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Innovation capacity of the European transport sector

A macro-level analysis

Grosso, M., van Balen, M., Ortega Hortelano, A., Haq, G., Gkoumas, K., Tsakalidis, A. and Pekár, F.

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Abstract

The Transport Research and Innovation Monitoring and Information System (TRIMIS) is the analytical support tool for the establishment and implementation of the Strategic Transport Research and Innovation Agenda (STRIA), and is the European Commission's (EC) instrument for mapping transport technology trends and research and innovation capacities. Seven STRIA Roadmaps have been developed which cover various thematic areas.

TRIMIS provides periodical assessments of transport research and development (R&D) for the various thematic areas. This report cuts through the STRIA Roadmaps and provides a macro-level assessment of the overall innovation capacity in the European transport sector. It does so by identifying and assessing the most relevant indicators on private and public funding, R&D personnel and researchers, engagement in innovation and on the types of innovation activities at the EU and Member State level.

The findings highlight the importance of R&D activities in the European transport sector. Innovation levels were found to be particularly high in the automotive manufacturing economic activities. On the lower end the transportation and storage economic activities are found.

The level of private investments in R&D has increased over the past seven years, making the transport sector with €42 billion a leader in investment in Europe in 2015. Business R&D expenditure has risen with the automotive industry leading this trend and accounting for more than 75% of the total business investments. Public support to R&D transport reached €3.3 billion in 2017, showing a moderate increase compared to the year 2016.

Transport companies are highly committed to innovation activities. This is mostly the case for manufacturing firms, with almost 60% of these declaring that they invest in R&D activities.

The analysis of human resources employed in transport R&D found that most R&D personnel is employed in the automotive industry, accounting for almost 70% of the total number of 273,000 people working on transport R&D in 2015.

The main barriers to innovation activities are linked to the high costs associated with R&D activities and financing barriers. Other relevant impediments to innovation are market dynamics, such as demand uncertainty and high sectoral competitiveness, as well as the lack of qualified personnel.

1 Introduction

Research and Development (R&D) has an important role in shaping the future of transport and ensuring that the European transport industry maintains its global competiveness. R&D and innovation are key aspects in the Europe 2020 strategy agenda, pursuing the objective of a smart, sustainable and inclusive European growth (European Commission, 2010).

The transport sector, being one of sectors with highest R&D investment in Europe (European Commission, 2018a), has an important role to sustain the economic competitiveness of European countries. Moreover, transport innovations can have profound beneficial impacts on society by creating new mobility opportunities, decreasing congestion and contributing to the development of a more sustainable transport system.

Based on this understanding, the European Commission (EC) adopted the Strategic Transport Research and Innovation Agenda (STRIA) as part of the "Europe on the Move" mobility package (European Commission, 2017a) which highlights the main transport Research and Innovation (R&I) areas and priorities for clean, connected and competitive mobility to complement the 2015 Strategic Energy Technology Plan (European Commission, 2015).

The STRIA working document "Towards clean, competitive and connected mobility: the contribution of Transport Research and Innovation to the Mobility package" (European Commission, 2017b), identifies seven priority areas (roadmaps) covering:

- Cooperative, connected and automated transport;
- Transport electrification;
- Vehicle design and manufacturing;
- Low-emission alternative energy for transport;
- Network and traffic management systems;
- Smart mobility and services; and
- Infrastructure.

In May 2018, the EC published the third "Europe on the move" policy mobility package (European Commission, 2018b) which included actions for Europe to become a world leader in innovation, digitalisation and decarbonisation[1].

TRIMIS provides periodical assessments of transport R&D for the various thematic areas. This report cuts through the different themes and provides a macro-level assessment of the overall innovation capacity in the European transport sector[2]. A set of topics is presented to provide an overview of the state of transport R&D, including indicators on private and public funding, R&D personnel and researchers, engagement in innovation, and on the types of innovation activities. The methodology was set out in Grosso et al. (2018).

The report provides an overview of the current status of transport R&D in Europe which acts as a reference when assessing the individual STRIA roadmaps. Moreover, it acts as a baseline to understand where transport innovation is standing and where it's heading.

[1] For a more extensive overview of the European transport policy context, initiatives and funding opportunities, see Annex 1.

[2] A forthcoming report will complement this report by providing insights on transport research trends, drivers, and bottlenecks, based on a survey and interviews with transport stakeholders.

The report is divided into five chapters. Chapter 1 briefly introduces the topic. Chapter 2 defines the concept of innovation and its measurement. Chapter 3 illustrates the methodological approach and chapter 4 shows the results of the analysis. Chapter 5 provides conclusions and recommendations for future work.

2 Innovation concepts and measurement

To contextualise the report's findings, it is useful to briefly reflect on the definition of innovation, which types of innovation exist, and how it can be measured.

2.1 The definition of innovation

There is no single definition of what innovation is (Gault, 2018; Oberg, 2017; Baregheh et al., 2009). One economic definition dates back to 1934, when Schumpeter (1934) connected ideas and innovations: *"as long as they are not carried into practice, inventions are economically irrelevant"*. Since then a number of additional definitions were conceived and various disciplines dealt with this concept (Baregheh et al., 2009).

The lack of a consensual definition can create ambiguity and confusion (Baregheh et al., 2009; McAdam et al., 2004) and thus, identifying and comparing innovation performances in companies or countries is challenging.

To overcome this issue, the Oslo Manual definition has been used in this report, as a widely acknowledged and precise explanation used for statistical measurement. The Oslo Manual definition states that: *"An innovation is the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations"* (OECD/Eurostat, 2005).

2.2 Different types of innovation

Within the Oslo Manual definition, a reference is made to different innovations that can concern both goods and services. There are four types of innovation that are listed below.

A *product innovation* is the introduction of a good or service that is new or significantly improved with respect to its characteristics or intended uses. This includes significant improvements in technical specifications, components and materials, incorporated software, user friendliness or other functional characteristics.

A *process innovation* is the implementation of a new or significantly improved production or delivery method. This includes significant changes in techniques, equipment and/or software.

An *organisational innovation* is the implementation of a new organisational method in the firm's business practices, workplace organisation or external relations.

A *marketing innovation* is the implementation of a new marketing method involving significant changes in product design or packaging, product placement, product promotion or pricing. (OECD/Eurostat, 2005).

2.3 Innovation measurement

Once it is clear how to identify and classify innovation, it has to be measured. This should allow a comparison over time and among different geographical areas (e.g. countries, regions, etc.).

The measurement of innovation can vary according to the scope of the analysis. Various types of indicators have been identified in the literature and their use has been linked to data availability and quality (Condeço et. al., 2013; Hyard, 2013; Tsamis et al., 2016).

According to the different innovation stages, i.e. concept definition, implementation and diffusion, several typologies of measurement can be identified, which can be linked to input, process and output indicators.

Among the innovation input, the assessment of R&D activities is among the most widespread types of measurements, that allows quantitative comparisons.

The Oslo Manual definition of R&D is the following: *"Research and experimental development comprises creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications".* R&D can be both intramural and extramural[3], including software development, constructing and testing of prototypes, acquisition of R&D services.

There are moreover other activities which are linked to product and process innovations, namely the acquisition of external knowledge, machinery and equipment or training activities. Additional innovation activities relate to marketing and organisational innovations, such as preparatory actions linked to the development or implementation of a certain marketing or organisational method.

The number of patents is a common output indicator that provides information on invention activities produced within a defined time period and geographical area. This indicator is associated with the protection of an invention and its commercialisation and is linked to technological innovations. (Basberg, 1987)

The list of innovation indicators could be further extended, nonetheless it would be unlikely to capture the entire innovation capacity. Other exogenous factors which are not easy to capture can influence and affect both positively or negatively the ability to produce innovative goods or services.

[3] Intramural expenditures are all expenditures for R&D performed within a statistical unit or sector of the economy during a specific period, whatever the source of funds. Expenditures made outside the statistical unit or sector but in support of intramural R&D (e.g. purchase of supplies for R&D) are included. Both current and capital expenditures are included. Extramural expenditures includes all the R&D expenditures spent outside of the statistical unit. Those data are a useful supplement to the information collected on intramural expenditures. These extramural expenditure data are essential for providing statistics on R&D performed abroad but financed by domestic institutions (OECD, 2018).

3 Methodology

The methodology followed in this report, as described in Grosso et al. (2018), clusters the identified indicators in four main areas: transport enterprises economic indicators, funding, human resources and innovation engagement.

The report examines the transport sector at European and Member State (MS) level, considering the most up-to-date data[4]. When data is missing a note has been added. To overcome problems in comparing data in time series, an estimation has been made, using the average method (i.e. using years before and after the gap year).

The Eurostat data used in this report, follows the Statistical Classification of Economic Activities (NACE) Rev.2 and the Statistical Classification of Socio-economic Objectives (NABS) 2007 classifications.

The NACE REV.2 classification provides a 4-digit specification of indicators, which is the most detailed level available for the different economic activities. Within the Eurostat datasets the level of data disaggregation varies. It is therefore not always possible to compare indicators on the same level of data disaggregation. In this study, where possible, the 3-digit codes have been considered, while in many cases the 2-digit level was the only available disaggregation. Transport activities mainly belong to the following NACE Rev.2 categories:

- C29 (Manufacture of motor vehicles, trailers and semi-trailers);
- C30 (Manufacture of other transport equipment) and
- H (Transportation and storage)[5].

Annex 2 provides a detailed description of each category of transport-related economic activities. For the majority of the indicators considered a distinction among C29, C30 and H is provided. The two manufacturing economic activities, C29 and C30, are presented separately as they substantially differ in characteristics and market structure.

In the NABS 2007 classification the transport sector is captured in Chapter 4-Transport, telecommunication and other infrastructures (see Annex 3).

The main source of information was Eurostat (European Commission, 2019), namely the following datasets:

- Structural Business Statistics (SBS);
- Research and Development;
- Community Innovation Surveys (CIS);
- Patents.

Moreover, supplementary information was collected from:

- EC – Industrial R&D Investment Scoreboard (European Commission, 2018a);
- EC – European Innovation Scoreboard (European Commission, 2018c);
- Organisation for Economic Co-operation and Development (OECD) – Science, Technology and Patents database (OECD, 2018b);
- United Nations – World Intellectual Property Office (WIPO) database (WIPO Database, 2018).

[4] Data was retrieved from October 2018 until February 2019.

[5] G45 (Wholesale and retail trade and repair of motor vehicles and motorcycles) also belong to the transport sectors within NACE Rev. 2, nonetheless no representative data is available for many of the indicators considered, therefore it is not included in this analysis.

For some indicators, the high number of missing data impose caution in interpreting the outcomes and could entail underestimation of the figures presented.

4 Assessment of the innovation capacity in the European transport sector

This section presents the analysis of the selected indicators, (see **Table 1**) based on the following classification: transport enterprises' economic indicators, funding, human resources and innovation engagement.

Table 1 Indicators

Area of Indicator	Indicator	Description
Transport enterprises economic indicators	**Turnover**	Totals invoiced by the observation unit during the reference period, this corresponds to market sales of goods or services supplied to third parties
Transport enterprises economic indicators	**Number of enterprises**	Count of the number of enterprises active during at least a part of the reference period
Transport enterprises economic indicators	**Personnel costs**	Total remuneration, in cash or in kind, payable by an employer to an employee in return for work done by the latter during the reference period
Transport enterprises economic indicators	**Value added at factor costs**	Gross income from operating activities after adjusting for operating subsidies and indirect taxes
Transport enterprises economic indicators	**Persons employed**	Total number of persons who work in the observation unit, as well as persons who work outside the unit who belong to it and are paid by it
Funding	**Business expenditure on R&D (BERD)**	BERD represents the component of GERD incurred by units belonging to the business enterprise sector. It is the measure of intramural R&D expenditures within the business enterprise sector during a specific reference period
Funding	**Business R&D Intensity**	Total business R&D spending as percentage of Gross Domestic Product (GDP)
Funding	**Total Government Budget Appropriations or Outlays for Research and Development (GBAORD)**	The GBAORD measures the government support for research and development activities. GBAORD include all appropriations given to R&D in central government budgets
Funding	**Total GBAORD as a % of total general government expenditure**	Percentage over government expenditure
Human resources	**Total R&D personnel in business enterprise**	Total number of persons employed in research in a specific sector
Human resources	**Total R&D researchers in business enterprise**	Total number of researchers employed in a specific sector
Innovation engagement	**Innovative enterprises**	Innovative enterprises are those who had innovation activities during the reference period
Innovation engagement	**Product innovative enterprises**	Product innovative enterprises are those who introduced new or significantly improved goods and/or services, during the reference period
Innovation engagement	**Process innovative enterprises**	Process innovative enterprises are those who implemented new or significantly improved production process, distribution method or supplying activity, during the reference period
Innovation engagement	**Organisational innovative enterprises**	Organisational innovation enterprises are those who implemented a new organisational method in the firm's business practices, workplace organisation or external relations, during the reference period
Innovation engagement	**Marketing innovative enterprises**	Marketing innovative enterprises are those who implemented, at least one new marketing concept or strategy that differs significantly from enterprises' existing marketing methods and which has not been used before
Innovation engagement	**Patent applications to the EPO (European Patent Office)**	Patent applications filed directly under the European Patent Convention or to applications filed under the Patent Co-operation Treaty and designated to the EPO

Area of Indicator	Indicator	Description
Innovation engagement	**Public funding in the enterprise**	Enterprises that received public funding for innovation (At different governmental levels: EU, Central Government, local or regional level, etc.), during the reference period
Innovation engagement	**Co-operation with partners**	Enterprise engaged in co-operation, during the reference period
Innovation engagement	**Important barriers to innovation in the enterprises**	Enterprise stating the importance of barriers related to innovation
Innovation engagement	**Environmental benefits due to innovation in the enterprises**	Enterprise stating the importance of environmental benefits due to innovation

Source: Grosso et al. (2018)

4.1 Transport enterprises economic indicators

Various factors define innovation engagement in the transport sector, such as firm and market size, market structure and regulations, etc. Moreover, the characteristics of each transport sub-sector, (i.e. road, rail, waterborne and air transport) play a role in shaping company willingness to innovate (Wiesenthal et al., 2015).

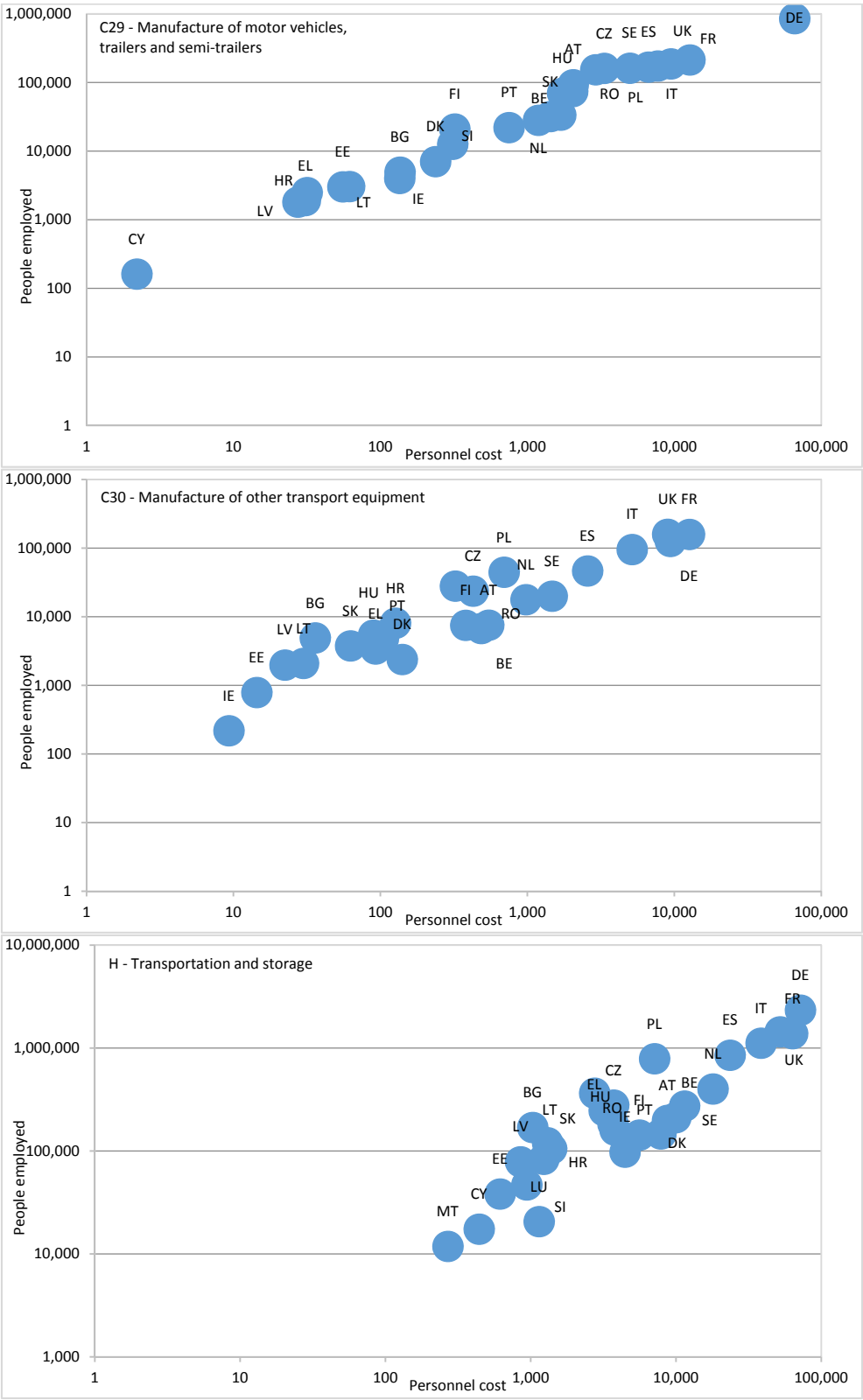
Describing the magnitude of the European transport sector and sub-sectors provide useful information for assessing R&D capacity. A list of economic indicators have been chosen for this purpose, such as the number of enterprises, the turnover, the personnel cost, the value added and the number of people employed.

The last available data is from 2016, when transportation and storage (H) employed almost 5.2% of the total European workforce, equal to around 11.5 million of people. Transport manufacturing activities (C29 and C30) counted more than 3.2 million people[6] working in Europe, in the same period. The cost for personnel[7] employed follows the same pattern, with the transportation and storage (H) having much higher costs than the manufacturing of motor vehicles, trailer and semi-trailers (C29) and the manufacturing of other transport equipment (C30) (see **Figure 1**).

[6] Data missing, in 2016, for: C29 (LU, MT), C30 (LU, MT, SI)

[7] Data missing, in 2016, for: C29 (LU, MT), C30 (LU, MT)

Figure 1 People employed (number of people) and personnel cost, in MSs, (million Euro), in transport related economic activities (2016)



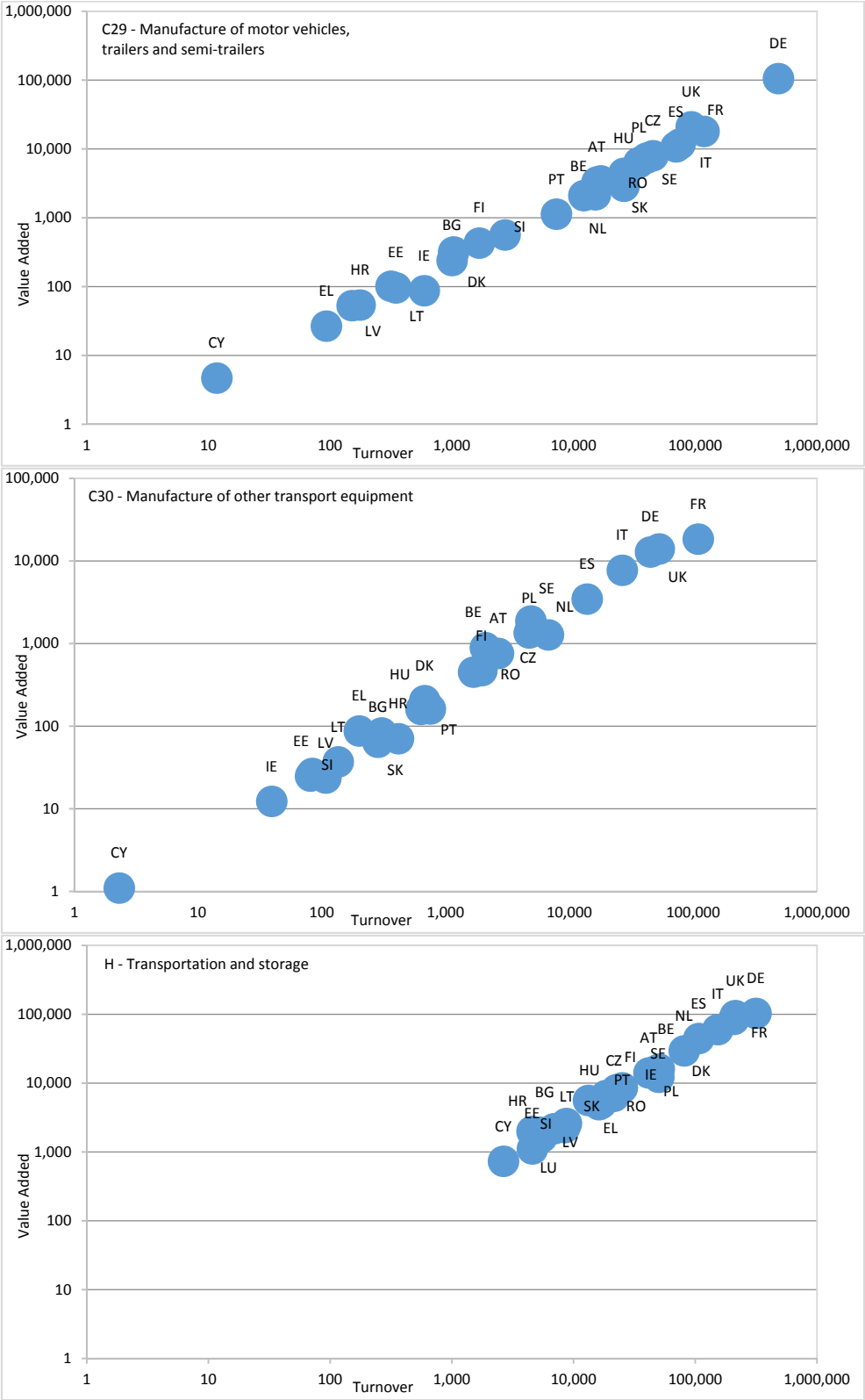
Data source: Eurostat (2016).

The number of enterprises belonging to the transportation and storage activities (H) was higher than the manufacturing one, almost 1,250,000 compared to the 35,000 active in the manufacturing of motor vehicles and other transport equipment[8] (C29 and C30). In contrast, the difference in turnover[9] and the valued-added[10] of the manufacturing and service economic activities (C and H) (see **Figure 2**) is less notable, especially between the automotive industry (C29) and the transportation and storage activities (H). Germany, France, UK and Italy were the MSs with higher turnover and value added created by the overall transport sector.

This information indicates that although the number of enterprises and the personnel employed in the transportation and storage economic activities (H) is much higher than the manufacturing ones (C), the gap between valued added and turnover is less significant between the two subdivisions.

[8] Data missing, in 2016, for: C29 (MT), C30 (MT)
[9] Data missing, in 2016, for: C29 (LU, MT), C30 (LU, MT), H (MT)
[10] Data missing, in 2016, for: C29, C30, (CY, DK, EL, FI, LU, MT, SE, UK), H ((CY, DK, EL, IE, FI, LU, MT, SE, UK)

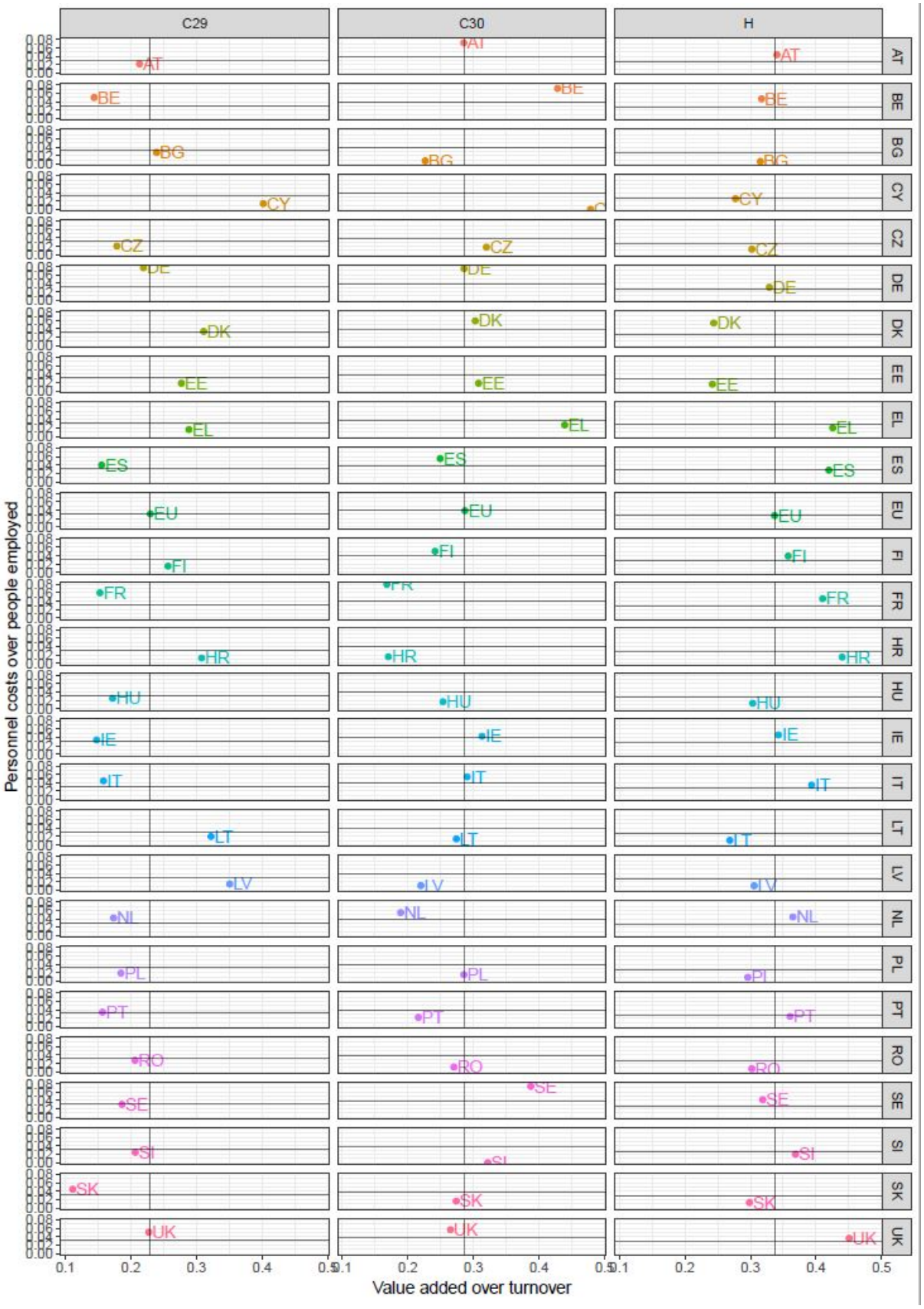
Figure 2 Turnover and value added in transport related economic activities in MSs (million Euro, 2016)



Data source: Eurostat (2016).

These indicators have been clustered for each MS according to personnel costs/people employed and values added/turnover, allowing the comparison of MSs with European average values. **Figure 3** shows how each MSs performs in relation to the European average in each of the transport related economic activities. Personnel costs over the total number of people employed indicates the average personnel cost per person, the value added over the turnover indicates the value of the output produced, less any intermediate consumption, over the transport turnover in each country.

Figure 3 Value added/turnover and personnel cost/people employed in transport related economic activities in MSs (number of people and million Euro, 2016)



Data source: Eurostat (2016).

For these indicators, information is also available for each transport sub-sector, as detailed in the following tables.

Table 2 illustrates data for each transport sub-sector operating in vehicle and equipment manufacturing (C) and highlights the importance of the European automotive industry. These data could be subject to underestimation due to the missing information for some MSs. In 2016, the automotive industry was responsible for 27% of the EU total R&D spending, with a total annual spending of €53.8 billion, and a growth of 7.4% compared to the previous year (ACEA, 2018 based on European Commission, 2018a).

Compared to other transport manufacturing sub-sectors, the number of shipbuilding companies was high, nonetheless the air transport industry employed more workers and the turnover reached almost €150,000 million. The civil aeronautics industry was a major investor in the transport industry (Wiesenthal et al., 2015) and private companies were much engaged in innovation activities, financing two-third of the total R&D investment in 2016 (ASD, 2017).

Table 2 Economic indicators of the transport manufacturing economic activities - C (2016)

Indicators	Manufacture of motor vehicles, trailer and semi-trailers (C29)	Building of ships and boats (C30.1)	Manufacture of railway locomotives and rolling stock (C30.2)	Manufacture of air and spacecraft and related machinery (C30.3)	Manufacture of transport equipment n.e.c. (C30.9)
Turnover (million Euro)	1,082,346	36,627	22,328	147,646	12,974
Personnel cost (million Euro)	125,962	5,269	2,793	28,189	2,000
Value added as a factor of cost (million Euro)	181,373	7,092	3,511	43,401	2,571
Persons employed (number)	2,490,127	168,338	105,580	393,079	63,350
Number of enterprises (number)	20,061	8,306	823	2,071	3,673

Data source: Eurostat (2016).[11]

Table 3 Economic indicators of the transportation and storage economic activities - H (2016)

Indicators	Land transport and transport via pipelines (H49)	Water Transport (H50)	Air transport (H51)	Warehousing and support activities for transportation (H52)	Postal and courier activities (H53)
Turnover (million Euro)	589,000	113,000	143,114	526,480	127,642
Personnel cost (million Euro)	157,611	10,380	23,747	105,107	50,348
Value added as a factor of cost (million Euro)	243,869	21,540	32,262	189,612	60,982
Persons employed (number)	5,831,247	217,570	372,875	2,860,000	1,823,486
Number of enterprises (number)	980,476	21,122	4,830	158,529	80,967

Data source: Eurostat (2016).[12]

In the transportation and storage economic activities, as it can be observed in **Table 3**, land transport had the largest share for all the indicators considered, followed by

[11] Data missing, in 2016, for: Turnover [C29 (LU, MT)]; Personnel cost [C29 (LU, MT), C30.1 (BE, ES, CY, MT, FR), C30.2 (BE, DK, EE, IE, FR, IT, LV, LT, HU, NL, AT, SI, FI, UK), C30.3 (EE, CY, LV, LT, NL, SE), C30.9 (CZ, DE, EE, IE, LT, LU, MT, SI, FI)]; Value added [C29 (CY, DK, EL, FI, LU, MT, SE, UK), C30.1 (BE, BG, ES, CY, MT, FR), C30.2 (BE, DK, EE, IE, FR, IT, LV, LT, HU, NL, AT, SI, FI, UK), C30.3 (BG, EE, CY, LV, LT, NL, SE), C30.9 (CZ, DE, EE, IE, LT, LU, MT, SI, FI)]; Persons employed [C29 (LU, MT)]; Number of enterprises [C29 (MT)].

[12] Data missing, in 2016, for: Personnel cost [H50 (IE, CY, LU, MT, RO), H51 (IE, CY, LU, RO), H52(LU), H53 (LU, MT)]; Value added [H49 (MT), H50 (IE, CY, LU, MT), H51 (IE, CY, LU, MT, RO), H52 (LU, MT), H53 (LU, MT)]; Persons employed [H50 (IE, CY, LU, MT, RO)]; Number of enterprises [H50 (IE, CY, LU), H51 (IE, CY)].

warehousing activities. In employment terms, the land transport services provided work to more than 50% of the people employed in the total sector in almost 80% of the total active firms.

These indicators provide an overview of transport sub-sectors highlighting that major differences exist, which may influence R&D. The market size and the level of competition among companies may act as barriers to innovation. This is the case in transportation and storage (H), where many companies compete to sell homogeneous goods and services and where the profit margin is mainly linked to costs. The situation is different in the automotive industry (C29), where the number of companies is limited, but the level of competition is rather high and is based also on product differentiation. (Hollanders et al., 2008 as cited Wiesenthal et al., 2011)

The differences among transport sectors should be kept in mind while analysing the following R&D indicators.

4.2 Funding

R&D activities need to be supported by financial means, which could be either private or public. The level of investments dedicated to such activities helps to determine the propensity to engage in R&D.

Four main indicators have been identified in this area: Business Expenditure on R&D (BERD), Business R&D Intensity, Government Budget Appropriations for Outlays for Research and Development (GBAORD) and GBAORD as a share of total general government expenditure. The first two indicators refer to business expenditures, hence private outflows, while the last two are related to public funding.

4.2.1 Business R&D expenditure

The OECD definition (OECD/Eurostat, 2005) identifies BERD as the component of Gross Domestic Expenditures on R&D, incurred in the business enterprise sector, namely the transport sector in this report.

The total transport business R&D expenditure in 2015 increased to €42 billion [13] from €30 billion in 2008 (see **Figure 4**). Available data are also present for 2016, nonetheless data quality is low since for many MSs the information is missing, hence 2015[14] has been chosen as reference year. Overall, the transport business R&D expenditure increased during the last eight years by almost 4.5%. In 2009 and 2013 a decrease in expenditure was experienced, in the first case most likely as a consequence of the financial crisis, while in 2013 the overall decrease was mainly due to a reduction in the resources spent in the other transport equipment economic activities, (C30). In 2015, the production of motor vehicles (C29) accounted for almost 75%, equal to €31.4 billion of the total expenditures, the construction of other transport equipment (C30) reached more than 24% or €10 billion, while 1.4% or €0.6 billion of the total transport R&D business expenditure came from transportation and storage (H). The dominance of higher level of funding in manufacturing of motor vehicles (C29) appears constant during the reporting years, compared to the other two economic activities groups considered.

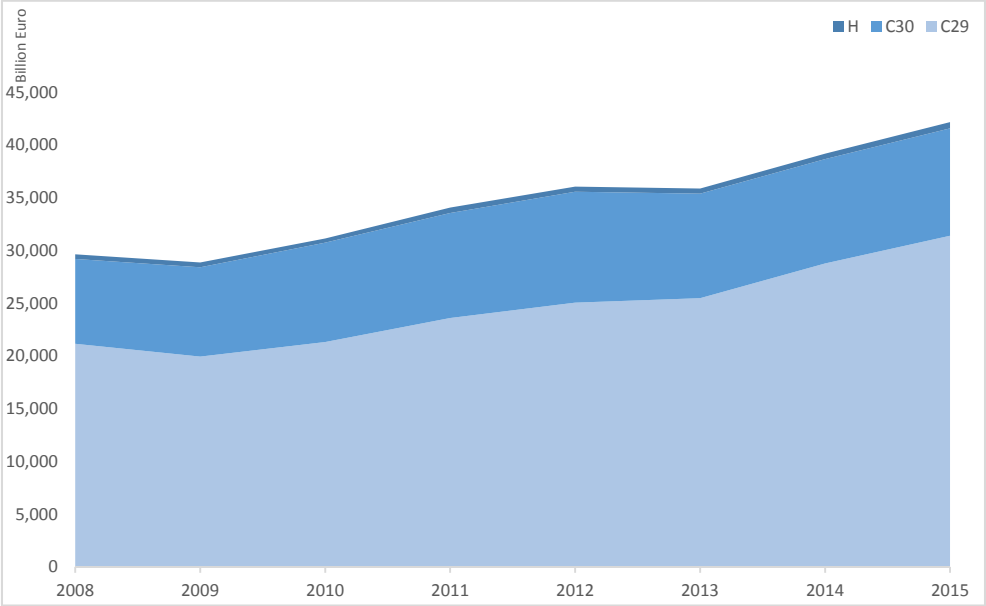
In 2015, Germany was the largest investor, both in the motor vehicles manufacturing (C29) and in transportation and storage (H), accounting for more than 75% and 24% respectively, over the total European R&D private spending. In the industry producing other transport equipment (C30), the country that had the highest private spending in R&D was UK, with 35%, followed by Germany, 32%. In transportation and storage (H), The Netherlands invested 23% over the total European business R&D funding, being the

[13] Based on JRC-TRIMIS elaborations for this report, in Current Euros.

[14] Data missing, in 2015, for: C29 (FR, LU, SE), C30 (EE, EL, FR, LU, LV, SE,), H (EE, FR, LU, LV). For CY all the values were zero, hence it is not represented in Figure 5.

second main investors after Germany. Italy was also among the countries with highest share of private R&D investments across the three different economic activities considered[15].

Figure 4 Business R&D expenditure in transport related economic activities (billion Euro, 2008-2015)



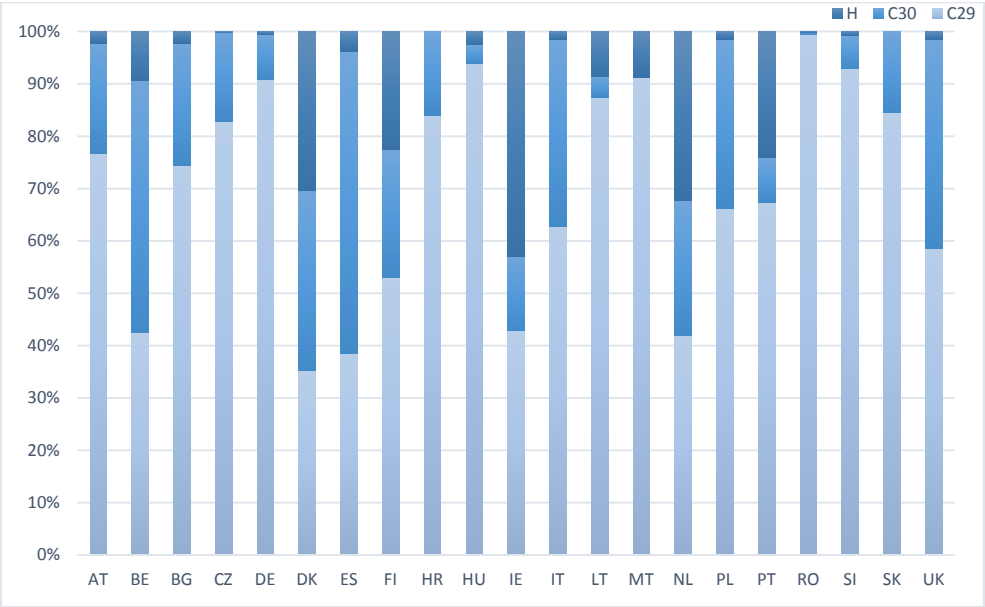
Data source: Eurostat (2015) and own elaboration.

The different levels of private investment, in MSs in 2015, for each of the transport related economic activities, are represented in **Figure 5**.

In 2016 automobiles and other transport activities accounted for 27% of European industry R&D investments, making the transport sector the largest private investor in R&D in Europe. Not surprisingly, the majority of firms producing automobiles and related parts are based in Germany, 21 companies in 2017, among which: Volkswagen, Daimler, Bosch which are moreover the three main investors in the European economy (European Commission, 2018a).

[15] It is important to highlight that for 2015, data for France was not available in none of the three transport sectors considered.

Figure 5 Business R&D expenditure in transport related economic activities in MSs (%, 2015)



Data source: Eurostat (2015).

In 2015, among the other different transport manufacturing sub-sectors, the aviation equipment and components industry was the one with highest amount of expenditures on R&D, almost €5 billion, as shown in **Figure 6**. The UK (€2 billion), Germany (€1.7 billion) and Italy (€0.7 billion) are the largest investors in this sector. Data is missing for France after 2013, until when it was the main investor in Europe in the aviation industry.

The business expenditure for the construction of ships and boats was the highest in the UK, Germany and Italy, confirming the leading roles of the first two countries and showing the increasing spending in the UK which doubled the outlays from €60 million in 2014 to almost €120 million 2015[16].

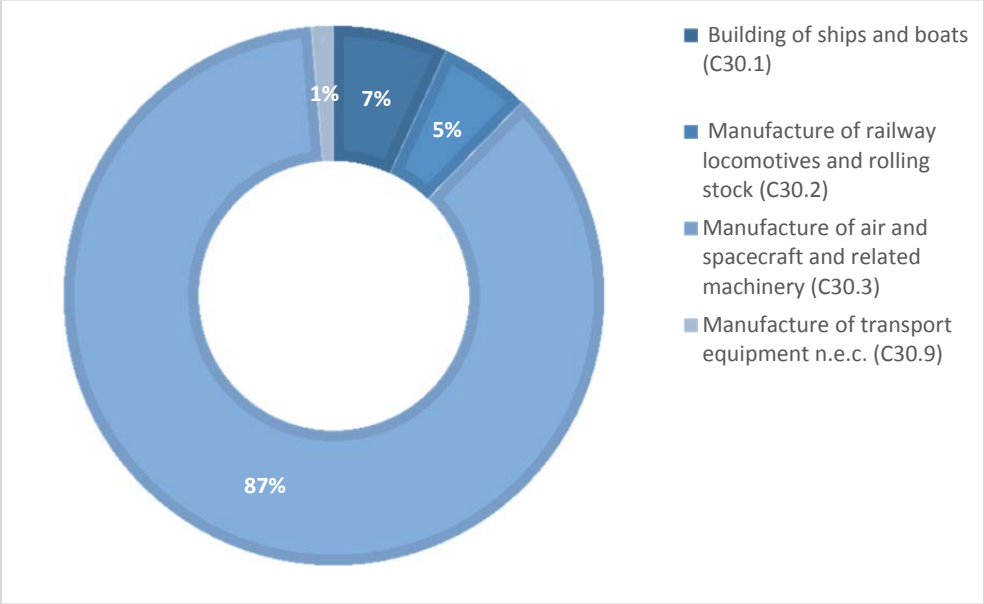
Germany was also the leader in private R&D expenditure in the manufacture of railway locomotives and rolling stock, with more than €150 million spent in 2015. Other major investors in the rail sector were Spain, Czech Republic, the UK and Italy.

The available data about business R&D financing other transport equipment (C30.9) shows that Italy has been the country that invested most in this area, followed by Austria.

The amount of business R&D investment allocated to transportation and storage (H) was considerably lower compared to the manufacturing economic activities (C); within the service activities, the available data indicates that the warehousing and support activities (H52) were the ones that received most of the R&D private funding.

[16] Data is missing, in 2015, for France.

Figure 6 Business R&D expenditure in the other transport equipment economic activities (C30) (%, 2015)



Data source: Eurostat (2015).

4.2.2 Business R&D intensity

R&D intensity is defined as the share of R&D expenditure over the value added created in a certain country. This measurement represents a key innovation indicator and allows the comparison among different countries. As it was highlighted in the European Commission Communication on "Taking stock of the Europe 2020 strategy for smart, sustainable and inclusive growth" R&D is one of the main areas to be addressed in the coming years to support innovation policy strategies and measures. Within the Communication a target related to increase of combined public and private overall investment in R&D has been set, which is 3% of GDP. (European Commission, 2014).

Data from 2015[17]shows that the R&D intensities in the transport manufacturing (C29 and C30) is higher than in transportation and storage (H), following the same pattern as for the business R&D expenditure. R&D intensity in the automotive industry (C29) was at 7.1%, and 8.2% in the area producing other transport equipment (C30). The value was 0.1% in transportation and storage (H). The data is slightly higher than the one in Wiesenthal et al. (2011 and 2015); most likely due to the aggregation of the transport manufacturing sub-sectors, in a single one, C30, which in Wiesenthal et al. (2011 and 2015) were presented separately, due to a different methodology.

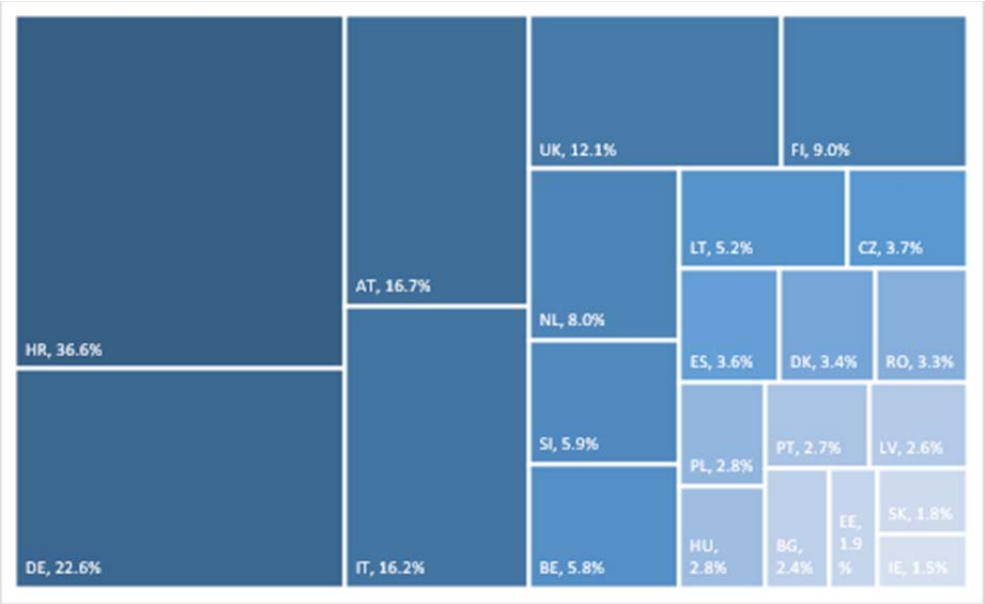
The data presented in Wiesenthal et al. (2015) shows that, in 2011, a clear difference among transport sub-sectors existed, with the automotive manufacturing and the civil aeronautics being the most prone to innovation activities; respectively with R&D intensity equal to 4.8% and 6.5%. The waterborne sector had 4.1% propensity to innovate and the rail sector 3.6%.

The differences among MSs are apparent and are similar to the figures on business expenditure. In 2015, Germany was among the best performers in the overall transport sector, together with Austria, Italy and UK.

[17] Data missing, in 2015, for: C29 (FR, LU, MT, SE), C30 (BE, CY, CZ, EE, EL, FR, LU, LV, MT, SE), H (EE, FR, LU, LV). For CY all the values were zero, hence it is not represented in Figure 7.

Croatia[18], Germany, Austria and Italy were the MSs with the highest automotive (C29) R&D expenditures as a proportion of value added. In 2015, the value for Germany was almost 23%; Austria and Italy had similar values of 16.7% and 16.2% respectively. The automotive industry has become an important manufacturing area also in Central and Eastern European countries, where the growth rate during the last years has shown to be relatively higher compared to Western European countries, as it the case of Poland and Lithuania. (**Figure 7**).

Figure 7 Business R&D intensity in the automotive economic activities (C29), in MSs (%, 2015)

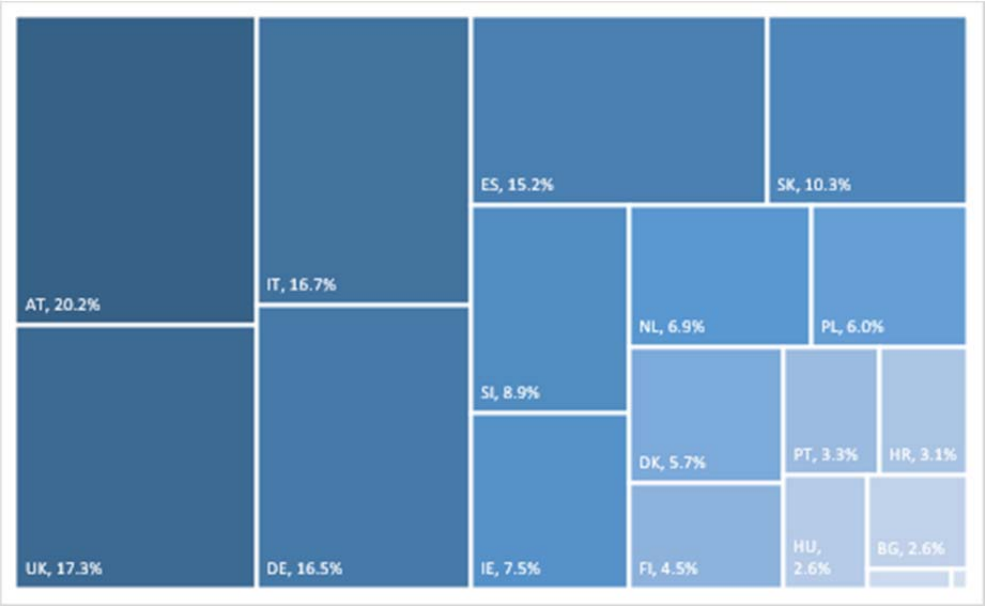


Data source: Eurostat (2015).

With regard to C30 (**Figure 8**), there were similar values for Austria (more than 20%) while UK, Germany, Italy and Spain shown more than 15% of R&D intensity.

[18] Very high level of Business R&D intensity, for Croatia, has been observed, since 2008, in the sector producing motor vehicle manufacturing (C29).

Figure 8 Business R&D intensity in other transport equipment economic activities (C30), in MSs (%, 2015)



Data source: Eurostat (2015).

4.2.3 Government R&D expenditure

Government Budget Appropriations for Outlays for Research and Development (GBAORD) measures government support to R&D, which includes all government spending allocated to R&D from central or provincial government budgets (European Commission, 2019).

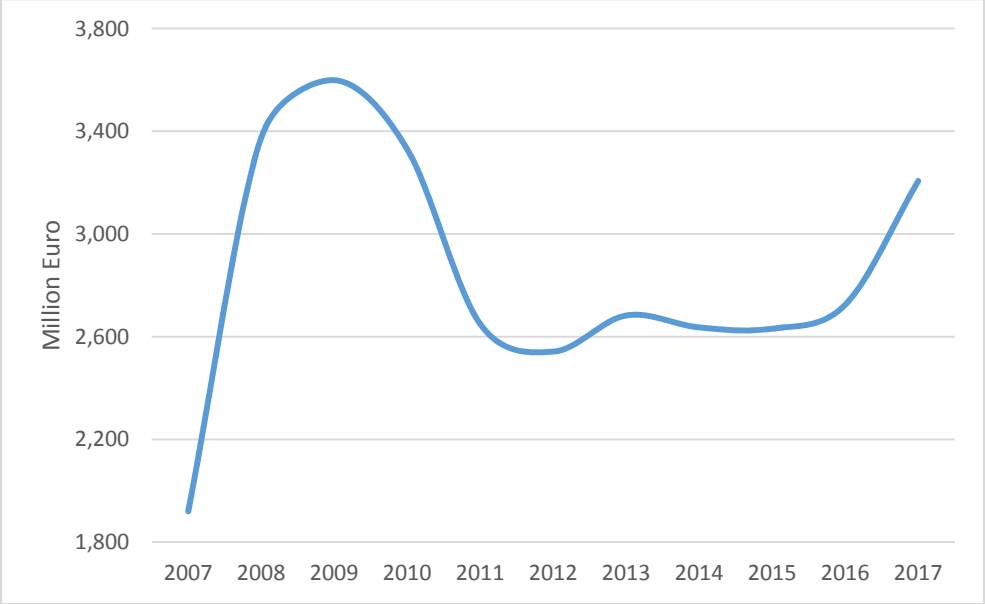
The classification used for calculating GBAORD in Eurostat is based on the NABS 2007 codes. Transport activities fall within the category NABS 04 "Transport, telecommunication and other infrastructures" (see Annex 3). It is important to note that this category includes other non-transport R&D appropriations such as telecommunication systems and water supply, while other NABS categories, as NABS 06 "Industrial production and technology", includes also transport-related activities, as the manufacturing of motor vehicles and other means of transport. This limitation - due to data aggregation - and the fact that this classification does not include information for transport sub-sectors, entails that results could be subject to underestimation.

The GBAORD evolution in the transport sector during the period 2007-2017 indicates a decline in 2010, followed by a relatively stable period until 2016 and an increase in 2017, re-establishing values similar to 2010. The GBAORD decrease experienced in 2010 can be presumably linked to effects produced by the 2009 financial crisis (European Commission, 2011a).

In 2017[19], the total amount of appropriations reached almost €3,300 million (see **Figure 9**). The distribution of GBAORD among MSs shows that almost the entire amount of funding originated from less than half of MSs (see **Figure 10**). In 2017, France accounted for almost 30%, the UK for almost 27% and Germany for 16%. Many MSs did not reach 1% of funding.

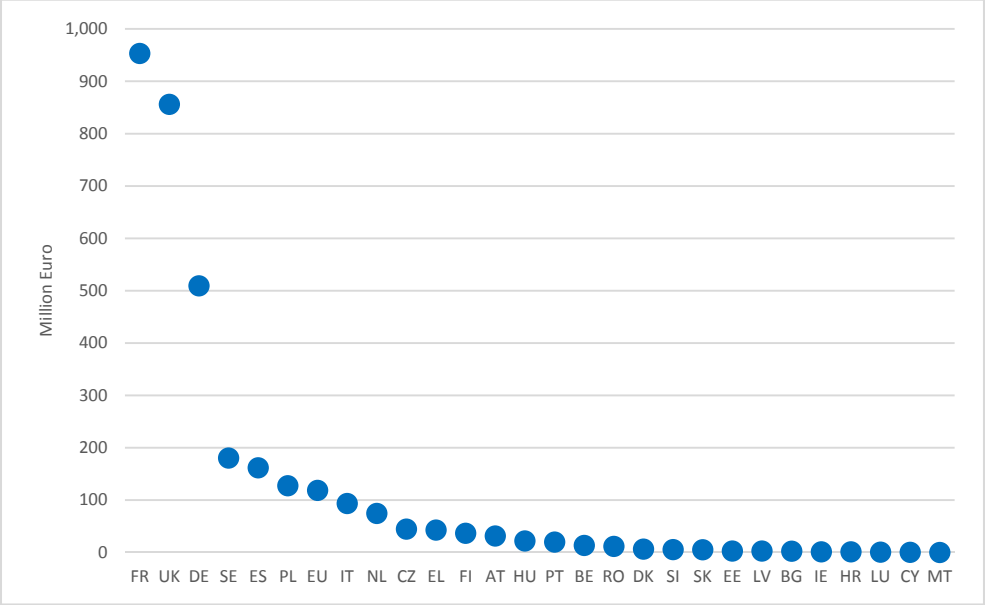
[19] Data missing, in 2017, for: LT; Provisional data, in 2017, for: UK; Estimated data, in 2017, for: DK, SE; Different definition, in 2017, for: AT, FR. Values expressed in Current Euros.

Figure 9 Trend in Transport GBAORD (million Euro, 2007-2017)



Data source: Eurostat (2017).

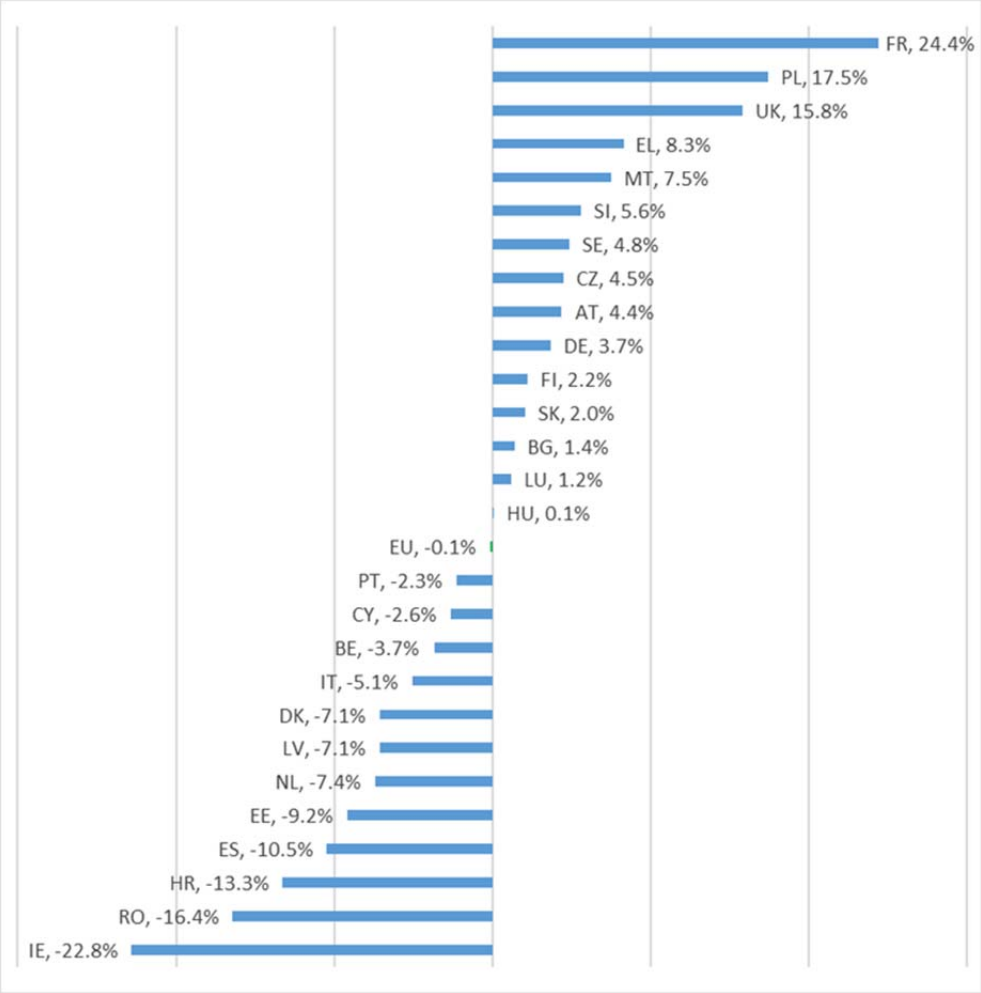
Figure 10 GBAORD in MSs (million Euro, 2017)



Data source: Eurostat (2017).

During the last ten years the average GBAORD annual growth associated to transport varied remarkably among MSs, as shown in **Figure 11**. The highest growth has been experienced by France, followed by Poland and the UK, while decreases were observed in Ireland, Romania and Croatia.

Figure 11 GBAORD Annual growth rate (%, 2007-2017)



Data source: Eurostat (2017).

Data on Governmental R&D funding, both at European and MSs level, allocated to transport sub-sectors is not systematically collected and existing data from available sources is incomplete. Some transport associations produce interesting statistics based on their own data sources, as in the case of the AeroSpace and Defence Industries Association of Europe (ASD, 2017). According to their analysis, the civil aeronautics R&D spending amounted to €10 billion in 2016 and 1/3 of it was financed by governments. Similar information is hard to obtain for the other transport sub-sectors.

Wiesenthal et al., (2011) and Tsamis et al., (2016) estimated the amount of public R&D expenditure through different approaches. They highlighted the possible underestimation due to data gaps. Wiesenthal et al., (2011) used a bottom up approach looking at public R&D investment by transport mode and research area. According to their estimation EU MSs invested at least €3.6 billion in 2008 in transport R&D. In the research developed by Tsamis et al., (2016), the public investment in R&D, has been measured looking at energy-related R&D in the transport sector, hence addressing only a part of the overall spending, counting for €370 million in 2013.

The work conducted in TRIMIS helps to partially overcome this data gap looking at R&D public funds allocated to projects and programmes, according to transport modes and STRIA Roadmaps. The total amount of European contribution, under the Horizon 2020

(H2020) Framework Programme, amounted to €2,400 million, over the entire period[20]. The allocation to the different modes of transport, based on the TRIMIS projects database, shows that road transport received around 36% of the total European funding in the transport sector within H2020. Air transport received 26%, followed by rail and waterborne, which received 9% and 7% respectively. An important share of the funding was received by multimodal projects, 22% of the total amount.

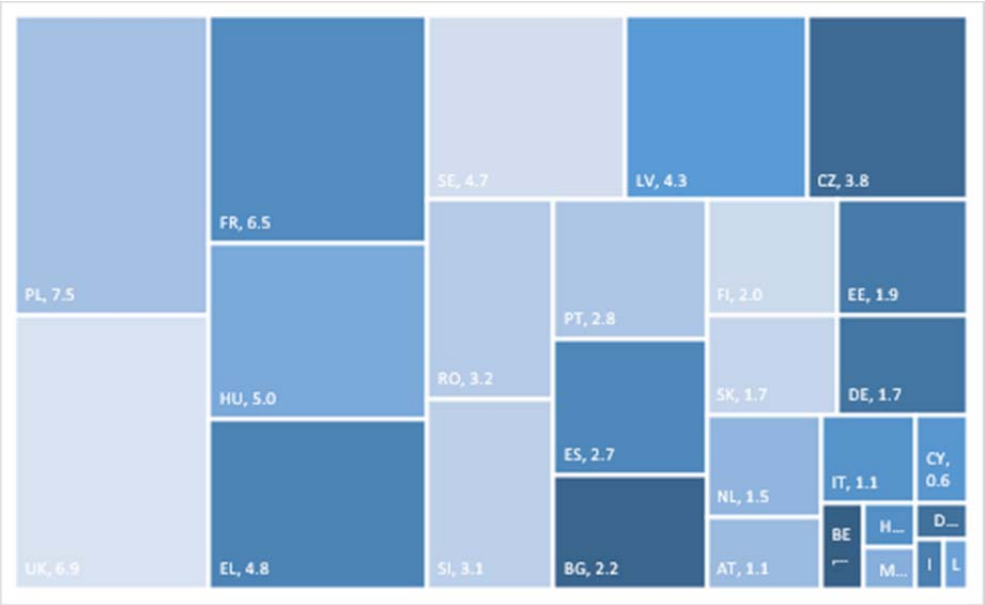
TRIMIS assesses the distribution of European funding among the STRIA roadmaps and additional information on this is available for the roadmaps on Connected and Automated Transport, Smart Mobility and Services and Infrastructure (van Balen et al. 2018a; 2018b; 2019). Still, disaggregated data on national public investment is not systematically collected, resulting in a scattered situation, which hampers a comprehensive analysis.

4.2.4 Transport GBAORD as a share of total R&D government expenditure

This indicator provides information on the share of total government expenditure allocated to transport R&D over the total GBAORD in each MSs. As already stated, this information need to be read cautiously due to its high level of aggregation[21].

For the transport sector, NABS 04, the latest figures[22] provide a clear picture of a heterogeneous situation across Europe. Poland had the highest value, 7.5%, followed by UK and France. Just below the first three countries, Hungary, Greece and Sweden follow with very similar shares ~ 4.8% of governmental expenditure allocated to transport R&D.

Figure 12 Transport GBAORD as a share of total GBAORD in MSs (%, 2017)



Data source: Eurostat (2017).

[20] Data is subject to underestimation considering the framework programme is still on-going

[21] As described earlier in the text NABS 04 "Transport, telecommunication and other infrastructures" includes other non-transport R&D appropriations such as telecommunication systems and water supply, and NABS 06 "Industrial production and technology", includes also transport-related activities, as the manufacturing of motor vehicles and other means of transport.

[22] Data missing, in 2017, for: LT; Provisional data, in 2017, for: UK; Estimated data, in 2017, for: DK, SE; Different definition, in 2017, for: AT, FR.

4.3 Human resources

Highly skilled human resources are fundamental to fostering innovation capacity and competitiveness. This indicator provides an insight on the priority a company or a country gives to R&D and makes a distinction between R&D personnel and researchers.

The OECD definition describes R&D personnel as “all persons employed directly on R&D as well as those providing direct services such as R&D managers, administrators, and clerical staff.”, while researchers are “professionals engaged in the conception or creation of new knowledge, products, processes, methods and systems and also in the management of the projects concerned." (Eurostat based on Frascati Manual, OECD 2002). This differentiation is very important since R&D personnel is needed for R&D related managerial and administrative tasks, as described above, whereas researchers generate knowledge and develop new ideas and products.

R&D personnel employed in all economic activities represented 1.2% of the total labour force in EU-28 in 2015, Denmark being the country with the highest share, 2%, and Cyprus the lowest, 0.3%. Official European statistics show that in 2016, almost half, 49.3%, of the researchers, in any economic area, worked in the business enterprise sector, followed by the higher education sector (38.6%) and the government sector (11.2%) and that almost two thirds (66.4%) of the total number of researchers were men. (European Commission, 2019)

4.3.1 R&D Personnel

R&D personnel is defined by the OECD as the number of people undertaking transport research activities, this includes researchers and other personnel providing direct services, as described above.

For this indicator, official figures are available for 2017 and 2016. Nonetheless the data quality for the last two years is low, although in line with the historical trend, hence 2015 has been chosen as the reference year. In 2015, almost 273,000[23] R&D personnel worked in the European transport sector.

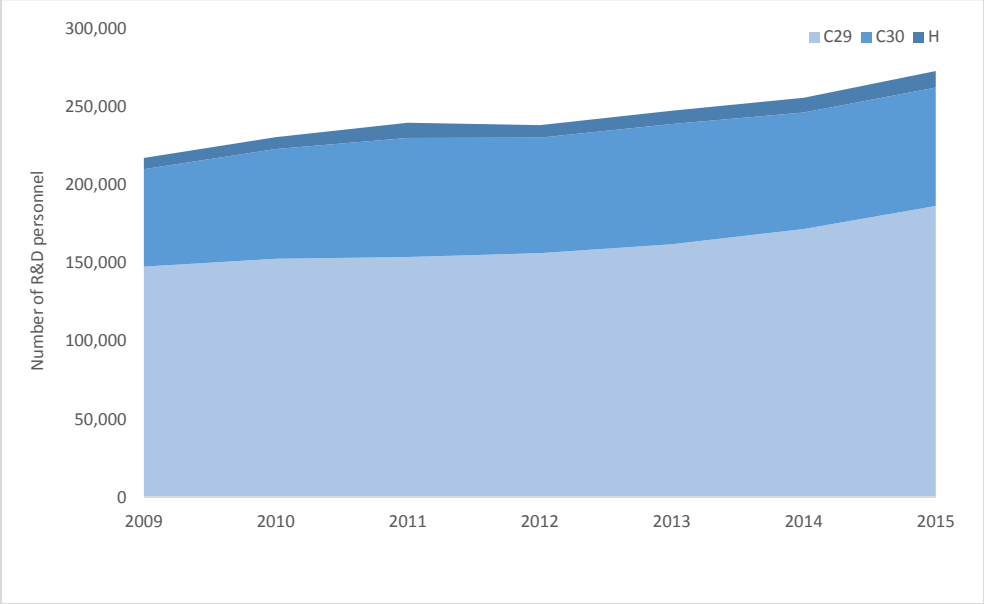
In 2015, the majority of R&D personnel was employed in activities within the automotive industry (C29) with more than 185,000 R&D people. Data shows that R&D personnel in manufacturing of other transport equipment (C30) and transportation and storage (H) were considerably less ~75.000 and ~10.000 people, respectively (**Figure 13**).

At country level, in the total transport sector in 2015[24], the absolute figures show that the highest number of R&D personnel was counted in Germany with more than 128,000 people, followed by the UK with ~33,000, and Italy with ~23,000 respectively.

[23] Based on JRC-TRIMIS elaborations for this report.

[24] Data missing, in 2015, for: C29 (FR), C30 (FR, LU, LV), H (FR, LU). Confidential data, in 2015, for: C29 (LU, SE), C30 (EE, EL, SE), H (DK, EE)

Figure 13 R&D personnel in transport related economic activities (number of people, 2009-2015)



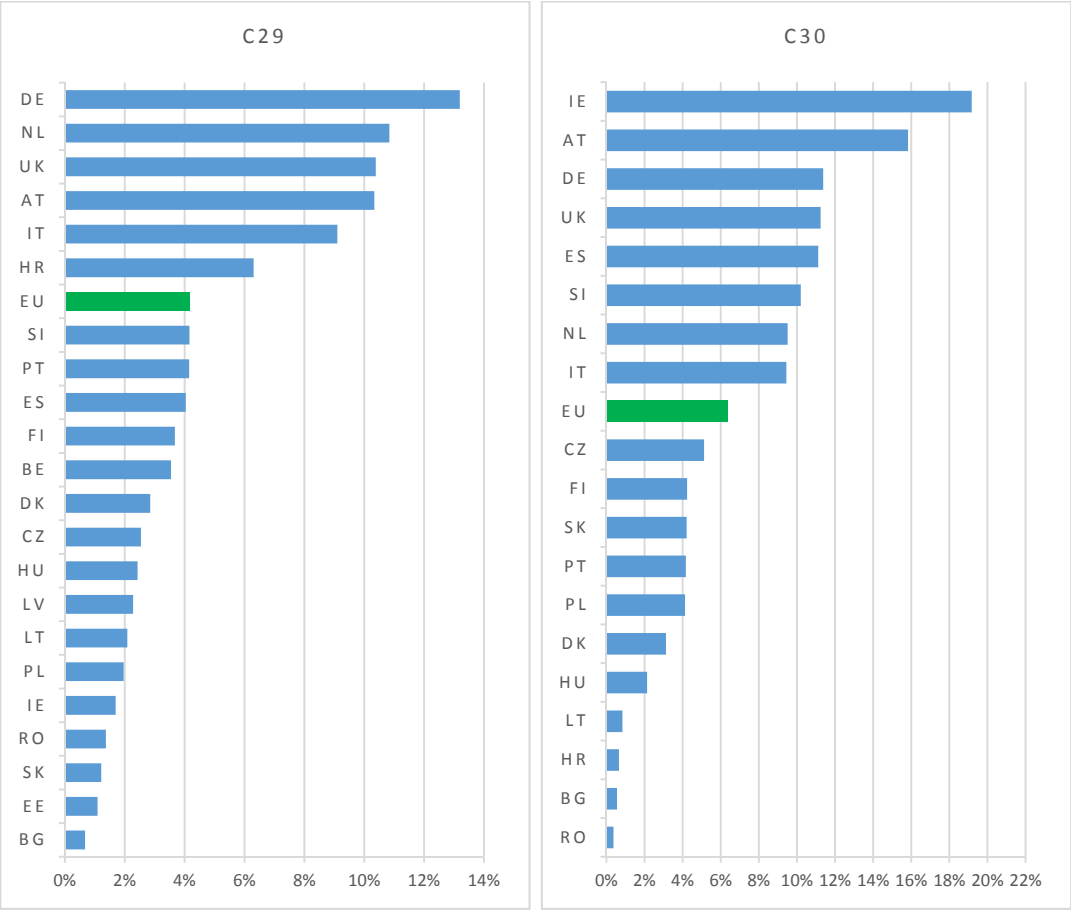
Data source: Eurostat (2015).

The share of R&D personnel in the total transport employment in 2015[25] (**Figure 14**[26]) shows that Austria, Germany, Ireland, Italy, Spain, the Netherlands and the UK had the highest number of transport employees dedicated to R&D activities. 6.4% (EU-average value) of the people working in the production of other transport equipment (C30) were performing R&D activities. This value is lower for the manufacturing of motor vehicles (C29), with a European average of 4.2%. Few R&D personnel worked in transportation and storage (H), specifically 0.1% in 2015 across Europe. In many countries, the share of R&D personnel working in the manufacturing of motor vehicles (C29) and other transport equipment (C30) is similar, for example, for Germany, the UK, the Netherlands and Italy.

[25] Data missing, in 2015, for: C29 (FR, LU, MT, SE), C30 (BE, EE, EL, FR, LU, LV, MT, SE), H (EE, FR, LU, SK)

[26] Data is present only for MSs with values above 0%; the transportation and storage sector (H) is not shown since the values were all aligned at ~0.1%.

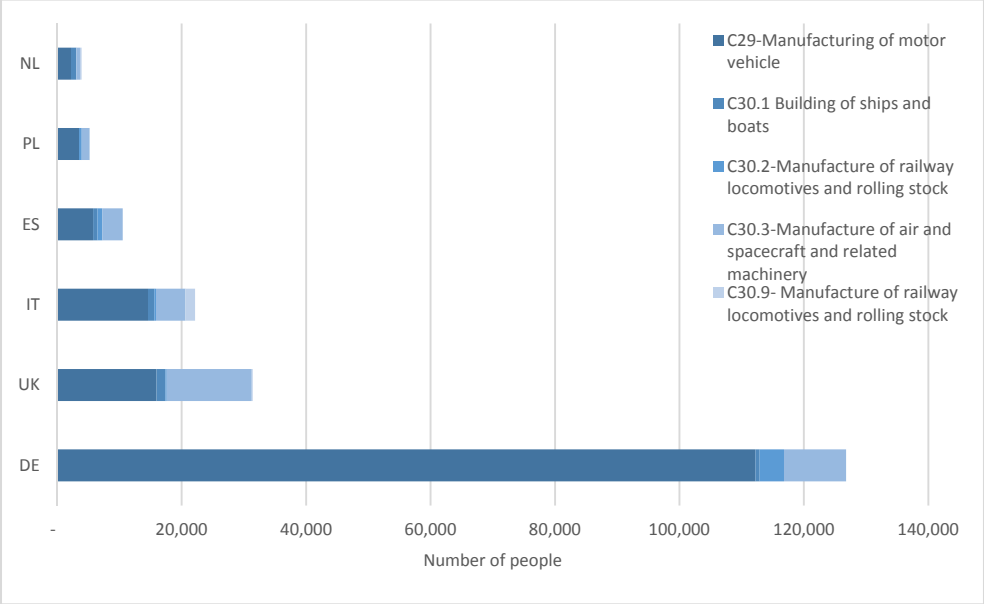
Figure 14 Share of R&D personnel in total transport employment, in the manufacturing economic activities (C29 and C30) (%, 2015)



Data source: Eurostat (2015).

Data for transport sub-sectors is scarce. Nonetheless, for MSs where the data is representative, a sub-split of R&D personnel allocated to the different transport sub-sectors is presented, for the year 2015 in **Figure 15**. In motor vehicle manufacturing (C29) the majority of R&D personnel (almost 66%) is working in Germany. C30.3, producing air and spacecraft machinery, with around 35,000 people is the second after C29 in R&D personnel employment. From the available data, many of these people worked in the UK and Germany. The countries where a significant number of R&D personnel was occupied in building of ships and boats (C30.1) were the UK and Italy; while in the production of rail equipment (C30.2) Germany was leading, followed by Spain, Czech Republic and Poland.

Figure 15 R&D personnel in other transport equipment economic activities (C30) (number of people, 2015)



Data source: Eurostat (2015).

4.3.2 Researchers

Researchers are employed to create new knowledge, products, processes and methods, as well as to manage the R&D projects (European Commission, 2019).

The overall number of researchers increased in Europe during the last decade, from 1.45 million in 2007 up to 1.95 million in 2017[27], with an EU-28 average increase of 33.8%. (European Commission, 2019).

The same trend can be observed in the transport sector. From 2009 until 2016[28], an average increase of around 14% in the number of researchers has been observed in Europe. In 2016[29], there were around 120,000[30] transport researchers in the EU. The majority of these researchers worked in the manufacturing of motor vehicles (C29), around 80%, the manufacturing of other transport equipment (C30) employed almost 20% of them, and only 2% of the total number worked in transportation and storage (H). Among MSs, in 2016, the highest share of transport researchers over the total national figure was observed in Germany, followed by the UK and Italy.

When analysing at MS level, information on gender differentiation among transport researchers is limited. From the most recent available data (2015) a low representation of women in transport R&D is observed, not showing any relevant differentiation among transport sub-sectors, nor at country level.

[27] Researchers measured in full-time equivalents, Provisional data for 2017

[28] Researchers measured in full-time equivalents, Last available comprehensive data are from 2016 and low quality data are available before 2009

[29] Data missing, in 2016, for: C29 (BE, IE, EL, FR, LU, AT, SE), C30 (BE, EE, IE, EL, FR, LT, LU, AT, SE), H (BE, EE, IE, EL, FR, LU, HU, AT, SE)

[30] Researchers measured in full-time equivalents

4.4 Innovation engagement

This section illustrates the level of innovation engagement of European transport companies. The analysis is developed looking at some key indicators linked to the type of innovations introduced in the business activities, the financial support received, the level of innovation cooperation and their patenting activities. The last part of the chapter is dedicated to the factors that hamper or foster innovation activities.

The information presented is mainly based on CIS survey data (CIS 2016[31] and CIS 2014), that refers respectively to the period 2014-2016 and 2012-2014.

4.4.1 Innovative enterprises

An important indicator of the level of engagement of private companies in research activities is provided by the number of companies that have declared to have undertaken innovation activities in a specific time period. The innovation activities could be successful, on-going or abandoned, as defined in Eurostat (European Commission, 2019). This specification highlights the propensity of these firms to engage in R&D activities, regardless the positive outcomes of the initiatives undertaken.

Between 2014 and 2016, more than 59% of companies working in the manufacturing of transport parts and components (C29 and C30) declared to have undertaken innovation activities. The share was lower in the transportation and storage economic activities (H), reaching nearly 34% of the companies interviewed[32] (see **Figure 16**). The comparison with the previous edition of the survey, covering the period 2012-2014, shows that a general increase has been observed for each of the transport economic activities considered. In the previous biennium of analysis, around 53% of both the interviewed companies producing motor vehicles (C29) and other transport equipment (C30) declared to have either introduced an innovation or have any kind of innovation activity. The positive trend was observed also in the case of transportation and storage services (H), from 31% up to 34%.

Based on the survey results, it appears that a good majority of companies belonging to the vehicle manufacturing activities (C29) have introduced innovation activities, namely in Finland, Austria and Belgium. All the interviewed Austrian companies producing other transport equipment (C30) declared to have introduced innovations, followed by 86.7% of the Portuguese ones. As already pointed out, the share of innovative companies in transportation and storage (H) is on average lower compared to the other two industries. In some countries, though, the share of companies declaring to have been innovative was relatively higher, as in Luxembourg, Portugal, Belgium and Germany.

[31] The results of the CIS 2016 survey have been released in February 2019 and at the moment of writing this report no metadata is available. It has been assumed that the methodology used is the same as for CIS 2014 survey and the analysis hereafter illustrated is developed accordingly.

[32] Data missing for: C29 (CY, LU, MT, NL, SI), C30 (CY, LU, MT, NL, SI)

Figure 16 Innovative enterprises in transport related economic activities in MSs (%, 2014-2016)

Data source: CIS Survey (2016).

Figure 16 provides insightful information on the declared innovation engagement of transport companies in MSs, showing the propensity to innovate at country level. Regardless of the official statistics showed earlier on private or public funding, as presented in 4.2, the information provided in this table shows the engagement in R&D activities in the transport field, also in countries where the level of investment was not particularly high, such as in Portugal, Lithuania, and Estonia.

4.4.2 Innovation types

Companies can introduce different types of innovation in their business, which can be related to the good or service they produce, to the production process, to the business organisation and to their marketing strategies.

This section provides information on the typologies of innovation introduced by transportation firms, according to the responses provided in the CIS 2016 survey. Although the results are based on a sample of European companies, the information provided are useful indicators to understand in which innovation activities companies were engaged[33].

[33] Data missing for Product innovation in: C29 (BE, BG, CY, EL, HR, LU, MT, NL, RO, SE), C30 (BE, BG, CY, EL, IE, LU, MT, NL, SE, SI), H (SE, SI); Process innovation in: C29 (BG, CY, EL, LU, MT, NL, RO, SE, SI), C30 (BE, BG, CY, EL, IE, LU, LV, MT, NL, RO, SE, UK), H (SE, SI); Organizational innovation in: C29 (BG, CY, EL, LU, MT, NL, RO, SE, SI), C30 (BE, BG, CY, EL, IE, LU, MT, NL, RO, SE, SI); Marketing innovation in: C29 (BE, BG, CY, EL, FR, HR, IE, LU, MT,

Figure 17 presents the CIS 2016 survey results with a focus on the three transport economic activities groups C29, C30 and H, looking at product innovations, process innovations, organisational and marketing innovations. However, data is incomplete and can influences the results of the analysis.

The innovation introduced on the *product* will significantly change the good or service manufactured, by mean of improvements of its characteristics or usage. The product may change in relation to technical specifications, components and materials, incorporated software, etc.

In CIS 2016, among the transport companies interviewed, a small number declared to have developed a product innovation. On average, 12%, of companies in the automotive industry (C29) had innovative products, a slightly higher share, 13.6%, was observed in the transport equipment (C30). New products were introduced just by the 3.5% of the companies working in transportation and storage (H).

In the automotive industry (C29), the UK, Slovenia, Estonia and Hungary were the countries with most product innovative companies. A higher share of German, Austrian and Finnish companies declared to have introduced innovative product in the manufacturing of other transport equipment (C30). In transportation and storage (H) only the UK with 12.2% and Portugal with 9.2% had a relatively high share of product innovative companies.

When talking about *process innovation* the novelty is introduced in the method used for producing or delivering goods or services. The changes can be introduced through new techniques, new equipment or software.

In the transport sector, the share of companies stating to have introduced process innovation between 2014 and 2016 was rather low, similarly to what was observed for product innovations. The European average value for the automotive industry (C29) was somewhat higher, 13.3%, compared to the industry producing other transport equipment (C30) which equals to 9.6%, and to the transportation and storage one (H), 10.8%. The difference observed in the transportation and storage activities (H) is remarkable, in which few companies declared to have introduced new products, while a relatively high number of companies had new production processes.

In relation to the manufacturing of other motor vehicles, (C29) Finland and Estonia had a higher number of companies that developed process innovations, when compared to the European average. Slovakia and Estonia scored best in the number of companies that introduced process innovations in manufacturing other transport equipment (C30). Estonia, Portugal, the Netherlands and Luxembourg were the countries with highest number of companies introducing this type of innovative activity in transportation and storage (H).

Introducing an *organisational innovation* in a company means to implement a new organisational method, a new workplace structure or to introduce a new method for external relations.

According to the available data of CIS 2016 survey, it appears that this type of innovation was relatively more common among transport companies, mainly the ones in the manufacturing industry; almost 24% of companies producing motor vehicles (C29) and almost 19% of the ones producing other transport equipment (C30) were involved in the implementation of this type of innovation. In transportation and storage (H), the share was lower, 10.4%. Austrian companies were the ones scoring highest, with more than half of companies in transport manufacturing (C29 and C30) having undertaken this type of innovation.

NL, RO, SE, SI, UK), C30 (BE, BG, CY, EL, FR, IE, LU, LV, MT, NL, RO, SE, UK). SI is not represented in the **Figure 17** since the available data was equal to 0.

A *marketing innovation* is introduced when a new marketing method is developed, entailing a significant change in the product design or packaging, in its placement, promotion or pricing.

Not many transport companies declared to have developed marketing innovations. The average value across the transport sector was 6.7%, with similar values for the transport manufacturing industry (C29 and C30) and even less presence in the transport service area, 4.5%.

Figure 17 Types of innovations implemented in transport related economic activities in MSs (%, 2014-2016)

Data source: CIS Survey (2016).

4.4.3 Public financial support

The sample of companies participating in the CIS 2016 survey was asked if they received public financial support for innovation activities. The funds could be European, national, regional or local and granted in various ways (e.g. tax credits or deductions, grants, subsidised loans and loan guarantees).

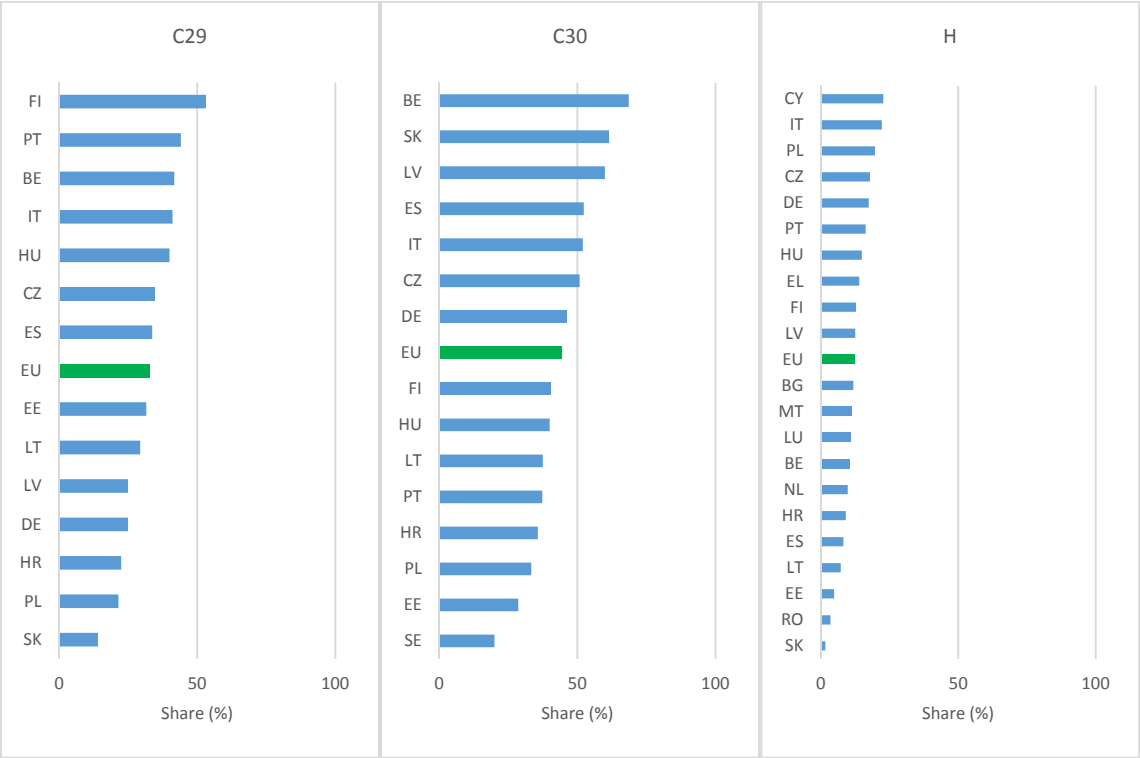
The number of MSs answering this question in transport manufacturing (C29 and C30) was low, higher response rate was observed for transportation and storage (H).

During the period 2014-2016[34], on average in Europe, 44.3% of companies working in the industry producing other transport equipment (C30) received public financing support. The shares of Belgian, Slovakian and Latvian companies that declared to have benefited by this financial support were the highest in Europe.

According to the survey results, the number of companies that received public financing in the automotive industry, (C29) was lower, with a European average value of 32.7%. In this industry, Finland was the MS with the highest share.

The number of companies working in the transportation and storage activities (H) that received public funding was much lower, only 12% on average in Europe (see **Figure 18**).

Figure 18 Public financial support in transport related economic activities in MSs (%, 2014-2016)



Data source: CIS Survey (2016).

When comparing the results of CIS 2016 with the previous edition, CIS 2014, a general decline can be observed for the industry producing motor vehicle (C29) and for transportation and storage (H). On the contrary, from 2014, the number of companies

[34] Data missing for: C29 (AT, BG, CY, DK, EL, FR, IE, LU, MT, NL, RO, SE, SI, UK), C30 (AT, BG, CY, DK, EL, FR, IE, LU, MT, NL, RO, SI, UK), H (AT, DK, FR, IE, SE, SI, UK)

producing other transport equipment (C30) that received public funding showed a slightly increase from 42% to 44.3%.

4.4.4 Cooperation with partners

Cooperation with partners can be a main driver for business innovation. The benefits that cooperation can bring are several, such as improvement of economic performance and efficiency, cost reduction, access to additional resources or new markets, to name a few.

The CIS 2016 survey aimed to capture innovation activities developed in cooperation with other enterprises or organisations. Companies can engage in cooperation with other private firms, within the sector, with suppliers or clients, with universities or governmental bodies, at local, national, European and international level. In this analysis, all the aforementioned typologies of collaboration are considered.

Overall, the declared level of cooperation for companies within the transport manufacturing (C29 and C30) is higher than for the transportation and storage one (H)[35]. Data from CIS 2016 show that the average share of cooperation among automotive firms (C29) in Europe was around 49%, and the value for the manufacturing of other transport equipment (C30) was slightly below, 48%. The level of cooperation declared by the firms working in transportation and storage (H) was relatively low (28.8%) (see **Figure 19**). However, data from some MSs is missing, especially in the economic activities C29 and C30.

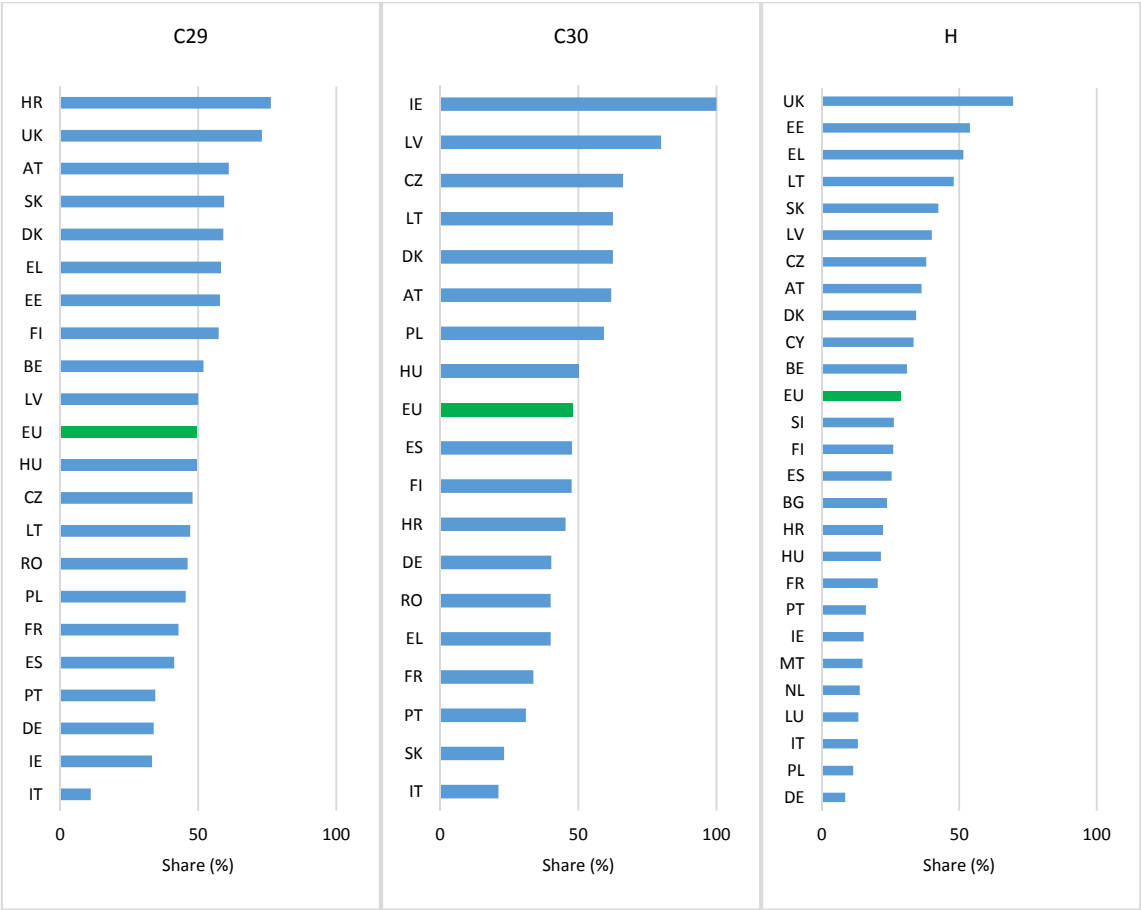
The highest level of cooperation within the motor vehicle manufacturing activities (C29), was declared in Croatia and the UK. In the manufacturing of other transport equipment[36] (C30) the level of cooperation was the highest in companies based in Ireland, Latvia, Czech Republic, Lithuania and Denmark. In the transportation and storage activities (H) the UK, Estonia and Greece were the countries with the highest levels of cooperation with partners.

Many of the MSs that indicated high levels of cooperation, as shown in **Figure 19**, are the same that had scarce business funding allocated to transport R&D. (See 4.2) The lack of funding combined with small company size, could be among the reasons for developing more cooperation, as already pointed out in Tsamis et al., 2016.

[35] Data missing for: C29 (BG, CY, LU, MT, NL, SE, SI), C30 (BE, BG, CY, EE, LU, MT, NL, SE, SI, UK), H (RO, SE)

[36] In the case of Ireland, the total number of companies interviewed declared to cooperate.

Figure 19 Co-operation in transport related economic activities in MSs (%, 2014-2016)



Data source: CIS Survey (2016).

4.4.5 Patents

Once innovations are produced within a firm, it is important to protect them with intellectual property rights. Patents recognise the right to the inventor, who could be a natural person or a legal entity. The purpose of patents is to: *"…protect the interests of inventors whose technologies are truly ground breaking and commercially successful, by ensuring that an inventor can control the commercial use of their invention"* (WIPO, 2018).

Nevertheless, patents are one possible way to protect innovation ideas over time in a specific area or region. Other intellectual property rights are: copyrights, design rights, trademarks and trade secrets which protects goods or services (e.g. artistic expressions, shape and form of products, know-how, etc.).

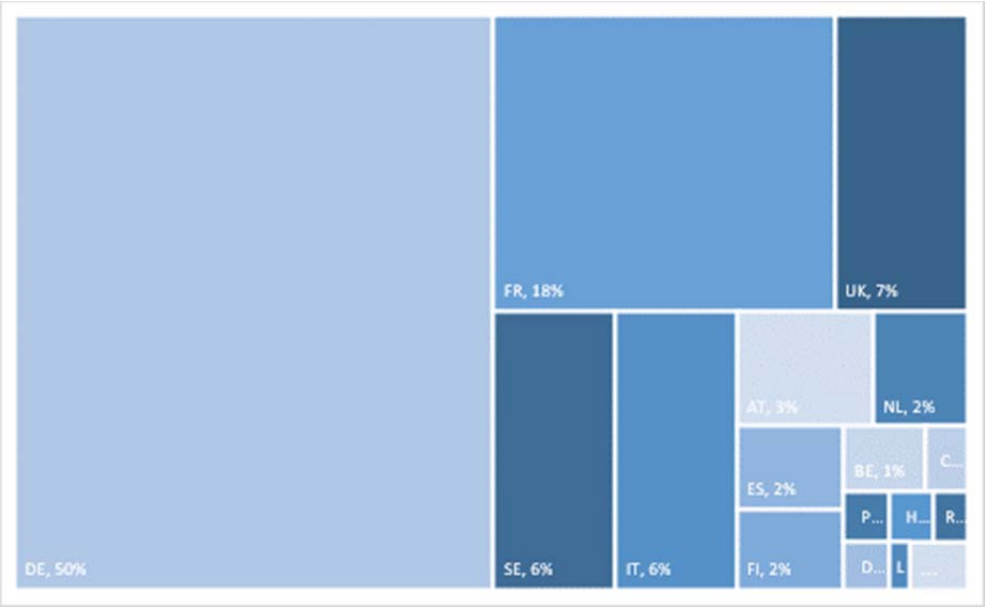
In this report, patent applications to the European Patent Office (EPO) are considered for the automotive industry (C29) and for the manufacturing of other transport equipment, (C30)[37]. Given that the last available data, from 2013, is all provisional (European Commission, 2019), data from 2012 is used here.

In 2012, almost 3,250 patents applications were submitted by the automotive industry (C29), and 1,090 by the other transport equipment manufacturing (C30). German and French companies led patenting activities, in these two economic activities. In 2012, half

[37] No data is available for the transport service (H). Data missing, in 2012, for: C29 (HR, LT, LV MT), C30 (CY, EE, LT, MT, RO)

of automotive (C29) patents applications originated from Germany and 18.5% from France, followed by the UK, Sweden and Italy. The provisional data from 2013 follow the same pattern (**Figure 20**).

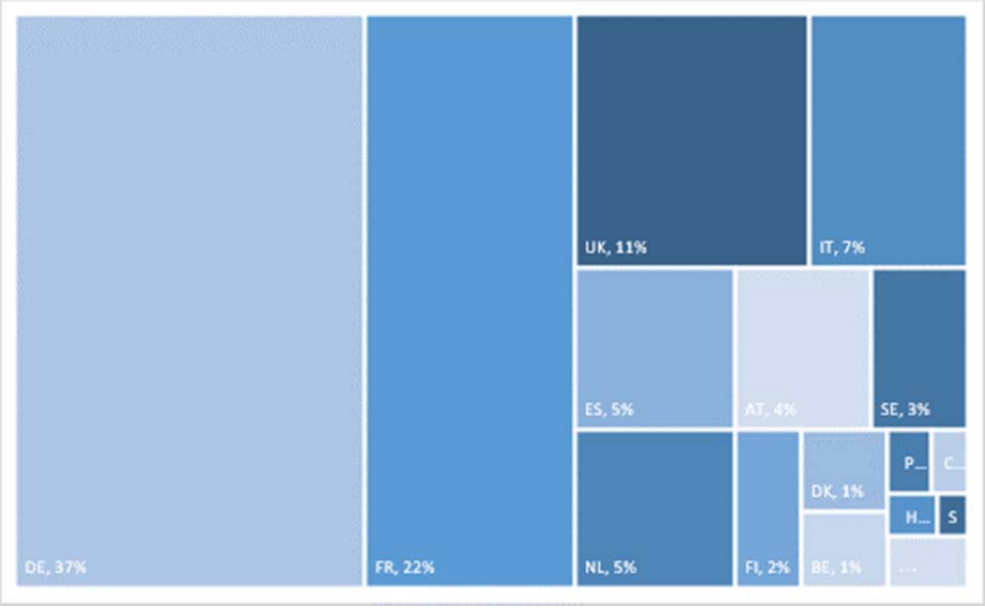
Figure 20 Patents applications in the automotive economic activities (C29) (%, 2012)



Data source: Eurostat (2012).

The importance of Germany is clear also when it comes to the production of rail, maritime and air equipment (C30), although the share was lower, at 37%, than in the automotive industry. France had a high number of patents applications in this area, 22% of the total European number, followed by the UK, Italy, Spain and the Netherlands (see **Figure 21**).

Figure 21 Patents applications in the other transport equipment economic activities (C30) (%, 2012)



Data source: Eurostat (2012).

When looking at these two manufacturing areas in the last years a general pattern can be observed from 2004 onwards: in the case of patents linked to the production of motor vehicles (C29), the overall number decreased, while patents associated to the manufacturing of other transport equipment (C30) increased[38,39].

4.4.6 Barriers to and benefits of innovations

Understanding the main factors that hamper or foster enterprises to innovate helps identifying possible measures and actions that could support innovation engagement. A list of possible barriers to innovation has been identified in the CIS 2016 survey and an in depth analysis of the outcome for the transport sector is provided hereafter.

The factors hampering innovation activities have been grouped for the purpose of this report in three main thematic areas: barriers related to funding and costs, to market structure and to presence of qualified personnel. The analysis takes into consideration companies that declared these factors having high importance in hampering their innovation activities.

Among possible benefits, a link between environment and innovation has been observed and analysed for the transport sector.

4.4.6.1 Lack of funding and company costs

Lack of innovation activities can be linked to shortage of financial means, which can be either allocated from companies' internal budget or obtained through private or public external support.

Lack of internal finance[40] has been found as one of the major barriers among transport companies. On average, 22.3% of European transport companies declared that lack of internal finance would hamper their innovation engagement. The highest share was observed in the other transport equipment manufacturing (C30), 27%, followed by the automotive industry (C29), 21%, and by transportation and storage (H), 19.3%.

Greek companies were among the MSs with highest number of companies stating that lack of internal finance prevented innovation activities, mainly in automotive activities (C29) and in transportation and storage (H). In Croatia, 56% of companies producing other transport equipment (C30) indicated the lack of internal finance as highly relevant in preventing them to innovate.

The difficulty to obtain *public grants and subsidies*[41] in the form of grants, loans, tax deductions, etc., was also identified as an important barrier, mainly in the industry producing other transport equipment (C30), with an average European value of 26%. Both in the manufacturing of motor vehicles (C29) and in transportation and storage (H), the share of companies expressing this concern was above 18%.

External financing[42] (i.e. credit or private equity) has been recognised as a hampering factor to innovation by 15% of the European transport companies interviewed in the CIS

[38] The annual growth rate varies according to the years considered. For the period 2004-2012, the European average annual growth rate for C29 was -1.9% and for C30 was +4.5%.

[39] For the patents granted by the United States Patent and Trademark Office (USPTO) in the last available years, 2009 and 2010, a similar distribution was observed. The highest number of authorised patents in the automotive industry (C29) was granted in Germany, with more than 65% of the total number of European patents. With regard to production of other transport equipment (C30), France, Germany and the UK accounted for almost 80% of the European patents granted in 2010.

[40] Data missing, for: C29 (BE, BG, CY, ES, LU, MT, SI), C30 (BE, BG, CY, ES, LU, MT, SI), H (ES)

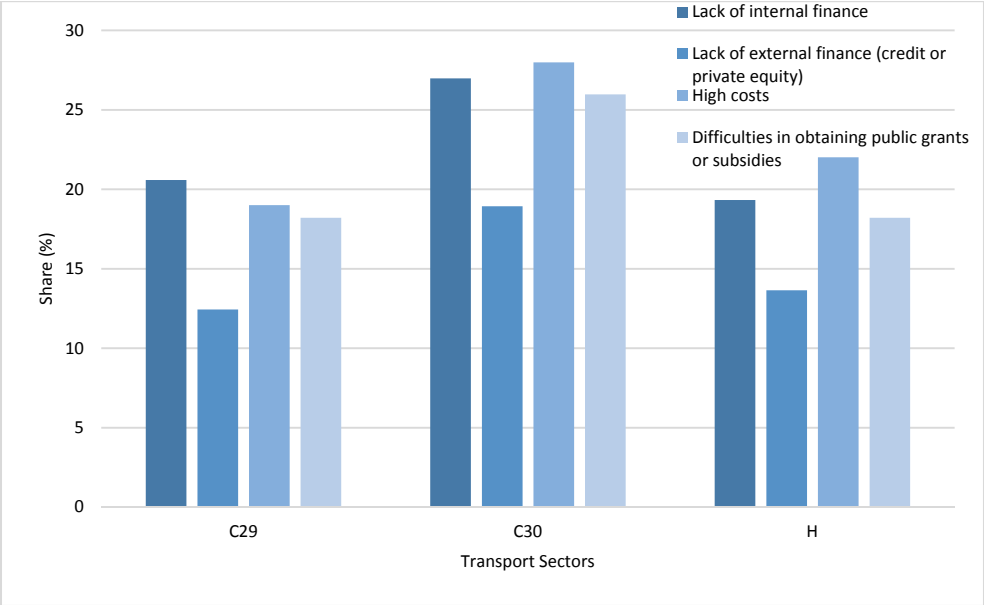
[41] Data missing, for: C29 (BE, BG, CY, EL, ES, FI, FR, LU, MT, RO, SI), C30 (BE, BG, CY, ES, FR, LU, MT, RO, SI), H (ES, FR)

[42] Data missing, for: C29 (BE, CY, CZ, EL, ES, FI, LU, LV, MT, RO, SI), C30 (BE, CY, CZ, EL, ES, HU, LU, MT, RO, SI), H (CZ, ES)

2016 survey. The highest value was observed for C30, producing other transport equipment, 19% of the total number of interviewed companies. For this area (C30) half of the Lithuanian companies identified this barrier as highly relevant in preventing them to innovate.

To conclude, the economical barrier that is perceived as one of the most challenging is the *high level of costs* [43] of performing innovation activities (**Figure 22**). In this case 28% of companies in the area producing other transport equipment (C30) and 22% of the ones in transportation and storage (H) consider this element of high importance. In the automotive economic activities (C29) the average European value was 19%. Relatively high shares of companies concerned about this hampering factor were located in Slovakia and Latvia.

Figure 22 Share of enterprises indicating that lack of funding and companies' costs are important barrier for innovating, in transport related economic activities (%, 2014-2016)



Data source: CIS Survey (2016).

4.4.6.2 Market structure

Market dynamics influence companies' strategies, hence also the choice to engage in innovation activities. Goods and services demand, competition in a market segment and the degree of collaboration with business partners are among the relevant innovation barriers.

These three aspects have been investigated in CIS 2016 survey and the answers received by transport companies are summarised hereafter (**Figure 23**).

High competition[44] seems to affect more companies in transportation and storage (H), almost 23%, rather than in the manufacturing industry (C29 and C30), where the average European value represents ~15% of the companies in the area.

The risk of uncertainty associated to *market demand*[45] is perceived as one important reason preventing transport companies to engage in innovation activities. This barrier is

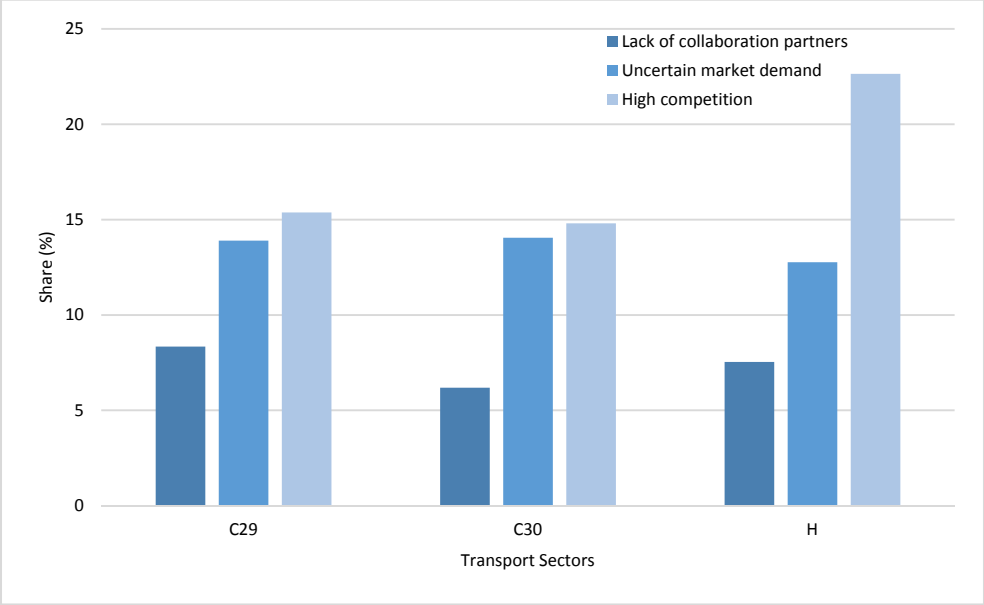
[43] Data missing, for: C29 (BG, CY, CZ, EL, ES, LU, MT, RO, SI), C30 (BE, BG, CY, CZ, EL, ES, LU, MT, SI), H (CZ, ES)
[44] Data missing, for: C29 (BE, BG, CY, CZ, EL, ES, LU, MT, RO, SI), C30 (BE, BG, CY, CZ, EL, ES, FR, LU, MT, RO, SI), H (CZ, ES)

felt as an important one by all the transport companies interviewed, regardless their business specialisation, with an average European share of around 14%.

Lack of collaboration[46] with partners could also compromise the degree of business innovation. Those enterprises that were most concerned about not having enough collaboration with partners were the ones in the automotive industry (C29), 8%, followed by transportation and storage (H) with 7.5% of companies making this statement. A smaller number of companies, 6%, producing other transport equipment (C30) in Europe, considered this as a high barrier for developing innovations.

Unfortunately, the scarce number of answers to this question entails a low representativeness of the results.

Figure 23 Share of enterprises indicating that market elements are important barrier for innovating, in transport related economic activities (%, 2014-2016)



Data source: CIS Survey (2016).

4.4.6.3 Lack of qualified employees

Research activities are carried out by people that need to be knowledgeable and highly qualified, hence their shortage could be a potential risk in performing innovation activities.

This factor has been identified in CIS 2016 survey[47] and recognised as relevant by on average 21% of European companies working in the automotive industry (C29) 16% of the ones in the manufacturing of other transport equipment (C30) and 15% in transportation and storage (H).

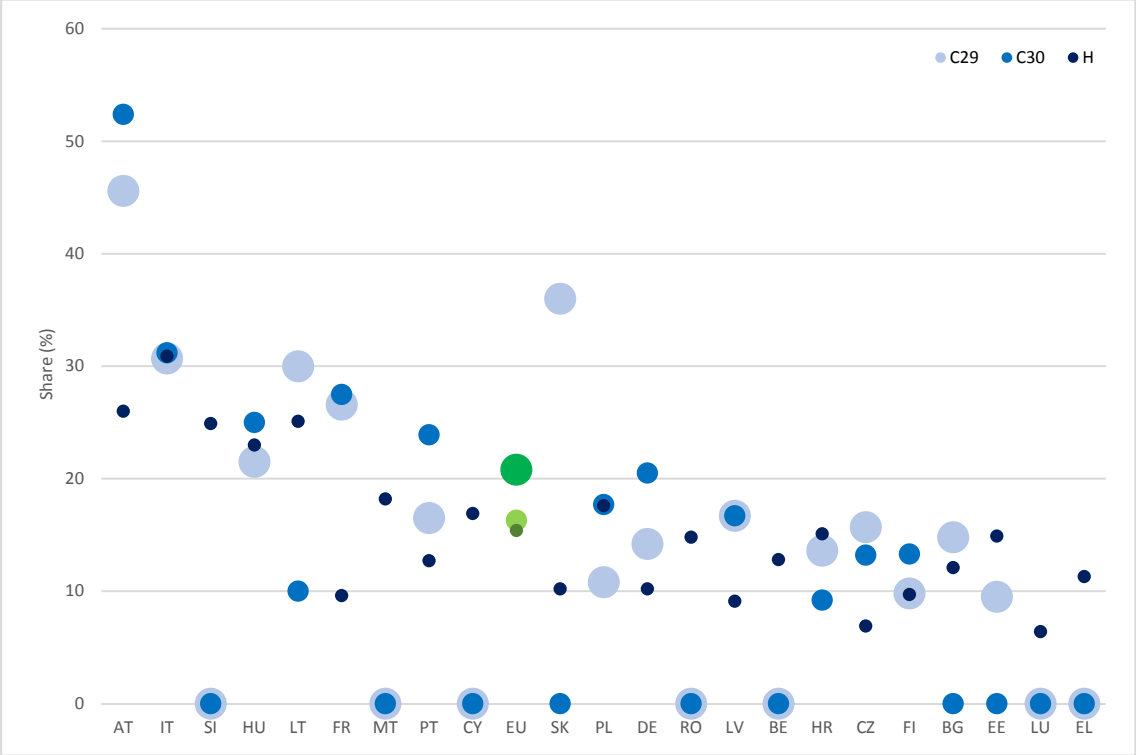
In Austria and Italy the share of companies stating that lack of qualified personnel is hampering innovation activities was above the European average in transport manufacturing (C29 and C30), as it can be observed in **Figure 24**.

[45] Data missing, for: C29 (BE, BG, CY, CZ, ES, LU, MT, RO, SI), C30 (BE, BG, CY, CZ, EL, ES, LU, MT, SI), H (CZ, ES, RO)

[46] Data missing, for: C29 (BE, BG, CY, CZ, EL, ES, FI, FR, LU, LV, MT, RO, SI), C30 (BE, CY, ES, FI, FR, LU, LV, MT, RO, SI), H (BE, ES, RO)

[47] Data missing, for: C29 (BE, CY, EL, ES, LU, MT, RO, SI), C30 (BE, CY, ES, LU, MT, RO, SI), H (ES)

Figure 24 Share of enterprises indicating that lack of qualified employees is an important barrier for innovating, in transport related economic activities (%, 2014-2016)



Data source: CIS Survey (2016).

4.4.6.4 Environmental benefits and innovation

CIS 2014 survey, included a section on environmental benefits linked to innovation activities[48]. This indicator relates to the introduction of innovation actions and environmental benefits, both obtained within the enterprise and by the end user. **Figure 25** illustrates the different shares in C29, C30 and H.

The automotive industry (C29) is the area where MSs have achieved the most environmental benefits with their innovations, on average 59% of companies across Europe. Lower share, but still relatively high, was observed in other transport equipment (C30) with 52% on average, and for transportation and storage (H), 47.6%.

[48] Data missing, for: C29 (BE, CY, ES, FR, IE, LU, MT, NL, SE, SI, UK), C30 (BE, CY, ES, FR, IE, LU, MT, NL, SE, SI, UK), H (BE, ES, FR, IE, NL, SE, UK)

Figure 25 Share of enterprises that introduced an innovation with environmental benefits, in transport related economic activities (%, 2012-2014)

Data source: CIS Survey (2014).

5 Conclusions

This report provides an assessment of the innovation capacity in the European transport sector through a quantitative review of key innovation indicators. The main conclusions of this analysis are as follows.

The characteristics of each transport sub-sector, for example the market structure, the level of competition, the good or service demand can influence the propensity to innovate, which needs to be considered when assessing innovation capacity. This entails that a thorough analysis of R&D capacity should look at each transport sub-sector separately.

R&D activities are key in transport, where the private sector is mostly engaged. Business investments in R&D in the transport sector amounted to more than €42 billion in 2015; business R&D expenditures have increased with the automotive industry leading the trend.

Total European public investment in transport R&D has remained overall stable in the period from 2011 until 2016 (around €2.6 billion), showing an increase in 2017, when the total amount was around €3.3 billion. Distribution among MSs is uneven, with a concentration of funding in a few countries, namely France, the UK and Germany. Official data on public R&D investment in transport is probably underestimated and do not provide transport sub-sectors differentiation. A further data breakdown that would consider transport modes within manufacturing and service activities, would help in providing a more accurate analysis. The work developed in TRIMIS helps to provide a more comprehensive understanding of the public spending in transport R&D, providing a capacity assessment based on STRIA roadmaps, as well as transport modes and sectors.

Human resources performing R&D activities represent roughly 2% of the overall employment in the transport sector. In 2015, 273,000 people were estimated to be involved in R&D activities, either research or supporting tasks in Europe. The distribution of R&D personnel follows a similar pattern to the one of R&D expenditure, with the automotive industry having the most R&D personnel employed, with fewer R&D personnel working on the transportation and storage activities.

Transport companies are keen to introducing innovation. A high level of innovation engagement has been observed in transport manufacturing, especially in the automotive area where almost 60% of companies declared to have been engaged in innovation activities in the period 2014-2016. The share was lower for transportation and storage with about 34%.

The cooperation with partners to foster innovation activities is rather common in the manufacturing industry, accounting for around 48.5% of the cases, while it is lower in transportation and storage, where also the number of innovative companies is lower.

More companies declared to have developed innovation activities linked to organisational changes, on average almost 18% in the entire transport sector; product and process innovations were introduced less frequently.

The high cost associated to R&D activities is commonly recognised as one of the most important barriers to innovation, followed by the difficulties to obtain funding.

Other uncertainties linked to the market structure, such as the demand volatility or the high competition, are perceived as hampering factors to innovation, mainly for the transportation and storage economic activities. The lack of qualified personnel is also among the main barriers to innovation for transport companies.

A link has been found in producing environmental benefits through the implementation of innovation activities, mainly in the automotive industry.

Although the macro-level assessment presented in this report provides an overview of the current state of R&D capacity in the European transport, it is important to highlight that a number of limitations exist that hamper a thorough analysis:

- Limited availability of data to perform the analysis, especially for some transport sub-sector indicators and for public funding of R&D in transport.
- Incompleteness of data that prevents a homogeneous analysis in terms of geographical coverage and timeframe, to compare MSs performance.
- The analysis - assessing the transport sector using official classifications - does not cover research activities than are developed in other sectors, (e.g. energy, tele-communications) that may as well influence the transport R&D capacity.

As recommended in the Oslo Manual (OECD/Eurostat, 2005), "qualitative data on innovation activities should be also collected" in order to complement and integrate the quantitative assessment.

A further qualitative analysis of transport R&D in Europe is necessary to complement the findings this report. This analysis will gather additional insight from transport stakeholders, from the business and public sector, aiming at identifying transport research trends, innovation drivers and bottlenecks that will support the definition of future policy measures.

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List of abbreviations and definitions

ACARE	Advisory Council for Aeronautics Research in Europe
ALICE	Alliance for logistics innovation thought collaboration in Europe
AT	Austria
ATM	Air traffic management
BE	Belgium
BERD	Business Expenditure on R&D
BG	Bulgaria
CEF	Connecting Europe Facility
CIS	Community Innovation Survey
CY	Cyprus
CS2	Clean Sky 2
CZ	Czech Republic
DE	Germany
DG MOVE	Directorate-General for Mobility and Transport
DG RTD	Directorate-General for Research and Innovation
DK	Denmark
EC	European Commission
ECS	Electronic Components and Systems
ECSEL	Electronic Components and Systems for European Leadership
EE	Estonia
EL	Greece
EPO	European Patent Office
ERRAC	European Rail Research Advisory Council
ERTRAC	European Road Transport Research Advisory Council
ES	Spain
EU	European Union
EU-28	European Union of 28 Member States
FCH2	Fuel Cells and Hydrogen 2
FI	Finland
FP7	7th Framework Programme
FR	France
GBAORD	Government Budget Appropriations for Outlays for Research and Development
GDP	Gross Domestic Product
H2020	Horizon 2020
HR	Croatia
HU	Hungary

IE	Ireland
IT	Italy
JRC	Joint Research Centre
JTI	Joint Technology Initiative
JUT	Joint Undertaking Initiative
LT	Lithuania
LU	Luxembourg
LV	Latvia
MS	Member State
MT	Malta
NABS	Nomenclature for the Analysis and Comparison of Scientific Programmes and Budgets
NACE	Nomenclature statistique des activités économiques dans la Communauté européenne
NL	The Netherlands
OECD	Organisation for Economic Co-operation and Development
PL	Poland
PT	Portugal
R&D	Research and Development
R&I	Research and Innovation
RO	Romania
SBS	Structural Business Statistics
SE	Sweden
SESAR	Single European Sky ATM Research
SI	Slovenia
SK	Slovakia
SRA	Strategic research agenda
STRIA	Strategic Transport Research and Innovation Agenda
TRIMIS	Transport Research and Innovation Monitoring and Information System
TTPs	European Transport Technology Platforms
UK	United Kingdom
USPTO	United States Patent and Trademark Office
WIPO	World Intellectual Property Office

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Annex 1: The European transport policy context, initiatives and funding opportunities

This annex shows the current policy context of the Strategic Transport Research and Innovation Agenda and the policy evolution. Moreover, a description of the current transport R&I-policy related initiatives existing at European level is included. An overview of the main funding instruments that have been put in place in Europe to finance research, namely on transport, is provided.

The European transport policy context

The EC set out three priorities in 2010 (European Commission, 2010). A new vision was established for Europe 2020, which included a strategy for smart, sustainable and inclusive growth. The smart economic growth will only be possible by developing an economy based on knowledge and innovation. In order to achieve it, 3% of the EU's Gross Domestic Product (GDP) should be invested in R&D. This goal should be reflected into national targets through seven themes: innovation union, youth on the move, a digital agenda for Europe, resource efficient Europe, an industrial policy for the globalisation era, an agenda for new skills and jobs, and finally, a European platform against poverty.

The first one of the seven topics is at the core of that strategy, and analyses the risks and opportunities of innovation in Europe (European Commission, 2011a). Member States (MSs) are committed to reach the 3% R&D target, although they are reaching his target at different peace, and a growing gap exists between the EU and its competitors, China, the United States and Japan (European Commission, 2011a). This gap is broadly explained by the impact of the economic crisis on business R&D investments. It is also highlighted the efforts from some MSs to maintain or even increase their public investments in R&D as well as foster public-private cooperation. In this sense, a comprehensive and integrated approach is key to address the issue of a fragmented European market for innovation, which at the end, hampers structural change in Europe.

The EU transport system is key to maintain EU's living standards and to a well-functioning internal market. However, the challenge of carbon emissions, as well as other negative externalities, could limit the freedom of movement. In order to avoid that undesirable situation, the transport system must be transformed without sacrificing its efficiency. This problem is well acknowledged in the White Paper (European Commission, 2011b) which establishes ten goals to guide policy actions and measure progress.

The "Roadmap for moving to a competitive low carbon economy in 2050" (European Commission, 2011c) provides a pathway to a cleaner, climate-friendly and competitive European economy in the long term. In order to achieve an 80% reduction in carbon emissions compared to 1990 by 2050, investment in clean and energy-efficient technologies needs to be increased by 1.5% of GDP per year, which is equivalent to €270 billion. The benefits due to lower energy bills and an improved air quality, the latest reflected in reducing air-polluting control and healthcare costs, will largely outweigh the investment. Fortunately, the 20% reduction has been achieved before 2020, since according to the European Environmental Agency between 1990 and 2016 the emissions were reduced by 22% whilst the GDP growth by 54%. Therefore, a new objective is being discussed which would accomplish the elimination of those gases by 2050.

Investments in clean technologies will be essential to achieving the new objective as well as supporting economic growth and creating new jobs. Mobilising R&I capacities will be a critical point to address the challenge of the actual fragmented European market. Additionally, the EC found that the majority of the research was dedicated to

demonstrating the feasibility of certain technologies with very little money spent on market development and rolling out new technologies. For this, the EC recommends making the most of the 'Single European Transport Area' set up in the White Paper (European Commission, 2012). For instance, the strategy to gradually replace oil with alternative fuels in Europe is seen as a good example of how new technologies can generate added value for the society, since supporting the market development and investment in their infrastructure will foster the economy and create jobs (European Commission, 2013). However, it is also noteworthy that there is no single fuel solution for the future of transport and all options must be studied, focusing on the needs of each transport mode. Alternative fuels are one of the seven priority innovation roadmaps identified by experts in the consultation held by EC to transform the transport system up to 2050 (European Commission, 2017b). The seven priority areas, STRIA Roadmaps, were mentioned earlier in this report. These areas can be applied to all transport modes and should focus on the needs of users rather than existing capacity; that is, how to manage future user's requirements. Moreover, the mobilisation of all transport stakeholders will be critical, and the 'Single European Transport Area' must ensure the implementation of these seven roadmaps.

The European transport policy initiatives

The former innovation polices are supported by European policy initiatives, which are listed below. This list is not exhaustive, proving though information on the R&I work conducted by the European Transport Technology Platforms (TTPs) and Joint Technology Initiatives (JTIs), or Joint Undertaking Initiatives (JUTs) on this topic.

TTPs are supported by the EC and their goal is to foster and integrate research based on public-private partnerships. TTPs are generally forums where major companies, Universities, research institutes, associations and authorities gather to discuss technology and innovation research priorities for the future. The majority of them are transport mode specific. These are the most remarkable ones for transport:

- Advisory Council for Aeronautics Research in Europe (ACARE). Aviation in Europe is very important: it generates €600 billion, of which €7 billion are reinvested every year in civil aeronautics R&I, and creates, among others, highly skill jobs. This was recognised through the birth of ACARE which was launched at the Paris Air Show in June 2001 and attracted over 40 member organisations including manufacturing industry, airlines, airports, service providers, regulators, research institutes and academia. ACARE is aimed at developing and maintaining the strategic research agenda (SRA) of the sector. The SRA is a roadmap highlighting the strategic orientations that aviation must consider to meet the new requirements. ACARE bring important benefits for the aviation industry, including EU collaborative research in Aeronautics and Air Transport (e.g. Horizon 2020), the Clean Sky JTI, the SESAR JUT, MSs Programmes and private company programmes (ACARE, 2018).
- European Rail Research Advisory Council (ERRAC). The rail technology platform was established in 2001, and its scope is to create a single European platform to make the most of the European rail sector by enhancing its competitiveness, boosting innovation and guiding research efforts. All the main stakeholders are present in this body which allows a comprehensive understanding of all kinds of rail transport. ERRAC also produces a strategy vision of R&I whose goal is to increase the visibility of the sector across European institutions and stakeholders, and on the other hand to influence a favourable funding landscape for railway research and innovation, through calls for projects and joint undertaking like Shift2Rail (ERRAC, 2018).
- Alliance for Logistics Innovation thought Collaboration in Europe (ALICE). The European Technology Platform ALICE was officially set up in 2013. It main objective is to develop a comprehensive strategy for research, innovation and market deployment of logistics and supply chain management innovation in Europe. The platform supports, assists and advises the EC into the implementation of the EU Programmes for research (e.g. Horizon 2020 in the area of logistics). ALICE engages all key

stakeholders in the logistics sector and is based on the recognition of a holistic approach on logistics and supply chain planning and control, where shippers and logistics service providers closely collaborate to reach a higher efficiency (ALICE, 2018).

- European Road Transport Research Advisory Council (ERTRAC). This road advisory council provides a strategic vision for road transport R&I in Europe. It also develops a SRA and roadmaps to achieve this vision. Similarly to the former platforms, it enhances networking activities between main road stakeholders and fosters investments in R&I activities on road transport through for example supporting the implementation of the European funding schemes (ERTRAC, 2018).
- WATERBORNE was established as an industry-oriented technology platform in which all relevant waterborne stakeholders are engaged, namely: classification societies, shipbuilders, ship-owners, maritime equipment manufacturers, infrastructure and service providers, universities or research institutes, as well as EU Institutions, including MSs. Thanks to this dialogue, research coordination between important stakeholders at European level can be more effective and consequently, effective mechanisms are developed to foster cooperation. The main objectives of the WATERBORNE platform are to develop an R&I vision and a SRA as well as contribute to an efficient allocation of financial resources (WATERBORNE, 2018).

JTIs or JUTs represent a collaboration of two or more companies, involving also the EU, to undertake a common project or to pursue a specific objective. To this end, companies bring together their common resources and capabilities, such as project funding, capital equipment, know-how and intellectual property. The scope is to create a legally independent company to develop a competitive advantage by commercialising a new product or service. This partnership is regulated by the Article 187 of the Treaty on the Functioning of the European Union (European Union, 2007), which establishes that JTIs should address strategic technologies that will underpin growth and jobs in globally competitive sectors. Below, the most important transport related JTIs are briefly described.

- Clean Sky 2 (CS2). This JUTs formally started in 2008 under the name of Clean Sky 1 with over 600 entities from 24 countries. Clean Sky 1, had a total budget of around €1.6 billion, whilst this has been increased to more than €4 billion in Clean Sky 2. Its main goal is to develop innovative technology whilst reducing CO2, gas emissions and noise levels produced by aviation. It contributes to strengthening European aero-industry collaboration, global leadership and competitiveness. There are four types of partners. First, the EC, which is represented on the Clean Sky Governing Board and contributes to almost 50% of the actual funding scheme. Second, the leaders, whose role is to further advance the technologies developed under Clean Sky 2 and contribute to the remaining budget. Third, Core Partners, which are organisations selected through open competitions to carry out work packages in one or more projects usually from the beginning to the end of Clean Sky. Finally, partners are organisations involved in specific tasks for a limited period of time. (Clean Sky 2, 2018)
- Shift2Rail aims to develop better trains and railway infrastructure that will drastically reduce costs and improve capacity, reliability and punctuality. Shift2Rail is an initiative aimed at boosting R&I and at speeding up the integration of new technologies that can help the rail industry find solutions in a challenging context. Railway undertakings, infrastructure managers and public transport operators are present in Shift2Rail ensuring that the issue of limited standardisation across Europe is also overcome by completing the Single European Railway Area. All stakeholders should benefit from this cooperation, since an enhanced competitiveness attractiveness of rail services combined with doubling railway capacity will help rail increase the transport share, contributing to the reduction of traffic congestion and CO_2 emissions (Shift2Rail, 2018).

- Single European Sky ATM Research (SESAR) 2020 develops the new generation of European Air Traffic Management (ATM) system that will enhance the performance of air transport. SESAR joint undertaking was set up in 2007 and aimed at modernising European ATM. Its role is double: on the one hand, to coordinate and concentrate all ATM key R&I in the EU, on the other hand, to define, develop and deploy the future European intelligent air transport system. Nevertheless, ATM lies on ageing technology and procedures which need to be updated, particularly in the context of the traffic growth expectations. SESAR, will help with this process. SESAR encompasses around 3,000 experts across the world and is the technological pillar of the single European Sky. SESAR is crucial for the wellbeing of European citizens, since aviation industry employs around 1.4 million people and additionally supports around 5 million jobs.(SESAR, 2018)
- Fuel Cells and Hydrogen 2 (FCH2) aims to accelerate market introduction of clean and efficient technologies in energy and transport. The main goal of the FCH2 scheme is to speed up the introduction of fuel cell and hydrogen technologies which are key to achieve a carbon free energy system and contribute to economic growth and employment. In order to play this significant role, R&D and deployment strategies are needed. These should involve all stakeholders in a shared objective. Established in 2008 gathers the EC, Hydrogen Europe, on behalf of fuel cell and hydrogen industries, and finally, the research community represented by Hydrogen Europe Research. FCH2 also develops the SRA of the sector, and has a total budget of €1.33 billion which is shared between the three members. (FCH2, 2018)
- Electronic Components and Systems for European Leadership (ECSEL) was established to boost Europe's electronics manufacturing capabilities. The last JTI related to transport is the ECSEL which funds R&D projects that deliver innovation in for Electronic Components and Systems (ECS). The importance of ECS is a priority in a modern economy, since it influences all types of industries: such as the ones producing smartphones, smart cards, smart energy grids, etc. In ECSEL 30 countries and the EC participate by financing projects on this topic (ECSEL, 2018).

The European financial instruments

This section describes the main EU financial instrument that support transport R&I in Europe. The three largest and most recent financial instruments supporting the aforementioned policy initiatives are the 7th Framework Programme (FP7), the Horizon 2020 (H2020) and Connecting Europe Facility (CEF). These are listed in chronological order:

- FP7 was the 7th Framework Programme for Research and Technological Development, and its role was to improve competitiveness, and to maintain leadership in a global knowledge economy. It started in 2007 and ended in 2013 with a total budget of over €50 billion. It was aimed at co-financing research, technological development and demonstration projects. All the funded projects had to demonstrate a European added value through research projects and those were carried out by consortia which included participants from different European countries.
- H2020 is an EU R&I programme with nearly €80 billion of funding available over 7 years (2014 to 2020). By coupling R&I, it enables excellence in science, industrial leadership and tackle societal challenges. Its goal is to ensure Europe produces world-class science, removes barriers to innovation, and makes it easier for the public and private sectors to work together in delivering innovation.
- CEF supports the development of high-performing, sustainable and efficiently interconnected trans-European networks in the field of energy, telecommunications and transport. CEF removes bottlenecks along trans-European transport corridors, and it allows the development of projects that otherwise would have been deployed by the market. It also minimises bureaucracy and decreases the costs for the EU budget by promoting synergies through a centrally managed infrastructure funds. It

has a total budget of €24.05 billion for period 2014-2020, out of which €22.4 million are allocated to transport projects.

Moreover the European Structural and Investment Funds are funds to support economic development across all EU countries, in line with the objectives of the Europe 2020 strategy. These funds may also support R&I through five main funds: European Regional Development Fund (ERDF), European Social Fund (ESF), Cohesion Fund (CF), European Agricultural Fund for Rural Development (EAFRD), European Maritime and Fisheries Fund (EMFF). In the period 2014-2020, transport and energy networks were considered under the thematic priority TO7. Among the areas of funding, particular focus was on investments in transport services and infrastructure. Smart mobility, multi-modal transport, clean transport and urban mobility are particular priorities for Cohesion Policy during the 2014-2020 funding period. Cohesion policy also supports investments in infrastructure for smart energy distribution, storage and transmission systems (particularly in less developed regions). (European Commission, 2018d)

Annex 2: Statistical classification of economic activities (NACE), Revision 2 transport-related sectors

The table below shows the transport related economic activities relevant for this analysis.

C29 - Manufacture of motor vehicles, trailers and semi-trailers
C29.1 - Manufacture of motor vehicles
C29.1.0 - Manufacture of motor vehicles
C29.2 - Manufacture of bodies (coachwork) for motor vehicles; manufacture of trailers and semi-trailers
C29.2.0 - Manufacture of bodies (coachwork) for motor vehicles; manufacture of trailers and semi-trailers
C29.3 - Manufacture of parts and accessories for motor vehicles
C29.3.1 - Manufacture of electrical and electronic equipment for motor vehicles
C29.3.2 - Manufacture of other parts and accessories for motor vehicles
C30 - Manufacture of other transport equipment
C30.1 - Building of ships and boats
C30.1.1 - Building of ships and floating structures
C30.1.2 - Building of pleasure and sporting boats
C30.2 - Manufacture of railway locomotives and rolling stock
C30.2.0 - Manufacture of railway locomotives and rolling stock
C30.3 - Manufacture of air and spacecraft and related machinery
C30.3.0 - Manufacture of air and spacecraft and related machinery
C30.4 - Manufacture of military fighting vehicles
C30.4.0 - Manufacture of military fighting vehicles
C30.9 - Manufacture of transport equipment n.e.c.
C30.9.1 - Manufacture of motorcycles
C30.9.2 - Manufacture of bicycles and invalid carriages
C30.9.9 - Manufacture of other transport equipment n.e.c.
G - Wholesale and retail trade; repair of motor vehicles and motorcycles
G45 - Wholesale and retail trade and repair of motor vehicles and motorcycles
G45.1 - Sale of motor vehicles
G45.1.1 - Sale of cars and light motor vehicles
G45.1.9 - Sale of other motor vehicles
G45.2 - Maintenance and repair of motor vehicles
G45.2.0 - Maintenance and repair of motor vehicles
G45.3 - Sale of motor vehicle parts and accessories
G45.3.1 - Wholesale trade of motor vehicle parts and accessories
G45.3.2 - Retail trade of motor vehicle parts and accessories
G45.4 - Sale, maintenance and repair of motorcycles and related parts and accessories
G45.4.0 - Sale, maintenance and repair of motorcycles and related parts and accessories
H - Transportation and storage
H49 - Land transport and transport via pipelines
H49.1 - Passenger rail transport, interurban
H49.1.0 - Passenger rail transport, interurban
H49.2 - Freight rail transport

H49.2.0 - Freight rail transport
H49.3 - Other passenger land transport
H49.3.1 - Urban and suburban passenger land transport
H49.3.2 - Taxi operation
H49.3.9 - Other passenger land transport n.e.c.
H49.4 - Freight transport by road and removal services
H49.4.1 - Freight transport by road
H49.4.2 - Removal services
H49.5 - Transport via pipeline
H49.5.0 - Transport via pipeline
H50 - Water transport
H50.1 - Sea and coastal passenger water transport
H50.1.0 - Sea and coastal passenger water transport
H50.2 - Sea and coastal freight water transport
H50.2.0 - Sea and coastal freight water transport
H50.3 - Inland passenger water transport
H50.3.0 - Inland passenger water transport
H50.4 - Inland freight water transport
H50.4.0 - Inland freight water transport
H51 - Air transport
H51.1 - Passenger air transport
H51.1.0 - Passenger air transport
H51.2 - Freight air transport and space transport
H51.2.1 - Freight air transport
H51.2.2 - Space transport
H52 - Warehousing and support activities for transportation
H52.1 - Warehousing and storage
H52.1.0 - Warehousing and storage
H52.2 - Support activities for transportation
H52.2.1 - Service activities incidental to land transportation
H52.2.2 - Service activities incidental to water transportation
H52.2.3 - Service activities incidental to air transportation
H52.2.4 - Cargo handling
H52.2.9 - Other transportation support activities
H53 - Postal and courier activities
H53.1 - Postal activities under universal service obligation
H53.1.0 - Postal activities under universal service obligation
H53.2 - Other postal and courier activities
H53.2.0 - Other postal and courier activities

Annex 3: NABS Classification - Transport, telecommunication and other infrastructures

The table below shows the transport related sectors relevant in this analysis.

NABS-CHAPTER 4: Transport, telecommunication and other infrastructures
This chapter includes R&D related to:
- Infrastructure and land development, including the construction of buildings;
- The general planning of land-use;
- Protection against harmful effects in town and Country planning.
This chapter also includes R&D related to:
- Transport systems;
- Telecommunication systems;
- General planning of Land-use;
- Construction and planning of building;
- Civil engineering;
- Water supply.
NABS-CHAPTER 4 does not include R&D related to other types of pollution than harmful effects in town (included in Chapter 2).

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