A Detailed Transport Stock and Activity Dataset for Policy Assessment Purposes

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Abstract

This paper presents the main outcomes and results of the work performed under the framework of the TRACCS project, funded by European Commission (DG CLIMA) from Jan. 2012 to Dec. 2013 (http://traccs.emisia.com). The full project title was “Transport data collection supporting the quantitative analysis of measures relating to transport and climate change” and the principal objective was to provide updated historical transport data (stock, activity, economic) at EU level for the period 2005-2010 to be used in the various activity and emission modeling/projection tools and inventories for policy assessment purposes in Europe. The main contribution of the project is the creation of a final processed, complete and consistent dataset with no gaps, for each transport mode (road, aviation, rail, maritime) on a per country basis. This detailed dataset can be used by a wide range of experts in transport statistics, emission modeling, projections of vehicle fleet, etc. Changes in European transport sector are provided, composition and structure of vehicle fleet, gasoline/diesel trends, fuel consumption per vehicle category, and more.

Introduction

Combating global warming and climate change is one of the most important environmental challenges in recent years. As a result of its heavy dependence on fossil fuels, the transport sector is a significant consumer of energy and a major source of GHG emissions; in particular, it accounted for 31.8% of total final energy consumption and was responsible for 24.3% of GHG emissions (including international bunkers) in EU28 in 2012 (European Commission, 2014). Road transport is the dominant mode, emitting 71.9% of all transport-related GHG emissions; however, there are also significant emissions from the aviation and maritime navigation sectors. A major concern is that, although total GHG emissions in EU28 decreased from 5,806 to 4,824 million tonnes of CO_2 equivalent from 1990 to 2012, emissions from transport increased from 963 to 1,173 million tonnes of CO_2 equivalent for the same time period. This is mainly due to the increase of transport activity (passenger and freight) as the following numbers reveal (for the period between 1995 and 2012):

- Passenger transport by all modes in EU28 increased by 19% (1% increase per year).
- Freight transport by all modes in EU28 increased by 22.8% (1.2% increase per year).

However, by focusing on the time period 2005-2010, many countries reported reductions in GHG emissions from road transport. These reductions have mainly been attributed to the economic recession and, secondarily, to specific measures taken at local or global level aiming at reducing fuel consumption.

In addition to GHG emissions, the transport sector has a negative impact on air quality by emitting significant amounts of pollutants such as PM, NO_x, CO, and NMVOC (European Environment Agency, 2013a). The transport sector is clearly the largest contributor to NO_x and the second source of CO and NMVOC emissions. It also significantly contributes to PM_{10} and to $PM_{2.5}$ emissions.

The ultimate aim of the TRACCS project (http://traccs.emisia.com) was to help environmental researchers and emission modelers understand how the transport sector affects climate change and assist in further calculations and projections of pollutant emissions at a very detailed and disaggregated level (per mode of transport, per specific vehicle category, type, fuel used, and age distribution) on a per country basis (EU28 Member States, plus IS, NO, CH, FYROM, TR).

TRACCS largely followed up on two similar projects executed in the past: the one on road transport was called FLEETS (Ntziachristos et al., 2008) and collected statistics on road vehicles in Europe until 2005; the second project, covering non-road modes in the same period, was called EX-TREMIS (Chiffi et al., 2007). However, TRACCS had a wider scope than the two preceding projects, since it included the collection and streamlining of more data categories, including cost and various economic data of transport.

Transport stock, activity, and economic data are more or less available from various sources, either centralized (e.g. Eurostat) or from national statistical authorities. However, if one tries to collect complete time series of detailed and disaggregated data with age distributions for all countries, in order to use them for bottom-up calculations and further processing, will come up against issues and difficulties such as the following:

- Available official statistical data are usually aggregated and present minor or more significant gaps (e.g. whole countries or years missing); moreover, they do not always satisfy the detailed modeling requirements of the user.
- There are inconsistent definitions and no common vehicle classification among various sources; furthermore, values for the same information from different sources do not always agree and, therefore, an explanation has to be provided for such diversifications.
- No single source provides all data required and no information can be found at all for some specific data categories in several countries (e.g. second hand registrations, de-registrations, and complete age distributions for all categories, are data difficult to find).

The above make clear that, in order to deliver a complete and consistent dataset, a processing methodology has to be developed that creates final data by synthesizing collected statistical information from various sources and following some predefined steps to fill in gaps, ensure internal consistency, and be as much as possible close to official statistical values (at least at aggregated level); this is exactly the main contribution of the project.

The rest of the paper is organized in sections corresponding to each mode of transport: road (passenger/freight), airborne, rail, and waterborne. Some interesting cross-modal results and extensions of the project are also provided in the end. For each mode, a short summary description is given for the first two phases followed to produce final results, data collection and data processing, while more emphasis is given on the third phase, which is presentation of results (numbers, figures, time series, indicators, comparison with other sources).

Road passenger and freight transport

Data collection phase

The road transport data were collected trying to comply with the following vehicle categories and classification requirements:

- Mopeds and Motorcycles (L category, according to UNECE classification (UNECE, 1999)).
- Passenger Cars (M1).
- Buses (M2, M3).
- Light Commercial Vehicles (N1).
- Heavy Duty Trucks (N2, N3).

Two main criteria were used to classify the above categories: i) vehicle type, ii) fuel used. The vehicle types are: 2/4-stroke for mopeds/motorcycles, market segments for passenger cars (small, lower-medium, upper-medium, executive), urban/coaches for buses, and GVW (gross vehicle weight) classes as in COPERT/HBEFA for heavy duty trucks (rigid from ≤7.5t to >32t, articulated from 14-20t to 50-60t). The fuels considered are: petrol (gasoline), diesel, LPG, CNG, flexi-fuel, B30, and a generic category ‘other’. Data had to be provided as totals per year and with complete age distributions (1-30) for each year. A summary of sources used for data collection is given in Table 1.

Table 1: Overview of sources used for data collection.

Source	Main data categories collected
Eurostat	Stock of vehicles, new registrations, vkm, pkm, tkm, other
EC Statistical Pocketbook	Stock of vehicles, new registrations, activity/energy data, other
ACEA	New registrations, PCs segments, economic data (tax guides)
ACEM	Stock and new registrations of mopeds/motorcycles
ANFAC Motor Vehicle Parc	Vehicles in use, deregistrations, other
National statistics web sites	Stock of vehicles, new registrations, activity data
Countries' experts	Stock of vehicles, new registrations, activity data
Mehlhart et al. (2011)	Second hand registrations of PCs and LCVs
Car price reports by EC	Car prices per model in EU27 organized in segments A-G
CESifo DICE database	Economic data gathered from various sources
CO_2 monitoring database	New registrations of PCs, CO_2 emissions
UNFCCC	Fuel consumption for road transportation reported by countries
EC4MACS project	Fuel consumption factors
Europe's Energy Portal	Fuel prices (unleaded-95, diesel)
Other sites, studies, reports	Various data

While collecting data from various sources, it became clear that there is no single source that provides all data to the level of detail required and there are also many problems such as inconsistencies, diversifications, difficulties in finding specific data categories, and more. Combining data coming from different sources in order to produce a final, processed, complete and consistent dataset with no gaps, and output values close to official statistics, was a major challenge with many difficulties. However, having collected data from various sources was helpful in the data processing phase and also to fill in gaps and make cross-checking in the end.

Data processing phase

A complete and detailed data processing methodology has been developed in order to produce the final dataset by synthesizing collected statistical information from different sources and applying the proposed steps (visual checking, gap filling, consistency checking, etc.). This methodology has been implemented with software modules (reconciliation module for stock data, QA/QC rules, energy balance, economic data, etc.) and applied to all 33 countries. It results in the production of a final, processed, complete, and consistent dataset with no gaps for all data categories for each country.

A short outline of the data processing methodology is given next; more technical details can be found in Papadimitriou et al. (2013). Figure 1 gives a quick overview of the main steps followed for the delivery of the dataset of each country.

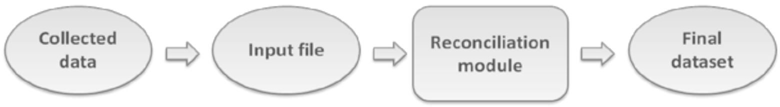


Figure 1: Overview of the data processing methodology (from collected data to final dataset).

The final dataset ('output' file) for each country is produced based on collected data and an initial 'input' file (intermediate file created for the needs of the methodology). The whole procedure consists of three basic steps and the outline can be summarized as follows:

- *Collected data file*: Collected information is stored for each country using a common template format (homogeneous data storing, the same cell contains the same information for all countries, various sources used).
- *'Input' data file*: An intermediate file is produced from collected data. This 'input' file is given to the reconciliation module to produce the final one. A first level of data processing and calculations takes place here; some values are filled in the appropriate cells and used for further processing and calculations to produce the final dataset. The 'input' file is created mainly using the collected data, but also utilizing any other source needed and justified assumptions (wherever it is necessary for disaggregation, if detailed info is missing).
- *'Output' data file*: This is the final, processed, complete and consistent dataset, containing no gaps and errors (at least according to the rules of the reconciliation module).

A summary of what has been delivered as an outcome of the data processing phase (road data in numbers) is shown in Table 2.

Table 2: Delivered road transport dataset in numbers.

33 countries
6 years (2005-2010)
30 vehicle age bins per year (1-30)
30 categories of data per country
~ 227,820 data cells per country
~ 7,518,060 individual values in total

The categories of all delivered road transport data are:

- *Energy data*: Fuel consumption, fuel consumption factors, CO_2 emissions.
- *Stock data*: population, new registrations, second hand registrations, deregistrations.
- *Activity data*: mileage, vkm, pkm, tkm (with loading capacity, actual payload, and loading factors), tkm share per trip class and cargo type, occupancy ratio, private/corporate/self-employed professional passenger cars, urban peak/urban non-peak/non-urban share.
- *Economic data*: purchase price, VAT, registration tax, ownership tax, operation cost, maintenance cost, insurance cost, labor cost, and tolls.

From the above categories, stock and activity data are necessary in order to calculate total fuel consumption and compare it with corresponding statistical value. However, not all data are of same importance, because their end effect on fuel consumption varies. Specifically, population, mileage, and fuel consumption factors are absolutely necessary data for such calculations. New registrations, second hand registrations, and deregistrations are used for calculation of population. Vkm are derived from population and mileage. Pkm, combined with reasonable occupancy ratios, are linked to vkm. Tkm are also linked to vkm through loading capacity and loading factors. The economic data on the other hand are not used in fuel consumption calculations; however, they are necessary for a complete impact assessment study and give an overview on costs and taxes related to vehicle acquisition, ownership, and circulation. A detailed study on the importance of all data needed for precise emission calculations can be found in Stavropoulos (2013) with indicators on data quality, significance, and availability.

The main task of the reconciliation process is to produce a consistent dataset for the main data categories (vehicle population, new registrations, second hand registrations, deregistrations, mileage, vkm, fuel consumption calculated and corresponding fuel consumption factors). All these data are closely related to each other, and the ultimate objective is that the calculated fuel consumption (FC_{calc}) matches with the statistical one (FC_{stat}) – energy balance.

There are three critical components on which the reconciliation module was based:

- *Vehicle processing rules*: a set of strict conditions that should not be infringed by the final dataset, e.g. total number of PCs equals the sum of corresponding subtotals (vehicle subcategories, age distributions, etc).

- *Basic global fleet balance equation*: population for a given year = population of previous year + new registrations of this given year + second hand registrations of this given year – deregistrations of this given year (main processing rule going from one year to the next). This rule must valid not only in total numbers, but also for every single age bin (1-30).

- *Energy balance*: activity data (mileage/vkm) are adjusted to match energy statistics (matching of calculated FC with statistical value) and respect activity statistics to the degree possible.

<u>*Presentation of results*</u>

In order to assess the quality, accuracy and confidence of project's output data, a number of different QA/QC indicators have been created, as well as percentage differences with other sources have been calculated. The main QA/QC indicators ensure the delivery of consistent datasets that satisfy all processing rules and fleet balance equations and contain no gaps and negative values. Comparing the project's output data with official statistics at aggregated level usually shows good (or even perfect) matching with at least one source for the most important data categories.

As an example, Figure 2 presents the comparison of the project's total passenger cars population with other sources (among those of Table 1). It shows 69% matching with Eurostat, 26% with experts, 4% with ANFAC, and 1% with EC Statistical Pocketbook. These percentages have been derived as follows. There are 198 comparisons to be made (33 countries * 6 years). For each one of them, sources are examined in a predefined order and the first source (e.g. Eurostat) for which the absolute value of the percentage difference (between values of TRACCS and source) is < 10%, is selected. The threshold of 10% has been set as an 'acceptable' differentiation between project's output and official statistics. For this specific example, all differences were below 10%, which confirms that total population of PCs is 'close' to at least one source for all countries and years. For 137 out of the 198 comparisons the corresponding source was Eurostat, that is 69% (in the same way, percentages have been derived for other sources). It is noted that similar observations have also been made for population of other vehicles (mopeds and motorcycles, buses, LCVs, HDTs).

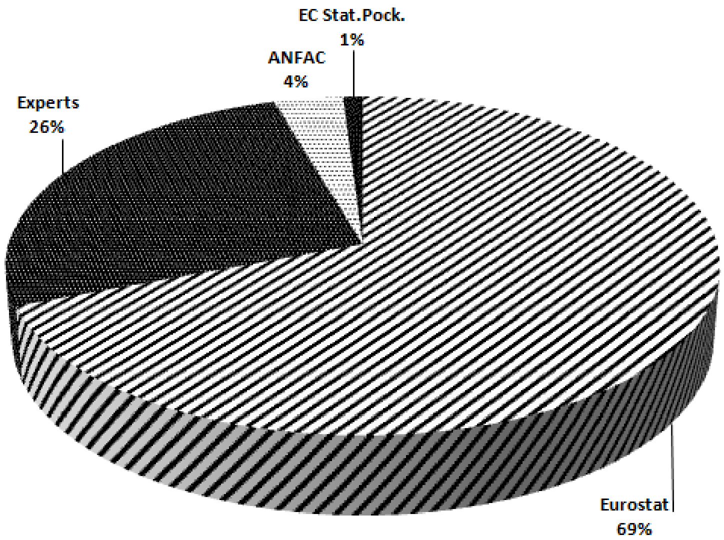


Figure 2: Overall indicator for comparison with other sources (population: PCs, Total).

By utilizing the huge dataset delivered and combining values from different vehicle or data categories, various synthetic measures, tables, graphs, indicators, and time series can be derived (by bottom up calculations) in order to be used for policy assessment purposes. Some indicative results are presented below; however, every single user of this dataset may produce own figures that satisfy particular needs.

Figure 3 shows total population of PCs (number of registered vehicles) for each country and years 2005, 2010. DE has the largest total number of PCs for 2010, followed by IT, FR, UK, ES. IS has the smallest total number of PCs for 2010, followed by MT, FYROM, LU, EE. Regarding the percentage (%) change from 2005 to 2010, RO has the largest difference (60%), followed by PL (40%), TR (31%), CY (28%), SK (28%). DE has the smallest difference (-8%), followed by BG (2%), UK (3%), HU (4%), FR (4%). It is noted that these percentage differences may not always actually imply the same change in 'real' operating (circulating) vehicle stock; sometimes there is a modification in how statisticians and/or modelers define the term 'passenger cars' (e.g. if some light commercial vehicles are included or not) and this may cause changes in the number of total stock (e.g. in case of DE the -8% is due to a change in definition of expert's statistical data from 2007 to 2008 and does not reflect a 'true' -8% decrease in PCs population).

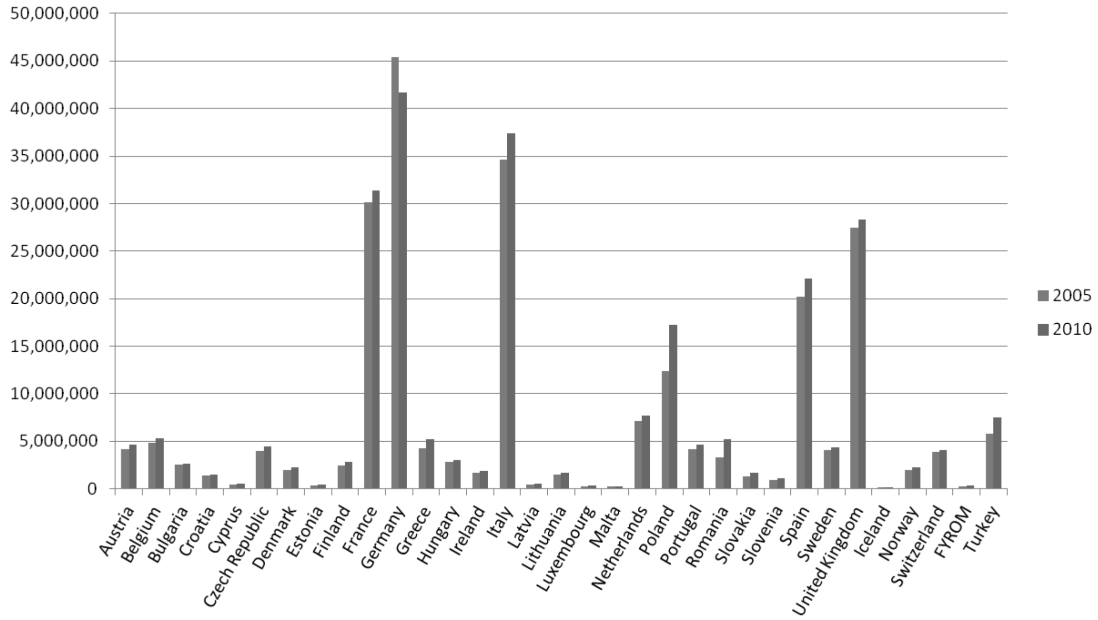


Figure 3: Total number of passenger cars for each country (2005, 2010).

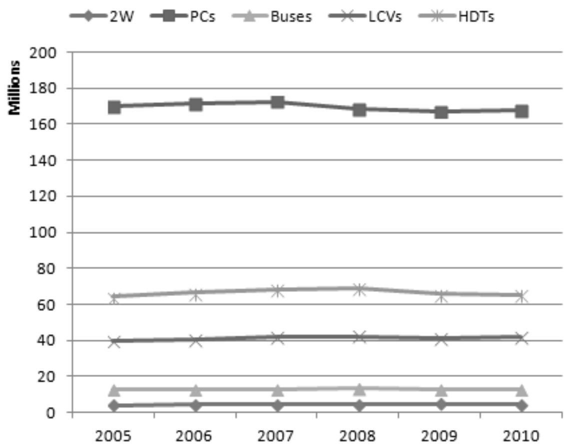
Countries	Population: PCs Gasoline	Population: PCs Diesel	Population: LCVs Gasoline	Population: LCVs Diesel
	% diff. 2005-2010	% diff. 2005-2010	% diff. 2005-2010	% diff. 2005-2010
Austria	-5	30	-19	12
Belgium	-13	32	-22	22
Bulgaria	-18	82	-72	2
Croatia	-2	20	-33	3
Cyprus	27	42	-16	1
Czech Republic	2	68	52	60
Denmark	-5	137	-33	3
Estonia	5	86	-15	16
Finland	9	84	-11	29
France	-19	29	-56	11
Germany	-16	15	-49	-13
Greece	19	140	9	5
Hungary	-1	28	-23	29
Ireland	-2	93	-53	20
Italy	-14	46	-15	19
Latvia	7	63	-25	24
Lithuania	3	71	41	129
Luxembourg	-22	43	-30	33
Malta	14	13	-11	9
Netherlands	7	16	-34	1
Poland	15	207	-16	59
Portugal	12	12	3	3
Romania	41	131	7	69
Slovakia	28	28	66	63
Slovenia	-5	96	-65	4
Spain	-10	36	-16	18
Sweden	-10	199	-31	43
United Kingdom	-8	47	-38	14
Iceland	2	53	-6	59
Norway	-8	141	-39	37
Switzerland	-4	94	-26	41
FYROM	15	56	27	39
Turkey	24	68	45	80
EU28	-7	39	-21	15
All 33 countries	-6	40	-5	16

Figure 4: Percentage difference of gasoline/diesel PCs and LCVs for each country from 2005 to 2010.

Figure 4 shows gasoline/diesel trends, i.e., % change of PCs and LCVs for each country (2005 to 2010). For gasoline PCs, there is a decrease in EU28 population (-7%) and a decrease in 17 countries individually (from -1% in HU to -22% in LU). For diesel PCs, there is an increase in EU28 population

(39%) and an increase in all 33 countries (from 12% in PT to 207% in PL). In absolute numbers (gasoline vs. diesel in EU28), in 2005 there were ~159 vs. 62 million vehicles, and in 2010 there were ~147 vs. 86 million vehicles. For gasoline LCVs, there is a decrease in EU28 population (-21%) and a decrease in 25 countries (from -6% in IS to -72% in BG). For diesel LCVs, there is an increase in EU28 population (15%) and an increase in 32 countries (from 1% in CY to 129% in LT). In absolute numbers (gasoline vs. diesel in EU28), in 2005 there were ~4 vs. 23 million vehicles, and in 2010 there were ~3 vs. 26 million vehicles.

Figure 5 presents some interesting fuel consumption statistics per vehicle category. The left part of the figure shows total fuel consumption (in million t) from road transport (EU28, 2005-2010) per vehicle category. PCs, as expected, have the largest fuel consumption (with a slight decrease -1% from 2005 to 2010). Corresponding % changes for other vehicles are: 15% (increase) for mopeds/motorcycles, 0% for buses, 6% for LCVs, and 2% for HDTs. The right part of the figure presents diesel fuel consumption split among different vehicle categories (EU28, 2010): 41% for PCs, 33% for HDTs, 20% for LCVs, and 6% for buses.



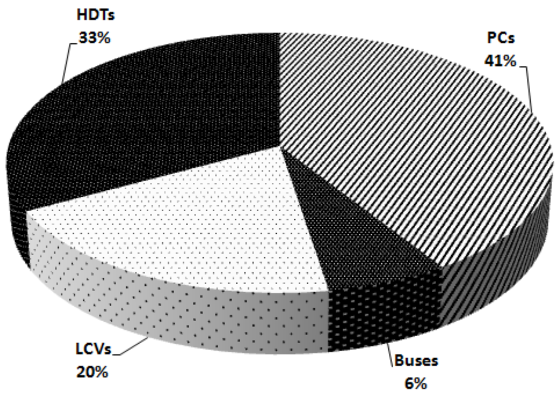


Figure 5: Total fuel consumption (in million t) from road transport (EU28, 2005-2010) per vehicle category (left). Diesel fuel consumption: share (%) per vehicle category (EU28, 2010) (right).

Figure 6 shows gasoline/diesel trends in fuel consumption for PCs and LCVs (EU28, 2005-2010). For PCs, there is a decrease in EU28 gasoline fuel consumption (-19%) and a decrease in 27 countries individually from -1% in EE to -34% in TR (not shown in figure); there is also an increase in EU28 diesel fuel consumption (23%) and an increase in 32 countries individually from 2% in ES to 267% in PL. In absolute numbers, fuel consumption of PCs gasoline is comparable to diesel, ~82 vs. 81 million t (2010). For LCVs, there is a decrease in EU28 gasoline fuel consumption (-28%) and an increase in diesel (10%). In absolute numbers, fuel consumption of LCVs gasoline is ~3 and diesel ~38 million t (2010).

Figure 7 provides implied fuel consumption factors (g/km) per country for passenger cars (total, gasoline, diesel) and years 2005, 2010. It also shows the percentage change from 2005 to 2010. These implied factors were derived by post-processing of the data, dividing fuel consumption (FC_{calc}) by vkm. It can be observed that there is an improvement at EU28 level both for gasoline (-2%, from 57.2 to 56.3 g/km) and diesel cars (-2%, from 50.4 to 49.2 g/km); this improvement is mainly due to the objective of reducing CO_2 emissions from new passenger cars (target set by EU Regulation 443/2009). Underlying data which were used for this process were from CO_2 monitoring database (http://www.eea.europa.eu/data-and-maps/data/co2-cars-emission-6) and (Katsis et al., 2012). On a per country basis, there is an improvement in gasoline cars for 24 countries and in diesel for 19 countries (out of 33 in total). At aggregated level (total passenger cars) the improvement is for 29 countries and the only countries for which the fuel consumption factor was not decreased are LV, LT, IS, FYROM.

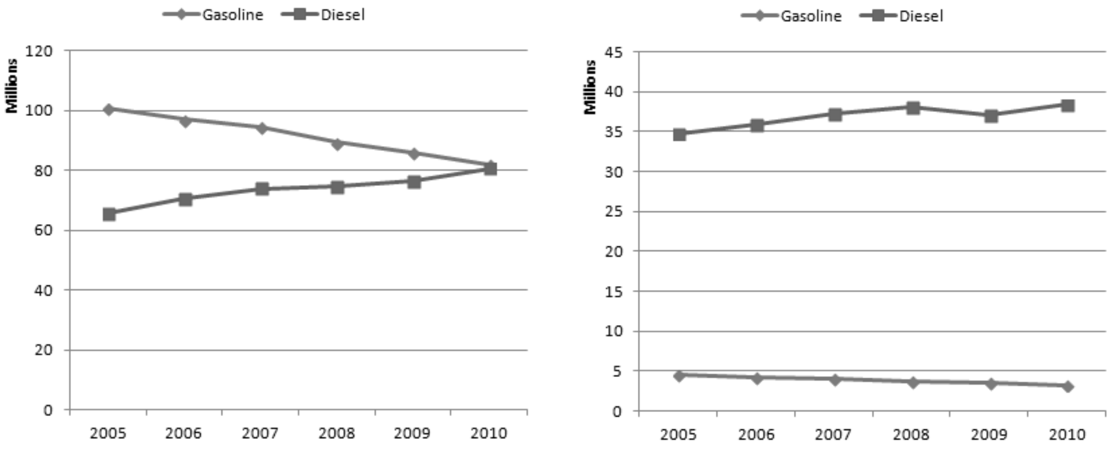


Figure 6: Gasoline/diesel fuel consumption (in million t) from PCs (left) and LCVs (right) (EU28, 2005-2010).

Countries	FCFs (g/km): PCs, Total		% diff.	FCFs (g/km): PCs, Gasoline		% diff.	FCFs (g/km): PCs, Diesel		% diff.
	2005	2010	2005-2010	2005	2010	2005-2010	2005	2010	2005-2010
Austria	52.6	52.3	-1	57.9	57.0	-2	50.1	50.3	0
Belgium	53.4	51.2	-4	58.0	56.9	-2	50.8	49.4	-3
Bulgaria	58.6	57.8	-2	62.4	62.6	0	52.5	52.7	0
Croatia	52.6	51.3	-3	55.9	53.9	-4	47.3	48.2	2
Cyprus	63.3	61.6	-3	62.4	60.8	-3	68.4	67.4	-1
Czech Republic	53.3	52.0	-2	55.7	54.1	-3	48.5	49.4	2
Denmark	52.8	50.0	-5	54.0	53.4	-1	48.4	44.8	-7
Estonia	56.3	55.8	-1	57.2	56.0	-2	53.9	55.6	3
Finland	58.8	58.7	0	59.3	60.2	1	57.0	56.0	-2
France	51.6	49.2	-5	53.5	52.3	-2	50.2	47.9	-5
Germany	57.9	56.2	-3	60.4	58.9	-2	53.8	53.3	-1
Greece	61.9	60.0	-3	62.0	60.1	-3	60.1	59.3	-1
Hungary	51.2	49.5	-3	53.0	51.4	-3	46.5	46.3	0
Ireland	55.0	54.8	0	55.9	56.2	1	51.9	51.5	-1
Italy	52.0	50.0	-4	54.5	53.0	-3	48.4	46.8	-3
Latvia	55.3	57.6	4	57.4	59.3	3	51.7	55.9	8
Lithuania	56.8	57.1	0	59.0	59.1	0	53.0	54.5	3
Luxembourg	58.3	55.1	-6	63.3	60.0	-5	55.1	53.3	-3
Malta	52.1	50.3	-3	53.6	51.2	-4	46.8	45.0	-4
Netherlands	60.7	59.3	-2	63.7	61.8	-3	55.7	56.0	0
Poland	52.1	51.4	-1	56.3	55.0	-2	47.3	47.4	0
Portugal	50.1	48.2	-4	52.0	50.1	-4	48.3	47.0	-3
Romania	60.1	58.6	-3	61.2	61.2	0	56.9	55.0	-3
Slovakia	52.3	50.4	-4	54.2	52.4	-3	45.9	46.0	0
Slovenia	53.2	51.8	-3	56.0	54.2	-3	48.2	49.1	2
Spain	52.7	50.0	-5	58.8	57.8	-2	48.8	46.7	-4
Sweden	64.0	62.3	-3	65.2	65.9	1	57.3	54.4	-5
United Kingdom	52.9	52.0	-2	54.3	54.1	0	48.2	48.0	0
Iceland	58.9	60.1	2	60.1	62.3	4	52.4	53.2	2
Norway	62.0	59.1	-5	64.7	64.9	0	53.9	53.4	-1
Switzerland	65.0	63.6	-2	66.0	65.4	-1	58.1	57.5	-1
FYROM	52.5	53.5	2	55.2	54.9	0	48.3	52.0	7
Turkey	65.9	65.9	0	66.6	66.8	0	62.0	64.0	3
EU28	54.3	52.6	-3	57.2	56.3	-2	50.4	49.2	-2
All 33 countries	54.7	53.0	-3	57.6	56.8	-1	50.5	49.4	-2

Figure 7: Fuel consumption factors (g/km) for PCs Total, Gasoline, Diesel (2005, 2010).

Remarks regarding road transport data

The main issue is the necessity for harmonization and usage of common vehicle classification, categories, and definitions between experts in different countries and fields. In particular:

- A common vehicle classification should be agreed and used by experts in emission modeling, transport statisticians, national authorities, Eurostat, etc.
- A common definition for each vehicle category is also necessary. Different naming and lack of common definition create inconsistencies and may lead to different results and conclusions from different sources.

Airborne transport

Airborne transport data includes data on number of flights, passenger transport (number of passengers, passenger-km, occupancies and unit prices), freight transport (number of tonnes, ton-km, load factors and unit prices) and fuel consumption (including CO_2 emissions).

In the final dataset the indicators are aggregated by country (allocating 50% of the activity data to the departure and arrival country each) and segmented by origin-destination type (domestic, to/from EU27 and to/from other countries), by distance bands and by aircraft types. Price data is additionally disaggregated by service types (scheduled, non-scheduled and low-cost carriers) and by classes (first and business, economy).

The collected data is based on various data sources. The key data suppliers are EUROSTAT for detailed flight-stage data (non-public statistics production data) and publicly available activity and price data, EUROCONTROL for flight activity (origin-destination data) and fuel consumption data (publically available "small emitters tool [SET]"), see EUROCONTROL (2013), as well as EASA for non-public price data (based on outputs of the AERO-MS model), see EASA (2010).

Data from these sources have been compiled and processed having undergone a thorough reconciliation in order to provide consistent datasets between countries, years and indicators.

In order to produce a complete and consistent dataset, data from the different sources were combined and therefore needed careful quality checking and reconciliation. In most cases, there has been relatively little contradiction between datasets, especially EUROSTAT flight stage data and EUROCONTROL activity data showed very good accordance.

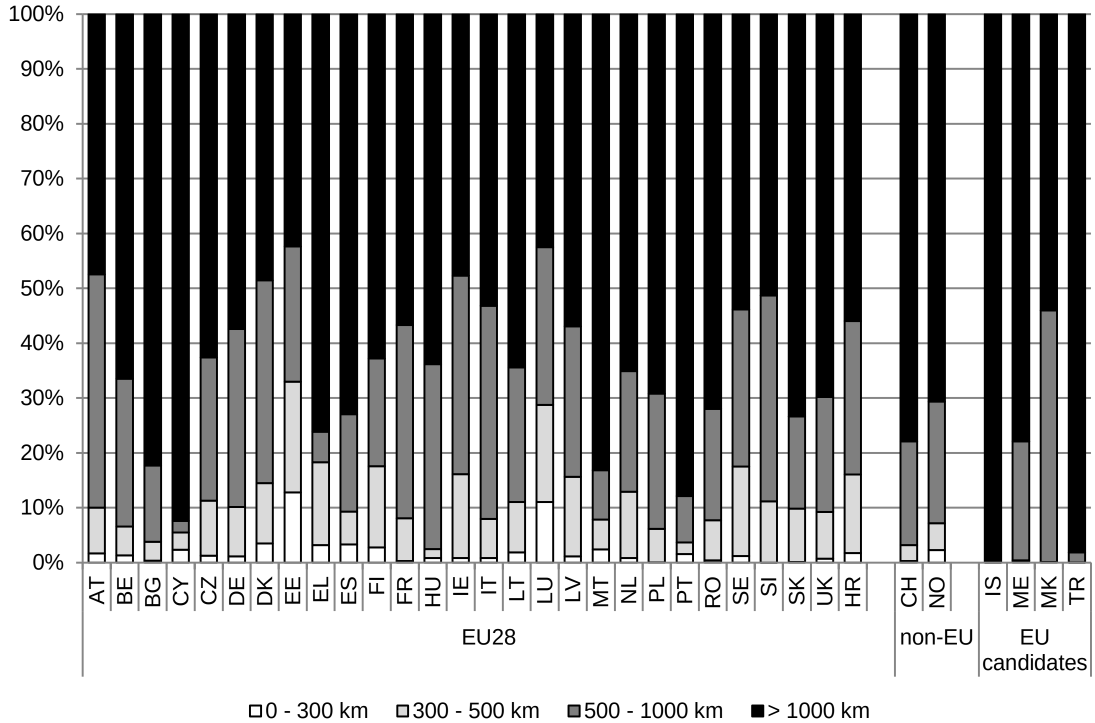


Figure 8: Shares of passengers per distance band by country in 2010.

Figure 8 shows the split of passengers by distance band and country. The shares vary considerably between countries. Relatively peripheral countries such as Malta (MT), Turkey (TR), Cyprus (CY) and Portugal (PT) naturally show high shares in the distance band greater than 1,000 km. Short distance bands (less than 500 km) shares are lower than 33% for all countries, with Estonia (EE), Luxemburg (LU) and Greece (EL) having the highest shares in this distance range.

Figure 9 shows the development of freight transport in tonnes, segmented per aircraft type for Germany as an example; data for all countries are available in Papadimitriou et al. (2013). For Germany, relative shares show a steady increase regarding tonnes in the category of wide body jets (such as the Boeing-777, MD-11 or the Airbus A340) over the years from 2005 to 2010.

Figure 9: Number of tonnes by aircraft type (dedicated freight aircraft and belly freight) for Germany, 2005-2010.

The aviation data produced in this project provide a consistent dataset across all indicators, countries and years. It has been shown that the figures agree well with authoritative sources such as EUROSTAT at the level of totals by country and year. At lower aggregation levels, uncertainty is naturally higher.

Rail transport

For rail transport, data on rolling stock, passenger transport (number of passengers, passenger- and train-kilometres), goods transport (tonnes transported, tonne- and train-kilometres), energy consumption and transport prices were collected, consolidated and evaluated.

Data sources included the EUROSTAT database (Eurostat, 2014), the International Union of Railways - UIC (IEA-UIC, 2012), and data from national statistics portals. Generally, the different sources agree well with each other; only scant information was available on transport prices and urban rail, however, and sometimes contradictory information existed on rolling stock, where data collection was not compulsory.

The available information was compiled and consolidated for each time series by filling gaps in the primary source (often EUROSTAT), or splitting the totals from the primary source into the target segmentation, using data from secondary sources. Interpolation was applied to gaps if no source could be located. Shares of passengers and tonnes by distance bands were derived by combining a distance matrix at NUTS2 level created from the GISCO railway lines layer with EUROSTAT regional statistics. The origin and derivation method of all values in the resulting database can be traced using the flag and source IDs saved along with every record.

The resulting time series generally show the impact of the 2008 financial crisis, which caused a decrease in most goods transport-related indicators. Passenger transport indicators in the European total also display a slight dip in 2009, but the general trend 2005-2010 is an increase (Figure 10).

The annual number of interurban railway passengers increased from about 8.3 billion (who covered 0.40 billion passenger-km) in 2005 to about 9.0 billion (covering 0.43 billion passenger-km) in 2010; however, the peak was reached in 2008 with a slightly higher number of passengers and passenger-kilometers than 2010 (compare Figure 10).

Additionally, about 84,500 (2005) to 92,300 passenger-km (2010) were covered by urban rail (tram and metro). 94% of journeys in 2010 were shorter than 300 km; 2.3% travelled 300-500 km, 1.8% 500-1,000 km, and only 0.04% of journeys by rail exceeded 1,000 km. The proportions by distance band remained quite constant in the period 2005-2010.

Railway freight transport experienced a decrease between 2007 and 2010 after an initial increase from 2005 to 2007. Starting at about 1,700 million tonnes in 2005, freight traffic in Europe reached a peak of over 1,800 tonnes in 2007, dropping to a low of 1,480 tonnes in 2009, and recovering to about 1,580 tonnes in 2010 (compare Figure 10).

All distance bands and cargo classes were similarly affected by these developments. Shifts in the shares of cargo classes between 2007 and 2008 may be artifacts caused by the change in the goods classification from NST-R to NST2007.

Total energy consumption decreased in the period 2005-2010. Disaggregation by transport and energy type shows that mainly diesel use in goods transport decreased, while electricity consumption experienced a very slight decrease only, with an increasing share of passenger transport.

The comparison of the developments of energy consumption and transport performance suggests an improvement in energy efficiency in the period considered, with energy consumption per passenger-km decreasing by 5% and energy consumption by ton-km even by 11%.

Passenger transport prices show a clear upward trend (from 0.12 €/passenger-km to over 0.14 €/passenger-km), while goods transport prices stagnated from 2006 at about 0.08 €/ton-km. Lowest prices for passenger transport are observed in Denmark (about 0.08 €/passenger-km in 2010) and the highest prices in the United Kingdom (above 0.30 €/passenger-km in 2010).

The railway data compiled in this project represent a consistent dataset across all indicators, countries and years. The values have been shown to agree with authoritative sources such as EUROSTAT at the level of totals by country and year. At lower aggregation levels, uncertainty is naturally higher.

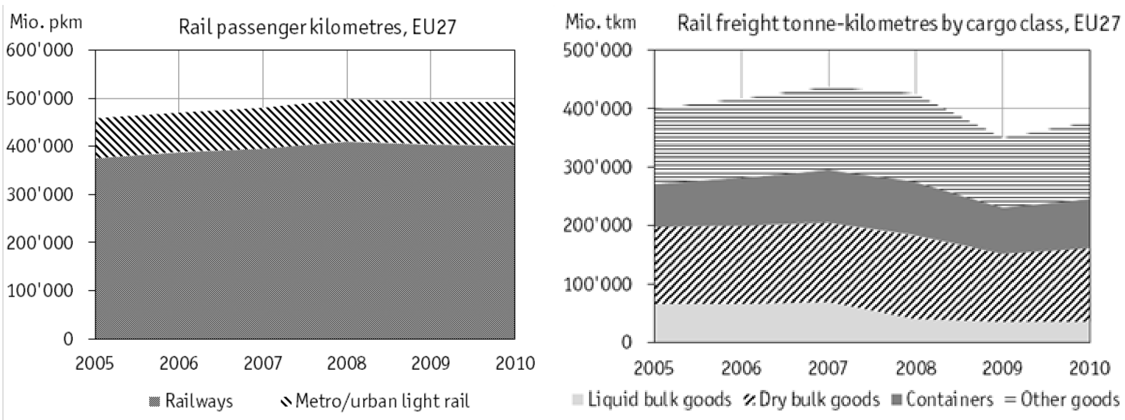


Figure 10: Rail passenger-km (left) and tonne-km (right) in the EU27, 2005-2010.

Waterborne transport

Waterborne transport data are divided into short sea shipping (SSS), deep sea shipping (DSS) and inland waterways (IWW), and have been delivered for EU28 countries, plus CH, NO, IS, FYROM, TR. For all three shipping modes, data include: freight data (in tonnes), number of ship calls, fuel consumption and CO_2 emissions (in tonnes and g/tonne-km), and freight service price (in Euro per tonne-km). Passenger transport data – passenger volumes, fuel consumption, CO_2 emissions and ticket price per passenger-km – only delivered for SSS.

Freight data are divided into four types of goods: liquid bulk, dry bulk, container and other. For SSS, data are split into three size classes according to gross tonnage (<5,000, 5,000-30,000, and >30,000 gross tonne) and four distance bands (<300 km, 300-500 km, 500-1,000 km and >1,000 km) indicating the distance of the transport. For DSS, the data are not split into different ship size classes and there is only one distance band (>1,000 km). For IWW, data are split into seven size classes according to load capacity (<250, 250-400, 400-650, 650-1,000, 1,000-1,500, 1,500-3,000, and >3,000 tonnes) and into the same distance bands as for SSS.

For SSS and DSS the main data sources are Eurostat for freight data, AIS data for ship calls and ship size distribution, and various literature sources for price data. Total fuel consumption and CO_2 emissions are calculated with a model linking the deadweight (dwt) of the ship with engine size and power usage. The average size of a ship in each size category is used in formulas corresponding to IMO EEDI calculation for different ship types, resulting in an emission factor in kg CO_2/km (MEPC, 2011). In order to calculate fuel consumption and CO_2 emissions per tonne-km, information on typical loads for each ship type and size class (Buhaug et al., 2009) and the correlation between the maximum cargo carrying capacity (the payload in tonnes) and dwt according to Clean Shipping Index (2010) are used. Average country specific fuel consumption and CO_2 emissions for IWW vessels are based on an EU study conducted by CE Delft (den Boer et al., 2011). Freight rates and ticket prices are mainly derived from shipping companies' homepages and UNCTAD annual reviews of maritime transport (UNCTAD, 2012). Concerning rates for freight transport in particular, but also for passenger transport, data are considered highly uncertain due to the lack of information.

Some indicative results for waterborne freight transport are presented next. Figure 11 shows that the predominant part of transport work (tonne-km) is conducted by ships in deep sea traffic; for the period 2005-2010, there was a peak in 2007, followed by a decline resulting in the lowest value in 2010 (EU28). The amount of transported goods (tonnes) is split ~40% SSS (dominated by the longer transport distances), ~40% DSS, and ~20% IWW (not shown in figure).

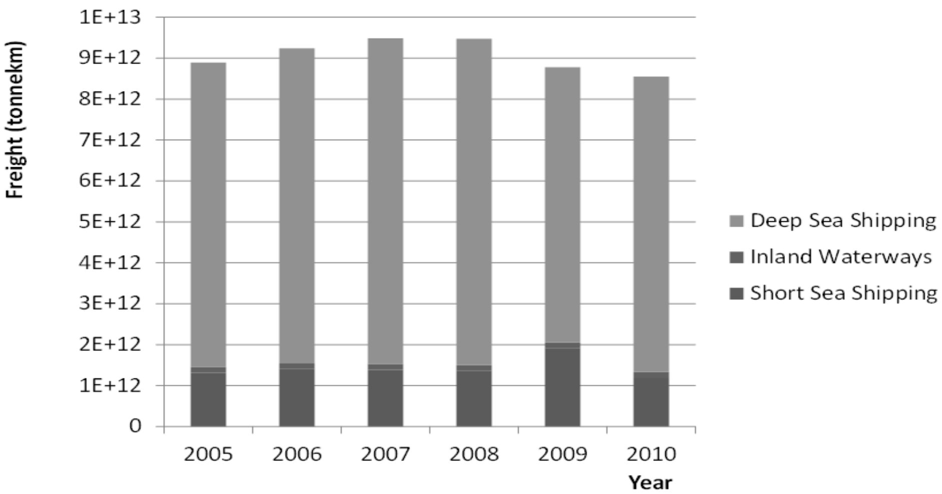


Figure 11: Freight transport work (tonne-km) by different types of shipping in EU28.

Figure 12 shows that DSS dominates CO_2 emissions from waterborne freight transport within EU28, followed by SSS at distances longer than 1,000 km; it is concluded that CO_2 emissions closely follow the trend for freight transport work. Transport with container ships presents a continuous and strong increase from 2005 to 2010 and is by far the predominating source of CO_2 emissions compared to other ship types (not shown in figure).

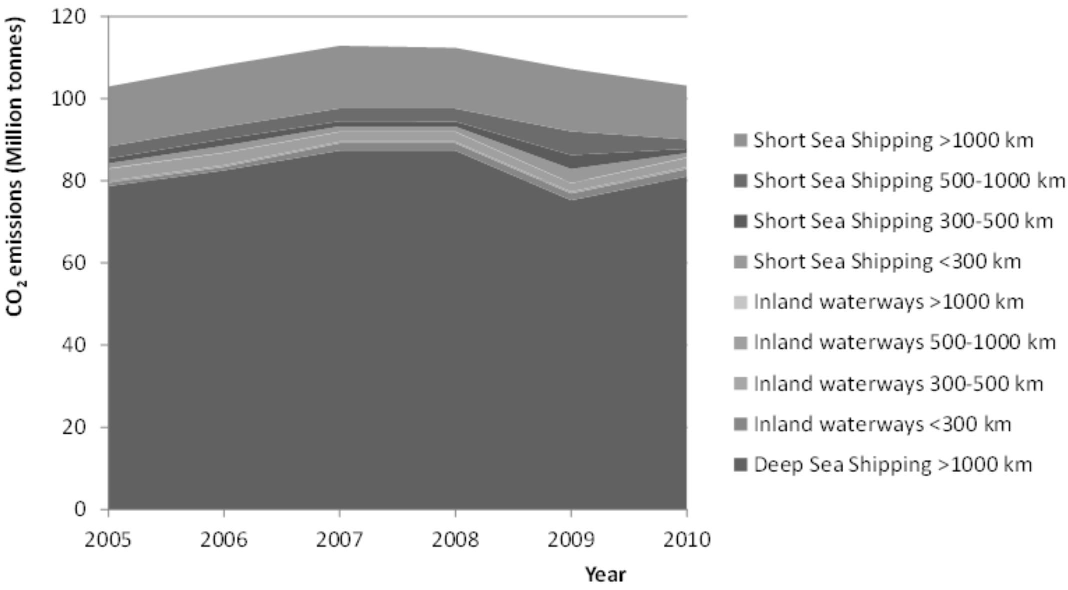
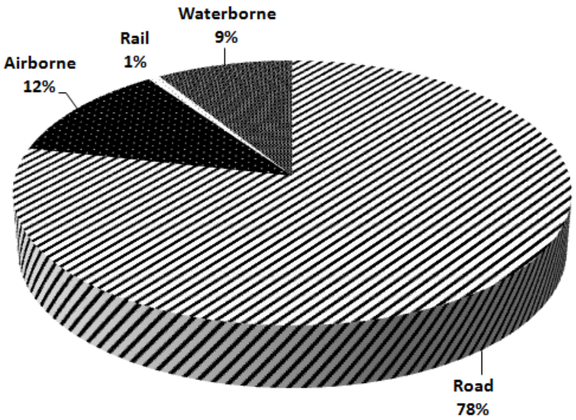


Figure 12: CO_2 emissions (in million t) from freight transport in EU28 by types of shipping and distance bands.

Cross-modal results

In this section of the paper, some interesting cross-modal results are presented (combing data from all modes of transport). These aggregated data have been estimated by bottom up calculations on the basis of the final delivered dataset for EU28. Hence, they can be also compared to aggregated data from other sources to identify consistency of the final dataset.

Figure 13 (left part) shows total fuel consumption from transport sector as percentage share (%) per mode of transport (EU28, 2010); road transport accounts for 78% of fuel consumption, airborne for 12%, rail 1%, and waterborne 9%. The right part of the figure presents total CO_2 emissions (in 1,000 t) (EU28, 2005-2010). For road transport the percentage change from 2005 to 2010 is negligible (~0%); for airborne there is a small increase 2%, for rail a decrease -9%, and for waterborne ~0%. In total (all modes of transport), CO_2 emissions remained almost unchanged from 2005 to 2010 (1,167 vs. 1,173 million t, respectively).



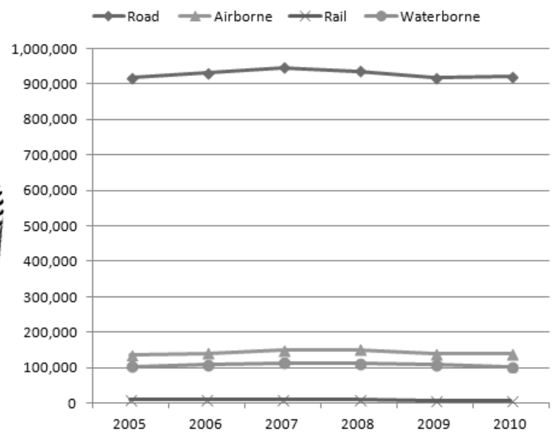


Figure 13: Total fuel consumption from transport sector: share (%) per mode of transport (EU28, 2010) (left). Total CO_2 emissions from transport sector (1,000 t) (EU28, 2005-2010) (right).

Figure 14 presents passenger and freight activity data, total pkm and total tkm from transport sector as percentage share (%) per mode of transport (EU28, 2010). Road transport accounts for 85% of pkm and 16% of tkm, airborne 8% of pkm and 0% of tkm, rail 6% of pkm and 4% of tkm, and waterborne 1% of pkm and 80% of tkm. It can be observed that passenger activity takes place mainly with road vehicles, while freight activity mainly with ships. The percentage change from 2005 to 2010 in total (all modes of transport) is 3% increase for pkm and -4% decrease for tkm (not shown in figure).

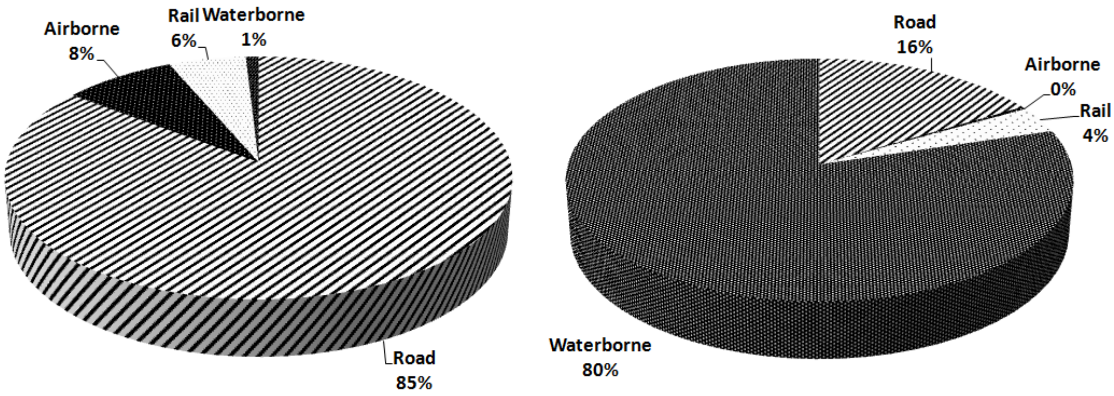


Figure 14: Total pkm (left) and tkm (right) from transport sector: share (%) per mode of transport (EU28, 2010).

Conclusions and extensions of work

A detailed transport dataset has been developed in the framework of the TRACCS project for each transport mode (road, aviation, rail, waterborne) on a per country basis for the period 2005-2010. In general, the main project achievements are:

- Collection of country-specific data (stock, activity, economic) for the various transport modes in each of the EU28 Member States, plus IS, NO, CH, FYROM, TR.
- Validation and interpretation of the data, quality checking, identification of inconsistencies and differences among various sources.
- Creation of a final processed detailed dataset that can be easily digested and incorporated by other models.
- Documentation of inconsistencies between data series and adjustment of data, when necessary, to ensure delivery of complete and consistent dataset with no gaps.
- Development of indicators on the economic, environmental and usage aspects of transport.

The delivered dataset can be utilized by a wide range of experts in transport statistics, emission modeling, vehicle fleet projections, etc. Two examples of extending this work are given below.

- Road transport data of the project are currently being used to provide the TERM (Transport and Environment Reporting Mechanism) 2014 indicators (report to be published in October 2014); latest published version in (European Environment Agency, 2013b).
- Road vehicle fleet and activity data of the project (covering the period 2005-2010) have been combined with the corresponding dataset of the previous FLEETS project (which was for the period 2000-2005) and with latest official statistics available (2011-2013), in order to produce aligned and up to date time series for the whole period 2000-2013. This extended and updated dataset will be useful for the various activity and emission projection tools, as well as for the compilation of national emission inventories with use of an emission modeling tool.

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