


Figure 51: Examples of partnerships worldwide for advanced biofuels
Source: JRC-IPTS
Note: Snapshot prepared in autumn 2010.

9.4.1 Key industrial actors

The automotive industry has a mature structure in manufacture, characterised by competition between a few main manufacturers and a limited number of important component suppliers[92]. Even though service operators play a significant role in forming market demand we focus mainly on the automotive manufacturers and component suppliers in the following.

The EU and world production of vehicles is dominated by a few large firms, with EU-based companies including Volkswagen, PSA Peugeot Citroën, Renault, Fiat, Daimler, BMW. Smaller brands are owned by other international companies, with the US and Japan dominating. However, Tata Motors (Indian) now owns Land-Rover and Jaguar, and manufacturers from South East Asia are also becoming important international players. Chinese manufacturers are still not very active at the global level, but they are entering into cooperation agreements with the main manufacturers. An important part of the production of vehicles is carried out by component suppliers, such as Bosch, Valeo, or Continental. These suppliers carry out around 75% of the vehicle production (IHS Global Insight, 2009), with large tier 1 (or: key) suppliers showing responsibility for pre-assembling, logistics and coordination of upstream suppliers in order to deliver complete functional units to the car manufacturers (Christensen, 2011). Consequently, they are crucial actors for innovation in this sector, accounting for almost one third of the total R&D investments of the automotive industry. In line with the concentration of vehicle manufacturing, also R&D investments are strongly concentrated on a limited number of actors, with 12 major industrial players – BMW, Bosch, Continental, Daimler, Fiat, Porsche, PSA Peugeot Citroën, Renault, Valeo, Volkswagen, Volvo and ZF – accounting for almost 90% of the sector's R&D investment in 2008 in the EU (see Figure 5 in Wiesenthal et al., 2010). But

[92] See Annex III for a list of key EU-based companies active in transport.

also the many SMEs at the lower level of the value chain are important innovators. It is therefore important that mechanisms for an effective flow of information on both directions, upstream and downstream in the suppliers pyramid are established and maintained, which will support technological collaboration of suppliers from different levels. Other crucial actors worth mentioning are the technology and research public and private providers

With the advent of novel technologies some niche manufacturers have entered the market. Some examples are Tesla in the US and Loremo in Germany. These new entrants target very specific niche markets and are based on non-Budd steel bodyshells that – unlike the traditional Budd bodyshell – do not currently have much cost reduction for mass production. Composites can reduce bodyshell weight by 60% (Cousins, 2003), which then reduces power requirement, enabling a small ICE for low consumption as with the Loremo, or a lower battery requirement for electric vehicles, like in the Tesla vehicle. Other new companies, targeting the small car segment, are: Smile, Reva, CitySax, Think. There are also some still not established or even failed small companies that introduced small electric vehicles in the 1990s, such as Hotzenblitz and Twike. Smaller than these small cars, new companies such as Segway are now producing and demonstrating electric micro vehicles (either called personal transporters or people movers), which are equivalent to scooters with battery power.

Also energy companies play a fundamental role in the industry. Traditionally these have been the oil companies, who have been vertically integrated corporations controlling oil extraction, refining, distribution and retail sales through petrol stations. Some of these companies, e.g. BP, are now actively pursuing renewable electricity technologies. The power generation companies, such as E.on and RWE, are also getting actively involved in providing charging infrastructure for plug-in hybrids. Battery and fuel cell companies are also becoming more important. These are either entering into strategic partnerships with car manufacturers or are being purchased (see e.g. the Li-Tec joint venture between Evonik and Daimler for Li-ion battery production).

9.4.2 Industry associations and private-public-partnerships

The **European Council for Automotive Research and Development (EUCAR)**[93] was created in 1994 by the automotive industry. Its central objective is to identify the future R&D needs for improving the competitiveness of this sector through e.g. strategic collaborative R&D. It plays the role of an interface between the European Commission and the EU automotive manufacturers (also providing guidance to ERTRAC, etc.). EUCAR regroups the major EU automotive manufacturers namely Daimler, Volkswagen, BMW, Porsche, Scania (subsidiary of Volkswagen), Volvo, Fiat, PSA Peugeot Citroën and Renault, as well as non-EU based companies such as DAF (Paccar Company), Ford and General Motors. It addresses common R&D needs through a number of working groups covering the following themes: mobility, commercial vehicles, powertrains, fuels, battery and fuel cell electric vehicles, electrification of vehicles, safety, human vehicle interaction, intelligent transport systems, electronics, materials, manufacturing, and virtual engineering. As an example of projects in which EUCAR is involved in, one can mention the joint evaluation with CONCAWE and the JRC dealing with the well-to-wheels energy use and GHG emissions for a wide range of potential future fuel and power train options.

Furthermore, the interests of the EU automotive suppliers are defended through the European Association of Automotive Suppliers (CLEPA)[94]. It plays a similar role as EUCAR but for the EU automotive supplier industry.

CONCAWE (CONservation of Clean Air and Water in Europe) is a non-profit making, scientific association representing all the companies having a crude oil refining capacity within the European Union. It aims to collect and disseminate scientific, economic, technical and legal information on environmental, health and safety issues relating to the refining of crude oil and the distribution and use of petroleum products. Its work also covers areas such as fuels quality and emissions, air quality,

[93] http://www.eucar.be/
[94] http://www.clepa.be/

water quality, soil contamination, waste, occupational health and safety, petroleum product stewardship and cross-country pipeline performance.

The European Automotive Research Partners Association (EARPA) is the association of independent R&D organisations in the automotive sector. It is open to commercial and non-profit R&D providers, including large and small commercial organisations as well as national research institutes and universities. It acts as a platform of automotive actors that aim at actively contributing to automotive research. EARPA seeks a close cooperation with the automotive industry, the automotive suppliers, the oil industry as well as the European Institutions and the EU Member States. It actively supports ERTRAC, the European Research Transport Advisory Council.

The **European Road Transport Research Advisory Council (ERTRAC)**[95] is the Technology Platform for road transport, launched in 2003. It brings together the European Commission, Member States and all major road transport stakeholders (automotive industry, energy suppliers, research providers, associations, etc.). Its main objective is to identify key R&D priorities for this sector and set up a Strategic Research Agenda (SRA) for the next decades. The main outputs from ERTRAC refer to the publication of the 'Vision 2020 and Challenges' in June 2004 followed by the first 'Strategic Research Agenda' in October 2004. In April 2006, ERTRAC published the 'Research Framework' that was followed by the 'Research Framework Implementation' in March 2008. In 2009, they published the 'Road Transport Scenario 2030+' and developed a European electrification roadmap with EPoSS (European Technology Platform on Smart Systems Integration) through the document 'Electrification of Road Transport', further updated in 2010. In 2010, ERTRAC published the 'Strategic Research Agenda 2010', a revision of the first ERTRAC Strategic Research Agenda.

The deployment of efficient R&D strategies for reducing GHG emissions of the transport sector has always been considered a priority by ERTRAC. The 2008 Research Framework identified four Strategic Research Priorities amongst which the research theme 'Energy, Resources and Climate Change', along with road safety, urban mobility and long distance freight. The adoption in 2009 of the 'Road Transport Scenario 2030+' has paved the way to the review of the 2004 SRA. In the SRA 2010 (ERTRAC, 2010b), the three main research needs are decarbonisation, reliability, and safety. The 2030 guiding objectives are presented in Table 13 below.

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

Table 13: 2030 guiding objectives (2010 baseline)
Source: ERTRAC (2010)

The means for achieving these ambitious (guiding) targets are based on the different EU and national research programmes towards advanced vehicle technologies (e.g. new engines, drive trains, etc.) but there is no doubt that it will also depend on the progress made on electric vehicles (HEVs, BEVs PHEVs). In this context, ERTRAC has set up the Electrification Task Force with the aim to develop an implementation plan for the electrification of European road transport for the European Green Cars Initiative (EGCI), which is part of the FP7 programme. The objective is to achieve 5 million of BEVs and PHEVs in the EU by 2020, with annual sales of 1.5 million vehicles (see ERTRAC et al. 2009).

The **European Biofuels Technology Platform (EBTP)**[96] certainly also impacts on road transport, considering that one of its main targets is to substitute 25% of road transport fossil fuels by biofuels in 2030. The key RD&D needs that are needed in order to realise this vision 2030 are identified by the

[95] All the documents quoted in this section are available on the ERTRAC website at www.ertrac.org
[96] http://www.biofuelstp.eu/

EBTP in the Strategic Research Agenda (published in January 2008), which takes into account the recommendations of the BIOFRAC 2030 vision report (BIOFRAC, 2006).

With bioenergy constituting one of the priorities of the European Strategic Energy Technology Plan[97], a roadmap for bioenergy has been developed together with the European Biofuels Technology Platform. On this basis, the **European Industrial Initiative on Bioenergy** has been launched in November 2010. It will address 'the technical and economic barriers to the further development and accelerated commercial deployment of bioenergy technologies for widespread sustainable exploitation of biomass resources, aiming to ensure at least 14% bioenergy in the EU energy mix by 2020, and at the same time to guarantee greenhouse gas (GHG) emission savings of 60% for bio-fuels and bio-liquids under the sustainability criteria of the new RES Directive.

Following the recommendations of the High Level Group on Hydrogen and Fuel Cell, the European Commission launched (under FP6) the **European Hydrogen & Fuel Cell Technology Platform** (HFP) in January 2004, with the objective to set up a research strategy to develop and deploy fuel cell and hydrogen technologies in the EU. The key outputs of the platform were the elaboration of the Strategic Research Agenda (FCH, 2005a), the Deployment Strategy (FCH, 2005b) and the Implementation Plan (FCH, 2007). The latter report aimed at implementing the RD&D activities defined by the Strategic Research Agenda and Deployment Strategy. The **Fuel Cells and Hydrogen Joint Technology Initiative (FCH JTI)**[98] is a public-private partnership that was established in May 2008 with the goal to accelerate the market entry of fuel cell and hydrogen technologies for applications in transport, but also in stationary and portable power. At least two of the five applications areas considered by the FCH JU Multi-Annual Implementation Plan (FCH JU, 2009) are relevant for transport, and in particular for the automotive sector: 'Transportation & refuelling infrastructure' and 'Hydrogen Production and Distribution'. Two others, 'Early Markets' and 'Cross-Cutting Issues', also address pertinent issues.

Other European Technology Platforms can also be relevant for the automotive sector even though it lies outside of their principal focus. The **EPOSS (European Technology Platform on Smart Systems Integration)** focuses on "smart systems", defined as intelligent, often miniaturised, technical subsystems with their own and independent functionality evolving from microsystems technology. The EPOSS Strategic Research Agenda for the automotive applications aims to be a reference for advanced micro- and nano-technology developments. Its R&D priorities are clustered around safety, driver assistance and convenience, energy efficient and environment friendly power trains and subsystems. Enabling technologies for full electrical vehicles, and cross-over technologies, are also included. The **ARTEMIS Joint Technology Initiative** is a public-private partnership that includes actors from industry, SMEs, universities, research centres and European public authorities working in the field of embedded computing systems. Its activities are relevant for the automotive innovation system because of the possible achievements delivered by embedded systems in this field. They include safety related applications, traffic management systems, as well as other achievements related to the field of car manufacturing, the integration of the supplier chain and related logistics. The safety-related applications include in particular the adoption of active safety systems, requiring context awareness in the Human Machine Interface (HMI) to reduce the workload of the driver and therefore relying on the use of sensors, actuators and smart software embedded throughout the vehicle, as well as a specific networking for car-to-car communication. The **European Construction Technology Platform (ECTP)**, also addresses topics that are important for road transport and the automotive sector. Nevertheless, it has a focus on transport infrastructures and is therefore analysed specifically in section 9.9.

9.4.3 Public actors

Public research actors include the European Commission, national Ministries and public research institutes, including universities.

[97] SEC(2009)1295
[98] www.fch-ju.eu

Standardisation is also particularly relevant for the automotive sector and the research activities related to it. The main European standards organisations related to the automotive sector are the **CEN (European Committee for Standardisation),** which deals with European standards in all domains except for electro-technical and telecommunications matters, and the **United Nations ECE (Economic Commission for Europe) World Forum for Harmonization of Vehicle Regulations (WP29)**, which offers a unique framework for globally harmonized regulations on vehicles on issues like road safety, environmental protection and trade.

The **CENELEC (European Committee for Electro-technical Standardization)**, and **ETSI (European Telecommunications Standards Institute)**, respectively addressing issues that are specific to electro-technical and telecommunications matters, are also relevant organisation for the automotive field (e.g. for the development of standards on electric vehicles).

9.4.4 Policy and governance

The **ERA-NET ROAD II**[99] (under FP7) aims to develop road research conducted by the European Research Area by coordinating national and regional road research programmes and policies. The ERA-NET ROAD II consortium regroups several national and regional road administrations (responsible for the development and management of the strategic road research programmes in their countries) and programme managers (for implementing national road research programmes under the supervision of the national road administrations) with the aim to promote, develop and facilitate collaborative trans-national programming, financing and procurement of road research. ERA-NET ROAD II is built on the success of ERA-NET ROAD (funded under FP6) that made considerable progress towards the networking of road research programmes across Europe.

The **ERA-NET Transport (ENT**) with its generally larger focus just finished a major transnational call 'Electromoblity+' to create long-lasting conditions for the development of electric mobility in Europe on the horizon of 2025. The involved national and regional authorities bring together € 20 million, and European Commission may contribute with a maximum of up to € 10 million. This call is the contribution of 13 European countries and regions to the **European Green Cars Initiative (EGCI).** The EGCI is one of the three Public Private Partnerships (PPP) of the European Economic Recovery Plan launched in 2008. It aims to 'support R&D on technologies and infrastructures that are essential for achieving breakthroughs in the use of renewable and non-polluting energy sources, safety and traffic fluidity'. Within the EGCI, there will be R&D activities through FP7 grants for research on greening road transport with a total budget of € 1 billion (€ 500 million from the Commission and € 500 million from industry and Member States). For more details see page 218.

Almost all Member States also have dedicated programmes for road transport research, either as a stand-along programme or embedded in programmes with a wider scope. In a number of Member States (e.g. Belgium, France, Hungary, Finland, Lithuania, Sweden, the UK), dedicated road transport public research institutes exist. Moreover, universities and independent research institutes play a significant role in the development of new automobile technologies. Independent research institutes carry out applied research under contract to automobile companies in areas such as aerodynamics, control and driver support systems, design support software and systems, materials, etc. In low carbon innovation, research into fuel cell materials and technologies including the application of nanotechnologies is mainly undertaken as university research, since this is still remote from market application.

In addition, as discussed above in section 2.3, government legislation, or the possibility of legislation, specifying emissions standards for vehicles has been the main driver of improvements in environmental performance. The EU has played a decisive role in technology legislation in Europe with air pollutant standards and legislation specifying required average emissions levels for the EU new car fleet (Regulation 443/2009).

[99] For more details, see http://www.eranetroad.org/

National Governments also play an important role through fiscal policy, climate policy, R&D support and industry support. Several countries introduced scrapping subsidies to increase the turnover of the car fleet, with the objective of accelerating the uptake of modern, more fuel efficient vehicles. The Konjunkturpaket in Germany, a subsidy on new car purchases which ran in 2008-9, acted along these lines. Such policies have acted as a subsidy for the current production structure, rather than encouraging new entrants with radical new technologies, even if they may be combined with instruments (like the French bonus-malus taxation related to vehicle performance with respect to CO_2 emissions or the subsidy programme for hybrids and other low carbon vehicles implemented in the UK) that promote advanced vehicle technologies.

In terms of market formation, government policy also has an important role in supporting demonstration projects, e.g. in the case of plug-in hybrids, local governments such as London Authority and national governments such as Germany have funded the provision of charging point for plug-in hybrid vehicles. Also on the demand side, preferences may be changing. There is now evidence that the car does not play such a central role in the culture of material consumption as for the last two generations (Bratzel, 2010). Young people care less about the car and are more willing to adopt new forms of service provision such as car sharing. The implication is that a shared or leased car is regarded more as a utility, similar to white goods. This then opens up the market for cars with lower performance in terms of range or maximum speed.

Regional governments have at times provided incentives for low carbon vehicles by tax relief or exemptions in congestion charging schemes e.g. the London Congestion charge removed for low-carbon vehicles (GLA, 2009). Cities such as London and Berlin are also supporting the installation of demonstration networks of charging points for electric vehicles.

Several lobbies also exercise a powerful influence on policy processes. This is also relevant in the case of research. The manufacturers' associations ACEA (European Automobile Manufacturers' Association), JAMA (Japan Automobile Manufacturers Association), KAMA (Korea Automobile Manufacturers Association) and VDA (Verband der Automobilindustrie, Germany) play an important role by engaging in the policy debate. Motoring organisations such as the AA (Automobile Association) in the UK, or ADAC (Allgemeiner Deutscher Automobil-Club) in Germany, as well as all other European members of the FIA (Fédération Internationale de l'Automobile) and the FIA itself, also play a role in representing the point of view of motor car users. They are particularly active on issues such as safety, mobility, the environment and consumer law. The interests of the EU automotive suppliers are defended by the European Association of Automotive Suppliers (CLEPA). On the fuel side, EUROPIA (EUROpean Petroleum Industry Association) backs the interests of crude oil refining and marketing of petroleum products. Its member companies account for 80% of EU petroleum refining capacity and some 75% of EU motor fuel retail sales. Some lobbies are also advocating for specific alternative fuels, as in the base of ePURE for ethanol and the European Biodiesel Board for biodiesel. Finally, other advocacies support strong policies for the implementation of a low carbon transport system: this is the case of T&E (Transport and Environment), Greenpeace and Friends of the Earth.

9.5 The aviation sector innovation system

Aviation is traditionally a high technology industry in which many of the major developments have come from military applications (Brandes and Poel, 2009). Engines form the most significant sub-system, with separate manufacturers who sell their engines for use on competing airframes. There is also an exceptionally strong emphasis on safety, with regulation of testing for new aircraft and components, operation of aircraft and maintenance of aircraft and engines. Since aviation is an international industry, an international regulatory authority – the International Civil Aviation Organization (ICAO) agrees standards of operation and international policy.

Fuel costs are already a large part of operating costs and the conventional jet airliner configuration has been continuously developed, with increasing energy efficiency since the Comet (in service 1952). The aviation industry therefore has a strong innovation system which is continuing to deliver improvements in energy efficiency and therefore emissions.

It is however locked in to the current airframe configuration since aircrafts are expensive vehicles and have a long average lifetime of around 22 years (Bächle, 2009). The total innovation cycles are even longer when considering that product development times for a new aircraft take around 10 years, which are then produced for some 25-30 years and serviced for another 30 years (Brandes and Poel, 2009). This implies that radical changes face a high barrier of existing product and market structures. The last major changes were the adoption of turbofans instead of turbojets in the 1970s and the adoption of fly-by-wire controls from e.g. the A320 onwards. Current new developments are composite materials for airframes, electrical actuation rather than hydraulic for control surfaces and landing gear, the integration of the engine generator and starter functions into a single unit, etc. Current airliners including upcoming models are direct technological descendents of the Comet. There are well known alternative technologies that could improve energy efficiency, in particular open rotor engines and blended wing body airframes. These have been produced and studied extensively as concepts, so the fundamental knowledge of these technologies is already available. However, the application to a radically different airliner (e.g. based on the flying wing concept) will be difficult and expensive to develop.

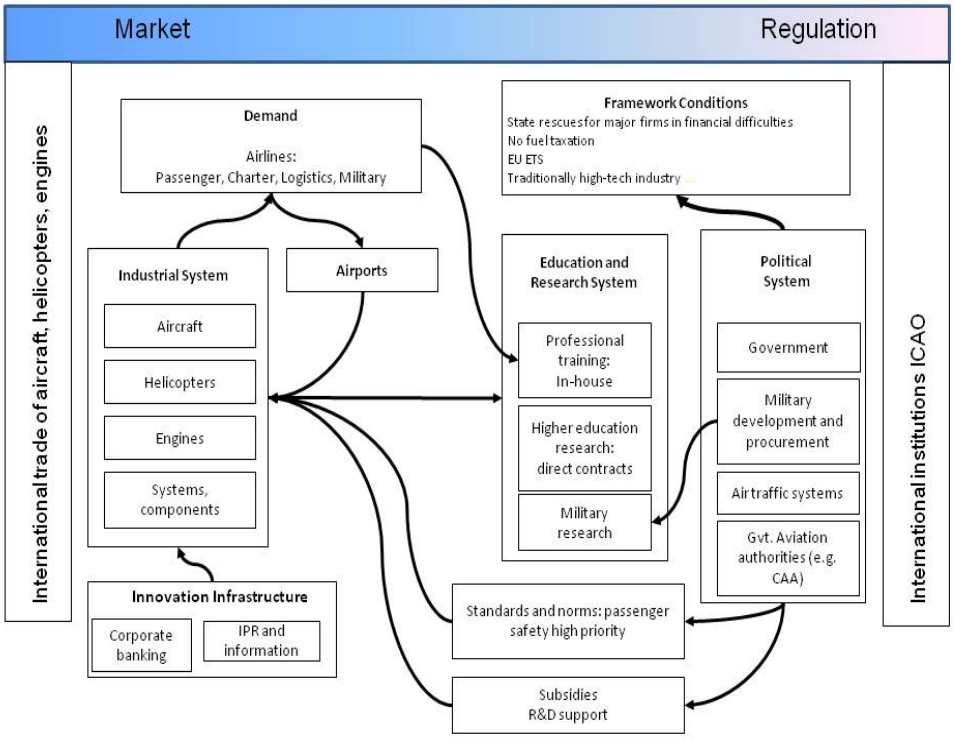


Figure 52: The aviation innovation system
Source: GHG-TransPoRD, published in Leduc et al. (2010)

9.5.1 Industrial actors

Following a consolidation process over the past decades, the aircraft manufacturing industry is today dominated by a very few airframe and engine manufacturers who all compete in a global market. In Europe EADS and BAE Systems emerged as the remaining systems integrators, and Thales and Finmeccanica as system suppliers. In 2009, the EADS Group - comprising Airbus, Eurocopter, EADS Astrium and EADS Defence & Security – generated revenues of € 42.8 billion and employed a workforce of more than 119,000[100]. In the US, Boeing, Lockheed Martin, Northrop Grumman and Raytheon emerged from this consolidation process (Ecorys et al., 2009b), with Russian and Chinese manufacturers (AVIC) mainly active in their internal markets. Main EU-based helicopter manufacturers include EADS (Eurocopter) and Finmeccanica (Agusta Westland). Rolls Royce, General Electric and Pratt & Whitney are the main global manufacturers of turbofan engines for large civilian aircraft.

As a result of this process, there are today a limited number of large system integrators, who rely on numerous companies in the supply chain following a pyramidical structure with some large tier-1 component suppliers and a number of smaller suppliers (see Figure 53). According to estimates by ASD (2010), which cover not only the European aerospace but also the defence industry, besides the few system integrators there are some 100 medium to large companies which act mainly as tier 1 and 2 suppliers, followed by a vast number of specialised SMEs. Innovation is carried out at all these levels.

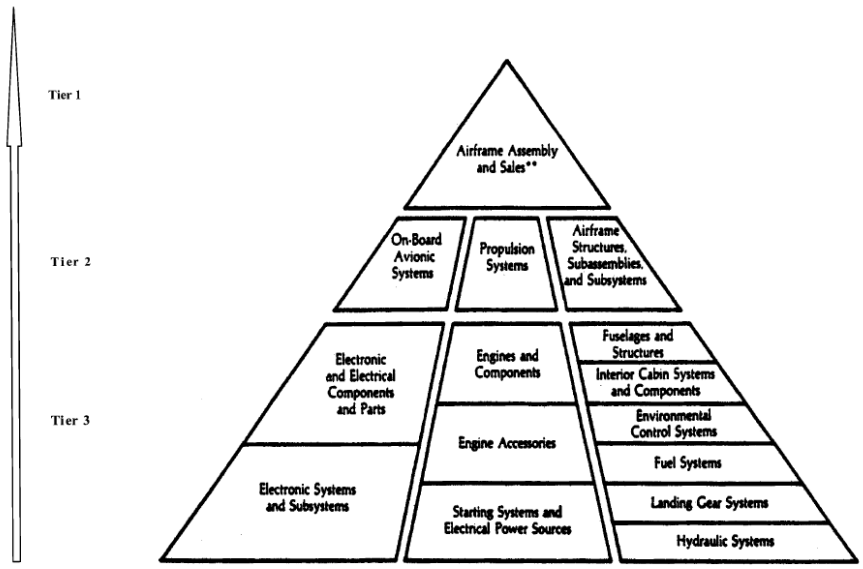


Figure 53: The producers pyramid
Source: Niosi and Zhegu, 2004

On the infrastructure side, the key players correspond to those active in other sectors of the construction industry. They are specifically addressed in section 9.9. Similarly, companies contributing to the development of ITS in aviation (e.g. through avionic and air traffic management applications) are included in section 9.10.

For what concerns services, the key players are the airlines. Examples include Air France-KLM and the International Airlines Group, which resulted form the merge between British Airways and Iberia. Airline and leasing groups are most interested in proven technologies that fulfil high safety and security requirements with low operating costs. Whereas it fosters incremental innovations, this is detrimental to radical innovations which are therefore more likely to occur first in the military segment or via publicly financed research (Brandes and Poel, 2009)

[100] See the EADS Annual Report 2009 available at http://www.eads.com/

9.5.2 Industry associations and private-public-partnerships

The **Aerospace and Defence Industry Association for Europe** (ASD Europe) promotes the interests of the aeronautics, space, defence and security industries in Europe. To this end, it coordinates initiatives and services at the European level, and acts as a contact point for the European institutions. The ASD also aims to facilitate the development of SMEs in the aerospace sector and to coordinate at the European level services and activities as research and technology. ASD members are 28 National Trade Associations in 20 countries across Europe[101].

The central body for coordinating corporate and public research activities at the European level is the **Advisory Council for Aeronautics Research in Europe (ACARE)**[102], the European Technology Platform for aeronautics. ACARE was launched in 2001 based on the Vision 2020 strategy with the aim to develop and maintain a Strategic Research Agenda (SRA) for aeronautics in Europe. It comprises about 40 members from the Commission, Member States and stakeholders (e.g. manufacturing industry, airlines, airports, service providers, research centres). The goal of the SRA is to define EU and national research programmes into new technologies for achieving challenging objectives of the Vision 2020 document. The first edition of the SRA was produced in 2002 and constituted a key input for the design of the aeronautics research programme in FP6. This first SRA was then improved and completed through a second edition published in 2004 (ACARE, 2004). It also formed an important input to the work programme of FP7. An Addendum to the SRA was published in 2008 to pave the way towards a next full review of the aviation sector (ACARE, 2008), and a document intended to stimulate analysis to build a vision for the European aviation sector towards 2050 (ACARE, 2010). A third edition of the SRA is expected by 2012, looking beyond the 2020 targets.

When focusing on the environment, the main targets for the year 2020 as defined in the SRA are the following (note that the reference is a year-2000 aircraft):

- 50% reduction in CO_2 emissions per passenger kilometre (i.e. 50% reduction in fuel consumption in the new 2020 aircraft compared to 2000)
- 80% reduction in NO_x emissions
- 50% reduction of perceived aircraft noise

With regard to CO_2 emissions, the 50% reduction is expected to be achieved by means of a 25% reduction due to airframe improvements (e.g. aerodynamics improvements, weight reduction, fuel cell APUs); a 15-20% reduction due to engine improvements (e.g. advanced engines); and some 5-10% reduction due to operational improvements (see SESAR programme). Moreover, it should be noted that huge R&D efforts have been undertaken to develop alternative aviation fuels. Several synthetic fuels that meet the specific properties for being used as jet fuel (e.g. in terms of energy content, density, thermal stability; see e.g. IFP, 2009a) have been successfully tested in real condition by different motorists and airline companies throughout the world (IATA, 2009).

The EU FP7 project AGAPE (ACARE goals Progress Evaluation; 2010) evaluated the progress towards the ACARE 2020 goals. It found that significant progress has been made towards all of the goals that were set by the Vision 2020, but more efforts are required for the goals to be fully achieved by 2020. The related first Strategic Research Agenda has proved to provide the right focus and to be comprehensive with regard to the research activities needed to achieve the 2020 goals. In addition, the power of the SRA in enabling harmonisation and integration between European projects and those of Member States has been underlined.

Other Technology Platforms related to different field of transport or ITS also directly or indirectly address aviation, even though aviation is not in their focus. These include the ARTEMIS Joint Technology Initiative and EPOSS (European Technology Platform on Smart Systems Integration). On aviation, the EPOSS Strategic Research Agenda followed the logic suggested by ACARE and

[101] EU15 minus Luxembourg, plus Bulgaria, Turkey, Czech Republic, Poland, Norway and Switzerland
[102] All the documents quoted in this section are available at http://www.acare4europe.com/

identified those aspects where developments are likely to be affected or determined by smart systems integration, defining four major areas of activity: the "electrical aircraft" (replacement of, for example, hydraulic components with electrical actuators), the "connected aircraft" (focused on the integration of the aircraft into an overall and global communication system), the "intelligent aircraft" (aiming for a full situational awareness of the aeroplane, which includes all relevant information gathering and processing of the aircraft's environment and direct-coupled feed-forward control) and the "efficient aircraft" (targeting cost and performance improvements). The European Biofuels Technology Platform (EBTP) also addresses issues that are relevant for the aviation sector. European Technology Platforms active in the field of ICT are also relevant for air transport (mainly because of avionic applications and air traffic management). Their activities are specifically addressed in section 9.10, dealing specifically with ITS, in combination with their application in other modes.

9.5.3 Public actors

Public research actors include the European Commission, national Ministries, civil aviation authorities, and public research institutes, including universities.

A number of national public research organisations with a specific aerospace focus are also organised within the **Association of European Research Establishments in Aeronautics (EREA)**, an organisation that aims at intensifying the cooperation between its members and at the integration of research activities in the field of civil, military and space-related aeronautics.

The **European Aeronautics Science Network (EASN)** has a similar profile and a partly overlapping membership base. It is a platform aiming to structure, support and upgrade the research activities of the European aeronautics universities and the incubation of knowledge and breakthrough technologies. The **European Conference for AeroSpace Sciences (EUCASS)** is also set up in a similar manner.

In addition, key public actors for the aviation sector comprise international organisations, like Eurocontrol and ICAO, active in the definition of regulations and standards for international civil aviation and also involved in research activities (e.g. on air traffic management).

Founded in 1960 with the intention of creating a single European upper airspace and active since 1963, **Eurocontrol** is the European Organisation for the Safety of Air Navigation. It is a civil-military intergovernmental organisation made up of 39 Member States and the European Community. Its main stakeholders include air navigation service providers of its Member States, civil and military airspace users (airlines, pilots, aircraft operators and passengers), airports, the aerospace industry (manufacturers of aircraft, aviation electronics and air traffic management infrastructure), professional organisations and intergovernmental organisations. It is currently committed to work on the reform the architecture of European Air Traffic Management (ATM) that involves research activities and is being carried out in the context of the Single European Sky initiative. Further information on this initiative is outlined in the following section.

The **International Civil Aviation Organisation (ICAO)** was established by the Chicago Convention, in 1944. The Organisation came into being 1947, after a few years of provisional operations. In the same year ICAO became a specialized agency of the United Nations linked to Economic and Social Council. ICAO aims at assuring that international civil aviation may be developed in a safe and orderly manner, that international air transport services are established on the basis of equality of opportunity and tat they are operated soundly and economically. It has established three strategic objectives: the enhancement of global civil aviation safety, security, environmental protection and sustainable development. ICAO plays an important role to set standards and recommended practices for the safe and orderly development of international civil aviation.

9.5.4 Policy and governance

As pointed out in section 9.4.2, public institutions involved in transport R&D policy making, its implementation and the performer of R&D are heterogeneous across Member States. Unlike for road transport, however, not all EU Member States are very active in aviation research. Significant public

R&D budgets dedicated to aviation can be found in France, Germany, Italy, the UK, Sweden, Spain, Slovakia, Hungary, Ireland, Portugal, Austria and Poland. The (incomprehensive) list of major R&D programmes displayed in Table 21 confirms that many of these Member States have special programmes set up for research into aviation (France, Germany, Sweden, the Netherlands, Austria, Spain, Italy) and/or special aviation authorities (e.g. UK, Sweden). In other Member States aeronautics research is included as one topic within broader research programmes, such as Italy, Poland, Greece, Ireland, Portugal, and Romania (AirTN, 2009).

The FP6 (and continued FP7) project **ERA-NET AirTN** coordinates aeronautics research in Europe through a consortium of 26 public/private stakeholders from 17 European States as well as Eurocontrol. AirTN (2009) provides an overview of the key aeronautics research funding mechanisms for 17 Member States.

Alongside the **FP7** collaborative research projects, two major EU initiatives have been launched: the Clean Sky Joint Technology Initiative, aiming at reducing the environmental impact of aviation, and the Single European Sky initiative.

The **Clean Sky Joint Technology Initiative** (Clean Sky JTI)[103] is a pillar for EU research in civil aviation. The Clean Sky JTI was launched beginning of 2008 with the clear objectives to turn the ACARE environmental goals into reality. It is one of the largest European research initiatives with a budget estimated at € 1.6 billion over seven years, of which half is funded by the European Commission and half by the EU aeronautics industry. It means that the Clean Sky programme accounts for more than 45% of the total public FP7 budget for the aviation sector. This public-private partnership brings together European R&D stakeholders to develop 'green' air vehicle design, engines and systems aimed at minimising the environmental impact of future air transport systems. Members of the Clean Sky JTI are the European Commission, ITD (Integrated Technology Demonstrators) leaders and associates.

The **Single European Sky (SES)** is an initiative launched by the European Commission in 2004 that aims to reform the architecture of European Air Traffic Management (ATM). Its main objectives are:

- to restructure European airspace as a function of air traffic flows
- to create additional capacity; and
- to increase the overall efficiency of the air traffic management system.

This evolution requires the separation of regulatory activities from ATM service provision, and the possibility of the setup of cross-border ATM services. It entails the reorganisation of the European airspace in a way that is no longer constrained by national borders and it needs common rules and standards, covering a wide range of issues, such as flight data exchanges and telecommunications.

The **SESAR (Single European Sky ATM Research)** programme (2004-2020) is the technological pillar of the Single European Sky (SES). It aims to eliminate the fragmented approach to European ATM, transform the ATM system, synchronise all stakeholders and federate resources in order to developing the new generation air traffic management system capable of ensuring the safety and fluidity of air transport worldwide over the next 30 years. It involves all aviation players and consists of three phases:

- the definition phase (2004-2008), which defined the content, the development and deployment plans of the next generation of ATM systems (contained in the ATM Master Plan);
- the development phase (2008-2013), to produce the required new generation of technological systems, components and operational procedures as defined in the definition phase;
- the deployment phase (2014-2020), with the scale production and implementation of the new air traffic management infrastructure.

[103] http://www.cleansky.eu/

The **SESAR Joint Undertaking** was created by the European Commission and Eurocontrol in 2007 as a legal entity to coordinate the development phase (2008-2013) of SESAR.

SESAR is expected to ensure the safety and fluidity of air transport over the next thirty years, to make flying more environmentally friendly and to reduce the costs of air traffic management. With the focus on environment, two main objectives for 2020 have been set[104]:

- 10% reduction in fuel consumption/CO_2 emissions per flight as a result of ATM improvements alone (see ACARE goals for CO_2 emissions reduction)
- Minimise noise emissions for each flight to the greatest extent possible.

In general, transnational research activities such as the Clean Sky JTI and SESAR have a higher importance in aviation than in other transport modes. This is confirmed by the fact that EU-funds account for the highest share in the total European public funds (i.e. EU plus Member States) of all modes (see Part II). In FP7, aeronautics research is allocated the most elevated funds of all modes, following significant increases between every research framework programmes since FP2.

As in the case of the automotive sector, aviation research polices are also subject to the influence of lobbies. One important advocacy groups is the **Aerospace and Defence Industries Association of Europe (ASD)**, described above. Another important player is the International Air Transport Association (IATA), a global organisation defending the interests of airlines and also aiming to increase the awareness of people on the benefits of aviation. The International Astronautical Federation (IAF) is a worldwide federation of organisations active in space and the leading space advocacy organisation. Other lobbies, like those focused on the fuel supply and on environmental issues have already been mentioned in the section dealing with the automotive sector. They are also relevant for civil aviation.

[104] For more details, see the European ATM Master Plan Portal https://www.atmmasterplan.eu/

9.6 The innovation system in the rail industry

The main actors involved in rail-related research and innovation include infrastructure managers, urban transport operators and rail operators, the manufacturing and construction industries, as well as companies involved in ICT activities. Infrastructure managers provide operation, operability, maintenance, modernization and development of the railway infrastructure. They are also responsible for the allocation of track and slot orders. Urban transport operators and rail operators offer rail-based transport services related to the mobility of passenger and freight.

The industrial component rail innovation system is also part of a mature sector. In contrast to road or aviation transport, it has a relatively small share of transport volumes, except in some particular markets – medium distance high speed passenger and bulk freight. Therefore, the industry is smaller than aviation or road transport. It has a long history, to the extent that most of the main rail infrastructure is based on routes constructed in the 19th century. In terms of the industrial structure, there is a particularly strong link between infrastructure and train operations, because train control comes from the infrastructure operator. Infrastructure and operations are often part of the same firm, usually in the EU a national railway.

Railway vehicles have a typical lifetime of 30-35 years (Competition Commission, 2007; Bombardier, 2010), and signalling and control systems have a similar lifetime. Safety standards are particularly high in the rail industry. To achieve this, there is a very complex process of acceptance – homologation - of both new trains and control systems. These factors make the market for new locomotives and rolling stock small and the development of major technological changes very difficult. There are therefore high barriers to entry in this market. Competition to the EU industry comes from firms established in other global markets.

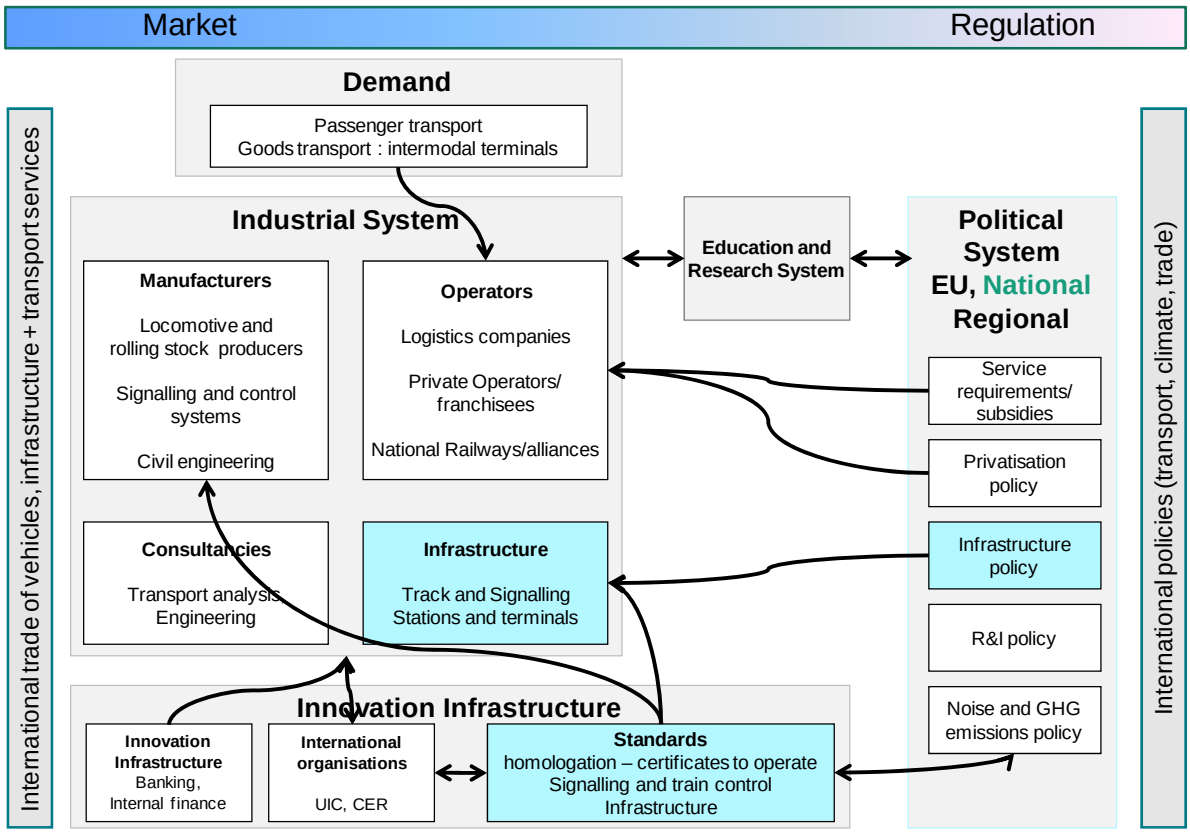


Figure 54: The innovation system railways
Source: GHG-TransPoRD, published in Leduc et al. (2010)

9.6.1 Industrial actors

R&D is mostly undertaken by locomotive/rolling stock and control systems manufacturers or the national railways. Manufacture is highly concentrated, the main manufacturers in Europe being Alstom and Siemens, with Bombardier in Canada, GE from the US and now Hitachi from Japan competing. These large firms have access to a strong innovation structure in terms of available finance and expertise in innovation. There is also a strong consultancy sector for technical and business support.

Other industrial actors include construction companies working on the development of rail infrastructures and companies involved in ICT activities for ITS in the rail sector. They are respectively addressed in detail in sections 9.9 and 9.10.

Service providers are well represented by traditional railway operators like, for instance, SNCF in France or Deutsche Bahn in Germany, or companies having stakes in different countries, like Veolia transport.

9.6.2 Industry associations and private-public-partnerships

The **European Rail Research Advisory Council (ERRAC)** is the Technology Platform for the rail transport. It was launched in 2001 with the aim to define research priorities and set up roadmaps for the implementation of the ERRAC Vision 2020 'Towards a single European railway system'. ERRAC brings together the European Commission, Member States and all the stakeholders from this sector (operators, manufacturers, infrastructure companies, etc.). Based on the ERRAC Vision 2020, the Strategic Rail Research Agenda 2020 was published in 2002 and updated in 2007. The SRRA set up the rail research strategy and needs for this sector and played a key role in the definition of EU and national rail research programmes (e.g. inputs to FP7). With regard to energy-related issues, the thematic 'Energy and Environment' is one of the seven strategic research priorities defined by the SRRA 2020. Alongside all research efforts needed to reduce the environmental impacts, key research areas also refer to the deployment of new technologies, weight reduction, noise reduction, etc. The ERRAC ROADMAP project (FP7) shall to deliver roadmaps to 'guide the rail research in order to provide a rail option that is reliable, environmentally friendly, efficient and economic to customers'.

The **European Inter-modal Research Advisory Council (EIRAC)**, focused on research, innovation and measures to enable changes in intermodal transport and logistics, is also a relevant actor for rail transport. The ARTEMIS Joint Technology Initiative activities are also relevant for rail applications, since rail is one of the fields of applications of embedded computing systems. Similar considerations can be extended to EPOSS.

A number of bodies are involved in advocacy, like the **Association of the European Rail Industry (UNIFE)**, the **Community of European Railway and Infrastructure Companies (CER)**, the **International Association of Public Transport (UITP)**, and the **International Union of Private Wagons (UIP)** also perform some research and are involved in the ERRAC activities.

9.6.3 Public actors

Public research actors include the European Commission, national Ministries, railway authorities, and public research institutes, including universities. National Ministries are in charge of strategic decisions and decisions affecting the total budget allocation for public research funds. Railway authorities focus on the aspects linked to the construction and maintenance of the rail infrastructure that relate to certification issues, regulations and oversight with respect to the fair treatment of different transport and rail operators. They also take care of administrative and certification-related issues concerning the safety of the railway network, and they are responsible for the implementation of transport policies and intervene in the case of incidents.

Research institutes carry out basic and applied research, as well as universities. The history of national railways has meant that part of the research activities in the railway sector (e.g. in the case of services) developed within the structure of public bodies like, for instance, national railway operators.

Historical reasons also explain the nature of the **International Union of Railways (UIC)**, an international organisation that was created in the 1920s to bring together integrated railway companies (mostly publicly owned, at the time) and to focus on international traffic for the standardisation and improvement of conditions of railway construction and operations. The UIC now represents integrated railway companies, infrastructure managers, and railway or combined transport operators and rail transport-related service providers. It aims to promote rail transport, including its interoperability and its ability to meet the challenges of mobility and sustainable development. In addition, it aims to facilitate international cooperation among members and to support them in their efforts to develop new business and new areas of activity. The UIC publishes statistics, analyses on strategic issues and technical reports with relevance for rail transport research. It is also involved in standardisation processes.

EURNEX (the EUropean rail Research Network of Excellence) is the association of the European transport research providers for SME & industries. Its members include several universities and scientific institutes active in the area of rail transport. It aims to improve and integrate rail research in Europe, to provide education on rail research and to contribute to the excellence of the European rail system.

Standardisation is particularly relevant for the rail sector, particularly because of issues related to interoperability of rail systems. The main European standards organisations related to the rail sector are the **European Railway Agency (ERA)**, set up in 2006 and delegated by the European Commission to develop and review Technical Specifications for Interoperability in order to extend their scope to the whole rail system in the European Union. In addition, the **CEN (European Committee for Standardisation)** has also been mandated by the European Commission to produce standards in support of public procurement and in support of the EC Directives concerning Interoperability for Conventional Rail and High Speed Rails Systems. The ERA and CEN work closely with stakeholders from the rail sector like the UIC, which is also responsible for putting forward specifications and standards to standardisation bodies. In addition to the CEN, the **CENELEC (European Committee for Electro-technical Standardization)**, and **ETSI (European Telecommunications Standards Institute)** are (respectively) addressing issues that are specific to electro-technical and telecommunications matters.

9.6.4 Policy and governance

The main influence of government action in the railway sector stems from decisions on new infrastructure investment, since they require extensive planning procedures and since technical specifications of projects and concessions are mainly defined by public sector institutions. Legislation concerning noise and engine emissions may also have a significant impact on the development of rolling stock and diesel engines.

EU collaborative research projects are important for innovation. Examples include projects undertaken in the FP6 and just concluded (like for instance INNOTRACK, URBANTRACK and RAILENERGY), as well as FP7 projects.

The EU has also supported the development of the **ERTMS (European Rail Traffic Management System)**, a major industrial project aiming at the replacement of more than 20 different national train control and command systems in Europe, a major technical barrier to international rail traffic. Since rail freight is competitive over longer distances and high speed rail often crosses national boundaries within the EU, common operating systems are vital for the future competitiveness of rail. One of the ERTMS components, the European Train Control System (ETCS), guarantees a common standard that enables trains to cross national borders. It introduces considerable benefits in terms of interoperability, maintenance cost savings, increased safety and increased traffic capacity, ultimately addressing a major weakness of the rail system: the organisation of its infrastructure, which has always been strongly affected by the national nature of its control system.

Another recent innovation has been the construction of new high speed rail links. These have high investment costs and are dependent on government decisions. Therefore, the construction of these new

links takes a long time. They do not yet form a comprehensive EU wide network, and not all of them are using the ERTMS. Nevertheless, the European Commission adopted in 2009 a European Deployment Plan for ERTMS which provides for the progressive deployment of ERTMS along the main European rail routes. Currently, high-speed rail links are successfully running with ERTMS in countries like Spain, Italy or Belgium (UNIFE, 2010).

Privatisation has been another important organisational innovation in several EU countries. The adoption of privatisation is one of the most important parts of EU policy on rail transport, but the application is dependent on national legislation. The separation of infrastructure and control systems from train operation is a part of these proposals. This enables new entrants in train operations from other transport sectors e.g. logistics companies and bus operators. There are some international consortia for international freight operations and for the operation of the Eurotunnel and Brussels-Cologne/Amsterdam high speed rail links.

Innovation in the rail sector is also affected by changes concerning intermodal freight transport. Innovations here can be required through changes in the external system. The adoption of higher containers has required the development of new container wagons. The pattern of traffic also then changes through events external to the railway industry. New or extended container terminals require new patterns of trains services and potentially infrastructure developments for new capacity. Government legislation in Germany, Austria and Switzerland has required the development of trains for HDV transport on certain corridors. The concept of Green Corridors, denoting long-distance freight transport corridors where advanced technology and co-modality are used to achieve energy efficiency and reduce environmental impact, is being supported by the European Commission. Launched at the beginning of 2010, the project SuperGreen will assist the Commission with developing the Green Corridor concept.

At the Member State level, Austria used to be the only European country to have a specific programme dedicated to rail research called ISB - "Intelligent Railway Systems", which has however been phased out definitely by 2007 (ERRAC, 2008). The programme line introduced thereafter, I2V - "Intermodality and Interoperability of Transport Systems" has a strong focus on logistics and goods transport, with the railway in its very heart - following the general Austrian policy approach to shift a maximum of goods transport from the road to rail and inland waterways. Though, I2V is no longer a dedicated railway research programme properly speaking.

As in the cases of road transport and aviation, a number of advocacy groups contribute to the policymaking process also in the railway sector. The main ones include:

- the Association of the European Rail Industry (UNIFE), which defends the interests of companies responsible for the design, manufacture, maintenance and refurbishment of rail transport vehicles, systems, subsystems and related equipment;
- the Community of European Railway and Infrastructure Companies (CER), which defines itself as the leading European railway organisation. It covers all policy areas that have the potential to impact on railway transport (focusing mainly on issues that concern rail infrastructure managers and rail transport operators). Its stated objective is the promotion of a strong rail industry;
- the European Rail Infrastructure Managers (EIM), promoting the interests and views of rail infrastructure managers (and setup after the liberalisation of the railway market);
- the European Rail Freight Association (ERFA), promoting European rail freight transport and its stakeholders active in that area through the complete liberalisation of this market;
- the International Association of Public Transport (UITP), which defines itself as the global advocate of public transport and sustainable mobility;
- the International Union of Private Wagons (UIP), which represents the interests of owners, loaders, users and other parties involved in activities concerning private rail freight wagons and aims to guarantee a future for the private wagon within a liberalized rail freight sector.

9.7 The waterborne innovation system

The shipbuilding industry has four main sectors: commercial (bulk cargo, container, ferry, cruise and specialised vessels), military, offshore energy and leisure (sail and motor yachts). The offshore and leisure markets are not considered here. The industry can be divided into shipyards, engines and systems suppliers with an extensive range of engineering consultancies for design.

The global shipbuilding market is dominated by a few very large shipyards, with the top 18 (measured by orderbook) all based in Korea, Japan and China (Ecorys et al., 2009a). However, EU shipyards have concentrated on both military or specialist ships and marine systems, acquiring a strong position in the building of submarines and other naval vessels. The European shipbuilding industry is today the global leader in the construction of complex vessels, including cruise ships, luxury yachts and offshore vessels. The operation of an increasing number of European shipbuilders in high-tech market niches requires continuously growing investments in research, development and innovation in order to maintain the leadership position held today (European Commission, 2003). Overall, the industry is very mature and concentrated for large ship construction. There are around 150 large shipyards in Europe, with around 40 of them active in the global market for large sea-going commercial vessels.

Unlike shipbuilding, the marine equipment suppliers consist of many, relatively small companies. For a wide range of products ranging from propulsion systems, large diesel engines, environmental and safety systems to cargo handling and electronics, the European marine equipment industry is the world leader.

A particular feature of shipping is the complex pattern of ownership and insurance. Ships are often not built for a shipping line, but for leasing intermediaries. All ships have to be insured for each voyage and the risk is aggregated through the Lloyds insurance market. This has had a major historical influence on innovation, because Lloyds developed the classification society system, under which classification societies in the major shipbuilding countries specify standards of construction and maintenance. Ships are required to be classified to be insured. A further important feature of standards setting is the International Maritime Organisation (IMO). Since shipping is an international activity, the IMO agrees on standards for operation and also applies international environmental policy. In the maritime sector therefore, there is a regulatory (sub) system which forms an important and distinct part of the innovation system.

The infrastructure in shipping consists of ports, waterways and coastal navigation aids. Navigation requirements and the 'rules of the road' for ship operations at sea are agreed through the IMO. Ports and waterways, in particular the Panama and Suez canals but also e.g. the Elbe river for access to the port of Hamburg determine overall dimensions for some ships. However, this infrastructure does not impose complex technological standards on ship construction.

A distinction needs to be made between deep sea and coastal shipping and inland waterways. Inland waterways vessels face different operating conditions. Compared to maritime shipping, inland navigation is operating under restricted fairway conditions that pose severe constraints on vessel dimensions. Moreover, it needs to comply with stricter environmental requirements and is exposed to direct competition with other (land based) modes of transport. Since inland navigation is not exposed to rough seas and salt water, equipment has a longer life span than marine vessels with bulk vessels on the Rhine being on average around 50 years old and liquid cargo ships some 30 years (Platina, 2011). Eventually, since inland waterways ships are comparatively small, they do not require very large construction facilities. Therefore, in contrast to the highly concentrated and global shipbuilders of deep sea ships, inland waterways and coastal shipbuilders and operators are often much smaller firms and often serve local national, rather than global demand.

All of this has an impact on their innovation incentives. The combination of smaller companies that face a higher competition – also with road and rail freight – and the longer turnover times may imply more limited resources for R&D and innovation. However, they share a common innovation system with deep sea shipping, with partially the same political, regulatory and R&D actors.

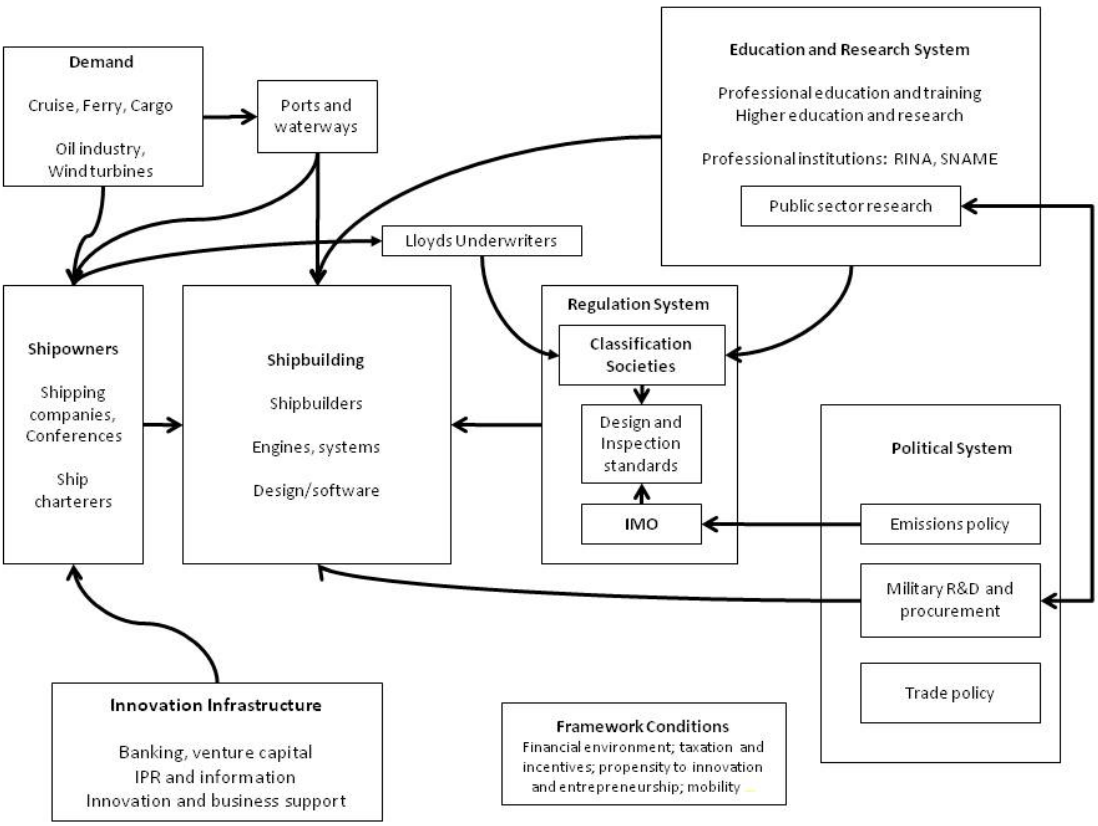


Figure 55: The innovation system waterborne
Source: GHG-TransPoRD, published in Leduc et al. (2010)

9.7.1 Main industrial actors and private-public-partnerships

Key industrial actors in the waterborne sector include shipyards like Meyer Werft, Fincantieri and the Marine Systems section of ThyssenKrupp, as well as marine equipment manufacturers like MAN Diesel & Turbo, Wärtsilä, and Rolls-Royce Marine.

The large shipbuilders have access to an extensive and effective innovation infrastructure, mostly within the companies themselves or through established industry consultancies.

Besides industry, the research system in the waterborne sector consists of national research institutes and universities, which undertake applied research in areas such as hull forms and propeller development. Engines and ship systems are mainly developed within the industry.

Professional societies, in particular **RINA** (Royal Institution of Naval Architects) in the UK and SNAME (Society of Naval Architects and Marine Engineers) in the US also play an important intermediary role in R&D and standards setting, providing fora for discussion on both standards and engineering innovation. The **European Community Shipowners' Association** (ECSA) promotes the interest of European shipping; it also actively participated in the research project Flagship.

Maritime research is currently handled in different ways by each country. However, WEGEMT, a European association of 40 Universities in 17 countries (also including members from the Community of Independent States) encourages universities to collaborate and to work collectively as a network. It aims also to increase the knowledge base, to update and extend the skills and competence of practicing engineers and postgraduate students working at an advanced level in marine technology and related sciences.

At the European level, the **EU Technology Platform for the waterborne sector (WATERBORNE-TP)** is a forum involving stakeholders from the waterborne sector (sea and inland). Similar to the other ETPs, the WATERBORNE-TP published a document in 2005 outlining a Vision for 2020 (WATERBORNE-TP, 2005), followed by the Waterborne Strategic Research Agenda (WSRA) in

2006 (WATERBORNE-TP, 2006) and an Implementation Plan in 2007 (WATERBORNE-TP, 2007). These documents have been reviewed and updated in 2008 (WATERBORNE-TP, 2008), in 2010 (WATERBORNE-TP, 2010) and recently in May 2011 (WATERBORNE-TP, 2011a and b) to reflect developments in the maritime sector and new environmental and economic challenges. The goal has been to clearly define long term R&D programmes (2020) of this sector. A more specific Research Agenda for Inland Waterways has been developed by Platina (see below).

9.7.2 Policy and governance

A European coordinated response to the competitive challenges of the European shipbuilding sector has been given by the **Leadership 2015** initiative. This initiative aims to foster the competitiveness of the EU shipbuilding industry. It takes into consideration the high-tech nature of this sector and the substantial investments made by yards on research, development and innovation, and considers that Europe's competitive advantage will continue to be based upon its ability to construct the most advanced vessels. The Leadership 2015 initiative is thought to provide tools for this industry to improve research and innovation.

At the European level, action related to research in the waterborne sector includes a number of initiatives related to Intelligent transport Systems. The **Vessel Traffic Monitoring and Information Systems (VTMIS)** in shipping was established by the Directive 2002/59/EC and amended by the Directive 2009/17/EC. Directive 2009/17/EC is also instrumental for the setup of the Community vessel traffic monitoring and information system, **SafeSeaNet**, where information for the purpose of maritime safety, port and maritime security, marine environment protection and the efficiency of maritime traffic and maritime transport is automatically sent by vessels and received by coastal stations. The **River Information Services (RIS)** for inland waterway transport is a similar system for inland navigation established within the framework of Directive 2005/44/EC. Other initiatives for maritime transport include the **Automatic Identification System (AIS)** and the **Long-Range Identification and Tracking (LRIT)**.

The European Action Programme for Inland Waterway Transport (**NAIADES -Navigation And Inland Waterway Action and Development in Europe**) specifically addresses Inland Waterways. It develops recommendations for action to be taken between 2006 and 2013 by the European Community, its Member States and other parties concerned. Out of this emerged the FP7 project PLATINA (Platform for the Implementation of NAIADES) together with industry, which has elaborated a Strategic Research Agenda for Inland Waterway Transport (Platina, 2011).

The **ERA-NET coordination action MARTEC** is a partnership of 28 European ministries and funding organisations responsible for funding RTD in maritime technologies from 24 countries. It aims at providing information and support for Europe’s maritime industry and its research activities (e.g. strategy for future research funding, development of transnational programmes). **MARTEC II** will continue improving implementation of joint activities and has ambitious goals for funding trans-national research and offering access to resources of other countries.

National governments in the EU play a role in innovation in shipping through two main links. They form the membership of the IMO and therefore determine international standards and policy. Many governments in the EU also have extensive national procurement programmes for their navies and this supports a considerable part of the remaining shipbuilding industry in Germany, UK, France, Italy, Spain and the Netherlands.

As in other transport sub-sectors, a number of advocacy groups also influence the policymaking process in Europe. Some of the main actors in this respect include the Community of European Shipyards' Associations (see Working Group on (CESA), the European Marine Equipment Council (EMEC), the European Council for Maritime Applied R&D (ECMAR) – representing engineering, science and technology consultancy actors in the waterborne transport sector, the Confederation of European Maritime Technology Societies (CEMT) – representing professional institutions involved in the field of maritime technology, and the European Barge Union (EBU).

9.8 Cross-modal innovation systems

While innovation systems are well established for the various transport modes, it is difficult to define this for cross-modal innovations. In general, cross-modal innovations are likely to be more pronounced in Member States that are actively involved in cross-modal policy development, especially if they are characterised by a high level of involvement in transport ownership and provision.

Cross-modal innovations can also be driven by industry interests where industrial actors are interested to find least-cost solutions to transport problems. Nevertheless, some significant obstacles remain in place in Europe. First, multi-modal transport would benefit from the setup of a single transport document, capable to reduce administrative hurdles. Much intermodal freight terminal capacity already exists, though often in the wrong locations and of the wrong type; a lock-in effect is associated to a legacy of past investment obstructing the development of new facilities; and, although new intermodal terminals could yield sustainability benefits, their development is likely to be resisted by local citizens concerned about their local environmental impacts (given their significant land requirements, intermodal freight terminals invariably require the involvement of numerous stakeholders and public acceptance can be difficult to win). Improved information exchange at logistical/intermodal hubs is also needed, and intermodal transport also faces regulatory issues concerning the rail system.

With respect to research, cross-modal innovation faces also the challenge to bring together different knowledge sets from companies and organisations with widely different functional backgrounds. Moreover, since many of the benefits derived from cross-modal innovations are dispersed across a wide range of users and difficult to recover under current pricing systems, there is often only limited incentive to invest in cross-modal innovations.

9.8.1 Industrial actors and private-public-partnerships

In case of freight transport, typical industrial actors on the cross-modal innovation system are freight logistics service providers, shipowners and shippers, railway undertakings, trucking and hauling companies, but also infrastructure service providers, like ports and, more generally, terminal operators. Other actors include handling equipment manufacturers, suppliers of rolling stock and loading units.

In the case of passenger transportation, public transport operators are primary players. Some infrastructure service providers (like airports operators) have also a genuine interest in bringing forward intermodal solutions, as demonstrated by the initiatives to improve intermodal and surface access from worldwide airports (ACI, 2008).

Most of the industrial players involved in cross-modal transport are characterised by a low R&D intensity: according to the analysis carried out in Part II of the present report the R&D intensity is close to 0.3% only, both in the case of transport service providers (including logistics) and infrastructure service providers (including, for instance, ports).

At the European level, the **European Intermodal Association (EIA)** promotes sustainable intermodal mobility in Europe by combining innovative rail, waterway, road, air and waterborne transport solutions. Its full members are active in railway undertakings, road/rail operators, carriers, shippers or forwarders who wholly or partially use intermodal techniques, manufacturers and suppliers of intermodal equipment and service providers with intermodal products, shipping lines, inland waterway barge operators, sea & inland waterway ports and manufacturing industries[105].

The **European Inter-modal Research Advisory Council (EIRAC)**[106] is focused on research, innovation and measures to enable changes in intermodal transport and logistics. It consists of representatives of the stakeholders of the European intermodal community and it developed a Strategic Intermodal Research Agenda (SIRA) for the year 2020. The SIRA aims to develop intermodal

[105] See www.eia-ngo.com/actual-members.html
[106] All the documents quoted in this section are available at: http://www.eirac.eu/

transport as an important part of the sustainable transport system. It identifies key research drivers and it addresses the challenges of interoperability, logistics, and security. The main 2020 objective mentioned by the SIRA is to achieve a 40% share of the total movement of goods in Europe via its intermodal transport system, featuring also multimodal and combined transport. The SIRA has been accompanied by an Implementation Plan that provides the basis on which the intermodal industry can act together to meet the challenges for the transport sector in the coming decades. The plan identified five priority areas for intermodal transport research: interoperability, logistics, security, socio-economic issues, and education & training.

The **European Construction Technology Platform (ECTP)**[107] identified in its 2005 Strategic Research Agenda a number of actions that are relevant for intermodal and cross-modal transport (ECTP, 2005). They include the implementation of efficient transport networks (incorporating in it interoperable and inter-modal networks, the coordination among operators to assure an enhanced service with a minimum number of interruptions, as well as integrated information and communication systems), the creation of multimodal centres allocated through the European transport network, the conception and adoption of systems capable to modernise sea and inland transport and revitalise rail transport, as well as concepts of design and construction of multiple choice/multiple speed infrastructural systems near roads. Nevertheless, intermodality became less prominent in the 2007 Implementation Action Plan than it was in the Strategic Research Agenda (ECTP, 2007).

In addition to EIRAC and ECTP, there may be a need to further exploit synergies across existing Platforms. Presently, most transport-related Technology Platforms follow a modal structure. In order to foster systemic innovations that affect several modes, a solution-based approach that overcomes the present structure is necessary. A joint intermodal working group – e.g. a Passenger Intermodality Working Group, as proposed within the LINK project (2010) – may be an appropriate approach, which could draw on the modal expertise of existing Platforms and on that basis identify synergies and areas of cooperation across stakeholders.

Other European Technology Platforms that are primarily active in the field of ICT are relevant for multimodal transport, since ICT can be an enabling element for it. Their activities are specifically addressed in section 9.10, dealing specifically with ITS, together with applications for individual transport modes. Similarly, the widespread use of embedded and intelligent computing systems means that technology platforms like EPOSS (European Technology Platform on Smart Systems Integration), the ARTEMIS Joint Undertaking and the ARTEMIS Industrial Association (ARTEMISIA) are relevant for cross-modal applications.

9.8.2 Public actors

Public research actors include the European Commission, national Ministries and public research institutes, including universities. In addition, standardisation is particularly relevant for the intermodal transport sector.

The **European Conference of Transport Research Institutes (ECTRI)** has been first established to unite the forces of the foremost multimodal transport research centres across Europe and groups a number of relevant actors in the field of cross modal research an innovation.

The **International Association of Public Transport (UITP)** also promotes cross-modality in the context of public transport. UITP is the promoter of innovations in the public transport sector, and brings together 3400 members from 92 countries.

The association of **European Metropolitan Transport Authorities (EMTA)** aims to foster the exchange of information and best practices between the public authorities responsible for planning, integrating and financing public transport services in the large European Cities.

Polis, a network of European cities and regions working together to develop innovative technologies and policies for local transport, also has a similar role. Polis aims to improve local transport through integrated strategies that address the economic, social and environmental dimensions of transport. In

[107] All the documents quoted in this section are available at: http://www.ectp.org and http://www.encord.org.

addition, Polis promotes the exchange of experiences and the transfer of knowledge between European local and regional authorities and it facilitates the dialogue between local and regional authorities also involving other actors of the sector such as industry, research centres and universities, and NGOs.

9.8.3 Policy and governance

At EU-level, the European Commission has been explicitly supporting the concept of Green Corridors, i.e. long-distance freight transport corridors where advanced technology and co-modality are used to achieve energy efficiency and reduce environmental impact. Launched at the beginning of 2010, the project SuperGreen (Supporting EU's Freight Transport Logistics Action Plan on Green Corridors Issues) will assist the Commission in developing the Green Corridor concept. The main aims of the project include:

- benchmarking of corridors on the basis of a set of performance indicators like energy consumption and emissions, operational aspects, and costs (infrastructure, internal and external);
- identifying bottlenecks and suggesting methods for improving the identified bottlenecks (including solutions to reduce emissions, like for instance novel propulsion systems, as well as improved handling and terminal technologies);
- analysing the opportunities offered by a better utilisation of ICT-flows already available in the multimodal chain.

The European Commission has also set up the Marco Polo programme, which entered into force in 2003, to ease road congestion by promoting a switch to railways, sea-routes and inland waterways. The programme is ultimately contributing to the deployment of cross-modal transport innovations, leveraging on the spare capacity that exist in non-road modes through the provision of financial support to companies proposing viable projects to shift freight transport from roads.

The importance of innovative intermodal solutions is also acknowledged and addressed by Member States, as indicated by the number of research project addressing intermodality (as verified in the TRKC database). However, only few Member States have specific intermodal transport units in their respective transport organisations: in several cases intermodal transport has been addressed in a distributed manner, either by expanding the scope of existing modal units or by incorporating it in existing modal organisations (OECD, 2001).

Amongst Member States, Austria, which is clearly advocating for a modal shift away from road towards rail (ERRAC, 2008) is an example where combined transport pays a relevant role in policy development and research, as demonstrated by the Programme I2V. Other Member States that launched research activities specifically targeting intermodality include the Czech Republic, France, and Portugal (ERRAC, 2008).

Despite on-going efforts, an institutional set-up of public transport research policy that has often grown alongside transport modes, and the fact that key R&D investing transport industries (in particular those manufacturing transport equipment) are usually focusing on a single mode may indicate that cross-modal innovations are not yet fully exploited. Moreover, agents that have a genuine interest in fostering cross-modal innovative solutions often operate at very low profit margins and have therefore fewer incentives to invest in research. In parallel, lock-in effects hamper some of the possibilities of development of cross-modal innovation.

The LINK project (2007-2010) aimed at creating a European Forum on Intermodal Passenger Travel. In line with the conclusions of the present report, it found that main barriers to intermodal (passenger) travel are the lack of powerful lobbies and the fragmented stakeholder interest; lack of awareness of policy makers; and little institutionalisation. Besides others, they recommended to create a European vision for a European door-to-door intermodal passenger travel information service, to establish a joint intermodality working group of existing Technology Platforms, and to introduce a new EU funding programme for long distance, international passenger intermodality. Also the importance of ticketing systems compatibility, an intermodal journey planner, and the creation of common standards for interchanges has been highlighted.

9.9 The innovation system for construction and maintenance of transport infrastructures

Innovation in the field of construction is characterised by little investment in R&D and in capital, and a significant decline in training practices for its workforce (Egan, 1998; EFILWC, 2005). However, since the construction industry innovates rather in improving processes and organisational schemes, research efforts are only one – and not an outstandingly – important factor for innovation (Gambatese and Hallowell, 2011). Successful innovation largely depends on the management of (tacit) knowledge (Kanapeckiene et al., 2010), which is influenced by the organisational structure, the mechanisms in which knowledge is managed and spread, and the management of human resources.

The nature of the construction work, the complexity of the system and the levels of competition act as a disincentive to innovation. This finding is further underlined by the low propensity of the construction sector to apply for patents: in the UK, only five per cent of large construction firms report applying for any patents (NESTA, 2007). However, the possibilities to innovate are also country-specific and depend, besides others, on the practice of awarding contracts. If this is done on a low-cost basis, it may act as a constraint to innovation.

As public authorities are heavily involved in the definition of technical specifications for the construction of transportation infrastructures and therefore they have the potential to play a proactive role to drive innovation in this area. To date, however, this potential appears to be underexploited.

Even though innovation in the construction industry may remain limited, large contractors have a central role as mediators between innovators (such as the manufacturers of equipments and products; specialists consultants etc.) and institutions that adopt these innovations (clients, regulators) (Miozzo et al., 2002, quoting Winch, 1998). In line with this, we found a significantly higher R&D intensity for manufacturers of construction equipment than for construction companies in part II of this report (section 5.3.7). Long-term relationships between contractors and collaborating companies can improve the knowledge flows between the different actors involved in innovation in construction (Miozzo and Dewick, 2002).

9.9.1 Industrial actors

The construction sector is broadly characterised by a very large number of small firms, and construction markets are generally characterized as local rather than national or even global markets, with only a small group of companies active across different countries and continents. As a result, the entire industry is often characterized as little concentrated.

However, a distinction needs to be made between the many small companies acting at local level, and the few very large construction companies that act at transnational levels. For those few very large construction companies, the international revenue is by no means small; in Germany, it amounted to 20% of the home market revenue in the year 2000 (Girmscheid and Brockmann, 2006).Competition is considered to be strong among small contractors who do basic labour, since the selection of designers and constructors is almost exclusively based on tendered prices (Egan, 1998), even if different types of firms can serve very different functions and so may have more of a vertical relationship than a horizontal one (OECD, 2008).

Unlike for the small companies with a local focus, the international construction market has been characterised as very concentrated (Girmscheid and Brockmann, 2006). Hence, some segments of the construction sector are much less fragmented than others (OECD, 2008). This holds especially true for large infrastructure developments, where a limited number of general contractors manage the very large projects, leveraging on the activity of many small subcontractors. The limited degree of competition seems to be especially important in the case of large and capital intensive applications, typically characterising the large transport-related infrastructures. Furthermore, transportation costs and safety or environmental standards may constitute formidable entry barriers in some constructions markets, and procurement procedures for construction projects may be structured in a way that could result in collusion (OECD, 2008). According to the OECD, cartels have also affected the construction

industry in many OECD countries. This problem is not perceived as something that is now subsiding (OECD, 2008).

Albeit different, all these indications, combined with the project-based nature of the work in the construction industry, are factors that are detrimental to innovation, which is confirmed by the low R&D intensity (0.3%. As indicated above, however, innovation in the construction sector is not primarily determined by the levels of R&D investments. Moreover, the importance of the infrastructure construction company as a mediator for innovative products needs to be kept in mind.

9.9.2 Industry associations and private-public-partnerships

The **European Construction Technology Platform (ECTP)**, which aims to represent all stakeholders in the European construction sector, identified a number of focus areas for its activity, differentiating them amongst those that address specific segments of the industry (cities and buildings, underground construction, networks and cultural heritage) and those having a cross cutting nature (quality of life, materials, processes and ICT). In 2005 it established a Strategic Research Agenda (SRA) to address the research needs of Europe in the field of Construction up to 2020 (ECTP, 2005). Some of the topics addressed in the Agenda are relevant for transport. This is the case for the following activities:

- actions that target the urban environment, including planning and urban design, and also addressing accessibility;
- the implementation of efficient networks for improved mobility, specifically targeting transportation network systems and stressing the importance of interoperable and inter-modal networks, coordination among operators to assure an enhanced service with a minimum number of interruptions, integrated information and communication systems;
- a further network improvement, especially for the longer term, including in particular the creation of multimodal centres allocated through the European transport network, the conception and adoption of systems capable to modernise sea and inland transport and revitalise rail transport, as well as concepts of design and construction of multiple choice/multiple speed infrastructural systems near roads;
- the reduction of natural resource consumption (including specific targets with respect to embodied energy in construction materials, raw materials, waste reduction and recyclability of construction materials), with innovative materials and technologies for the recycling and reuse of construction waste that are likely to have an impact on the logistic system;
- the capacity to manage the European transport network optimally, using R&D to extend the life-span of existing infrastructures, to achieve a better understanding of degradation and ageing processes, and to reduce disruptions from networks jamming.

Many of these items have been included in the Implementation Action Plan associated to the Strategic Research Agenda in 2007, where they are included amongst the priority issues (ECTP, 2007).

The **European Network of Construction Companies for Research and Development (ENCORD)** is a network of active members from the construction industry, represented by decision-makers and executives working on research, development and innovation (RD&I) and providing service to experts and the operational sides within the member companies. ENCORD has 19 members with head offices in 9 European countries and operations worldwide. All members are major European contractors and/or suppliers of construction material and are strongly devoted to research, development and innovation for increased competitiveness and growth. ENCORD organises workshops to exchange information on state-of-the-art in construction research and to set the agenda for future activities.

The ARTEMIS Joint Undertaking and the ARTEMIS Industrial Association (ARTEMISIA) focus on embedded computing systems, which are already widely used in transport-related infrastructures like airports. Similar considerations can be extended to EPOSS (European Technology Platform on Smart Systems Integration).

Besides technology platforms, the **European Union Road Federation (ERF)** is an advocacy group defending the interest of industrial and other actors involved in road infrastructure activities that also acts as a platform for dialogue and research on mobility issues and publishes regularly information on road statistics, relevant for socio-economic research in transportation.

9.9.3 Public actors

A number of different stakeholders are involved in transport research in the public sector: national Ministries and local authorities are in charge of strategic decisions and decisions affecting the total budget allocation for public research funds, as well as the financing of infrastructure development at different levels, ultimately affecting the deployment of innovations.

Road, railway, aviation and port authorities are also involved in activities affecting the construction and maintenance of transport infrastructures. Their activities relate to certification issues, regulations and oversight. Many of these actions have technical implications and are therefore relevant for research activities. Transport authorities also take care of administrative and certification-related issues concerning safety (a relevant research field in transport), they implement decisions concerning transport policies (which have an influence on research activities) and intervene in the case of incidents. In addition, research institutes carry out basic and applied research, as well as universities.

The **Forum of European National Highway Research Laboratories (FEHRL)** is an organisation grouping a number of European national road research and technical centres in Europe, as well as some associated institutes located outside the EU. Its research capacity is provided by the national institutes and makes use of the wide range of test facilities available to them. Most of the FEHRL members are either public or partly funded by the public sector. FEHRL is engaged in road engineering research topics including safety, materials, environmental issues, telematics and economic evaluation. It developed a longer term vision of both the future of roads and the research needed to support their development and operation, as well a Strategic European Road Research Programme (SERRP), underlying the importance of reducing congestion and increasing the reliability of road transport infrastructures.

The **Forum of European Road Safety Research Institutes (FERSI)** is an association of research institutes active in the field of road safety. As in the case of FEHRL, most of its members have a public nature or receive substantial funds from the public sector. Unlike FEHRL, FERSI has no legal status. Its stated aims include encouraging closer co-operation between a wide network of researchers, the exchange of research knowledge and good practice between member institutes, the enhancement of the scientific quality of research, and the encouragement of the exchange of researchers between countries. FERSI also aims to facilitate the dissemination of research results and to provide a forum for developing collaborative research projects on common road safety issues.

In addition, other **European Conference of Transport Research Institutes (ECTRI)** and **EURNEX (the EUropean rail Research Network of Excellence)** also contribute to the research undertaken by public actors for what concerns transport networks and their infrastructure, as well as public research actors involved in the development of ITS.

9.9.4 Policy and governance

Even the major construction companies (i.e. those who are most likely to be involved in major transport-related infrastructure developments) have been considered slow to adopt innovations (NESTA, 2007). Notwithstanding the possible underestimation of actual innovation taking place in the construction sector (e.g. when it occurs a micro-level in the context of individual projects and when it involves a wide range of partners, from supplying industries such as those building materials, to companies building equipment and machinery, architecture and design, as well as IT), it is unlikely that the conditions that apply to the construction industry could lead to the introduction of radical innovations. As a result, most of the innovations taking place in the construction sector remain incremental (OECD, 2009): even if their contribution over time may be significant, it is unlikely to be more pronounced than what has been observed in other transport-related industrial activities.

The peculiar nature of the transport-related construction market (often characterised by projects commissioned by public authorities), however, makes it particularly sensitive to innovation driven by regulations. In particular, the setup of standards that prescribe new sector-wide product or material attributes (e.g. structural integrity) or new features (for example, with respect to the integration of ICT solutions in new infrastructures, or with respect to the elimination of the bottlenecks affecting cross-modal transport) would be something that could encourage innovation. Notwithstanding the relatively poor performance of the construction industry with respect to innovation, this sensitivity to regulations represents a significant opportunity. This is even stronger in transport-related applications, since this is an area where the technical specifications of projects and concessions are mainly defined by public sector.

Since infrastructure projects funded by the public sector often focus on building and improving roads, bridges, railways, waterways, and airports, the ambitious redefinition of the building codes in transport-related infrastructures is also something that could also be crucial for the healthy survival of the European construction industry, which was heavily hit by the financial crisis (OECD, 2009). Nevertheless, it is important that regulatory measures are conceived to foster innovation and renewal in the sector, rather than simply stimulating the sector by fostering demand. For example, demand for the use of new technologies in the construction and upgrading of transport infrastructures may help create new sourcing partnerships between contractors and solution providers (OECD, 2009).

Given the characteristics emerging from the analyses that have been targeting the construction sector, regulatory drivers would need to be followed by an evolution in skills supply. The large role played by relatively small companies (albeit this is likely to be mainly relevant for the maintenance and the provision of services to large companies, in the case of transport infrastructure) may condition the response of the construction industry, eventually leading to some reorganisation. If such a process is conceived in a way that would promote innovations, it should be expected to reward the best performing actors, ultimately enhancing the competitiveness of the European construction industry.

Another opportunity is represented by the private finance initiatives (PFI) and public-private partnerships (PPP), considered as a factor that sustained construction company growth and the employment in the sector over the past few years (Deloitte, 2009). These projects have been very relevant in Western Europe, which is considered as the most dynamic region worldwide in this respect (Deloitte, 2009), and particularly important for transport, since transport-related deals made up more than 60% of the global PPP/PFI market in 2008 (Deloitte, 2009). Nevertheless, the same cautionary message mentioned for measures directly funded by the public sector shall be extended to the definition of PPP/PFI projects, since their specifications shall be conceived to foster innovation, rather than being conceived to foster demand.

As in other transport sub-sectors, a number of advocacy groups are involved in policymaking concerning the construction and maintenance of infrastructures. These groups include the European Union Road Federation (ERF), as well as a number of groups active in the construction sector, like for instance the European Construction Industry Federation (FIEC), the European Council for Construction Research, Development and Innovation (ECCREDI), and the Council of European Producers of Materials of Construction (CEPMC).

9.10 The innovation system in Intelligent Transport Systems

Intelligent Transport Systems (ITS) are solutions based on Information and Communication Technologies (ICTs) and electronic tools that aim to provide innovative services for transport applications.

ICTs can enable various transport system users to be better informed, contributing to the increased safety (e.g. through systems providing assistance to drivers, as well as vehicle to vehicle and vehicle to infrastructure communication). ICTs can also foster the more efficient use of transport infrastructures via the better management of transport routes and traffic. ICTs have also been identified amongst the solutions that bear a high potential to create interfaces and integration across different transport modes, specifically addressing some of the key barriers that limit the uptake of intermodal transport. Modern logistics is increasingly benefitting from ICT-based solutions like radio frequency identification (RFID), real-time management of supply chains, automated warehouse systems and telematics. Sensors and sensor networks are also important examples in this respect, since sensor technology contributes to better tracking of goods and vehicles and may result in a lower level of inventory, in less inventory infrastructure needs and also less need for transport (Atkinson and Castro, 2008). ICT solutions like virtualisation, digitisation and teleworking (albeit not generally listed amongst ITS applications) can even make freight and passenger transport unnecessary, replacing the need for mobility by the electronic delivery of digital contents.

If, on one hand, ITS can result in energy savings and reduced CO_2 emissions because of improved traffic conditions, journey time reduction and network capacity increases, on the other hand this same improvement may also induce a greater transport demand, reversing the energy saving and CO_2 mitigation benefit through a rebound effect. This is why the introduction of ICTs for the improvement of traffic management is likely to require a combined implementation of demand side management in order to achieve an overall reduction in the environmental impact and other externalities of transportation (Erdmann et al., 2004). ICTs solutions for ITS can also provide an answer to these issues, since several ICT-based instruments (including for instance global positioning systems, integrated payment systems, number plate recognition for access restriction and the enforcement of speed limits) specifically address the needs of policies aimed at the internalization of external costs of transport, including congestion (like, for instance, road pricing and congestion charging).

The use of ICT is closely linked to innovation, mainly because of the ability of ICT to favour the introduction of new products, services, business processes, and applications. In the case of transport, the importance of ICT as an engine of innovation is confirmed by the large amount of new products penetrating the automotive market, as well as logistics and the service sector.

In the case of the automotive and commercial vehicle sector, ICT products have become crucial for most of the technological advances over the last decade, and they are expected to remain crucial in next decade and beyond. Today a road vehicle has several microcomputer-based systems that control nearly all aspects of its operation, including powertrain operation, direction, speed, steering, braking, acceleration and suspension management, safety-related controls like airbags and seatbelts, driver assistance tools, passenger convenience and comfort systems, as well as entertainment and information products. The ITS fraction of the total value of a car has been estimated to be about 10 to 30% of its purchase price, depending on the vehicle type and its equipments (Juliussen and Robinson, 2010).

Similar considerations can be extended to the rail and the aviation sectors. In the latter case, ICTs are best represented by the wide range of avionic applications, comprising communications, navigation, the activation, display and management of aircraft systems, as well as hundreds of other systems meeting individual roles.

Logistics has been a fertile area for technological innovation based on ICTs. This includes hardware and software applications targeting activities like product identification (including electronic proofs of delivery), warehousing, fleet management, supply chain management, vehicle routing and scheduling and other transport technologies. Benefits provided by ICT include quick response and access to information, better customer service, increased competitiveness, faster data collection, processing and communication, the reduction of inventories and the better integration of activities throughout the

supply and distribution chains. The timely adoption and successful implementation of ICT in logistics has been perceived as a prerequisite for success.

For public transport, ICTs with implications for ITS range from software applications like journey planners to hardware solutions exploiting RFID for the integration of the payment of the services, eventually including non-motorised modes like bicycles.

For transport networks, transportation infrastructures and related services, the diffusion of ICTs may also have impacts that go beyond individual firms. This is because the ICTs involved in ITS are applications that produce greater benefits when more customers or firms are connected to the network because of the so-called spillover effects. For example, ICTs are expected to lead to a more efficient matching of supply (represented in transport systems by the infrastructure capacity) and demand (represented by the transport activity), enabling the time and energy savings that go beyond the advantages available for ITS users.

ICTs are also relatively cheap options and, as such, are less affected than other technologies by financial barriers. This is due to the low capital intensiveness of the industry and the important share of venture capital that continues to flow to the ICT sector (although the share has declined from the peaks of 2000-01). Within the group of ICTs, software applications are the least exposed to these issues. Limited financial issues also concern targeted hardware applications like embedded systems, since the financial needs are internalised in the activities of vehicle manufacturers, component suppliers and ICT companies, which are all typically characterised by relatively high R&D intensities and relatively easy access to capital (including venture capital, particularly in the case of small undertakings).

Nevertheless, some important barriers exist for ITS applications. The need for a critical level of market penetration before the achievement of effective results is extremely relevant in this respect, as well as the conflict between standardisation needs and the evolving nature of some technological solutions. In addition, high risks of obsolescence and leapfrogging typically characterise ICTs with respect to other sectors (and transport applications are not an exception), and ICTs applications with transport-relevance also face the need to properly address privacy-related issues (e.g. affecting RFID technologies). The long life of existing transport infrastructures represents an additional issue for some transport-relevant ICTs, since they emphasise some of the obstacles that are typically characterising innovations having a systemic nature (lock-in). Other important barriers relate to issues that include the difficulty to make business cases emerging from ownership and availability of data, the difficulty to find an agreement amongst those stakeholders that need to install some of the ITS infrastructure and those that are going to benefit from it, the compartmentalisation of some business sectors and the contextual interdisciplinary nature of ITS, and – last but not least – the novelty of ITS solutions, associated to difficulties in the assessment of risks and an inevitable uncertainty on the willingness to pay of final users of new services (Sampson, 2010).

9.10.1 Industrial actors

ITS integrate telecommunications, electronics and information technologies with transport engineering in order to plan, design, operate, maintain and manage transport systems. As such, they involve a wide number of different stakeholders: the main ones are the IT industry, vehicle manufacturers and their suppliers and companies providing services (including telecommunications, computer-based services, internet access, as well as insurance). Other stakeholders include transport and facilities operators, local authorities, research institutions, companies involved in the infrastructure construction and in their maintenance and, last but not least, final users.

Within the IT industry, many players have stakes in other industrial areas (like, for instance, vehicle manufacturing or telecommunications), while some are mainly targeting ICT applications for transportation or consider it one of their main fields of activity. In Europe, this is the case for companies like Indra (maritime and air traffic), Kapsch (road traffic telematic systems), Tom Tom and Trafficmaster (navigation systems), for instance.

Vehicle manufacturers and their suppliers are mainly focused on the use of ICT for embedded systems and infotainment. The latter applications are linked to ITS applications and have already led to the emergence of partnerships amongst vehicle manufacturers and IT companies.

R&D intensities are relatively high both in the vehicle manufacture and ICT sectors, averaging above 5% (according to the analysis carried out in Part II of the present report). The top 250 IT-related firms spent an average of around 6% of revenue on R&D during 2009, and the top 10 spent around 4% (OECD, 2010). Typical R&D intensities in the IT sector range between 3% and 15%, with companies involved in telecommunications, IT equipment, IT services and electronic components manufacturers at the lower end and internet, communications equipment, software and semiconductors firms at the higher end (OECD, 2010). As a result, R&D intensities of ICT companies mainly focusing on ITS are roughly aligned with the sectoral average characterising IT service, IT equipment and electronic component firms. These indications concur in the identification of a rather good performance of the ITS-related industries with respect to R&D.

9.10.2 Industry associations and private-public-partnerships

ERTICO - ITS Europe defines itself as the network of Intelligent Transport Systems and Services stakeholders in Europe. Its members include vehicle manufacturers and component suppliers, service providers, ICT companies, public authorities, consumer associations and research organisations. As advocacy group, it represents the interests of actors involved in the provision of ITS and related services, advising policy makers on issues that are relevant for its members. In addition, it connects public authorities, industry players, infrastructure operators, users, national ITS associations and other organisations. It contributed to the development of standards and frameworks for the development of ITS and constitutes a networking platform for international collaborative research and development on ITS. ERTICO also liaises with similar associations for the United States and Japan.

The **European Council for Automotive Research and Development (EUCAR)** aims to identify the future R&D needs for improving the competitiveness of this sector through e.g. strategic collaborative R&D. It plays the role of an interface between the European Commission and the EU automotive manufacturers and regroups the major EU automotive manufacturers. Its 'Working Group for Advanced Communication and Information Systems' covers technologies and standards for robust wireless communication and end-to-end system architectures for Intelligent Transport Systems and Services. In addition, its 'Human Vehicle Interaction Working Group' has also a relevant role in the field of ITS, since it aims to enhance the interaction among the human, the vehicle and the road/traffic environment.

The **European Road Transport Research Advisory Council (ERTRAC)** is the Technology Platform for road transport, launched in 2003, that brings together the European Commission, Member States and all major road transport stakeholders (automotive industry, energy suppliers, research providers, associations, etc.). ITS solutions are widely listed amongst its research recommendations Research Framework document of 2006. In particular, they appear under the research themes 'Urban Mobility and Freight Distribution' and 'Mobility Management & Information Provision' in the 'Mobility, Transport and Infrastructure', in several themes of the 'Safety and Security' area (e.g. 'Preventive and Protective vehicle systems including Vulnerable Road Users ', 'Cooperative Systems' and 'Human Factors'), in the 'Mobility Management, Road Infra-Structure Design and Advanced Traffic Management' theme of the 'Energy, Environment and Resources' area and in the 'Design, Data & Logistics' theme of the 'Design and Production Systems' area.

The **European Green Cars Initiative (EGCI)** is one of the three Public Private Partnerships (PPP) of the European Economic Recovery Plan launched in 2008. Its objective is to 'support R&D on technologies and infrastructures that are essential for achieving breakthroughs in the use of renewable and non-polluting energy sources, safety and traffic fluidity'. ICT represented a consistent fraction (about 20%) of its total budget for the period 2010-2013. The work programme 2011 includes Logistics and co-modality combined with intelligent transport system technologies amongst its three major R&D themes. In addition, ICT is one of the three groups of topics covering collaborative research activities as well as coordination and support actions.

The **Advisory Council for Aeronautics Research in Europe (ACARE)**, the European Technology Platform for aeronautics, is one of the central bodies for coordinating corporate and public research activities. It addresses the use of ICT for ITS in aviation in a number of documents including the Strategic Research Agenda of 2004 (ACARE, 2004), its Addendum of 2008 (ACARE, 2008), and a document intended to stimulate further analysis with the aim of building a challenging vision for European leadership in global aviation towards 2050 that was published in 2010 (ACARE, 2010). When looking at all these documents from the ITS perspective, a particular focus emerges on what concerns the Air Traffic Management (ATM) system at a pan European level. Nevertheless, activities that are related to ICTs are also included in other topics, like avionics, aircraft systems and equipment (e.g. electronics and microelectronics for on-board systems), integrated design and validation (e.g. IT tools for collaborative product and process engineering, simulator environments and virtual reality, decision support systems), human factors (man-machine interface) and innovative concepts.

Industrial actors of the aviation sector are also involved in the activities of **SESAR (Single European Sky ATM Research)** programme (2004-2020), which represents the technological pillar of the **Single European Sky (SES)** initiative, which is targeting specifically the ATM in the EU. The current involvement of industrial actors is concentrated in particular on the work of the **SESAR Joint Undertaking**, created in 2007 by the European Commission and **Eurocontrol** (the European Organisation for the Safety of Air Navigation, i.e. a civil-military intergovernmental organisation made up of 39 Member States and the European Community) as a legal entity to coordinate the development phase (2008-2013) of the SESAR programme.

The **European Rail Research Advisory Council (ERRAC)** is the Technology Platform for the rail transport. On ITS, the Vision outlined in the Strategic Rail Research Agenda (SRRA) includes the need to work on an Europe-wide intelligent infrastructure to support customer information for freight and passenger services, also underlining the need to provide compatible technology between Member States and across transport (ERRAC, 2007). Intelligent mobility, intended as a seamless cross border, network to network and intermodal transport to be achieved through improved passenger ticketing and freight customer information, is clearly listed amongst the research priority areas of the SRRA. Key elements characterising it are the establishment of an 'intelligent infrastructure' supporting customer information systems and offering a higher quality of service, telematic systems to better manage passenger and freight traffic, the secure transmission of passenger information, traffic management systems that include train positioning and related traffic management and independent databases to pool relevant information for operations management and logistical planning. Innovative communications technologies exploiting Galileo and mobile broadband are also expected to be part of the equation. In addition, the section of the SRRA concerning personal security research priority areas also mentions safety systems capable to make intelligent decisions and take preventive actions under dangerous conditions.

The **European Inter-modal Research Advisory Council (EIRAC)**, consisting of representatives of the stakeholders of the European intermodal community focused on research, innovation and measures to enable changes in intermodal transport and logistics, also refers to ITS in its Strategic Intermodal Research Agenda (EIRAC, 2005). In particular, it underlines that the use of information technology is a fundamental instrument to assure the proper functioning of intermodal transport and it mentions the extensive investment required on infrastructure, equipment and information systems to improve the transfer of loading units between the various modes of transport. For goods transport, ICT and ITS applications are expected to have the potential to lead to a system allowing the transport of all necessary accompanying data as loading bill and operational data. The SIRA also calls for an integration of information technology and logistics to form the "smart supply chain", controlled by IT systems on the basis of harmonised information and automated tracking and tracing features. In addition, information technologies are also mentioned as an instrument needed to exchange and record transport related information in a secure environment.

The **EU Technology Platform for the waterborne sector (WATERBORNE-TP,** see section 9.7) considers in its 2011 revision of the Strategic Research Agenda that integrated ICT and ITS, including the IMO e-Navigation Strategy and the EC e-Maritime initiative, as a key future capability (WATERBORNE-TP, 2011a). E-maritime solutions are also explicitly mentioned in their declaration

(WATERBORNE-TP, 2011c). Innovation in this field is deemed as essential, since it is expected to enable more efficient planning, booking, simulation, routing and control of cargo along the different transport modes as well as providing other services supporting efficiency, safety and security.

ITS are also mentioned in the Strategic Research Agenda published by the **European Construction Technology Platform (ECTP)**, a technology platform that aims to represent all stakeholders in the European construction sector. In particular, integrated information and communication systems are described in the ECTP Strategic Research Agenda as systems capable to improve communication between users, infrastructure and operators, improving mobility and supply (ECTP, 2005). They are considered as an instrument that construction R&D is expected to support, since they are listed amongst the new needs of users and citizens that the creation of a unified trans-European Network is going to address. The ECTP Strategic Research Agenda also mentions ITS application amongst its research areas for the medium term (ECTP, 2005). It refers explicitly to several solutions including:

- new information system between modes of transport;
- new coordination requirements for exchanging information among infrastructure and operators; systems for the management of risk and emergencies and partial functionality of the networked system;
- new concepts and models based on integrated sensors and information technologies for real-time control of network operation and the development;
- the implementation and application of ICT systems to optimise the traffic and to address issues related to serviceability and security of networks, integrating fleet and freight management, traffic monitoring, tolling, information to users, incident and crisis management, transport of hazardous goods, and service in adverse climate conditions.

The **ARTEMIS Joint Technology Initiative** is a public-private partnership that includes actors from industry, SMEs, universities, research centres and European public authorities working in the field of embedded computing systems. Its activities are divided between the **ARTEMIS Joint Undertaking** and the **ARTEMIS Industrial Association (ARTEMISIA)** and follow the work carried out by the **ARTEMIS Technology Platform**. They are relevant for ITS -related improvements because of the importance assumed by embedded computing systems in this field. Typical safety-related applications of embedded computing systems include in particular the adoption of active safety systems. Such systems require context awareness in the Human Machine Interface to reduce the workload of the driver and therefore relying on the use of sensors, actuators and smart software embedded throughout the vehicle, as well as a specific networking for car-to-car communication. Embedded systems can also lead to a better use of the transport infrastructures, contributing for instance to the operation of traffic management systems. Other achievements related to the field of car manufacturing, the integration of the supplier chain and related logistics. For transport services, embedded systems can provide solutions that increase simplicity of use, connectivity, interoperability, flexibility and security.

EPOSS (European Technology Platform on Smart Systems Integration) focuses on "smart systems", defined as intelligent, often miniaturised, technical subsystems with their own and independent functionality evolving from microsystems technology (EPOSS, 2009). Stakeholders involved in the EPOSS activities include automobile manufacturers, aerospace industries, automotive components providers, information and communication companies, SMEs, research institutes, universities and other partners. The relevance of EPOSS in transportation is mainly associated to the applications concerning the automotive and the aviation sectors, with some implications also for ITS (e.g. in safety-related applications, given the stated aim for a full situational awareness of vehicles, and in applications related to the overall and global communication system).

Net!Works (former eMobility) is a Technology Platform that has stakeholders from the industrial domain, the research domain (universities, research centres, etc.), SMEs and other fields (institutions, pre-standardisation bodies, state organisations, etc.). It focuses specifically on mobile and wireless communications. As such, it has implications for ITS: transport applications based on mobile and wireless technologies are specifically addressed by the Strategic Applications Research Agenda, published in 2010, specifically mentioning the contribution of these technologies for sustainable

development of cities, more efficient and effective transportation, new approaches for reducing traffic congestion, shortening travel times, and the provision of the most advanced and secure services while travelling (Net!Works, 2010). However, the core of the R&D activity associated to Net!Works is primarily targeting users, network operators, service providers, and manufacturers of network-related devices and involves network-specific solutions (like, for instance, research into new solutions for managing complexity seamlessly, or solutions leading in efficient use of spectrum and network resources). The transport-related implications of this are only of second order. Nevertheless, the Strategic Research Agenda aims to improve the individual's quality of life through the availability of an environment for instant provision and access to meaningful, multi-sensory information and content. This is something that could have implications for transport if it resulted in the reduction of transport demand.

NESSI (Networked European Software and Services Initiative) is the European Technology Platform for software and information and communication technology services. It represents a community of industrial and academic actors that are active in information and communication technologies. NESSI's vision of the future of software and services is one in which services will be increasingly smart and highly adaptable, globally accessible and pervasive, interoperable, supporting fast business and technology cycles, acting increasingly in real-time, capable to enable users to play more and more the role of producers of content and applications, as well as self-manageable, secure and trustworthy (NESSI, 2010). As in the case of Net!Works, the research implications of the NESSI Technology Platform for transport and ITS are mainly associated to the application of software to transport- and ITS-related activities. The R&D activities that are primarily targeted by the NESSI Strategic Research Agenda (NESSI, 2009) are not specifically looking at transport-relevant issues, but they are rather more focused on issues that span across software and information and communication technology services. Their impact on transport will be mediated by the need to develop the new software applications that this research will enable. In addition, and as in the case of Net!Works, some application may also have implications for transport if their use resulted in the reduction of transport demand.

NEM (Networked and Electronic Media) is a European Technology Platform that aims to foster the development and introduction of novel audiovisual and multimedia broadband services and applications. NEM identified a number of research priorities in its Strategic Research Agenda (NEM, 2009). The focus on subjects like the design of rich media content, the type of tools used for it, the integration of classical and new media applications, the creation or adaptation of content dedicated to specific user groups, future media delivery networks and network services, new user devices and terminals, as well as technologies providing security, privacy, and trust, amongst others. In addition, NEM aims at developing technologies and services capable to handle this and at the development of technologies in which the demand of energy will be reduced by a factor between 10 to 30 %.

In a position paper specifically targeting ITS (NEM, 2010), NEM clarified that a number of tools used by the NEM sector have the potential 'to improve the information available to transport users and operators, to make them more aware of the implications of their use and operation of the transport system, and thus to support transport policy objectives'. These instruments include, amongst others:

- tools based on user interaction capable to enable the exploitation of social media to improve transport efficiency (e.g. promoting car sharing, car pooling, bicycle rental availability, and parking availability);
- tools capable to process data in order to support integrated mobility management systems contributing to the enhancement of travel and traffic information systems, leveraging on the vast amount of information shared by users and using it in combination with data obtained from proprietary infrastructure;
- the stimulation of technical innovation and expansion of smartphones and similar, more advanced tools, capable to foster the successful penetration of ITS technologies by providing a hardware tool that can be compatible with cooperative vehicle to vehicle and vehicle to infrastructure systems and that can enable other key ITS services such as traffic management; electronic tolling, and infotainment;

- tools proving journey planning services that match user preferences and offered services, as well as multimodal integrated systems that keep passengers informed and entertained during their journey (e.g. on public transit systems);
- tools capable to provide information on passenger habits to transport operators, building on information shared by users and using it in combination with data obtained from proprietary infrastructure, in order to improve the services offered to transport users;
- driver training and assessment procedures implemented through the use of multimedia tools.

This list, together with the clarification on the main focus of NEM-related technologies, shows that the development of ITS-related NEM technologies and initiatives would benefit from activities that tackle the research priorities identified in the NEM Strategic Research Agenda. Eventually, other Technology Platforms address ITS, even though it lies outside of their core focus.

9.10.3 Public actors

A wide number of stakeholders are involved in ITS-related research. In the public sector, they include national Ministries, local authorities, research institutes (including universities) and standardisation bodies. In addition, the relevance of ITS for all transport modes implies that most of the public research actors participating in the activities of groups identified in other transport sub-sectors are also involved in ITS research. This is the case for the **Forum of European National Highway Research Laboratories (FEHRL)**, the **Forum of European Road Safety Research Institutes (FERSI)**, the association of **European Metropolitan Transport Authorities (EMTA)**, the **European Conference of Transport Research Institutes (ECTRI)**, the **European Automotive Research Partners Association (EARPA)**, the **EUropean rail Research Network of Excellence (EURNEX)** and also organisations like **Eurocontrol**.

In ITS, standardisation is needed to create pan-European interoperable systems and a European-wide market for related equipment. The main European standards organisations related to ITS are **CEN (European Committee for Standardisation)**, **CENELEC (European Committee for Electro-technical Standardization)**, and **ETSI (European Telecommunications Standards Institute)**. CEN deals with European Standards in all domains except for electro-technical and telecommunications matters, which are (respectively) addressed by CENELEC and ETSI. In addition, the **United Nations ECE (Economic Commission for Europe) World Forum for Harmonization of Vehicle Regulations (WP29)** offers a unique framework for globally harmonized regulations on vehicles on issues like road safety, environmental protection and trade.

Finally, **POLIS**, the network of European cities and regions working together to develop innovative technologies and policies for local transport, also explicitly addresses the use of ITS through their working group 'mobility and traffic efficiency'. ITS-related activities include network and traffic management, traffic information and integrated ticketing and charging.

9.10.4 Policy and governance

The future deployment of ITS in road transport, but also its interfaces with other transport modes has been specifically addressed by the **Action Plan for the Deployment of Intelligent Transport Systems**, adopted by the European Commission in 2008. The Plan attempted to provide a framework to harmonise the deployment and operational use of ITS throughout Europe and led, in 2010, to the **Directive on the framework for the deployment of Intelligent Transport Systems**. The Directive requires the development of specifications for ITS systems and services, within in a period of seven years, in four priority areas:

- the optimal use of road, traffic and travel data (including the definition of the necessary requirements for multimodal travel information, real-time traffic information, existing road and traffic data and digital maps, as well as the definition of minimum requirements for universal traffic information associated to traffic events, to be provided to everyone);

- the continuity of traffic and ITS services related to freight management (including minimum requirements for the continuity of IT services for passenger and freight transport, across modes and corridors, as well as the definition of the necessary measures for tracking and tracing freight in logistics and the definition of the necessary interfaces for the interoperability and the compatibility of ITS);
- ITS applications to improve road safety and security (including the definition of the necessary measures for the eCall, information and reservation of safe and secure parking for trucks and commercial vehicles, human-machine interface operation, the operation of portable information and communication devices, and the integration of driver support systems falling outside the type approval regulations);
- the linkage between the vehicle and transport infrastructure (including the definition of the necessary measures concerning integrated ITS applications and the progress of cooperative systems).

Within these priority areas, six priority actions are also identified. They include specific actions on the provision of EU-wide multimodal travel information services, real-time traffic information services, road safety related minimum universal traffic information (free of charge to users), an interoperable EU-wide eCall, as well as information and reservation services for safe and secure parking places for trucks and commercial vehicles.

The Directive also clarifies that it will not be mandatory for every Member State to take forward all of the priority actions. Nevertheless, all deployment of ITS in the priority areas will have to comply with specifications made in the framework it provides. Finally, the directive provides a framework on issues like privacy, security and re-use of information, as well as liability, referring to existing Community legislation on these topics.

For privacy issues, ITS are not expected to be different from other applications. As such they will have to comply with the existing provisions on the protection of individuals with regards to the processing of personal data and the free movement of such data (Directive 95/46/EC) and the provisions on the processing of personal data and the protection of privacy n the electronic communications sectors (Directive 2002/58/EC). Notwithstanding the existence of a clear legislative framework in the EU, and even if the technical possibility to design ITS to function anonymously (by separating the information on movements from personal identification data) is certainly available, some important difficulties remain. They are primarily related to the perception of the management of personal data by companies and to the limited trust associated to the guarantee of anonymity, even if this does seem to be contradicting the tendency to concede a lot of information (e.g. on the web, or through loyalty cards in supermarkets) that characterises the way of life of most individuals today (Sampson, 2010).

For what concerns liability, the provisions of Directive 85/374/EEC, essentially defining the liability of defective products and determining the framework of responsibility that shall be born by producers, importers and own-branders of products. In addition, applications that provide advice to drivers are unlikely to be liable for issues ultimately associated to the actions falling under the responsibility of the person in charge of the vehicle (i.e. the driver). On the other hand, the liability of producers, importers and own-branders is unlikely to be lifted for applications requiring the driver to delegate the control of the vehicle to a given system (like for instance a collision avoidance tool).

The European Commission is also working on an **Action Plan for the development of applications for Galileo** (Europe's initiative for a global navigation satellite system) and EGNOS (a system that improves the current GPS signal). **Galileo**, Europe’s civilian global navigation satellite system, is expected to provide a highly accurate, guaranteed global positioning service, making it suitable for applications where safety is crucial, such as running trains, guiding road vehicles and landing aircraft. GALILEO is fully funded by the European Community and managed by the European Commission.

In addition to the Action Plan for the Deployment of Intelligent Transport Systems and the Directive on the framework for the deployment of Intelligent Transport Systems, several technical and regulatory frameworks are well advanced for the development and harmonised deployment of ITS in Europe, also contributing to more integrated operations across the borders.

The **Single European Sky air traffic management system (SESAR)** for civil aviation is the technological pillar of the Single European Sky (SES) initiative that aims at developing a new, more efficient air traffic control systems with the objective is to ensure the safety and fluidity of air transport over the next thirty years. It is expected to make flying more environmentally friendly and reduce the costs of air traffic management.

The **European Rail Traffic Management System (ERTMS)** is a tool aimed at the removal of the technical barriers that hamper the development of rail transport at the European level that has been specifically encouraged and supported by the Communication on the deployment of the European rail signalling system . It consists in a unique signalling standard (also requiring the communication between vehicles and the rail tracks) that is now recognised as the global reference.

The **Vessel Traffic Monitoring and Information Systems (VTMIS)** in shipping was established by the Directive 2002/59/EC and amended by the Directive 2009/17/EC. Directive 2009/17/EC is also instrumental for the setup of the Community vessel traffic monitoring and information system, **SafeSeaNet**, where information for the purpose of maritime safety, port and maritime security, marine environment protection and the efficiency of maritime traffic and maritime transport is automatically sent by vessels and received by coastal stations. The **River Information Services (RIS)** for inland waterway transport is a similar system for inland navigation established within the framework of Directive 2005/44/EC. Other initiatives for maritime transport include the Automatic Identification System (AIS) and the Long-Range Identification and Tracking (LRIT).

The **European Electronic Toll Service (EETS)**, linked to the Community framework on the charges for the use of road infrastructure established by the Directive 2006/38/EC (namely because it allows internalising the costs related to pollution and congestion caused by heavy goods vehicles), is particularly relevant for the transport of goods. Directive 2004/52/EC (complemented by a Commission Decision 2009/750/EC, defining technical and contractual aspects of the EETS) provides a layout of the conditions for the interoperability of electronic road toll systems in the EU and allows users to subscribe to a single contract with an EETS provider to pay the charges related to any charging scheme requiring an on-board equipment. The Directive also requires that all new electronic toll systems brought into service satellite positioning (GNSS), mobile communications (GSM-GPRS), or microwave technology (DSRC).

In the case of road transportation, the setup of a European framework for the development of ITS required a long and evolutionary process that started before the 1990s. The ITS subject is now organised around seven application areas: traveller information, traffic management, electronic pricing and payment, freight and logistics, vehicle safety systems, co-operative systems and ICT Infrastructure.

Some of the main achievements reached to date in the field of road transport ITS include:

- The success of the Traffic Message Channel (TMC), a traffic information service whose development has been co-funded by the European Commission;
- For public transport, the emergence of standards that are relevant for new technologies for smart ticketing systems are gaining importance, including a standard on data elements (EN 1545), on a framework for interoperable ticketing (EN 15320), and on the fare management system architecture (ISO 24014-1);
- The outline of the vision of e-freight, i.e. a paperless information flow accompanying the physical shipment of goods, leveraging on the opportunities offered by emerging technologies such as Radio Frequency Identification (RFID) and the possibilities offered by satellite services will revolutionise freight transport and described in the Freight Transport Logistics Action Plan;
- The proposal from the European Commission to introduce the Electronic Stability Control in all new cars from 2012, Advanced Emergency Braking Systems (AEBS) and Lane Departure Warning (LDW) Systems on trucks and other heavy vehicles from 2013. These proposals follow the request to introduce Brake Assist Systems (BAS) by 2009 to protect pedestrians;

- The European Recommendation on the European Statement of Principles on human-machine interface for in-vehicle information and communication systems issued in 1999 and lastly revised in May 2008 to acknowledge the increasing use of portable devices.;
- The specification of a common framework architecture for cooperative systems (based on results from the projects COOPERS, CVIS and SAFESPOT), carried out under the coordination of the COMeSafety project;
- The European Decision to reserve the 5.9 GHz band for safety related ITS applications;
- The development of the DATEX standard for information exchange between traffic control centres.

Other EU policy initiatives relevant for ITS include the 'Intelligent Car' Initiative, EasyWay, the Freight Transport Logistics Action Plan and the Action Plan on Urban Mobility.

The **Intelligent Car** initiative is one of the key proposals under i2010 (a strategic framework to boost Europe's digital economy) aimed to find common solutions to Europe's mobility problems and to improve the take-up of ICT in road transport. It includes eSafety , an initiative aimed to foster the development, deployment and use of intelligent vehicle safety systems.

EasyWay is a project driven by national road authorities and operators with associated partners including the automotive industry, telecom operators and public transport stakeholders for the deployment on main trans-European road corridors.

The **Freight Transport Logistics Action Plan** outlines, amongst other things, the vision of e-freight. In particular, it mentions the importance of Galileo in this respect, as well as technologies like RFID. The same document also underlines the need for standardisation that is necessarily associated to the materialisation of this vision.

The **Action Plan on Urban Mobility** mentions explicitly the optimisation of urban mobility amongst its action themes, including issues like interoperability, integration and interconnection in it and specifically indicating the need to develop ITS for urban mobility. Examples provided in this respect include electronic ticketing, traffic management, travel information and the opportunities provided by Galileo.

Finally, as in the case of other transport sub-sectors, a number of advocacy groups influence the policymaking process. ERTICO – ITS Europe is the main one in this field.

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ANNEXES

Annex I – Definition of the transport sector according to various classification schemes

Note: The tables below are not necessarily complete as they focus on the categories related to transport. Main transport sectors are put in bold and form the basis of the assessment using this classification. Other sectors that may contain companies with transport-related activities are also mentioned.

ICB sector	ICB code	Relevance to transport R&D? (with ICB subsector when appropriate)
Aerospace & defense	**271**	2713 – Aerospace: Manufacturers, assemblers and distributors of aircraft and aircraft parts primarily used in commercial or private air transport. Excludes manufacturers of communications satellites, which are classified under Telecommunications Equipment. 2717 – Defence: Producers of components and equipment for the defense industry, including military aircraft, radar equipment and weapons.
Alternative energy	58	0583 - Renewable Energy Equipment 0587 - Alternative Fuels: Companies that produce alternative fuels such as ethanol, methanol, hydrogen and biofuels that are mainly used to power vehicles, and companies that are involved in the production of vehicle fuel cells and/or the development of alternative fuelling infrastructure.
Automobile & parts	**335**	3353 – Automobiles: Makers of motorcycles and passenger vehicles, including cars, sport utility vehicles (SUVs) and light trucks. Excludes makers of heavy trucks, which are classified under Commercial Vehicles & Trucks, and makers of recreational vehicles (RVs and ATVs), which are classified under Recreational Products. 3355 – Auto parts: Manufacturers and distributors of new and replacement parts for motorcycles and automobiles, such as engines, carburetors and batteries. Excludes producers of tires, which are classified under Tires. 3357 – Tires: Manufacturers, distributors and retreaders of automobile, truck and motorcycle tires.
Chemicals	135	Ex: BASF
Commercial vehicles & trucks	**2753**	Manufacturers and distributors of commercial vehicles and heavy agricultural and construction machinery, including rail cars, tractors, bulldozers, cranes, buses and industrial lawn mowers. Includes nonmilitary shipbuilders, such as builders of cruise ships and ferries.
Electrical components & equipment	2733	Makers and distributors of electrical parts for finished products, such as printed circuit boards for radios, televisions and other consumer electronics. Includes makers of cables, wires, ceramics, transistors, electric adapters, fuel cells and security cameras. Ex: Siemens
Gas, water & multiutilities	757	Ex: RWE
General industrials	272	Ex: Evonik Industries, Voith, Abengoa
Industrial machinery	2757	Designers, manufacturers, distributors and installers of industrial machinery and factory equipment, such as machine tools, lathes, presses and assembly line equipment. Includes makers of pollution control equipment, castings, pressings, welded shapes, structural steelwork, compressors, pumps, bearings, elevators and escalators Ex: Alstom, SKF, Deutz
Industrial metals & mining	175	Ex: ThyssenKrupp
Industrial transportation	**277**	2771 - Delivery Services: Operators of mail and package delivery services for commercial and consumer use. Includes courier and logistic services primarily involving air transportation. 2773 - Marine Transportation: Providers of on-water transportation for commercial markets, such as container shipping. Excludes ports, which are classified under Transportation Services, and shipbuilders, which are classified under Commercial Vehicles & Trucks.

		2775 – Railroads: Manufacturers, distributors and retreaders of automobile, truck and motorcycle tires. 2777 - Transportation Services: Companies providing services to the Industrial Transportation sector, including companies that manage airports, train depots, roads, bridges, tunnels, ports, and providers of logistic services to shippers of goods. Includes companies that provide aircraft and vehicle maintenance services. 2779 –Trucking: Companies that provide commercial trucking services. Excludes road and tunnel operators, which are classified under Transportation Services, and vehicle rental and taxi companies, which are classified under Travel & Tourism
Oil & gas producers	53	Ex: Total, BP, Eni
Software	9537	
Travel & leisure	575	

Table 14: Main transport-related ICB classes
Source: http://www.icbenchmark.com/docs/Structure_Defs_English.pdf

NACE R1 section	Description
DK29	Manufacture of machinery and equipment n.e.c. 29.1 Manufacture of machinery for the production and use of mechanical power, except aircraft, vehicle and cycle engines (29.11 Manufacture of engines and turbines, except aircraft, vehicle and cycle engines) 293-296 Manufacture of agricultural and forestry machinery; machine-tools; other special purpose machinery; weapons and ammunition
DL311	Manufacture of electrical machinery and apparatus n.e.c. DL311 Manufacture of electric motors, generators and transformers; DL314 Manufacture of accumulators, primary cells and primary batteries; DL316 Manufacture of electrical equipment n.e.c.
DM34	**Manufacture of motor vehicles, trailers and semi-trailers** **34.1 Manufacture of motor vehicles** This includes the manufacture of passenger cars, manufacture of commercial vehicles (vans, lorries, over-the-road tractors for semi-trailers, dumpers for off-road use, etc.), manufacture of buses, trolley-buses and coaches, manufacture of motor vehicle engines, manufacture of chassis fitted with engines, manufacture of other motor vehicles (snowmobiles, golf carts, amphibious vehicles; fire engines, street sweepers, travelling libraries and banks, etc.) **34.2 Manufacture of bodies (coachwork) for motor vehicles; manufacture of trailers and semi-trailers** This division includes the manufacture of bodies, including cabs for motor vehicles, outfitting of all types of motor vehicles, trailers and semi-trailers, manufacture of trailers and semi-trailers (tankers, caravan trailers, etc.), manufacture of containers for carriage by one or more modes of transport. **34.3 Manufacture of parts and accessories for motor vehicles and their engines** This class includes the manufacture of diverse parts and accessories for motor vehicles (brakes, gear boxes, axles, road wheels, suspension shock absorbers, radiators, silencers, exhaust pipes, clutches, steering wheels, steering columns and steering boxes), manufacture of parts and accessories of bodies for motor vehicles (safety belts, doors, bumpers). This division also includes manufacture of inlet and exhaust valves of internal combustion engines.
DM35	**Manufacture of other transport equipment** **35.1 Building and repairing of ships and boats** The sub-division 35.11 includes the building of commercial vessels (passenger vessels, ferry-boats, cargo ships, tankers, etc.), building of warships, building of fishing boats, construction of hovercraft, construction of drilling platforms, floating or submersible, construction of floating structures (floating docks, pontoons, coffer-dams, floating landing stages, buoys, floating tanks, barges, lighters, etc.), maintenance, repair or alteration of ships, shipbreaking. The sub-division 35.12 includes the building of inflatables, building of sailboats with or without auxiliary motor, building of motor boats, building of other pleasure and sporting boats (canoes, kayaks, skiffs).

	35.2 Manufacture of railway and tramway locomotives and rolling stock This includes the manufacture of electric and diesel rail locomotives, manufacture of self-propelled railway or tramway coaches, vans and trucks, maintenance or service vehicles, manufacture of railway or tramway rolling stock, not self-propelled (passenger coaches, goods vans, tank wagons, self-discharging vans and wagons, workshop vans, crane vans, tenders, etc.), manufacture of specialized parts of railway or tramway locomotives or of rolling stock (bogies, axles and wheels, brakes and parts of brakes; hooks and coupling devices, buffers and buffer parts; shock absorbers; wagon and locomotive frames; bodies; corridor connections, etc.) **35.3 Manufacture of aircraft and spacecraft** This class includes the manufacture of aeroplanes for the transport of goods or passengers, for use by the defence forces, for sport or other purposes, manufacture of helicopters, manufacture of gliders, hang-gliders, manufacture of dirigibles and balloons, manufacture of spacecraft and spacecraft launch vehicles, satellites, planetary probes, orbital stations, shuttles, manufacture of parts and accessories of the aircraft of this class (major assemblies such as fuselages, wings, doors, control surfaces, landing gear, fuel tanks, nacelles, etc., airscrews, helicopter rotors and propelled rotor blades, motors and engines of a kind typically found on aircraft, parts of turbojets and turbopropellers), manufacture of aircraft launching gear, deck arresters, etc., manufacture of ground flying trainers. 35.4 Manufacture of motorcycles and bicycles 35.5 Manufacture of other transport equipment n.e.c.
E	Electricity, gas and water supply
G	Wholesale and retail trade; repair of motor vehicles, motorcycles and personal and household goods
G50	Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of automotive fuel This includes all activities (except manufacture and renting) related to motor vehicles and motorcycles, including lorries and trucks (wholesale and retail sale of new and second-hand vehicles, maintenance and repair, wholesale and retail sale of parts and accessories, activities of commission agents involved in wholesale or retail sale of vehicles, washing, polishing and towing of vehicles, etc.). This also includes retail sale of automotive fuel and lubricating or cooling products.
I	**Transport, storage and communications** This includes activities related to providing passenger or freight transport, whether scheduled or not, by rail, pipeline, road, water or air, supporting activities such as terminal and parking facilities, cargo handling, storage, etc., postal activities and telecommunication, renting of transport equipment with driver or operator.
I60	**Land transport; transport via pipelines** 60.1 Transport via railways; 60.2 Other land transport; 60.3 Transport via pipelines
I61	**Water transport** 61.1 Sea and coastal water transport; 61.2 Inland water transport
I62	**Air transport** 62.1 Scheduled air transport; 62.2 Non-scheduled air transport; 62.3 Space transport
I63-64	63- Supporting and auxiliary transport activities; activities of travel agencies; 64 Post and telecommunications

Table 15: Main transport-related NACE Rev. 1 classes
Source: Eurostat (1996)

NACE R2 section	Description
C27	Manufacture of electrical equipment
C28	Manufacture of machinery and equipment n.e.c.
C29	**Manufacture of motor vehicles, trailers and semi-trailers** This includes the manufacture of motor vehicles for transporting passengers or freight, the manufacture of various parts and accessories, as well as the manufacture of trailers and semi-trailers.
C30	**Manufacture of other transport equipment** This includes the manufacture of transportation equipment such as ship building and boat manufacturing, the manufacture of railroad rolling stock and locomotives, air and spacecraft and the manufacture of parts thereof.
G	Wholesale and retail trade; repair of motor vehicles and motorcycles
G45	**Wholesale and retail trade and repair of motor vehicles and motorcycles** This includes all activities (except manufacture and renting) related to motor vehicles and motorcycles, including lorries and trucks, such as the wholesale and retail sale of new and second-hand vehicles, the repair and maintenance of vehicles and the wholesale and retail sale of parts and accessories for motor vehicles and motorcycles. Also included are activities of commission agents involved in wholesale or retail sale of vehicles as well as activities such as washing, polishing of vehicles etc. This division does not include the retail sale of automotive fuel and lubricating or cooling products or the renting of motor vehicles or motorcycles.
G46	Wholesale trade, except of motor vehicles and motorcycles
G47	Retail trade, except of motor vehicles and motorcycles
H	**Transportation and storage**
H49	**Land transport and transport via pipelines** This includes the transport of passengers and freight via road and rail, as well as freight transport via pipelines
H50	**Water transport** This includes the transport of passengers or freight over water, whether scheduled or not. Also included are the operation of towing or pushing boats, excursion, cruise or sightseeing boats, ferries, water taxis etc. Although the location is an indicator for the separation between sea and inland water transport, the deciding factor is the type of vessel used.
H51	**Air transport** This division includes the transport of passengers or freight by air or via space.
H52	**Warehousing and support activities for transportation** This includes warehousing and support activities for transportation, such as operating of transport infrastructure (e.g. airports, harbours, tunnels, bridges, etc.), the activities of transport agencies and cargo handling.
H53	**Postal and courier activities** This division includes postal and courier activities, such as pickup, transport and delivery of letters and parcels under various arrangements. Local delivery and messenger services are also included.
J	Information and communication
M71	Architectural and engineering activities; technical testing and analysis
M72	Scientific research and development

Table 16: Main transport-related NACE Rev. 2 classes
Source: Eurostat (2008)

NABS07 section	Description
NABS01	Exploration and exploitation of the earth
NABS02	Environment
NABS03	Exploration and exploitation of space
NABS04	**Transport, telecommunication and other infrastructures**
NABS05	Energy
NABS06	Industrial production and technology
NABS07	Health
NABS08	Agriculture
NABS09	Education
NABS10	Culture, recreation, religion and mass media
NABS11	Political and social systems, structures and processes
NABS12	General advancement of knowledge: R&D financed from General University Funds (GUF)
NABS14	Defence

Table 17: Main transport-related NABS07 classes

NABS92 section	Description
NBS01	Exploration and exploitation of the earth
NBS02	Infrastructure and general planning of land-use
NBS0204	Transport systems
NBS03	Control and care of the environment
NBS04	Protection and improvement of human health
NBS05	Production, distribution and rational utilization of energy
NBS05054	Research into biomass conversion (particularly into the areas of pyrolysis, gasification, extraction and enzyme processing); research on the proces...
NBS06	Agricultural production and technology
NBS07	Industrial production, and technology
NBS0705	**Manufacture of motor vehicles and other means of transport**
NBS07051	**Aerospace equipment manufacturing and repairing**
NBS07052	**Manufacture of motor vehicles and parts (including agricultural tractors)**
NBS07053	**Manufacture of all other transport equipment**
NBS13	Defence

Table 18: Main transport-related NABS92 classes

IPC code	Description
B	Section B - Performing operations; transporting
B60	**Vehicles in general**
B61	**Railways**
B62	**Land vehicles for travelling otherwise than on rails**
B63	**Ships or other waterborne vessels; related equipment**
B64	**Aircraft; aviation; cosmonautics**
E01	Construction of roads, railways, or bridges
F	Section F - Mechanical engineering; lighting; heating; weapons; blasting
F01	Machines or engines in general; engine plants in general; steam engines
F02	Combustion engines; hot-gas or combustion-product engine plants
F23	Combustion apparatus; combustion processes

Table 19: Main transport-related IPC classes

Note: for more details, see the World Intellectual Property Organization http://www.wipo.int/

IEA category	Description
I.3 Transportation	• analysis and optimisation of energy consumption in the transport sector; • efficiency improvements in light-duty vehicles, heavy-duty vehicles, non-road vehicles • public transport systems; • engine-fuel optimisation; • use of alternative fuels (liquid, gaseous); • fuel additives; • diesel engines; • stirling motors, electric cars, hybrid cars; • other.
III.4.1 Production of transport biofuels including from wastes	• conventional bio-fuels; • cellulosic conversion to alcohol; • biomass gas-to-liquids; • other.
V.1 Total Hydrogen	Total Hydrogen = Hydrogen production + Hydrogen storage + Hydrogen transport and distribution + Other infrastructure and systems R&D
V.2 Total Fuel Cells	Total Fuel Cells = Stationary applications + Mobile applications + Other applications
V.2.2 Mobile applications	mobile applications of fuel cells
VI.3 Energy Storage	• batteries; • super-capacitors; • superconducting magnetic; • water heat storage; • sensible/latent heat storage; • photochemical storage; • kinetic energy storage; • other (excluding fuel cells).

Table 20: Main transport-related classes in the IEA RD&D statistics

Source: IEA (2009b)

Annex II – Institutions involved in public transport-related R&D in EU Member States

The following table aims at providing a systematic overview on the key players involved in national public transport research. To the extent possible, it has been tried to allocate actors to decision making and priority setting, implementing R&D policies and conducting and carrying out of research itself. Note, however, that a clear distinction between these divisions is very often somewhat artificial. For example, public research organisations often act both as a performer of research, but are active also in the policy implementation by allocating funds. Similarly, Research Advisory Councils are sometimes involved both in the policy making and the implementation processes. Due to the large numbers of universities relevant for transport research, we have abstained from listing them in a comprehensive manner.

For a more in-depth description of the national transport research processes, we refer to the country profiles of the Transport Research Knowledge Centre (TRKC, 2009), the country reports of the EAGAR FP7 project, information collected by the ERA-NET Transport, the on-going FP7 project TransNEW with the focus on new member and associated states and chapter 10 in Leduc et al. (2010).

Table 21: Institutions involved in public R&D policy setting and implementation in EU Member States
Source: Based on multiple sources including TRKC (2009), EAGAR ,TransNew project; national information sources, direct contact with Member States' representatives, Wiesenthal et al. (2008)

	Ministries (or other setting transport R&D priorities or funding transport R&D)	Agencies and Intermediary organizations (Implementation)	Public Research Organizations/ universities (incomprehensive)	PPP / private institutes	Regional research	Transport R&D programmes
Austria	Ministry for Transport, Innovation and Technology (BMVIT) Ministry of Economy, Family and Youth Ministry of Agriculture, Forestry, Environment and Water management Ministry for Science and Research Research Councils	Research Promotion Agency Austrian Climate and Energy Fund Austria Wirtschaftsservice Kommunalkredit Public Finance Austria Tech – Federal Agency for Technological Measures	Austrian Institute for Technology (AIT) Joanneum Research (energy and transport unit) Austrian Transport and Mobility Research Centre	A3PS – Austrian Agency for Alternative Propulsion Systems Austrian Transport Telematics Cluster Rail Technology Cluster Austria	The Länder have individual programmes	IV2Splus - Strategy Programme on Mobility and Transport Technologies for Austria (2007-2011, € 75m), including the following programmes: • A3plus: Alternative propulsion systems and fuels • i2V: Intermodality and inter-operability of transport systems • ways2go: Technologies for evolving mobility needs TAKE OFF - Austrian Aeronautics Research and Technology Programme (2002-2012, € 50m) IKV - Innovation programme combined transport of goods (road/rail/ship, 1992-2014)

	Ministries (or other setting transport R&D priorities or funding transport R&D)	Agencies and Intermediary organizations (Implementation)	Public Research Organizations/ universities (incomprehensive)	PPP / private institutes	Regional research	Transport R&D programmes
Belgium	Federal level: • FOD/SPF (Federale Overheidsdienst/Service Public Federal) – Mobility and Transports • FOD/SPF – Economy, S.M.E.s, Self-employed and Energy • FOD/SPF – Health, Food chain safety and Environment Flemish Government • Policy domain Environment, Nature and Energy • Policy domain Mobility and Public Works Walloon Public Service (from 2008) • Policy domain Environment and Natural Resources • Policy domain Transport and Mobility	IWT-Flanders: Institute for the promotion of innovation by science and technology in Flanders FWO Flanders: Fund for scientific research in Flanders FNRS : Fonds de la Recherche Scientifique Technology Stimulation Agency (AST) – (Walloon Region)	Belgian Road Safety Institute (IBSR) Flanders Institute for Logistics (VIL) Institut Scientifique de Service Public (ISSeP) VITO (Flemish Government)	Belgian Road Research Centre (BRRC) CENAERO (Simulation technologies for Aeronautics) Competitiveness clusters (Logistics in Wallonia, Skywin)	Flemish Region: • Flanders Mobility (Mobiel Vlaanderen) • Flemish Foundation for Traffic knowledge (FFT) • Flanders Drive Walloon Region: • Walloon Public Service (DGO6) • Standing Conference on Territorial Development (CPDT)	Science for a Sustainable Development Programme (2005-2009, € 65.4m) Policy Research Centre Mobility & Public Works, track Traffic Safety (2007-2011) Prospective research in Brussels programme (PRIB)

	Ministries (or other setting transport R&D priorities or funding transport R&D)	Agencies and Intermediary organizations (Implementation)	Public Research Organizations/ universities (incomprehensive)	PPP / private institutes	Regional research	Transport R&D programmes
Bulgaria	Ministry of Education and Science (MES) National Council for Scientific Research National Science Council Ministry of Transport and Communications (MOTC Ministry of Economy, Energy and Tourism Ministry of Regional Development and Public Works (MRDPW)	National Science Fund National Innovation Fund (managed by the Bulgarian SME Promotion Agency) Road Executive Agency (REA) (from MRDPW) Environment Protection Agency (EPA)	Bulgarian Academy of Sciences Agricultural Academy (formerly National Centre of Agrarian Sciences) Technical University of Sofia (TU-Sofia)	Central Roads and Bridges Laboratory (CRBL)		National innovation strategy Strategy for Development of Bulgarian Transport System (2010-2020) National Strategy for Scientific Research for the Period 2005-2013
Cyprus	Planning Bureau National Council for Research and Innovation Cypriot Science Council Ministry of Education and Culture	Research Promotion Foundation (RPF)	Cyprus International Institute (CII) for the environment and public health (in association with the Harvard School of Public health). Cyprus Institute of Technology			National Strategic Development Plan (2007-2013)

	Ministries (or other setting transport R&D priorities or funding transport R&D)	Agencies and Intermediary organizations (Implementation)	Public Research Organizations/ universities (incomprehensive)	PPP / private institutes	Regional research	Transport R&D programmes
Czech Republic	Ministry of Transport Ministry of Education, Youth and Sports Ministry of Industry and Trade Ministry for Regional Development Ministry of the Environment of the Czech Republic Council for Research, Development and Innovation Czech Science Foundation Technology Agency of the Czech Republic	Association of Innovative Entrepreneurship CR	CDV - Transport Research Centre Technical Universities of Prague, Brno, Pardubice and Ostrava	VZLU - Aeronautical Research and Testing Institute VZU Plzeň - Research and Testing Institute Plzeň VUKV - Research Institute of Railway Rolling Stock VUZ –Railway Research Institute		Ministry of Transport - Support of Sustainable Transport Development (2007-2011) Czech Technical University of Prague - Development of Design and Operation Methods for Transport Network Optimisation (2007-2013) Transport Research Centre - Sustainable mobility - a chance for the future (2004-2011) Technology Agency of the Czech Republic - Programme ALFA, subprogramme Sustainable Transport Development, (2011 onwards)
Denmark	Danish Council for Research Policy Ministry of Science, Technology and Innovation Ministry of Transport Ministry of the Environment	Danish Agency for Science, Technology and Innovation Danish Council for Independent Research (DFF) Danish Councils for Strategic Research Danish National Advanced Technology Foundation National Research Foundation Danish Road Directorate Rail Net Denmark Danish Board of technology Danish Civil Aviation Administration (CAA-DK) Danish Maritime Fund	Danish Road Institute (Ministry of Transport) Technical University of Denmark • DTU Transport • Risø DTU – National Laboratory for Sustainable Energy Approved Technological Services Institutes (GTS)			TRIP - Transport Research on environmental and health Impacts and Policy (2000 onwards) Strategic Transport Research 08 (2008-2012, € 4.4m) Strategic Transport Research 09 (2009-2012, € 3.4m)

	Ministries (or other setting transport R&D priorities or funding transport R&D)	Agencies and Intermediary organizations (Implementation)	Public Research Organizations/ universities (incomprehensive)	PPP / private institutes	Regional research	Transport R&D programmes
Estonia	Ministry of Economic Affairs and Transportation Ministry of Education and Research Research and Development Council (TAN)	Enterprise Estonia Estonian Science Foundation Archimedes Foundation Estonian Road Administration Estonian Technology Agency	Estonian Academy of Sciences Tallinn University of Technology Archimedes Foundation			Estonian National Road Traffic Safety Programme (2003-2015) Long Term Programme for Road Management (2002-2010)
Finland	Ministry of Transport and Communications Ministry of Education and Culture Ministry of Employment and Economy Science and Technology Policy Council	Finnish Transport Agency Finnish Transport Safety Agency Finnish Funding Agency for Technology and Innovation (TEKES) The Academy of Finland finances fundamental academic research	VTT Technical Research Centre of Finland Technical University of Helsinki Technical University of Tampere Technical University of Lappeenranta University of Turku	Centers of Excellence, e.g. Tivit Ltd. and Rym Ltd.		Transport Administration Research Programme (2011-2014)/The Finnish Transport Agency TRANSECO - Research programme on road transport energy efficiency (2009-2013, € 3m) LINTU – Long-term Research and Development Programme for Road Safety (2002-2010) Safe Traffic 2025 (2008-2011) INTRANS – Innovation programme for intelligent transport systems (2011-2013) OSKE - Finnish Maritime Cluster Programme (2007-2013) BioRefine 2007-2012 - New Biomass Products Electric Vehicles Systems (2011-2015)

	Ministries (or other setting transport R&D priorities or funding transport R&D)	Agencies and Intermediary organizations (Implementation)	Public Research Organizations/ universities (incomprehensive)	PPP / private institutes	Regional research	Transport R&D programmes
France	Ministry of Ecology, Sustainable Development, Transport and Housing Ministry of Higher Education and Research Ministry of Defence and Veteran Affairs Ministry of Economy, Finance and Industry Ministry of Agriculture, Food, Fisheries, Rural Life and Country Planning	ANR – National Research Agency ADEME - French Environment and Energy Management Agency	IFSTTAR – Institut français des sciences et technologies des transports, de l'aménagement et des réseaux IFP Energies Nouvelles CNRS - National Centre for Scientific Research CEA - French Atomic Energy and Alternative Energies Commission INRIA – Institut national de recherche en informatique et en automatique ONERA – French Aerospace Laboratory CETMEF (Centre d'Études Techniques Maritimes et Fluviales) CERTU (Centre d'Études sur les Réseaux, les Transports, l'Urbanisme et les Constructions Publiques) SETRA (Services d'Etudes sur les Transports, les Routes et leurs Aménagements) STAC (Service Technique de l'Aviation Civile)	Pôles de compétitivité	RT3 network (Inter-regional Network for Technological research and Land Transport) GRRT – Regional Group for Research in Transport in Nord-Pas-de-Calais (part of RT3 network) Regional Research and Technology Delegations DRRT Regional Consultative Committees on Technological Research and Development CCRRDT Regional Innovation and Technology Transfer Centre CRITT	PREDIT 4 - 4th Inter-ministerial Land Transport Research and Innovation Programme (2008-2012, € 400m) PAN-H French Fuel Cell Research and Innovation Network (2003-2013) RGC&U - Research network on civil and urban engineering National Research Programme on Bioenergy French national aeronautical research programme (DGAC, MEEDDM)

	Ministries (or other setting transport R&D priorities or funding transport R&D)	Agencies and Intermediary organizations (Implementation)	Public Research Organizations/ universities (incomprehensive)	PPP / private institutes	Regional research	Transport R&D programmes
Germany	Ministry for Economy and Technology (BMWi) Ministry of Education and Research (BMBF) Ministry of Transport, Building and Urban Affairs (BMVBS)	DFG – German Research Foundation (project funding at universities) Projektträger (Programme Administrating Agencies), incl. Project Agency Jülich	Helmholtz Society, out of which in transport research are DLR; FZ Jülich Fraunhofer Society, out of which in transport research are ISI; IBP; IAO, FVV Leibniz-society, out of which special and urban planning are ARL; ILS Max-Planck Society Several so called "Forschungsverbände" or research-networks aim to coordinate the activities of non-university research centres in specific fields (see also under PPP).	German Federation of Industrial Cooperative Research associations AIF A number of institutionalised cooperations, e.g. Innovation Alliance Lithium Ion Battery (LIB 2015) Innovation Alliance Electronics for Motor Vehicles (EENOVA)	Within the federalist setting of the German research system, funding of R&D is organised both on the national and the federal level, with (basic) university funding mainly in the competence of Länder and more applied funding under shared competence of the federal government and the Länder. Funding of regional research centres such as ZSW, ZAE, ISFH, DEWI, ISET	3rd Transport Research Programme "Mobility and Transport Technology" (2008-2014, € 60m) including LIB 2015, BIP, EENOVA (BMWi, BMU, BMBF, BMVBS) 2nd Recovery Package including LIB 2015, BIP, EENOVA (BMWi, BMU, BMBF, BMVBS) LuFo IV - Federal research programme aeronautics (2007-2013, € 600m) Research Programme 2005-2010 (BMWi) Climate protection through innovation in materials for the automotive sector (BMBF) Meseberg Programme (BMWi, BMU, BMBF, BMVBS, BMELV) 5th Energy Programme "Innovation and Energy Technology" (BMWi, BMU, BMELV, BMBF) Shipping and Maritime Technologies in the 21st Century (started in 2010) Road Construction Research Programme National Hydrogen and Fuel Cell Technology Innovation Programme (NIP)

	Ministries (or other setting transport R&D priorities or funding transport R&D)	Agencies and Intermediary organizations (Implementation)	Public Research Organizations/ universities (incomprehensive)	PPP / private institutes	Regional research	Transport R&D programmes
Greece	Ministry of Education, Lifelong Learning and Religious Affairs Ministry of Regional Development and Competitiveness Ministry of Infrastructure, Transport and Networks National Council for Research and Technology Ministry of Maritime Affairs, Islands and Fisheries Ministry for the Environment, Energy and Climate Change	General Secretariat for Research and Technology (GSRT)	Centre for Research and Technology Hellas (CERTH), including: • Hellenic Institute of Transport (HIT) • Informatics and Telematics Institute (ITI) National Centre for Scientific Research (Demokritos) Centre for Renewable Energy Sources (CRES)	GSRT also aims to encourage partnerships between research organisations and industry National Engineering Research Institute of Greece (NERIG)		Operational Programme Competitiveness and Innovation 2007-2013 Strategic Development Plan for Research, Technology and Innovation Under the 2007-13 NSRF Framework
Hungary	Research and Science Policy Council Ministry of Education and Culture (OM) Ministry of Transport, Telecommunication and Energy (KHEM) National Transport Authority Hungarian Academy of Science	National Office for Research and Technology Research and Technological Innovation Council National Transport Authority	Institute for Transport Sciences (KTI) Hungarian Academy of Sciences			Mid-term science, technology and innovation policy strategy (2007-2013) National Technology Programme (NKFP-JEDLIK) Transportation Operative Program (2007-2013, rail) Hungarian medium-term road research programme Transport safety action programme Hungarian Scientific Research Fund (OTKA)

	Ministries (or other setting transport R&D priorities or funding transport R&D)	Agencies and Intermediary organizations (Implementation)	Public Research Organizations/ universities (incomprehensive)	PPP / private institutes	Regional research	Transport R&D programmes
Ireland	Department of Transport, Tourism and Sport Department of Education And Skills Department of Enterprise, Jobs and Innovation Department of the Environment, Community and Local Government Department of Agriculture, Marine and Food Irish Energy Research Council	Environment Protection Agency (EPA) Enterprise Ireland Irish Research Council for Science , Engineering and Technology (IRCSET) Sustainable Energy Authority of Ireland (SEAI) Agriculture and Food Development Authority (TEAGASC) National Transport Authority	Agriculture and Food Development Authority (TEAGASC) The Marine Institute		Dublin Transportation Office	National Development Plan (NDP) 2007-2013 Science Foundation Ireland (SFI) Programme for Research in Third Level Institutions (1998-2012) National Roads Authority - Research programme
Italy	Inter-Ministry Committee for the Economic Planning Ministry of Education, University and Research (MIUR) Ministry of Infrastructure and Transport (MIT) Ministry for Public Administration and Innovation Ministry of Economic Development Ministry for Environment and Territory National Research Council (CNR)	Ministries are directly funding research, in particular: Ministry of Education, University and Research (MIUR) Ministry of Economic Development	Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA) National Institute for Statistics (ISTAT) Italian Aerospace Research Centre (CIRA, mainly public) Combustion Research Institute (biomass) National Research Council (CNR) Italian Technology Institute	CETENA (Ship Research Centre) CIRA (Italian Aerospace Research Centre) ELASIS, CRF (Fiat Group)	Regional agency for innovation (VENNInn)	National Operation Programme (NOP) Scientific Research, Technological Development, Higher Training (PON Ricerca e Competitività 2007-2013) Industria 2015 programme (from 2008) National Space Plan (NSP) Technology Innovation in Shipbuilding (2007-2009) Aerospace Research Programme

	Ministries (or other setting transport R&D priorities or funding transport R&D)	Agencies and Intermediary organizations (Implementation)	Public Research Organizations/ universities (incomprehensive)	PPP / private institutes	Regional research	Transport R&D programmes
Latvia	The Ministry of Education and Science Latvian Council of Sciences Ministry of Transport Ministry of Economics Ministry of Agriculture Investment and Development Agency	Latvian Council of Science Science and Education Agency (SuZA) Latvian Academy of Science Investment and Development Agency of Latvia	Transport and Telecommunication Institute (TTI) Riga Technical University Maritime Administration of Latvia Transport National Research Centre of Excellence (proposed)	Latvian Transport Development and Education Association (LatDEA)	Interreg IIIB programmes	NTDP - Latvian Transport Development Programme (1996-2010)
Lithuania	Science Council of Lithuania Ministry of Education and Science Ministry of Transport and Communications Ministry of Economy	International Science and Technology Development Agency Lithuanian State Science and Studies Foundation Lithuanian Road Administration (LRA)	Transport and Road Research Institute Vilnius Gediminas Technical University Kaunas University of Technology Klaipeda University	Development Agency for SMEs		National Transport Research Programme (up to 2012 Lithuanian Road Research Programme
Luxembourg	Inter-Ministerial Coordination Committee for Technological Research and Development's Higher Research and Innovation Committee Ministry of Higher Education and Research - The Luxembourg Portal for Innovation and Research Ministry of Sustainable Development and Infrastructure - Department of Transport	Luxinnovation Highways Directorate National Research Fund (Fonds National de la Recherche Luxembourg)	Henri Tudor Public Research Centre (CRPHT) Gabriel Lippmann Public Research Centre			INTER programme: Promotion of International Collaboration IVL - Integrated concept for transport and spatial development in Luxembourg

	Ministries (or other setting transport R&D priorities or funding transport R&D)	Agencies and Intermediary organizations (Implementation)	Public Research Organizations/ universities (incomprehensive)	PPP / private institutes	Regional research	Transport R&D programmes
Malta	Ministry for Infrastructure, Transport and Communications (MITC) Ministry of Education, Employment and Family Malta Council for Science and Technology (MCST)	Malta Environment and Planning Authority (MEPA) Malta Transport Authority Malta Enterprise	University of Malta	Malta Enterprise		National Strategic Plan for Research and Innovation 2007-2010
Netherlands	Ministry of Transport, Public Works and Water Management (VenW) Ministry of Education, Culture and Science Ministry of Economic Affairs Ministry of Housing, Spatial Planning and the Environment Advisory Council for Science and Technology	Senter Novem Netherlands Organisation for scientific research (NWO) Royal Netherlands Academy of Arts and Science (KNAW) NL Agency	Royal Netherlands Academy of Arts and Science (KNAW) Institute for Road Safety Research (SWOV) Energy Research Centre of the Netherlands (ECN) TNO (Research organisation for Applied Natural Sciences) Wageningen UR institute for agro technology and food innovation NLR - National Aerospace Laboratory KiM - Netherlands Institute for Transport Policy Analysis	Connekt Information and Technology Centre for transport and Infrastructure (CROW)		High Tech Automotive Systems (HTAS) innovation programme Energy Research Strategy of the Netherlands DBR/SAR - Sustainable Accessibility of the Randstad (2008-2014) Transumo - TRANsition to SUstainable Mobility (2004-2010, € 30m) Eco-driving (2006-2010) Innovation for shipbuilding industry (2007-2009) Maritime Innovation Programme (2007-2011) Sustainable Hydrogen (2002-2010) Strategic Research Programme Aeronautical Cluster (2006-2010)

	Ministries (or other setting transport R&D priorities or funding transport R&D)	Agencies and Intermediary organizations (Implementation)	Public Research Organizations/ universities (incomprehensive)	PPP / private institutes	Regional research	Transport R&D programmes
Poland	Ministry of Science and Higher education Ministry of Economy Ministry of Infrastructure Ministry of Environment	National Research and Development Centre (NCBiR) National Scientific Centre (NCN) Leading Technical Organisation Innovation Centre (NOT) Information Processing Centre (OPI) Polish Agency for Enterprise Development	Motor Transport Institute Railway Engineering Institute Maritime Institute Gdansk Technical University Warsaw Ship Design and Research Centre S.A. Institute of aviation Institute for Road and Bridge Research (IBDiM) National Centre for Research and Development (NCBiR)	WSK 'PZL-Rzeszow' on Aviation Research	Regional Development Agencies	National Programme for Scientific Research and Development Activities State Transport Policy for 2006-2025 Operational Program of Infrastructure and Environment
Portugal	Ministry of Science, Technology and Higher Education Ministry of Economy, Innovation and Development Ministry of Public Works, Transport and Communications Ministry for Environment and Spatial Planning Science and Technology Coordinating Council Council for Higher Education	Innovation Agency (ADI) Science and Higher Education Observatory (OCES) Foundation for Science and Technology (FCT) Portuguese FP7 Promotion Office (GPPQ) Institute of Support to SMEs and Innovation (IAPMEI) Portuguese Office for Electric Mobility (GAMEP) Committee for advice and supervision of research performed with public contracts (CAF)	Associated Laboratory for Energy, Transports and Aeronautics (LAETA) National Laboratory for Energy and Geology (LNEG) CEEETA - Centro de Estudos em Economia da Energia, dos Transportes e do Ambiente National Laboratory for Civil Engineering (LNEC)	Innovation Agency (ADI)		National Programmes for Scientific Research and Development Activities (2009-2011) National Strategic Reference Framework - QREN (2007-2013) Transport Research under the 1% contribution from Public Contracts above 25 M€ (n. 7, Art 42, Law 18/2008) Innovation Support Fund – FAI Portuguese Carbon Fund (2008-2012)

	Ministries (or other setting transport R&D priorities or funding transport R&D)	Agencies and Intermediary organizations (Implementation)	Public Research Organizations/ universities (incomprehensive)	PPP / private institutes	Regional research	Transport R&D programmes
Romania	Ministry of Education, Research, Youth and Sport Ministry of Transport and Infrastructure National Authority for Scientific Research	National Authority for Scientific Research (ANCS) Romanian Academy	Transport Research Institute (INCERTRANS) National Institute of Aerospace Research 'Elie Carafoli' (INCAS) Polytechnic University of Bucharest			National Research Development and Innovation Plan II (2007-2013) National Transport Plan
Slovak Republic	Government Board for Science and Technology Ministry of Education Ministry of Transport and Communications Ministry of Economy	Slovak Innovation and Energy Agency Slovak Research and Development Agency VEGA grant agency National Agency for Development of SMEs	Slovak Academy of Science (SAS) Transport Research Institute (TRI) Slovak University of Technology in Bratislava University of Žilina			Research Programme of Ministry of Transport and Communications (2005-2015)
Slovenia	Ministry of Transport Ministry of Higher Education, Science and Technology Council for Science and Technology	Slovenian Research Agency (ARRS) Public Agency for Technology of the Republic of Slovenia (TIA) Slovenian Road Directorate (DRSC)	University of Ljubljana Jožef Stefan Institute University of Maribor Slovenian National Building and Civil Engineering Institute			National Research and Development Programme (2006-2013) Competitiveness of Slovenia (2006-2013) Transport Policy Plan (2006)

	Ministries (or other setting transport R&D priorities or funding transport R&D)	Agencies and Intermediary organizations (Implementation)	Public Research Organizations/ universities (incomprehensive)	PPP / private institutes	Regional research	Transport R&D programmes
Spain	Ministry of Science and Innovation (MICINN) Ministry of Public Works and Transport (MF) Ministry of Industry, Tourism and Trade (MITC) Ministry of Environment (MARM) Interior Ministry (MI) Inter-ministerial Commission for Science and Technology (CICYT)	Centre for the Development of Industrial Technology (CDTI) Centro de Estudios y Experimentación de Obras Públicas (CEDEX) Spanish Railways Technological Platform - PTFE (technical secretariat performed by the Spanish Railways Foundation – FFE)	High Council for Scientific Research (CSIC) Public universities (e.g. Polytechnic University Madrid, Centro de Investigación en Tecnologías Ferroviarias – CITEF; University of Valencia; Universitat Politècnica de Catalunya, Centre d'Innovació del Transport – CENIT) Administrador de Infraestructuras Ferroviárias (ADIF), Railway Technology Centre, ADIF Instituto de Investigación en Seguridad y Factores Humanos (ESM)	Research and Development Centre in Transport & Energy (CIDAUT) The Composites Research, Development and Application Centre (FIDAMC) Instituto de Investigación Aplicada al Automóvil (IDIADA) Instituto Universitario de Investigación del Automóvil (INSIA) Galician Technological Centre for the Automobile (CTAG) TECNALIA Research & Innovation	Science, Technology and Innovation Plan 2010 (Basque Country) Inter-ministerial Council for Research and Technological Innovation (Government of Catalonia) Similar programmes in other autonomous regions	National Plan of Research, Development and Technological Innovation (2008-2011) Aeronautic National Plan (2008-2016) CENIT - National Strategic Consortium in Technical Research (2006-2011) Aid scheme on innovation for shipbuilding industry (2007-2011)

	Ministries (or other setting transport R&D priorities or funding transport R&D)	Agencies and Intermediary organizations (Implementation)	Public Research Organizations/ universities (incomprehensive)	PPP / private institutes	Regional research	Transport R&D programmes
Sweden	Ministry of Enterprise, Energy and Communications Ministry of Education and Research	Swedish Energy Agency (STEM) Swedish Research Council (VR) Swedish Agency for Innovation Systems (VINNOVA) Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning (Formas) Swedish Road Administration Swedish National Rail Administration Swedish Maritime Administration Swedish Civil Aviation Administration	VTI – Swedish National Road and Transport Research Institute CTS – Centre for Transport Studies Foundation for Strategic Environmental Research Swedish Institute of Agricultural and Environmental Engineering Technical Research Institute of Sweden			VINNOVA Transport Research Programmes Aeronautical Development and Demonstration Programme (2007-2010, € 23.6m) Swedish National Aeronautic Programme (2009-2012, € 40m) Biomass Programme Energy System Programme Swedish Energy Agency Research Programmes Swedish National Rail Administration Research innovation strategy (2006-2011) Swedish Road Administration Research and Development Programme (2000-2009, € 18.5m)

	Ministries (or other setting transport R&D priorities or funding transport R&D)	Agencies and Intermediary organizations (Implementation)	Public Research Organizations/ universities (incomprehensive)	PPP / private institutes	Regional research	Transport R&D programmes
UK	Council for Science and Technology Department for Transport (DfT) Department of Environment, Food and Rural Affairs (DEFRA) Department for Trade and Industry (DTI) Department of Energy and Climate Change Department for Communities and Local Government Technology Strategy Board UK energy research centre Energy Research Partnerships Scottish Government (Transport)	Department for Business, Innovation and Skills. There are 6 grant-awarding Research advisory councils; most relevant for transport R&D are the Engineering and Physical Sciences Research Council and the Economic and Social Research Council Commission for Integrated Transport Office for Low Emission Vehicles (under Dft) Highway Agency Maritime and Coastguard Agency Civil Aviation Authority Energy Technologies Institute Carbon Trust Energy Saving Trust	Research Council Institutes	Energy Research Partnerships Energy Technologies Institute: The ETI's six private members are BP, Caterpillar, EDF Energy, E.ON, Rolls-Royce and Shell. Innovation Platforms on Intelligent Transport Systems and Services and Low Carbon Vehicles	Regional Development Agency	Highways Agency Research Programme Low Carbon Vehicles Innovation Platform (2007-2014) Railways Research Programme Road Safety Research Programme Roads Performance Research Strategy Traffic Management Programme Transport Analysis and Economics Research Civil Aviation research Transport Technology and Standards Programme

Annex III – Key EU-based companies and divisions

The following table provides an overview of the divisions and brands that are allocated to the parent companies. In general, the bottom-up approach followed considers information at the level of parent companies.

Note that the table is not a comprehensive list of all companies assessed. In total, 163 transport-related companies have been assessed in detail based on their financial reports.

Parent company	Brands/Divisions	Field of activity
Volkswagen	VW Passenger Cars	Automotive manufacturer – Passenger cars
	Audi (incl. Lamborghini)	Automotive manufacturer – Passenger cars
	Skoda	Automotive manufacturer – Passenger cars
	Seat	Automotive manufacturer – Passenger cars
	Bentley	Automotive manufacturer – Passenger cars
	VW Commercial Vehicles	Automotive manufacturer – Commercial vehicles
	Scania	Automotive manufacturer – Commercial vehicles
Daimler	Mercedes-Benz Cars (Mercedes-Benz, Smart, Maybach)	Automotive manufacturer – Passenger cars
	Daimler Trucks (Mercedes-Benz, Freightliner, Western Star and Fuso)	Automotive manufacturer – Commercial vehicles
	Mercedes-Benz Vans	Automotive manufacturer – Commercial vehicles
	Daimler Buses (Mercedes-Benz, Setra and Orion)	Automotive manufacturer – Commercial vehicles
BMW	BMW	Automotive manufacturer – Passenger cars
	Mini	Automotive manufacturer – Passenger cars
	Rolls-Royce	Automotive manufacturer – Passenger cars
Renault	Renault	Automotive manufacturer – Passenger cars
	Dacia	Automotive manufacturer – Passenger cars
	Renault Samsung Motors	
Fiat	Fiat Group Automobiles (Fiat, Abarth, Alfa Romeo, Lancia, Fiat Professional)	Automotive manufacturer – Passenger cars
	Maserati	Automotive manufacturer – Passenger cars
	Ferrari	Automotive manufacturer – Passenger cars
	CNH – Case New Holland (Agricultural and Construction Equipment)	
	Iveco (Trucks and Commercial Vehicles)	Automotive manufacturer – Commercial vehicles
	FPT Powertrain Technologies	*Engine + transmission R&D (automotive, marine, etc.)*
	Magneti Marelli (Components)	Automotive supplier
	Teksid (Metallurgical Products)	
	Comau (Production Systems)	
	Note that in 2009, Fiat held 20% of Chrysler	
PSA Peugeot Citroën	Automobile Division (Peugeot and Citroën)	Automotive manufacturer – Passenger cars
	Faurecia (Automobile Equipment)	Automotive supplier
	Gefco (Transport and Logistics)	
	Peugeot Scooters	

Volvo	Volvo Trucks	Automotive manufacturer – Commercial vehicles
	Renault Trucks	Automotive manufacturer – Commercial vehicles
	Mack Trucks	Automotive manufacturer – Commercial vehicles
	Nissan Diesel	Automotive manufacturer – Commercial vehicles
	Volvo Buses	Automotive manufacturer – Commercial vehicles
	Volvo Construction Equipment	
	Volvo Penta	Maritime transport
	Volvo Aero	Air (civil and military aeronautics and space)
MAN	MAN Nutzfahrzeuge - Commercial vehicles	Automotive manufacturer – Commercial vehicles
	MAN Latin America - Commercial Vehicles	Automotive manufacturer – Commercial vehicles
	MAN Diesel - Power Engineering	Marine (among others)
	MAN Turbo - Power Engineering	Marine (among others)
	Renk - Power Engineering	
EADS	Airbus (commercial aircraft)	Air – Civil aeronautics
	Airbus Military	Air – Military
	Eurocopter	Air (civil and military)
	Astrium	Space
	Defence & Security	
	Other (incl. ATR, EADS EFW, EADS Sogerma, Socata, EADS North America)	
Finmeccanica	Aeronautics (Alenia Aeronautica, Alenia Aermacchi, Alenia Aeronavali)	
	Helicopters (AgustaWestland)	
	Space	
	Defence Electronics and Security	
	Defence Systems	
	Energy (Ansaldo Energia incl. Ansaldo Nucleare, Ansaldo Ricerche, Ansaldo Fuel Cells, Asia Power Projects Private Ltd, Ansaldo ESG AG and Ansaldo Thomassen BV group)	
	Transportation (Ansaldo STS, AnsaldoBreda)	Rail
Robert Bosch	Automotive Technology - Gasoline Systems - Diesel Systems - Chassis Systems Brakes - Chassis Control - Electrical Drives - Starter Motors and Generators - Car Multimedia - Automotive Electronics - Automotive Aftermarket - Steering Systems (ZF Lenksysteme GmbH; 50% Bosch-owned)	Automotive supplier
	Industrial Technology - Drive and Control Technology (Bosch Rexroth AG) - Packaging Technology - Solar Energy (Bosch Solar Energy AG)	
	Consumer Goods and Building Technology - Power Tools - Thermotechnology (Bosch Thermotechnik) - Household Appliances (BSH Bosch und Siemens Hausgeräte GmbH; 50% Bosch-owned) - Security Systems (Bosch Sicherheitssysteme	

	GmbH)	
Continental	Automotive Group	Automotive supplier
	Rubber Group	Automotive supplier
Alstom	Power Systems	
	Power Service	
	Transport	Rail
CAF		Rail
Talgo		Rail
Safran	Aerospace Propulsion - Snecma - Turbomeca - Snecma Propulsion Solide - Techspace Aero	Air (civil and military)
	Aircraft Equipment - Aircelle - Messier-Dowty - Messier-Bugatti - Hispano-Suiza - Labinal	
	Defence - Sagem	
	Security - Sagem Sécurité	
Rolls-Royce	Civil aerospace	Air – Civil
	Defence aerospace	Air – Defence
	Marine	Marine
	Energy	
Valeo	Powertrain Systems	Automotive supplier
	Thermal Systems	
	Comfort and Driving Assistance Systems	
	Visibility Systems	
	Valeo Service	

Table 22: EU-based transport-related parent companies and their divisions and brands
Source: company's annual reports
Note: The list represent only a small extract of the 150 companies with their headquarters based in EU Member States, which form the basis of the bottom-up analysis of the present report.

Annex IV – Key players and initiatives at EU level

An overview of the main EU initiatives related to transport research is shown below in Figure 56 (see also Table 12). They are explained in more detail in the remainder of the present annex. Note that relevant parts have been already introduced in the analysis of the innovation systems in transport (Part III of the present report), in particular ERA-NETs, and will not be repeated here.

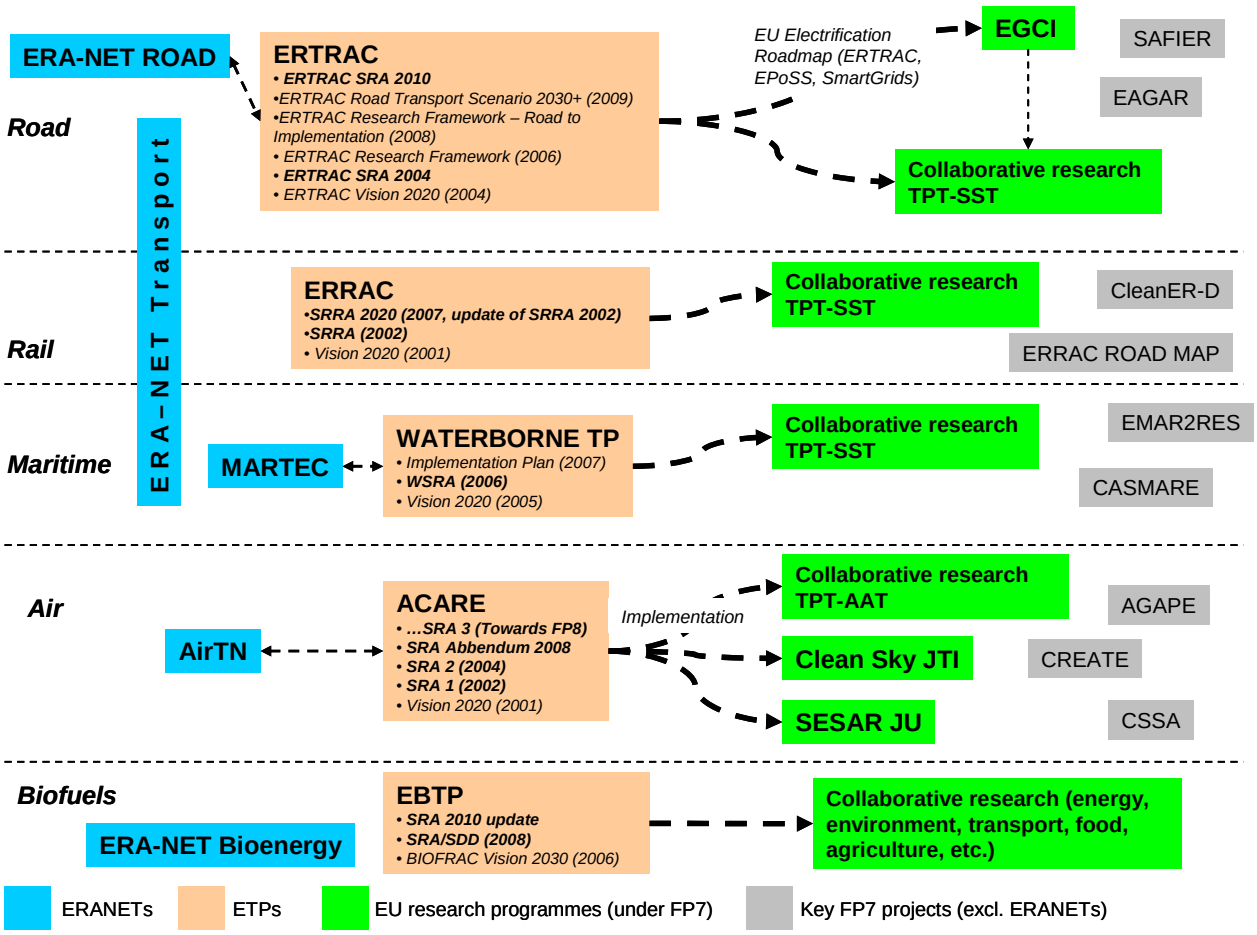

Figure 56: Overview of key EU actors and programmes in transport research (simplified)
Note: EU research on fuel cells and hydrogen (FCH JTI) as well as the platforms on transport infrastructure (ECTP) and intermodal transport (EIRAC) are not displayed on this chart.

European Technology Platforms

The tables below summarise the main features of the ETPs with regard to their R&D targets and strategies[108].

ACARE		
Full name	**Advisory Council for Aeronautics Research in Europe**	
Launching date	2001	
Members	Around 40 members including: • Member States • European Commission • Manufacturing industry • Airlines • Research establishments • Airports • Regulators • Eurocontrol • Academia	
Field of interest	Aeronautical research	
General objectives	The ACARE platform launches, approves and updates the SRA periodically. It provides strategic and operational recommendations as well as commission studies for implementing the SRA and achieving the 2020 Vision; evaluates the overall results and benefits of the SRA for Member States, the Commission and stakeholders groups; recommends measures for optimising the use of existing research infrastructures and achieving cost-effective investments; recommends measures for improving educational policies to attract the scientists, engineers and other skills that the sector needs; develops and implements a communication strategy to promote awareness of the SRA (within the stakeholders community as well as to larger public audiences) and to disseminate information on stakeholders' research programmes for facilitating consensus on priorities.	
Targets	**2020**	ACARE environmental goals for 2020 (2000 baseline and assuming kerosene as main fuel): - Reduce CO_2 emissions by 50% per passenger-km - Reduce NO_x emissions by 80% - Reduce perceived aircraft noise by 50% Note that the aviation industry has committed to stop the growth of CO_2 emissions from 2020 compared to 2005 levels (see e.g. IATA, 2009). The 50% CO_2 emissions reduction target will require the contribution of: - Engines (15-20%) - Airframes (20-25%) - Improved air traffic management and operational efficiency (5-10%)
	2050	No specific ACARE targets for this horizon (yet). They are looking beyond the 2020 targets, developing the SRA 3 (R&D needs from 2020, implementation in FP8, etc.). Note that the aviation industry has committed to reduce net CO_2 emissions by 50% in 2050 compared to 2005 levels (see e.g. IATA, 2009).
Research and innovation priorities	The 'Ultra Green' Air Transport System HLTC technology pool includes the following objectives (ACARE, 2004): • Contribution of aircraft (airframe, rotorcraft and engines): aerodynamic improvements, weight reduction, fuel-efficient engines and systems, novel aircraft concepts, configurations, propulsion integration, adaptive structures and other airframe technology breakthroughs, noise-shielding and active noise control techniques, for rotorcraft, adaptive rotor and new turbo-shaft engine architecture. • Contribution of airlines in terms of choice of aircraft, routes and speed, approach and departure procedures, and use of cleaner products. • Contribution of airports in terms of construction, de-icing fluids, crisis management, ground vehicles, alternative solutions for aircraft taxiing, refuelling facilities, freight management, building restrictions around airports. • Contribution of ATM in terms of 'green routes', 'green areas' and 4D-trajectories optimised for the environment. Alongside FP7 collaborative research on air transport, the ACARE objectives are implemented through two key EU research programmes namely the Clean Sky JTI and the Single European Sky ATM Research Programme (SESAR). Note that the development of alternative jet fuels (e.g. xTL, HVO) is viewed as a complementary solution to reduce GHG emissions.	

[108] All this information is taken from the different ETP's websites and its official documents (SRA, Implementation Plan, roadmaps, etc.).

Required R&D investments/budget	ACARE (2010) reports that: *ACARE believes that government support for R&D is higher in the USA than in Europe because of sizeable American civil aeronautics support budgets and the greater industrial use made of defence aeronautics funding in the USA: 56% of turnover is exported, giving a sizeable positive contribution to the balance of payments (…) European aeronautics in collaboration with their partners, invested around 12% of their turnover (which is in excess of € 94 billion) in Research and Development in 2007 (source ASD). A significant proportion of this has the objective of reducing the environmental impact of products and operations.*

ERTRAC		
Full name	**European Road Transport Research Advisory Council**	
Launching date	2003	
Members	More than 50 member organisations including: • Automotive manufacturers • Automotive suppliers • Energy/fuel suppliers • Service providers • Cities and Regions • European Commission and Member States • Intelligent Transport Systems • Road infrastructure • Research providers • Users/Consumers	
Field of interest	• Urban Mobility • Long Distance Transport • Energy & Environment • Road Transport Safety • Global Competitiveness	
General objectives	ERTRAC provides a strategic vision for the road transport sector with respect to research and development; defines strategies and roadmaps to achieve this vision through the formulation and maintenance of a Strategic Research Agenda (SRA) and Strategic Research Recommendations (SRR); stimulates increased effective public and private investment in road transport research and development; contributes to improving co-ordination between the European, national, regional and private research and development actions on road transport; enhances the networking and clustering of Europe's research and development capacity; promotes European commitment to research and technological development ensuring that Europe remains an attractive region for researchers and competitive industries.	
Targets	**2030**	To achieve a 50% more efficient road transport system by 2030 (incl. decarbonisation, reliability and safety). The 2030 guiding objectives for decarbonisation are (2010 baseline; see ERTRAC, 2010b): - Energy efficiency urban passenger transport: +80% - Energy efficiency long-distance freight transport: +40% - Renewables in the energy pool: • 25% of road transport fossil fuels • 5% substitution of road transport fuels with electricity (generated from RES) In total, this would amount to a decarbonisation of transport by around 20% in 2030, as compared to a BAU approach.
	2050	No specific targets for 2050. Scenarios have been defined in ERTRAC (2009).
Research and innovation priorities	**Vehicles** - Up to 2015: Integrated drivelines; Energy management; v2v and v2i communications and cooperative systems - Up to 2020: Electric vehicles; Reduced resistance to motion; Advanced driver support systems; Matching vehicles to tasks - Up to 2025: Automated systems such as automated transfer of goods in the medium term and fully introduction of automated systems (e.g. platooning, 'reserved lane' concept, etc.) in the longer term	
	Infrastructure - Up to 2015: Advanced road surface and bridge materials; Efficient infrastructure maintenance and reconstruction; Dynamic demand management; Integrated mobility planning - Up to 2020: Multi-modal infrastructure and interfaces; Integrated management of network infrastructure - Up to 2025: Dedicated infrastructure (i.e. optimizing use of the infrastructure by targeting traffic separation and lane prioritization, and through the eventual introduction of electrified corridors for goods vehicles)	
	Logistical and mobility services - Up to 2015: Integrated information services; Understanding users mobility behaviour - Up to 2020: Integrated and optimized logistics services; Services at transport interfaces; Sustainable	

	mobility services
	Energy and resources - Up to 2020: Energy storage and battery systems; Biofuels production; Advanced fuels production - Up to 2025: Closed loop recycling - Up to 2030: Grid-integration and reliability; High performance from abundant materials
Road Maps for innovations	The 'European roadmap on electrification of road transport' has defined the following objectives (ERTRAC et al., 2009; note that this strategy document was used as an input to the implementation of the European Green Cars Initiative): • 2012: Introduction phase - Adapting existing vehicles • 2016: Intermediate phase - 2nd Gen EV updated power train • By 2020: Mass production of dedicated vehicles. Five million of PHEVs/BEVs sold by 2020 in the EU (i.e. about 2% of the European fleet of passenger cars by 2020; In the road transport scenario 2030+ document, they stated that by 2030, it is expected that more than 20% of new passenger cars sold will be fully electric or hybrid electric vehicles). Target for energy use in 2050 have been discussed in ERTRAC (2010a). See also the initiatives at MS level related to the development of fully electric vehicles and the required infrastructure[109].
Required R&D investments/budget	No quantitative information about the required R&D investments to achieve the objectives. In the ERTRAC SRA (ERTRAC, 2010b), it is mentioned that: *Over the transitional period leading towards 2030, a considerable level of additional public investment will be required to guarantee success. ERTRAC therefore recommends that the European Commission and the Member States, in their respective framework programmes, reserve a budget for road transport, that reflects the major significance of the sector to the economy and to society.*

ERRAC		
Full name	**European Rail Research Advisory Council**	
Launching date	2001	
Members	45 representative (manufacturers, operators, infrastructure managers, European Commission, EU Member States, academics and users' groups).	
Field of interest	ERRAC covers all forms of rail transport: from conventional, high speed and freight applications to urban and regional services.	
General objectives	Define research priorities and set up roadmaps for the implementation of the ERRAC Vision 2020 'Towards a single European railway system'.	
Targets		Targets have been defined in the ERRAC Roadmap WP 01 'The greening of Surface Transport', Deliverable 'Energy Roadmap for the European Railway sector' (ERRAC, 2010). Note that the sources of energy, the production and the transmission are not part of the ERRAC Energy Roadmap's consideration.
	2030	**Climate change** - By 2030 the European railways will reduce their specific average CO_2 emissions from train operation by 50% compared to base year 1990; measured per passenger-km (passenger service) and gross tonne-km (freight service). - In addition, by 2030 the European railways will not exceed the total CO_2 emission level from train operation in absolute terms even with projected traffic growth compared to base year 1990. **Energy efficiency** - By 2030 the European railways will reduce their specific final energy consumption from train operation by 30% compared to the base year 1990; measured per passenger-km (passenger service) and gross tonne-km (freight service). **NO_x and PM10 emissions** - By 2030 the European railways will reduce their total exhaust emissions of NO_x and PM10 by 40% in absolute terms even with projected traffic growth compared to base year 2005.
	2050	**Climate Change** - The European railways will strive towards carbon-free train operation by 2050 and provide society with a climate neutral transport alternative. **Energy efficiency** - The European railways will strive towards halving their specific final energy consumption from train operation by 2050 compared to the base year 1990; measured per passenger-km (passenger service) and gross tonne-km (freight service). **NO_x and PM10 emissions** The European railways will strive towards zero emission of nitrogen oxides (NO_x) and particulate matter (PM10) from non-electric trains by 2050.
Research and innovation priorities	As reported in the updated SRA (ERRAC, 2007), new research areas include: - Weight reduction methods to reduce deadweight per passenger - Streamlining the infrastructure for more efficient land use such as removing bottlenecks, building high speed flyovers and reducing the number of level crossings	

[109] http://www.green-cars-initiative.eu/documents/Report_WS_EC-MS_Electric_Vehicle_R-D.pdf/view

	- Improve standards for noise, emissions and diesel engines - Develop new lightweight and low noise freight wagons - Hot versus cold braking benefits - Low frequency sub-station noise based on research in other sectors - Research into the optimisation of the GSM-R network to remove capacity constraints - Noise abatement systems such as low level barriers - Land use
	An ERRAC roadmap has been established in the context of the ERRAC Road Map project WP 01 'The Greening of Rail Transport' for the years 2015, 2020, 2030 and 2050 (ERRAC, 2010). **2015** Main improvements related to infrastructure and operation: - Standardize EE Driving - Parked Trains Management - Advanced Traction Energy Supply (Increase of line voltage to decrease the losses, new caternary materials) **2020** - Lighter trains - Development of hybrid traction (e.g. on-board energy storage technologies, engine stop at stations) - Energy storage in the infrastructure - Monitoring system about energy consumption in the railway system - Re-use of kinetic energy - Development of EE auxiliaries (e.g. powering auxiliaries with kinetic energy) - Traffic flow management - Next generation of power semi-conductor **2030** Main improvements related to infrastructure and railway system - Smart Grids and the multiplication of energy sources - Sector Smart Grids **2050** - Innovative propulsion - Implementation of H2/FC in due consideration of RAMS (Reliability, Availability, Maintenance, Safety) and LCC (Life Cycle Costs) incl. the aspect of H2 production & storage) - Infrastructure Sections without catenary (railway lines without caternary operated with particular adapted Rolling Stock (traction energy supply by pantograph and energy storage on board))
Required R&D investments/budget	No information available

WATERBORNE-TP	
Full name	**European Technology Platform Waterborne**
Launching date	2005
Members	Industry stakeholders, EU Member States, the European Commission and stakeholders from science and society.
Field of interest	Waterborne (sea & inland)
General objectives	Define and share a common Vision and a Strategic Research Agenda, driving the necessary innovation efforts forward. The waterborne medium and long term vision is carried by three main research topics or pillars (WATERBORNE TP, 2006): 1. Safe, sustainable and efficient waterborne transport 2. A competitive European waterborne industry 3. Managing and facilitating the growth in transport volumes and the changes in trade patterns
Research and innovation priorities	In pillar 1, key RD&I priority areas for reducing GHG emissions concern (WATERBORNE TP, 2007): 1.4. "Low Emission" Vessels and Waterborne Activities 1.4.1 Marine Fuel Cell - Fuel Operation Test Facility 1.4.2. Fuel Supply and Fuel Systems 1.4.5. The Future Sustainable Recreational Craft In pillar 2, some RD&I priority areas for reducing GHG emissions are: 2.1. Innovative Vessels and Floating Structures 2.1.1. Future Ship Designs for Short Sea 2.2. Innovative Marine Equipment and Systems 2.2.1. More Efficient Propulsion 2.2.2. Prime Mover Development 2.2.3. Next Generation Power and Propulsion Concepts 2.4. Next Generation Production Processes 2.4.3 Electric Power & Propulsion Component Design
	Within the research topic **1.4. Low Emissions Vessels and Waterborne Activities**, there are three main roadmaps defined for reducing GHG emissions (WATERBORNE TP, 2007):

	1.4.1 Marine Fuel Cell - Fuel Operation Test Facility Fuel cells with efficiencies up to 70% are being developed for land-based applications running on natural gas. Marinisation of this technology will significantly reduce marine power system emissions and provide clean, efficient power sources for niche marine applications. Widespread application of fuel cells in power propulsion requires the development of a cost effective diesel oil reformation technology 2010: Pilot fuel processing/reformation plant operation. Development fuel cell power system operation. 2015: Prototype marine fuel cell APU sea trials See the results of the FELICITAS project *1.4.2. Fuel Supply and Fuel Systems* Fuel processing and alternative fuels should be considered for cost reduction and environmental benefits for shipping, including coastal and inshore and inland shipping. The use of alternative fuel such as RME, LNG, Methanol, and LPG need research regarding application and technical standards. Technology transfer from automotive and clean land based local power generating systems should be investigated. Research is required into the reformation of diesel fuel and removal of sulphur and other contaminants for future marine fuel cell applications. 2015: Prime movers operate on low sulphur fuels, Prime movers able to operate on synthetic oils and fuels. Diesel oil reformation technology commercially available. See the results of the HERCULES project *1.4.5. The Future Sustainable Recreational Craft* The use of more efficient power and propulsion systems (including regenerative hybrid diesel/electric drives), and innovative sail design, reduced overall power consumption, minimal emissions to both air and water, together with low noise, vibration and wash. 2010: - Analytical tools: 20% reduction in overall vessel weight; 50% reduction in noise; automotive levels of internal noise and vibration. - Tools for life cycle analysis: 100% of materials to be recycled on disposal - Sustainable materials and manufacturing processes: 30% reduction in energy and carbon tariffs and through life costs. - Integrated waste management systems: emissions to air reduced ahead of legislative demand, to water by 80%. - Alternative propulsion and power systems: Overall fuel consumption reduced by 25%, whilst meeting noise, vibration and weight targets. 2015: Improved instrumentation, navigation, decision support and safety systems: zero collision between recreational and commercial craft; 50% improvement in accessibility for the elderly and disabled. A demonstration craft illustrating the opportunities and improvements created by the research programme. Other roadmaps have been set up in pillar 2, such as: *2.1.1. Future Ship Designs for Short Sea* *2.2.1. More Efficient Propulsion* *2.2.2. Prime Mover Development:* Typical applications would include turbochargers and injection systems. Engines must be designed for multi-fuel capability to enable efficient operation on new cleaner fuels. Future engines will have intelligent adaptive control systems optimising their operating parameters for fuel type and emissions, ambient conditions and load - 5 Years: New high temperature engine materials - 10 Years: Prime movers able to operate on synthetic oils and fuels; Adaptive engine management systems *2.2.3. Next Generation Power and Propulsion Concepts* (e.g. expansion of electric propulsion options with increased efficiency and environmental benefit could be achieved by the adoption of high power fuel cells. Alternative energy sources can be developed through photovoltaic and wind/wave energy conversion technology for propulsion, for hybrid electricity generation systems and energy storage through hydrogen production) *2.4.3 Electric Power & Propulsion Component Design* (research, develop and validate advanced concepts and technologies towards an all-electric ship)
Required R&D investments/budget	According to WATERBORNE TP (2007), around € 1.65-1.75 billion should be spent for research per year for the implementation of the WSRA.

EBTP	
Full name	**European Biofuels Technology Platform**
Launching date	2006
Members	More than 150 individuals representing stakeholders (industry, academia, research, associations).
Field of interest	RD&D on biofuels
General objectives	To contribute to the development of sustainable, cost-competitive, world-class biofuels technologies, to the creation of a healthy biofuels industry and to accelerate the deployment of biofuels in the European Union through a process of guidance, prioritisation and promotion of research, development and demonstration.

Targets	25% substitution of road transport fossil fuels by biofuels in 2030.
Research and innovation priorities	The SRA has identified R&D priorities through the activities of the five workgroups of the Biofuels TP. They relate to the availability and supply of biomass resources, conversion processes, end-use of biofuels as well as sustainability issues (EBTP, 2008).
Road Maps for innovations	Roadmaps have been elaborated in the SRA/SDD document, for the short, medium and long term (EBTP, 2008).
Required R&D investments/budget	The EBTP SRA reports that (EBTP, 2008): *The sustained financial effort required to implement R&D&D priorities as previously identified in the SRA will be high, being roughly in the range of 300-600 million € per year. This includes demonstration up to prototype or semi-industrial size, but still excludes full-size "first-of-a-kind" industrial facilities.* In the updated SRA (EBTP, 2010), it is mentioned that: *The selection and funding of demonstration and/or reference plants projects will constitute the core activity of EIBI*. With an estimated budget of 8 billion € over 10 years, 15 to 20 demonstration and/or reference plants could be funded.* *(*European Industry Bioenergy Initiative)*

EIRAC*	
Full name	**European Intermodal Research Advisory Council**
Launching date	2005
Members	Intermodal operators, terminal handling, freight villages, modal transport operators, forwarders, ports, equipment suppliers, cargo owners, high educational institutions and authorities.
Field of interest	Intermodal transport
General objectives	- Optimise the use of public funding, in order to encourage the main stakeholders to invest in research activities - Manage the results of research, in order to improve the potential available on the market, and to provide their assessment both before and after the execution of the project - Communicate EIRAC activities and results in professional manner vis-à-vis non-EIRAC members and International Parties - Stimulate the application of the contents of the Implementation Plan to national programmes of research - Expand the EIRAC network towards national key players (both public and private) - Encourage the participation of SMEs in innovation and research activities - Find a common position on changes necessary to make transport greener, safer/more secure, and smarter
Research and innovation priorities	Research priorities refer to the following areas (EIRAC, 2005, 2006): **Interoperability between modes:** Standardised intermodal equipment; Transfer Nodes; Consistent regulations; IT Systems; Transport documentation; Systems of transfer. **Logistics:** Harmonised Framework conditions for all Modes; High quality and efficient Intermodal Services; European Intermodal Network. **Security:** Harmonisation of the Security Policy Framework; Security IT Infrastructure; Physical Security Model for the Assessment of Mitigation Measures. **Socio-economic aspects:** Intermodal tran sport innovation scenarios; Specific solutions. **Education and training:** Attract people to work in the intermodal sector; Harmonise the European Intermodal Training framework (Curricula, Didactics, Content); Develop new methods and solutions of intermodal learning and training; Awareness of intermodal transport.
Required R&D investments/budget	The required research funding in several areas have been roughly estimated (EIRAC, 2006).

** Non-official EU ETP. See the list of ETPs at: http://cordis.europa.eu/technology-platforms/individual_en.html*

ECTP	
Full name	**European Construction Technology Platform**
Launching date	2004
Members	Contractors, Materials and Equipment manufacturers Designers, Architects, Engineers Owners/Operators/Clients Users/Consumers Service and Technology Providers Research Centres and Universities Cities and Regions Financial Institutions
Field of interest	Construction
General objectives	For the transport network, R&D activities should relate to (ECTP, 2007): - Reduction in service failures, number of accidents and mitigation of consequences - Reduction in number, size and duration of construction and maintenance interventions (time,

	congestions, emissions and interruptions) both in urban and extra urban context - Enhanced efficiency and higher level of management and service; cost optimisation - Extension of life cycle and improved knowledge - Increase in recycling and re-use of materials and reduction in waste materials - Interoperability of infrastructure and information - Increased competitiveness of the sector toward non-EU countries
Research priorities	Strategic research priorities have been defined in the SRA (ECTP, 2005). With regard to transport, the priority **'Sustainable Management of Transports and Utilities Networks'** includes the following research themes (total cost of around € 1 billion; see ECTP, 2007): - New methods/tools for the comprehensive management of transport and utilities infrastructure in urban and extra urban context to reduce impact on service - Standards, models and databases to assess, follow and predict the long-term performance of structures and components subject to ageing and deterioration - New concepts to extend the life time of structures or increase their capacity, with no reduction in safety and with positive impact on maintenance - New testing methods for early detection of damage for structures and infrastructures, even buried, with minimal impact on traffic and supply - Develop, design, build and operate, with new or non-conventional multifunctional materials or with traditional materials of enhanced performances, with low environmental impact, high durability, reduced maintenance and operation costs, and increased comfort for users and citizens - Integrated life-cycle assessment systems combining cost-efficient and easy-tomaintain sensors, monitoring and performance prediction systems, and covering all stages of construction control, asset management, and optimization of maintenance - ICT and ITS systems to optimize traffic, serviceability and security of networks integrating traffic and transport monitoring and management, information to users, tolling, incident and crisis management
Required R&D investments/budget	The total cost of projects under the priority 'Sustainable Management of Transports and Utilities Networks' is around € 1 billion (ECTP, 2007).

Other European Technology Platforms are also relevant for some aspects of transportation. Their characteristics and their R&D targets and strategies are illustrated below.

EPOSS (European Technology Platform on Smart Systems Integration) focuses on "smart systems", defined as intelligent, often miniaturised, technical subsystems with their own and independent functionality evolving from microsystems technology (EPOSS, 2009). Stakeholders involved in the EPOSS activities include automobile manufacturers, aerospace industries, automotive components providers, information and communication companies, SMEs, research institutes, universities and other partners.

Net!Works (former eMobility) is a Technology Platform that has stakeholders from the industrial domain, the research domain (universities, research centres, etc.), SMEs and other fields (institutions, pre-standardisation bodies, state organisations, etc.). It focuses specifically on mobile and wireless communications.

The core of the R&D activity associated to Net!Works is primarily targeting users, network operators, service providers, and manufacturers of network-related devices and involves network-specific solutions (like, for instance, research into new solutions for managing complexity seamlessly, or solutions leading in efficient use of spectrum and network resources).

The Strategic Research Agenda aims to improve the individual's quality of life through the availability of an environment for instant provision and access to meaningful, multi-sensory information and content.

NESSI (Networked European Software and Services Initiative) is the European Technology Platform for software and information and communication technology services. It represents a community of industrial and academic actors that are active in information and communication technologies.

NESSI's vision of the future of software and services is one in which services will be increasingly smart and highly adaptable, globally accessible and pervasive, interoperable, supporting fast business and technology cycles, acting increasingly in real-time, capable to enable users to play more and more

the role of producers of content and applications, as well as self-manageable, secure and trustworthy (NESSI, 2010).

The R&D activities that are primarily targeted by the NESSI Strategic Research Agenda (NESSI, 2009) are focused on issues that span across software and information and communication technology services.

NEM (Networked and Electronic Media) is a European Technology Platform that aims to foster the development and introduction of novel audiovisual and multimedia broadband services and applications.

NEM identified a number of research priorities in its Strategic Research Agenda (NEM, 2009). The focus on subjects like the design of rich media content, the type of tools used for it, the integration of classical and new media applications, the creation or adaptation of content dedicated to specific user groups, future media delivery networks and network services, new user devices and terminals, as well as technologies providing security, privacy, and trust, amongst others. In addition, NEM aims at developing technologies and services capable to handle this and at the development of technologies in which the demand of energy will be reduced by a factor between 10 to 30 %.

European research initiatives

The European Green Cars initiative

The European Green Cars Initiative (EGCI) is one of the three Public Private Partnerships (PPP) of the European Economic Recovery Plan launched in 2008. The objective of this initiative is to 'support R&D on technologies and infrastructures that are essential for achieving breakthroughs in the use of renewable and non-polluting energy sources, safety and traffic fluidity'[110].

The three dimensions of the EGCI[111] refer to:

- R&D activities through FP7 grants for research on greening road transport, with a budget of € 1 billion (€ 500 million from the Commission[112] and € 500 million from industry and Member States)
- Support to industrial innovation through EIB (European Investment Bank) loans with a budget of € 4 billion in the context of the European Clean Transport Facility (see section 3.6.3) in addition to existing loans
- Demand side measures & public procurement, such as reduction of circulation and registration taxes for low-CO_2 cars

The main research focus of the EGCI is on the electrification of mobility and road transport. It should be noted that research efforts not only focus on passenger cars but also on trucks, internal combustion engines, logistics, ITS, both at vehicle and system level. The R&D areas are listed below:

- Research for trucks;
- Research on greening internal combustion engines;
- Research on bio methane use;
- Logistics, transport system optimisation; and
- Research on electric and hybrid vehicles, notably research on:
- High density batteries;

[110] http://www.green-cars-initiative.eu/
[111] http://ec.europa.eu/research/industrial_technologies/lists/green-cars_en.html
[112] The EU funding of € 500 million will be spent over four years (2010 to 2013) with the following indicative breakdown (€ 95m in 2010; € 115m in 2011; € 145m in 2012 and 2013).

- Electric engines;
- Smart electricity grids and their interfaces with vehicles.

The first calls for the EGCI was launched in July 2009 with a total budget of € 108 million for the year 2010, out of which € 68 million from the 'transport' theme[113]. Note also that € 25 million are allocated to the joint call on electric batteries. The work programme 2011 (2011 calls, published in July 2010) covers three major R&D themes: Research for heavy duty vehicles based on internal combustion engines; Research on electric and hybrid vehicles; Logistics and co-modality combined with intelligent transport system technologies[114].

The Clean Sky Joint Technology Initiative

The Clean Sky Joint Technology Initiative (Clean Sky JTI; see also section 9.5.4) is one of the largest European research initiatives with a budget estimated at € 1.6 billion over seven years, of which half is funded by the European Commission and half by the EU aeronautics industry. The budget will be spent on the following research programmes:

- Smart Fixed Wing: € 372m (24%)
- Green rotorcraft: € 155m (10%)
- Green regional aircraft: € 177m (11%)
- Green engines: € 419m (27%)
- Systems for green operation: € 295 (19%)
- Eco-Design: € 109m (7%)
- Technology evaluator: € 31m (2%)
- Running costs: € 48m (3%)

The first six programmes have set different targets for reducing CO_2 emissions, NO_x emissions and noise (see e.g. Denos, 2009).

The SESAR Joint Undertaking

See section 9.5.2 for a description of the SESAR JU.

The Fuel Cells and Hydrogen Joint Technology Initiative

The Fuel Cells and Hydrogen Joint Technology Initiative (FCH JTI)[115] is a public-private partnership launched in 2008 with the goal to accelerate the market entry of fuel cell and hydrogen technologies for applications in transport, stationary and portable power. To summarise, the set up of the FCH JTI mainly results from a three-step process initiated in 2002:

- The High Level Group on Hydrogen and Fuel Cells (HLG) was asked in 2002 by the EU to formulate an integrated vision of the EU's strategy on hydrogen and fuel cells and their role on sustainable policy. This was undertaken through the HLG vision report produced in 2003 presenting the required actions to boost the introduction of hydrogen and fuel cells (HLG,

[113] Themes covered by the EGCI and their indicative research budget for the period 2010-2013:
- Transport (€ 220 million i.e. 44% of the total budget)
- Energy (€ 50 million)
- Environment (€ 50 million)
- ICT (€ 120 million)
- NMP (€ 60 million)

[114] 2011 calls (20 July 2010) http://www.green-cars-initiative.eu/open-fp7-calls/calls-for-proposals

[115] All the documents quoted in this section are available at: http://ec.europa.eu/research/fch/

2003). This report recommended the creation of a technology partnership between the different public and private stakeholders of the sector.

- Based on these recommendations, the European Commission launched (under FP6) the European Hydrogen & Fuel Cell Technology Platform in January 2004, with the objective to set up a research strategy to develop and deploy fuel cell and hydrogen technologies in the EU. The key outputs of the platform were the elaboration of the Strategic Research Agenda (July 2005), the Deployment Strategy (August 2005) and the Implementation Plan (March 2007). The latter report aimed at implementing the RD&D activities defined by the Strategic Research Agenda and Deployment Strategy.
- Finally, based on the above-mentioned documents produced by the HFC platform, the FCH JTI was established in May 2008 to speed-up the development of fuel cell and hydrogen technologies so that to bring them on the market by 2020. The FCH JTI will run until 2017 with a minimum budget of € 940 million (€ 470 million from both the European Community and the private sector). The FCH JU (that implements the FCH JTI) became an autonomous legal entity in November 2010.

As described in the FCH JU Multi-Annual Implementation Plan (FCH JU, 2009), five application areas are considered namely 'Transportation & Refuelling Infrastructure', 'Hydrogen Production and Distribution', Stationary Power Generation & CHP', 'Early Markets' and 'Cross-Cutting Issues'. It is worth mentioning that around one third (32-36%)[116] of the total FCH JU budget is allocated to the transportation and refuelling infrastructure area, while another 10-12% is directed to RD&D on hydrogen production and distribution.

The Advanced Research & Technology for EMbedded Intelligence and Systems Joint Technology Initiative

The ARTEMIS (Advanced Research & Technology for EMbedded Intelligence and Systems) Technology Platform is a public-private partnership that included actors from industry, SMEs, universities, research centres and European public authorities working in the field of embedded computing systems (i.e. specialised computers used in automobiles, airplanes and other vehicles, but also on thousands of other products like home appliances, communication and control machines, medical devices, electrical networks, etc.)

The ARTEMIS Technology Platform published in 2006 a Strategic Research Agenda, aiming to establish and implement a coherent and integrated European research and development strategy for embedded systems (ARTEMIS, 2006). The Strategic Research Agenda focuses on the evolution of the field of embedded systems from a medium to long-term perspective and identifies a number of important technological challenges that have to be met in order to implement the Vision outlined in the 2003 document 'Building ARTEMIS' (ARTEMIS, 2003). It includes a set of high level targets to be attained by 2016. One of its main ambitions is to overcome the fragmentation that follows the development of embedded systems in different industrial applications and as a result of a wide range of differing technical requirements (ARTEMIS, 2006).

Since 2009, the ARTEMIS Joint Undertaking is implementing autonomously the ARTEMIS Joint Technology Initiative by means of a budget from both the EU and participating Member States and under the supervision of the European Commission, following a research agenda that is closely following the recommendations of the Strategic Research Agenda developed by the ARTEMIS Technology Platform. In particular, the JU manages and coordinates research on embedded computing systems through a 10-year, € 2.5 billion research programme.

Other activities of the ARTEMIS Technology Platform have been continued in the ARTEMIS Joint Technology Initiative by the ARTEMIS Industrial Association (ARTEMISIA), which also represents the interests of industry and the research community within the Joint Undertaking.

[116] It represents € 144-162 million out of which € 94-106 million are allocated to demonstration activities.

European Commission

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Abstract

This report provides an overview of the innovation capacity of the European transport sectors. The analysis addresses transport-related innovation from three different angles. It identifies drivers and barriers to innovation in transport; it assesses the levels of transport-related R&D investments of the main industrial R&D investors and public funders; and it maps the key actors for transport research and knowledge flows between them. The analysis finds that the transport industry strongly invests in R&D, in particular the manufacturers of passenger cars and airplanes. At the same time, transport service provides and companies involved in the construction of transport infrastructure have low incentives to invest in research. Despite the significant on-going research efforts in transport the potential for systemic innovations that go beyond modal boundaries and leave the currently pre-dominant design are under-exploited due to prominent lock-in effects caused by infrastructure and the institutional set-up of the innovation systems.

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