



State of play of Internalisation in the European Transport Sector

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List of abbreviations

Term	Explanation
CCR	Central Commission for the navigation of the Rhine
EGR	Exhaust Gas Recirculation
ETS	Emissions Trading Scheme
GDP	Gross Domestic Product
GHG	Greenhouse gas
HGV	Heavy Goods Vehicle
HSL	High Speed Line
HST	High Speed Train
IWT	Inland Waterway Transport
LCV	Light Commercial Vehicle
LTO	Landing and Take-Off
MC	Motorcycle
MSCP	Marginal Social Cost Pricing
pkm	Passenger-kilometre
PPS	Purchasing Power Standards
SCR	Selective Catalytic Reduction
tkm	Tonne-kilometre
vkm	Vehicle-kilometre
WTT	Well-To-Tank

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1 Introduction

1.1 Background of the study

Transport is a precondition for a proper functioning of our modern society, for the well-being of people and for the economy. At the same time, transport comes with various external effects, like air pollution, accidents and congestion. In addition, constructing, maintaining and managing transport infrastructure gives rise to significant costs. In contrast to the benefits, the external and infrastructure costs of transport are, without policy intervention, generally not borne by the transport users and hence not taken into account when they make a transport decision. By internalising the external and infrastructure costs (i.e. making these costs part of the decision making process) the efficiency of the transport system can be increased.

According to economic theory, marginal social cost pricing results in an efficient amount and allocation of transport. However, there are several alternative approaches of internalisation often applied and sometimes even more appropriate in the context of policy making. For example, charging vehicles at their average costs ('average cost pricing') ensures that total external and/or infrastructure costs are covered. Furthermore, under average cost pricing, users of vehicles have to pay for all costs they cause. Another alternative internalisation approach is Baumol pricing. This approach recommends to set taxes/charges at a level at which a certain objective (e.g. congestion level) is met. Finally, Ramsey pricing is a fourth often mentioned internalisation approach, which aims to choose charge levels in a way total revenues are maximised.

The 'Strategy for the internalisation of external costs' (COM(2008) 435) presents the European Commission's plans to adapt Europe's transport pricing system, to ensure that pricing more accurately reflects all of the costs generated by transport. To achieve this, and increase the efficiency of the transport pricing system, the strategy outlines a number of measures to internalise external costs, such as tolls and taxes. The communication defines social marginal cost pricing as the preferred principle of internalisation, but recognises that it is difficult to judge the exact level of marginal costs (as they vary according to time and place) and hence that a certain degree of simplification is inevitable. Applying a specific type of average cost pricing (using the average of variable costs as a proxy for marginal costs) is mentioned as a good solution. Both pure marginal cost pricing as average variable cost pricing are further discussed in Chapter 2. The communication concludes with a set of next steps for the transport pricing system, highlighting the need to account for external costs, apply appropriate instruments and set common principles across Member States, to reduce the likelihood of distorting the internal market.

In practice, there are large differences in the approaches considered to internalise infrastructure (and external) costs in the EU. For example, Directive 2011/76/EU, a revision of the Eurovignette Directive outlined in the following paragraph, prescribes that road infrastructure charges for heavy goods vehicles in Europe have to be based on the principle of cost recovery, i.e. the weighted average infrastructure charges have to be related to the construction costs and the costs of operating, maintaining and developing the infrastructure network concerned. Member States have the option to recover only part of the costs. On the other hand, Directive 2012/34/EU requires that rail usage charges in the EU are based on the direct costs on a network-wide basis, i.e. the cost that is directly related to the use of the rail infrastructure.

A central element in the EU policy for internalisation of external costs is the so-called Eurovignette Directive (Directive 1999/62/EC, as amended), which provides the basis for the EU charging policy for heavy goods vehicles. Directive 1999/62/EC has been amended twice: in 2006 and in 2011. This Directive enables Member States to charge the full infrastructure costs and, since its 2011 revision, also some external costs (air pollution and noise). In addition, charges can be differentiated to some extent, in order to reduce road congestion or to provide incentives to use cleaner vehicles. In 2017, the European Commission presented a proposal to amend the Eurovignette Directive again, among other things, by extending its scope to buses/coaches and light vehicles, including cars, and by enabling the modulation of charging according to CO₂ emissions (European Commission, 2017).

In addition to the Eurovignette Directive, the EU has adopted the Energy Taxation Directive (European Council, 2003)¹, which provides a European framework for taxing motor fuels, heating fuels and electricity. This Directive provides mandatory minimum levels for fuel taxes that should be used by all EU Member States, but also mandatory (e.g. for energy use by commercial aviation or shipping in Community waters) and optional (e.g. electricity use by rail transport) exemptions from these taxes.

For the non-road modes, the EU has implemented several policies to internalise the external costs. For example, Directive 2012/34/EU provides a framework for rail usage charges in the EU (European Parliament, 2012). Furthermore, the EU has introduced frameworks to ensure that airport charges and (maritime) port charges do reflect the actual (air)port costs, without setting any minimum levels to European (air)ports (European Parliament, 2009; European Parliament, 2017). One of the main aims of these frameworks is to improve the financial transparency of airports and ports in Europe.

In shipping, at the global level, the International Maritime Organization (IMO) adopted in April 2018 an initial strategy on the reduction of GHG emissions from ships with the objective to reduce emissions by 50% by 2050, compared to 2008 while pursuing efforts to achieve full decarbonisation as soon as possible. The European Parliament and the Council adopted in April 2015 the Regulation (EU) 2015/757 on the monitoring, reporting and verification of carbon dioxide emissions from maritime transport. This EU MRV scheme will start providing information on ships' efficiency to relevant markets as from June 2019.

Aviation has been included in the EU ETS since 2012, and has so far contributed to reducing an estimated 100 million tonnes of CO₂ emissions between 2012 and 2018, under the EU ETS cap. At its inception in 2012, the inclusion of aviation in the EU ETS also covered flights to and from Europe. Presently, the EU has limited the scope of the EU ETS to flights within the EEA, to support the development of a global measure, the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), under development in International Civil Aviation Organization (ICAO). CORSIA aims to stabilise CO₂ emissions at 2020 levels, by requiring airlines to offset the growth of their emissions after 2020, by purchasing international credits for emissions reduction that took place elsewhere or by taking action themselves to limit emissions. Its rulebook for offsetting is still under development.

So, given the theoretical and policy background of the internalisation of external and infrastructure costs of transport, it is relevant to have an understanding of the total, average and marginal cost coverage of transport in Europe. The aim of this study is to present these figures in order to better understand to what extent the existing internalisation policies have made progress in internalising the costs of transport and to

¹ At the time this report was written, this Directive was in the process of being evaluated.

discuss ways that further internalisation could be achieved. Some previous studies have addressed cost coverage, but none for all transport modes at the EU level and for both infrastructure and external costs. For example, a report on transport internalisation for freight transport on EU motorways was published in 2016 (CE Delft, 2016a). In 2008, a report was released of an assessment of the cost coverage (against external costs only) for light and heavy goods vehicle transport in London (Allen, et al., 2008).

This report is part of a broader project on the internalisation of external and infrastructure costs of transport in Europe. This is explained in more detail in the following text box.

Overview of the study and other deliverables

This report has been developed in the framework of the study ‘Sustainable Transport Infrastructure Charging and Internalisation of Transport Externalities’ commissioned by the European Commission DG MOVE, by a consortium led by CE Delft. The objective of this study is to assess the extent to which the ‘user-pays’ and the ‘polluter-pays’ principles are implemented in EU Member States and in other developed countries. This will allow DG MOVE to take stock of the progress of Member States towards the goal of full internalisation of external (and infrastructure) costs of transport and to identify options for further internalisation.

The full list of deliverables of this study are:

- The state of play of internalisation in the European transport sector (current report).
 - This report shows the extent to which external and infrastructure costs are internalised by current taxes and charges for all countries and transport modes. It also investigates recommended options for further internalisation.
- Handbook on external costs - version 2019.
 - This report provides an overview of the methodologies and input values that can be used to provide state-of-the-art estimates for all main external costs of transport. Furthermore, the report and corresponding excel file present the total, average and marginal external costs for all relevant countries.
- Overview of transport infrastructure expenditures and costs.
 - This report provides an overview of the infrastructure costs of all transport modes in all relevant countries.
- Transport taxes and charges in Europe - An overview study of economic internalisation measures applied in Europe.
 - This study provides an overview of the structure and level of transport taxes and charges applied for the various transport modes in the EU28 Member States (and the other relevant countries). Furthermore, this study presents the total revenues from transport taxes and charges for the various transport modes and countries.
- Summary report.
 - Providing an overview of the main findings of deliverables.

1.2 Objective

This report presents results from Tasks B and C of the overall study ‘Sustainable Transport Infrastructure Charging and Internalisation of Transport Externalities.’ The objective of Task B is to assess the extent to which expenditure on infrastructure investment and maintenance in each country is covered by (a) infrastructure charges and (b) earmarking of funds from transport-related taxes, charges, fees and levies. The objective of Task C is to assess the current state of play of internalisation for the different transport modes in the various countries and the potential for further internalisation.

Both Task B and C outputs in this report are based on the data collected and estimated in Task A of the study, i.e. infrastructure costs, external costs and taxes and charges. The report presents total, average and marginal cost coverage ratios for transport in Europe. These terms are explained in Chapter 2. Further details are provided in the following subsections of the data used for the basis of the cost coverage figures presented in this report.

1.3 Scope

1.3.1 Transport modes

This report considers road transport, rail transport, inland waterway transport (IWT), maritime transport and aviation. Total and average cost coverage ratios are produced for the vehicle categories shown in Table 1. An exception is maritime transport, for which average cost coverage ratios could not be calculated as the data for average maritime costs in tkms could not be collected for this study. Marginal cost coverage ratios are produced for the scenarios shown in Section 2.4.2.

Table 1 - Transport modes and vehicle types covered under total/average cost coverage ratios

Road transport	Rail transport	IWT	Maritime transport	Aviation*
– Passenger car – Motorcycle – Bus – Coach – Light Commercial Vehicle (LCV) – Heavy Goods Vehicle (HGV)	– High speed passenger train (HST) – Passenger train electric – Passenger train diesel – Freight train electric – Freight train diesel	– Inland vessel	– Freight vessel	– Passenger aircraft

* Freight aviation is not considered in this report, as the data to provide reliable figures is missing for revenues and external costs.

1.3.2 Geographical coverage

For road transport, average cost and marginal coverage ratios are produced for all EU28 countries, Norway, Switzerland, while a comparison with the non-European countries (Japan, Canada, and the United States) is included where the data is deemed to be reliable. For rail transport, cost coverage ratios are produced for the EU26, as Cyprus and Malta have no railways. For Canada and the United States average costs and revenues are considered at the province/state level, i.e. California, Missouri (both US), British Columbia and Alberta (both Canada)².

For inland waterways, average cost and marginal coverage ratios have been produced for a subset of the 17 European Economic Area (EEA) countries with significant inland waterway networks.

² Both for the US and Canada, a front runner and laggard state/province with respect to the internalisation of external costs have been selected. For the US, California has been selected as a front runner state, among other things because fuel and vehicle taxes are among the highest in the US and broad enabling legislation for

For aviation, average cost and marginal cost coverage ratios are not provided at the national/state level, but at the level of individual airports³. The selection of airports considered in this study is given in Table 2.

This selection is made based on the following criteria, which ensures that only international airports (with international flights) are covered in the analysis:

1. Of all considered countries the largest airport is analysed.
2. In Canada and the US, the two largest airports are included.
3. In Europe, the five largest airports, which are not already included in the criteria above, are a considered.

For maritime transport, marginal cost coverage ratios are considered (See Chapter 7)⁴. These ratios are provided for individual ports, rather than at the national/state level. The initial selection of ports considered in this study, given in Table 2, includes 34 EU ports. In addition, Chapter 3 provides a comparison of total/average cost coverages in the EU28, through using the same selection of ports, as most cost and revenue figures are not available at the EU28 level for maritime transport.

Table 2 - Airports and maritime ports covered

Country	Airport(s)	Maritime port(s)	
		Freight ports	Ferry ports
Austria	Wien - Schwechat		
Belgium	Brussels	Antwerp	Antwerp
Bulgaria	Sofia	Varna	
Croatia	Zagreb Pleso	Rijeka Split	Rijeka Split
Cyprus	Larnaka	Lemessos	
Czech Republic	Prague Ruzyně		
Denmark	Copenhagen - Kastrup	Arhus Helsingør (Elsinore)	Arhus Helsingør (Elsinore)
Estonia	Lennart Meri Tallinn	Tallinn	Tallinn
Finland	Helsinki - Vantaa	Helsinki	Helsinki
France	Paris - Charles de Gaulle Paris - Orly	Calais Le Havre Marseille	Calais Marseille
Germany	Frankfurt Munich	Hamburg Bremerhaven	Travemünde
Greece	Athens Eleftherios Venizelos	Piraeus	Piraeus

toll roads has been implemented. Furthermore, California is known for its progressive policies in the transport sector (e.g. regarding electric vehicles). Missouri, on the other hand, shows relatively low fuel and vehicle taxes as well as limited road charging legislation, suggesting a low level of internalisation. For that reason, Missouri is selected a laggard state. According to Corporate Knights (2015), British Columbia can be regarded as the Canadian province with the highest environmental performance for the transport sector, while Alberta is ranked lowest. Therefore, British Columbia (front-runner) and Alberta (laggard) has been selected as Canadian provinces in this study.

³ This is done to be consistent with the other studies carried out within the broader study on the internalisation of external and infrastructure costs (see text box in Section 1). Both in the study on infrastructure costs and the study on taxes and charges the (air)port level is a more appropriate scope than the country level, as data on infrastructure costs and taxes/charges are mainly available at the (air)port level.

⁴ Section 7.2 contains details on data issues that prevent the accurate calculation of average cost ratios for maritime transport.

Country	Airport(s)	Maritime port(s)	
		Freight ports	Ferry ports
Hungary	Budapest Liszt Ferenc		
Ireland	Dublin	Dublin	Dublin
Italy	Roma - Fiumicino	Genova Trieste Venice	Genova Trieste Venice
Latvia	Riga	Riga	Riga
Lithuania	Vilnius	Klaipėda	Klaipėda
Luxembourg	Luxembourg		
Malta	Luga	Marsaxlokk	
Netherlands	Amsterdam - Schiphol	Rotterdam	Rotterdam
Poland	Warsaw Chopina	Gdansk	Gdansk
Portugal	Lisboa	Sines	
Romania	Bucharest Henri Coandă	Constantza	
Slovakia	Bratislava M.R. Stefanik		
Slovenia	Ljubljana Brink	Koper	
Spain	Barcelona - El Prat Adolfo Suarez Madrid - Barajas Palma de Mallorca	Algeciras Barcelona Bilbao Valencia	Algeciras Barcelona Bilbao Valencia
Sweden	Stockholm - Arlanda	Goteborg	Goteborg
United Kingdom	London - Heathrow London - Gatwick	Felixstowe	
Norway	Oslo - Gardermoen	Oslo	Oslo
Switzerland	Zurich		
Canada	Toronto/Lester B Pearson Intl. Ont. Vancouver International B.C.	Vancouver Montreal	
United States	Atlanta Hartsfield - Jackson International Los Angeles International	Los Angeles Savannah	
Japan	Haneda Airport Tokyo	Tokyo	

1.3.3 External costs of transport

External costs of transport refer to the difference between social costs (i.e. all costs to society due to the provision and use of transport infrastructure) and private costs of transport (i.e. the costs directly borne by the transport user). This report takes into account all main externalities of transport for cost coverage ratios that involve external costs. These are explained further in Section 2.2.1.

The source of data for external costs in this report is the related study report that provided an updated Handbook on the external costs of transport, along with cost estimates for each country included in the study under each category of cost. There are specific robustness concerns for the data collected in each external cost category (in addition to the robustness of transport performance data described in Section 1.3.7) and described in detail in the updated Handbook on the external costs of transport.

These data concerns are summarised as follows:

- **Accidents:** There is some uncertainty on the human costs of accidents (VSL value) and the value used in the new handbook from the OECD is significantly higher than in previous editions. The calculations also make assumptions about the proportion of costs that are already internalised and thus excluded from the values calculated. These are with respect to costs insured (all excluded), non-driver human costs (100% included), medical and administration costs (50% excluded), production loss (45% excluded), and consumption loss (100% included).
- **Air pollution:** Emission factors used for road transport from the COPERT database may not fully reflect the latest findings on real world emissions. In addition, the differentiated emission factors for rail, inland waterways, and maritime are more uncertain than for other modes. There is some uncertainty in the literature on the value of life year lost (VOLY) to value immaterial damages.
- **Climate Change:** A central climate change avoidance cost estimate of € 100 per tonne CO₂ equivalent for medium-term was used, but the valuation is subject to targets set to reduce GHG emissions.
- **Noise:** The EEA noise maps used as the basis for the cost estimates have missing data and corrections were carried out for these. For example, the number of people exposed to road noise is missing for Greece and aviation noise exposure data is missing for Zagreb Plesno Airport and Ljubljana Brnik Airport. In addition, the most recent noise maps available date back to 2012. Finally, cost factors used in this study do not take into account the new exposure response functions developed by the WHO in 2018.
- **Congestion (road mode only):** Road congestion costs are highly dependent on the methodological approach and specific for local conditions, so there is a huge variation in existing total, average and marginal congestion cost estimations. For this study, total and average road congestion costs have been estimated using deadweight loss in a simplified approach to make them comparable to other external costs presented in the Handbook⁵. No reliable way to estimate congestion or scarcity costs for non-road modes has been found.
- **Well-to-tank emissions:** There is some uncertainty in emission levels and cost factors due to uncertainty about where the impacts take place (which are indirect).
- **Habitat damage:** It is not possible to make a generally applicable estimation of the marginal costs of habitat damage, as habitat damage is only affected to a minimal extent by changes in transport activity. Instead, the magnitude of habitat damage is primarily linked to changes in the infrastructure network and therefore, it is assumed that the marginal costs of habitat damage are negligible.

⁵ An alternative approach would be to use delay cost. In this approach, road congestion costs are defined as the value of the travel time lost relative to a free-flow situation. The deadweight loss approach, on the other hand, determines the economically optimal solution. Therefore, the deadweight loss approach is taken for the analyses in this report, as it defines the congestion cost in a manner that is regarded as a proper basis for transport pricing.

1.3.4 Infrastructure costs of transport

Transport infrastructure costs are considered in this study for cost coverage ratios involving infrastructure costs. This includes both fixed and variable infrastructure costs. We consider the entire network for road, rail and inland waterway transport and a selection of ports and airports for maritime transport and aviation.

The definition of infrastructure costs and types of costs considered as part of this study are explained in Section 2.2.2. Some important uncertainties with respect to the expenditures on transport infrastructure are:

- As there is no coherent framework for accounting transport infrastructure expenditures, differences may exist in the scope and definition of infrastructure expenditures used in the various countries (ITF, 2013a; ITF, 2013b). Although we have tried to align the definition and scope of infrastructure expenditures between countries (by assessing national data sources and cross-checking data from various sources), differences between countries still exist. Therefore, comparisons between countries should be made very carefully.
- The datasets on infrastructure expenditures and costs available for this study do contain some significant data gaps. Particularly data on transport infrastructure investments in Eastern European countries before 1995 is often missing. But also data on depreciation costs and/or maintenance costs for maritime ports is often not publicly available. In order to estimate infrastructure costs for all transport modes in all relevant countries, these missing data have been estimated. It should be clear that these estimations cause a considerable amount of uncertainty in the infrastructure cost figures estimated in this study.
- Data on the breakdown of total investments (into enhancement and renewal expenditures) and total O&M expenditures (into operational and maintenance expenditures) as well as between fixed and variable expenditures is often not available at the country level. To deal with this issue in the most appropriate way we have assessed the available data and literature to come up with EU average default values for these breakdowns. Although this approach may increase the consistency between infrastructure cost estimates between countries, it may also ignore to some extent country-specific characteristics of the transport infrastructure (costs).

The main uncertainties with respect to the methodology and supporting data used are:

- The allocation of infrastructure costs per transport mode to the various relevant vehicle categories requires the selection of relevant cost drivers. In order to select the most appropriate cost drivers we have carried out a literature review on cost drivers applied in transport infrastructure cost studies. However, it should be noted that the final selection of cost drivers does affect the results per vehicle category and that applying an alternative of cost drivers would end up with different results.
- There have also been uncertainties with respect to the input data (e.g. vehicle-kilometres, passenger-kilometres, tonne-kilometres, average weight of vehicles, etc.) used for the calculation of the infrastructure costs per vehicle category. These input data have been based on reliable sources, but inconsistencies between sources and missing data cause some uncertainty in these data as well. The main uncertainty with respect to input data is related to the transport performance data used for road transport. As explained in Section 1.3.7, in this study we use data from Eurostat, following the nationality principle. The use of these data affects the results of this study and in some cases hampers some of the assessments to be carried out in this study, since the scope of these data differs from the scope of the infrastructure expenditure/cost data, which is in line with the territoriality principle. Particularly the results for HGVs may be significantly affected at country level. This affects the

calculation of average and marginal infrastructure costs (e.g. resulting in too high average and marginal cost figures for countries with a lot of transit traffic⁶), but also the allocation of road infrastructure costs to the various vehicle categories (as this is partly based on transport performance data). As a consequence the results for road transport in this study, are not always comparable to the results found by previous studies (e.g. (CE Delft, 2016a; CE Delft, 2016b)).

Because of the uncertainties described above, the results presented in this study should be regarded as an indication of the transport infrastructure costs in the various (European) countries. More detailed national (or airport or maritime port specific) studies would be required to validate the results from this study.

Given the uncertainties described above, it can be concluded that figures on total costs are – in general – more reliable than figures per vehicle category, as the allocation of total figures to vehicle categories does create some additional uncertainties at country level. Furthermore, total cost figures are more reliable than average and marginal ones, as the latter have to deal with relatively large uncertainties in traffic performance data. Finally, total cost figures are more reliable than those at country level.

1.3.5 Transport taxes and charges

In this study, we focus on the transport taxes and charges that have been in place in 2016. The definition of transport taxes are provided in Section 2.2.3. This study provided an overview of the structure and level of transport taxes and charges applied in the EU28 and some other countries. This overview is based on actual data collected from reliable sources like the ACEA Tax guide, documents of the national tax authorities, documents/websites of infrastructure managers, etc. Therefore, the data on the structure and level of transport taxes/charges presented in this study can be considered robust.

In addition to the tax/charge structure and levels, this study also discusses the total/average revenues from transport taxes and charges. The main uncertainties with respect to these results are:

- for some taxes/charges (or countries), the total revenues in 2016 have been estimated, using data for earlier years or a bottom-up approach;
- the allocation of total tax/charge revenues to various vehicle categories has often been estimated, resulting in a certain extent of uncertainty in the final results.

To estimate the average revenues (e.g. in €/1,000 passenger-kilometre or €/1,000 tonne-kilometre), transport performance data have been used. These data have been based on reliable sources, but as described in Section 1.3.7, inconsistencies between sources and missing data cause some biases in these results as well. An important bias with respect to input data is related to the transport performance data used for road transport. As explained in Section 1.3.7, in this project we use road transport performance data from Eurostat, which at a detailed level, is only reported on the basis of the nationality principle. However, the scope of these data differs from the scope of some of the taxes and charges applied for road transport (e.g. fuel taxes, road tolls, vignettes) as these are more in line with the territoriality principle. These differences in scope may seriously affect some of the assessments in this study, particularly for lorries (e.g. calculation of average revenues from taxes/charges in tonne-kilometre) and in some cases we even had to apply alternative, second-best approaches. As a consequence, the results for road transport, as

⁶ As the total cost figures are divided by only part of the relevant transport performance data (i.e. by domestic vehicles).

found by this study, are not always comparable to the results found by previous studies (e.g. (CE Delft, 2016b)).

Marginal taxes and charges are based on the tax/charge levels that are relevant for the specific marginal cost scenarios considered in the assessment of marginal cost coverage ratios.

Apart from internalisation, other motives for taxation, such as revenue generation or the incentive to establish a level playing field between modes, also exist. This study does not assess whether these motives would justify (further) taxation, focusing on the externalities listed above only.

1.3.6 Transport subsidies

In general, this study does not consider transport subsidies and public service obligations (PSO), with two main exceptions. First, tax/charge breaks or exemptions are implicitly addressed when assessing taxes and charges. Second, transport infrastructure subsidies (including European funds, like CEF) are considered as part of the infrastructure cost assessment. Other subsidies are not considered, as data availability on subsidies is rather poor. Only a few, incomplete and older studies are available on this subject at the European level (e.g. (CE Delft, 2017; Ecologic; CE Delft; TU Dresden, 2006; Ecologic, 2005)). Collecting data on all transport subsidies applied in Europe has therefore been out of the scope of this study (also because a large number of subsidy and PSO schemes exist, both at the national and regional/local level).

1.3.7 Transport performance data

To estimate the various total, average and marginal cost coverage ratios, several types of transport performance data (e.g. vehicle-kilometres, tonne-kilometres, passenger-kilometres) have been used. For the purpose of this report a consistent set of transport performance data have been composed, mainly based on EU aggregated sources (like Eurostat and COPERT).

Road transport performance data is taken from Eurostat, following the nationality principle, i.e. transport activity is allocated to countries where the vehicle is registered. In an alternative approach, the territoriality principle, transport activity is allocated to the countries where the activity actually takes place. For example, kilometres driven by Polish vehicles in Germany are accounted to Poland if the nationality principle applies, and to Germany if the territoriality principle applies. The territoriality principle would have been more consistent with the scope of the external and infrastructure costs. However, a detailed EU-wide data set on road transport performance, based on the territoriality principle, is not available. Therefore, the official Eurostat data set, based on the nationality principle, has been used for this study⁷. This choice (i.e. to apply road transport performance data based on the nationality principle) affects the results, in particular the allocation of the noise, congestion, accident and infrastructure costs from road transport to different vehicle categories. In particular, the results for HGVs may be significantly affected at country level.

⁷ For the calculation of infrastructure costs, data on the weight (and axle load) of road vehicles is required as well. Territorial activity is presented by Eurostat only at aggregate level, i.e. no data on weight and axle load is available. See CE Delft (2019) for more details.

In addition, the data for motorcycles does not use consistent vehicle definitions between Member States, making the results unreliable in comparisons between Member States. For this reason, motorcycle results have been suppressed from the road chapter.

1.3.8 Base year

All costs, taxes and charge levels quoted in this report are presented for 2016. If some data was not available for 2016, data for the most recent year (preferably 2015) was used.

1.3.9 Price level

All financial figures are expressed in Euro price levels of 2016. Data from sources where price levels from other years were used, are translated to price level 2016 by using relevant price index figures (from Eurostat). Furthermore, all financial figures are adjusted for differences in purchase power between countries (by using Purchasing Power Standards, PPS), in order to allow for direct comparisons between countries. This implies that all financial figures are shown for the EU28 average price level.

1.4 Outline of the study

The study is structured as follows:

- Chapter 2 introduces the concept of cost internalisation in transport, earmarking for taxes and charges, and the cost coverage ratios presented in this study. It also introduces the role of broader non-price instruments.
- Chapter 3 compares transport modes for the EU28, discussing total, average and infrastructure cost coverage ratios. It also introduces broader non-pricing measures that cut across all modes of transport.
- Chapters 4-8 are transport-mode specific chapters with the same overall structure. Sections X.2 address average cost-based internalisation. Average costs from all infrastructure costs, as well as variable infrastructure costs, plus all external costs are compared against the average revenues from all internalisation measures plus infrastructure access charges. The analysis is carried out for both passenger and freight transport for road and rail modes. Although vehicle types are aggregated in some cases (e.g. all road passenger vehicles), Annexes D-I provide the breakdown of modes by vehicle type (e.g. passenger car, motorcycle, bus and coach). Sections X.3 analyses' the marginal cost-based internalisation by comparing marginal external and infrastructure costs against marginal revenues from taxes and charges for three to four specific scenarios. Sections X.4 present the average infrastructure cost coverage and earmarking for road and rail transport and Sections X.5 address the broader context of internalisation of external costs for that mode. In addition, there are comparisons between the different transport modes in Chapter 4. Chapter 9 provides the overall conclusions and recommendations of the study.

The study also includes a number of annexes⁸:

- Annex A elaborates on the results of external only cost coverage;
- Annex B conducts a cost comparison for motorways;
- Annex C compares fuel/energy costs with related charges;
- Annex D (Excel document) provides the raw data and charts for cross modal comparisons between average cost coverage ratios;

⁸ Whenever a specific country falls out of the magnified subset shown in the report, its data are available in the Annexes.

- Annex E (Excel document) provides the raw data and charts for the road transport average cost coverage ratios;
- Annex F (Excel document) provides the raw data and charts for the rail transport average cost coverage ratios;
- Annex G (Excel document) provides the raw data and charts for the IWT average cost coverage ratios;
- Annex H (Excel document) provides the raw data and charts for the aviation transport average cost coverage ratios;
- Annex I (Excel document) provides the raw data and charts all the marginal cost coverage ratios presented in this study.

2 Internalisation of external and infrastructure costs

2.1 Introduction

This chapter provides a methodological framework for this study. We start by defining some main concepts, i.e. external costs, infrastructure costs and transport taxes and charges (see Section 2.2). In Section 2.3, we define the concept of internalisation, including an overview of the various internalisation approaches that can be distinguished. In this section we also make a selection of the internalisation approaches to be considered in this study. Based on these selected internalisation approaches, indicators to assess the extent by which external and infrastructure costs are internalised are developed in Section 2.4. These indicators are targeted on internalisation by use of taxes and charges. However, also non-pricing instruments can contribute to the objectives of internalisation strategies. This is discussed in more detail in Section 2.5.

2.2 Defining some main concepts

Before we discuss the issue of internalisation, we first briefly define some main concepts relevant for this discussion. These concepts include external costs, infrastructure costs and transport taxes/charges. The definitions presented below for these concepts are in line with the definitions used in the other deliverables of this project, i.e. CE Delft et al. (2019a) (2019b), and (2019c) For more detailed information on external costs, infrastructure costs and transport taxes/charges, we refer to these three documents.

2.2.1 External costs

External costs arise when the social or economic activities of one (group of) person(s) have an impact on another (group of) person(s) and when that impact is not fully accounted, or compensated for, by the first (group of) person(s). In other words, external costs are generally not borne by the transport user and hence not taken into account when they make a transport decision. Cars exhausting NO_x emissions, for example, cause damage to human health, imposing an external cost. This is because the impact on those who suffer damage to their health is not taken into account by the driver of the car when deciding on taking the car.

An overview of the external costs considered for the various transport modes in this report is shown in Table 3.

Table 3 - External costs covered per transport mode

Transport mode	Variable external costs						Fixed external costs
	Accidents	Air pollution	Climate change	Noise	Congestion	Well-To-Tank emissions	Habitat damage
Road transport	x	x	x	x	x	x	x
Rail transport	x	x	x	x		x	x
IWT	x	x	x			x	x
Maritime transport	x	x	x			x	
Aviation	x	x	x	x		x	x

As shown in Table 3 , most external costs of transport can be considered variable costs, i.e. their levels vary with transport volumes. For example, air pollution costs will increase when more kilometres are travelled. Only habitat damage can be considered a fixed cost, as these costs mainly depend on the existence of transport infrastructure (and not on the extent by which this infrastructure is used)⁹.

In this report we distinguish between total, average and marginal external costs. Total external costs refer to all external costs within a geographical boundary (e.g. EU28 or a country) caused by (a specific mode of) transport. Average external costs are closely related to total costs, as they express the cost per transport performance unit (e.g. in €/1,000 passenger-kilometres or €/1,000 tonne-kilometres). Finally, marginal external costs are the additional external costs occurring due to an additional transport activity. These three cost categories are considered for all externalities mentioned in Table 3 , with one exception: as the marginal costs of habitat damage are assumed to be negligible¹⁰, they are not considered in this study.

Externalities are, in general, not traded on actual markets and hence no market prices are available for them. Therefore, alternative valuation methodologies have been applied to quantify external costs. In CE Delft et al. (2019c) state-of-the-art methodologies have been used to provide a robust set of external cost figures. The uncertainties in these figures differ widely between external cost categories. We refer to CE Delft et al. (2019c) for a detailed discussion on these uncertainties.

⁹ As explained in CE Delft et al. (2019c), habitat damage consists of habitat loss (i.e. the land use of transport leads to loss of habitats/ecosystems) and habitat fragmentation (i.e. transport infrastructure have negative fragmentation and separation effects for animals). As these effects mainly depend on the existence of infrastructure (and to a lesser extent on the transport flows), habitat damage is considered fixed in this study.

¹⁰ As mentioned above, the level of habitat damage mainly depends on the size of the infrastructure network and just to a small extent on transport volumes. Therefore, the additional habitat damage resulting from an additional transport activity is probably very small and therefore considered zero.

2.2.2 Infrastructure costs

Infrastructure costs can be defined as the direct expenses on transport infrastructure plus the financing costs or - regarded from a different point of view - the opportunity costs for not spending the resources for more profitable purposes (Fraunhofer-ISI; CE Delft, 2008).

As is shown in Table 4 , infrastructure costs consist of various types of costs:

- *Enhancement costs*: costs of new infrastructure or expansion of existing infrastructure.
- *Renewal costs*: costs associated with the renewal of (parts of) the infrastructure. The renewed infrastructure will at least have a lifetime of more than 1 to 2 years.
- *Maintenance costs*: costs associated with ‘ordinary’ maintenance, i.e. relatively minor repairs with an economic lifetime of less than 1 or 2 years.
- *Operational costs*: costs made to enable an efficient use of the infrastructure (e.g. lighting).

As is presented in Table 4 , some of the infrastructure costs can be considered fixed (i.e. do not vary with transport volumes), while another part of the infrastructure costs can be considered variable. In line with external costs, total, average and marginal infrastructure costs can be considered. As for the marginal infrastructure costs, these are assumed to be equal to the variable part of the average costs¹¹.

Table 4 - Overview infrastructure costs covered

	Fixed infrastructure costs	Variable infrastructure costs
Investments	– Enhancement costs – Fixed renewal costs	– Variable renewal costs
Operational and Maintenance costs	– Operational costs – Fixed maintenance costs	– Variable maintenance costs

In CE Delft et al. (2019a), state-of-the-art methodologies are applied to estimate the infrastructure costs for all transport modes and all countries. However, there are many gaps in the data required to calculate the infrastructure costs, which results in significant uncertainties in the figures produced (particularly for maritime transport and aviation). Because of inconsistencies in the accounting framework applied in the various countries, there may also be differences in the infrastructure costs calculated for the various countries. This complicates the direct comparison between countries. Because of these and other uncertainties¹² the infrastructure costs presented in this study should be regarded as an indication of the transport infrastructure costs in the various (European) countries.

2.2.3 Transport taxes and charges

Transport taxes and charges are defined in this study as all taxes/charges that are directly related to the ownership and use of transport vehicles, including the taxes/charges related to infrastructure use. This definition excludes general taxes like profit taxes and wage taxes (e.g. for truck drivers), as they are only indirectly related to transport activities¹³.

As for transport charges, only compulsory (non-administrative) payments to governments and infrastructure operators (e.g. road and rail authorities, ports, airports, etc.) are

¹¹ This implies that only part of the renewal and maintenance costs can be considered marginal infrastructure costs.

¹² See CE Delft (2019a) for a more detailed discussion on the robustness of the infrastructure costs figures.

¹³ VAT is excluded for the same reasons, with one exception: VAT levied on transport taxes and charges are considered transport taxes in this study and hence taken into account.

considered. Payments for transport services delivered by other semi-private agents are considered internal costs of transport and hence are not taken into account. An overview of the types of transport taxes and charges is given in Table 5.

Most taxes/charges are defined as variable taxes/charges. Some fixed taxes are also applied but only for road transport. As for external and infrastructure costs, we distinguish between total tax/charge revenues, average tax/charge levels and marginal tax/charge levels. In this respect, all variable taxes/charges are considered marginal taxes/charges.

Table 5 - Overview of transport taxes/charges per transport mode

Transport mode	Variable taxes/charges	Fixed taxes/charges
Road transport	– Fuel taxes – Electricity taxes – Road tolls and vignettes^a – ETS – VAT on variable transport taxes/charges	– Vehicle taxes (purchase and ownership taxes) – Insurance taxes – VAT on fixed transport taxes/charges
Rail transport	– Fuel taxes (diesel) – Electricity taxes – Rail infrastructure charges – ETS	
IWT	– Fuel taxes – Infrastructure charges (port charges, fairway dues, dues for locks and bridges) – Water pollution charges	
Maritime transport	– Infrastructure charges (port dues, fairway dues)	
Aviation	– Fuel taxes – Aviation taxes – Airport charges – ETS	

^a Vignettes are considered variable charges in this study, although they are only indirectly linked to the number of kilometres driven. However, as vignettes can be purchased for different periods of time (including shorter periods), they can be considered at least somehow variable. Furthermore, for the purpose of this study, we would like to consider road tolls and vignettes in the same way, such that we can assess to what extent costs are covered by road charges, regardless of how these charges are implemented.

The tax/charge levels and revenues have been based on actual data collected from reliable sources like the ACEA Tax guide, documents of national tax authorities, documents/websites of infrastructure managers, etc. Therefore, in general the tax/charge levels and revenues in this study can be considered rather robust, particularly at the transport mode level. At the level of vehicle categories, total/average revenues have been estimated by allocating the total revenues per mode to the various vehicle categories (based on specific allocation approaches). This approach results in a certain level of uncertainty. For a more detailed discussion on the robustness of the tax/charge levels and revenues, see CE Delft et al. (2019b).

2.3 Internalisation of external and infrastructure costs

2.3.1 Definition and objectives of internalisation

As discussed in the previous section, transport activities result in both external and infrastructure costs. In contrast to the benefits of transport, these costs are, without policy intervention, generally not borne by transport users and hence are not taken into account when they make a transport decision. Transport users thus take only part of the social costs¹⁴ into account when making a transport decision, resulting in sub-optimal outcomes (and hence welfare losses).

The internalisation of external and infrastructure costs means making such effects part of the decision making process of transport users. This can be done by using market based instruments (e.g. taxes, charges, emission trading). Internalisation of external (and infrastructure) costs by using market based instruments is one of the leading principles of the EU's transport policy. The 2011 EU White Paper on Transport argues that transport charges and taxes must be restructured in the direction of wider application of the 'polluter-pays' and 'user-pays' principle (European Commission, 2011a). More recently, the Commission Communication on 'A European Strategy for Low-Emission Mobility' emphasized the need for making steps forward in applying the 'polluter-pays' and 'user-pays' principles (European Commission, 2016a).

Objectives of internalisation

The motives for applying internalisation measures for transport can be various. In general, three main objectives can be distinguished. (CE Delft et al. (2008), based on (Verhoef, 2004)):

- *Influencing behaviour*, to improve the efficiency of the transport system by:
 - reducing environmental impacts of traffic and enhancing traffic safety;
 - allowing an improved flow of traffic (i.e. reducing congestion).
- *Generating revenues*, to:
 - finance new, extended or modernised infrastructure (which may in turn be related to the aim of improving freer flow of traffic);
 - cover costs of infrastructure management, operation and maintenance;
 - finance mitigation measures and/or alternatives for road transport;
 - finance the general budget (or reduce other taxes such as labour taxes).
- *Increasing fairness*, to:
 - make the polluter/user pay (polluter/user-pays principle);
 - level the playing field for the competition between transport modes;
 - level out changes in income distribution or avoid overburdening socially vulnerable groups.

¹⁴ The social costs are all costs to society due to the provision and use of transport infrastructure.

It is the sum of the private costs of transport (i.e. the costs directly borne by the transport user) and the external + infrastructure costs. Without internalising the latter costs, only private costs are taken into account when making a transport decision.

Clearly, internalisation measures may have multiple objectives. For example, the three main objectives presented above are all underlying the so-called Eurovignette Directive (European Parliament, 2011a), which provides a legal framework for road pricing for heavy goods vehicles in the EU. The initial aim of the Directive was to improve the efficiency of the transport system by levelling the playing field among EU hauliers (by harmonising the annual vehicle tax and regulating road charges). With subsequent revisions, the aim to reduce the negative impacts of transport became more prominent, e.g. by mandating the variation of charges according to the emission class of the vehicle or by allowing charge variation aimed at optimising the transport systems. At the same time, the Directive allows the recovery of infrastructure and external costs and, in exceptional cases, the generation of funds through mark-ups to provide for new infrastructure (i.e. generating revenues). Finally, the Directive is also meant to support the application of the ‘user-pays’ and ‘polluter-pays’ principles, contributing to a fairer transport system.

But even if internalisation measures have one explicit objective, it may affect the other objectives as well. For example, a CO₂ differentiated purchase tax that is introduced to incentivise people to purchase a car with no or low CO₂ emissions may also increase fairness by making the polluter pay or may also affect the generation of revenues for the government.

The role of non-pricing instruments

Implementing transport taxes and charges¹⁵ are not the only policy instruments that can be used to achieve the objectives mentioned above. Also non-pricing instruments (including subsidies) play an important role in this respect. For example, command-and-control measures like CO₂ regulation for vehicles result in a reduction of external costs. Command-and-control measures or subsidies may also be used to remove some barriers on the internal transport market, improving the level playing field for competition between transport modes and hence contributing to a fairer transport system.

According to economic theory, using transport taxes and charges are the most efficient way to achieve the objectives presented above. However, in real-world there may be several market failures that may require the implementation of other policy instruments, for instance the lack of information in a market, market power, or deviations from purely rational decision making by consumers. Furthermore, political reasons can exist to prefer standards: if social (and political) acceptance for tax increases can be lower than for vehicle regulation, implementing standards could be more achievable.

The role of non-pricing instruments (including subsidies) in achieving the objectives of internalisation is discussed in more detail in Section 2.5.

2.3.2 Internalisation approaches

Depending on the objective(s) of internalisation, several approaches can be applied when developing internalisation measures. Some main internalisation approaches are marginal social cost pricing, average cost pricing, Baumol pricing and Ramsey pricing.

¹⁵ Or an emission trading scheme.

Marginal social cost pricing

Marginal social cost pricing (MSCP) is considered - from a theoretical economic point of view - as a first-best approach. Pure MSCP is defined as a situation where transport users are charged with a levy equal to marginal external (and infrastructure) costs. By applying this levy¹⁶, transport users will take account of the additional external costs of their transport decisions in just the same way as they would do with private costs and hence the transport market can work in achieving social efficiency. In other words, the right incentives are given to ensure that the costs of transport do not exceed the benefits of society.

Marginal social cost pricing is in line with the framework set in the EU Transport White Paper (European Commission, 2011a) for smart pricing and taxation for transport. However, implementing internalisation measures in line with pure MSCP is not a simple task, as marginal costs vary strongly according to time, place and type of vehicle as well as the level of demand (thin, dense, congested traffic). For example, marginal external congestion costs vary for each road segment and from minute to minute, which complicates the estimation of the actual marginal external cost level. And even if marginal cost levels could be estimated, it is questionable whether transport users can take account the highly differentiated charges. Transport users will not understand or take into account continuously fluctuating marginal external congestion cost levels and even then, technological solutions to charge such rapidly varying levies are not straightforward either. For these reasons, a certain degree of simplification (i.e. averaging of marginal cost figures) is inevitable when implementing MSCP.

Although MSCP results in an optimal allocation of transport, this is only the case under certain theoretical assumptions. An important one is that MSCP is applied throughout the whole network. However, internalisation measures often have a limited scope, as they are limited to a single mode of transport or only to part of the network. This may result in boundary effects, in particular a shift from prices modes or parts of the network to the other parts or modes. For example, the introduction of a road toll for heavy goods vehicles (HGVs) in Belgium resulted in a shift to (non-charged) light commercial vehicles (MOW Vlaams Gewest, 2017).

Finally, by applying MSCP there is no guarantee that total infrastructure costs are covered. By using mark-ups or multipart tariffs, additional revenues can be raised, but they will adversely affect the efficiency of the internalisation measures.

Average cost pricing

Compared to MSCP, average cost pricing can be seen as a second-best but more pragmatic approach. This approach is defined as the situation where transport users are charged with a levy that is equal to the average external (and infrastructure costs). This approach is in line with the polluter-pays and user-pays principles and it guarantees that the total external/infrastructure costs are paid for by transport users, and not just the marginal costs. From a fairness perspective, average cost pricing is therefore a very relevant internalisation approach: it ensures that transport users pay for the full cost they induce (user-pays principle).

¹⁶ This levy is also known as a Pigouvian tax.

As average external and infrastructure costs can be estimated more easily and accurately than marginal cost values, applying average cost pricing in real-world situations is easier than applying MSCP. Additionally, average cost levels are less volatile and hence easier to understand for transport users. These may be the reasons that average cost pricing is used for actual internalisation measures, e.g. for the German HGV toll or French motorway tolls.

The main disadvantage of average cost pricing is that it results in price incentives that do not perfectly reflect the costs of transport decisions of individuals, particularly with respect to accident, noise and congestion costs¹⁷. As a consequence, transport users will not take the actual social cost into account when making a transport decision, resulting in sub-optimal decisions (see also Section 2.3.1).

Baumol pricing

A third approach to internalisation policy says that the tax is set at a level which is estimated to be sufficient to achieve a given (environmental) objective. This approach can be traced back to Baumol (1972) and Baumol and Oates (1976). The implementation of CO₂ differentiations in vehicle taxes in many European countries can be seen as an example of Baumol pricing, as it often has the objective to incentivize individuals to purchase vehicles with low or no CO₂ emissions.

In general, Baumol pricing will be effective in reducing (specific) external costs, which may contribute to its social and political acceptability. However, as the charge levels set by Baumol pricing can be higher or lower than what would be calculated from marginal costs, these charges may be too high or low from a social efficiency perspective. Furthermore, this approach will not guarantee that total external/infrastructure costs are paid for by transport users (user-pays and polluter-pays principles are not necessarily met).

Ramsey pricing

The main aim of Ramsey pricing is to secure efficient financing. For this purpose, this approach requires that marginal cost-based charge levels are increased and that this increase is inversely proportional to the price elasticity of demand. In this way, Ramsey pricing maximizes social welfare subject to budget constraints. The deviation from social efficiency depends on the difference between the desired revenues and the socially optimal revenues.

In this approach, charge levels may differ between transport services (e.g. peak versus off peak, passenger versus freight) because price elasticities may differ. This may result in charge levels that are considered counterintuitive and maybe even unfair. For example, by applying this approach road charges may be lower during rush hours (as peak price elasticities are lower than off peak elasticities), although the (marginal) congestion costs in these hours are considerably higher than in off peak hours.

¹⁷ As explained in CE Delft et al. (2019c), for these externalities, the cost levels do depend on the density of the traffic flow (e.g. a car entering a road with free flow traffic will cause marginal external congestion costs that are significantly lower than the average external congestion costs) and therefore the marginal costs may differ significantly from the average costs. On the other hand, for externalities like air pollution and climate change cost levels do not/hardly depend on the density of the traffic flow and therefore marginal and average costs are (approximately) equal.

Elements of Ramsey pricing are often applied, particularly as transport taxes/charges are used to generate revenues by almost all governments. However, this approach is not in line with internalisation principles like the polluter-pays and user-pays principles.

Conclusions

A summary of the various internalisation approaches, their main objective(s) and their relevance is given in Table 6. MSCP and average cost pricing were selected to be used to assess the state of play of internalisation for the five transport modes in this study. Both approaches are (partly) in line with the ‘user-pays’ and ‘polluter-pays’ principles, which are cornerstones in the European internalisation strategy (see the EU Transport White Paper (European Commission, 2011)). Furthermore, MSCP can be regarded as a theoretical first-best approach and hence can be considered a good benchmark to evaluate the state of play with respect to internalisation in the various European countries. Average cost pricing, on the other hand, provides insight in the extent by which total external and infrastructure costs are covered by taxes and charges and is from the perspective of fair charging a relevant approach to consider.

Considering the state of play of internalisation from the perspective of Baumol pricing can be relevant as well, particularly as the design of many transport taxes/charges have recently been changed in order to increase their effectiveness in achieving a specific environmental goal (e.g. by adding CO₂ differentiation to existing taxes/charges). However, assessing the state of play of internalisation from this perspective would require a detailed assessment on all relevant policy objectives for all transport modes, externalities and countries, which is beyond the scope of this study.

Finally, the perspective of Ramsey pricing is not applied in this study as it is not in line with the internalisation principles of the European Commission.

Table 6 - Overview of main internalisation approaches

Internalisation approach	Brief description	Main objective(s)	Relevance
Marginal social cost pricing (MSCP)	Charges/taxes are set at the level of marginal infrastructure and/or external costs	– Influencing behaviour to improve efficiency of the transport system	– Theoretical optimum – Approach applied e.g. for external cost charging in the Eurovignette Directive
Average cost pricing	Charges/taxes are set at the level of average infrastructure and/or external costs	– Increase fairness – Generating revenues	– Often applied – Fairness is socially/ politically relevant criterion
Baumol pricing	Charges/taxes are set at the level that is expected to be sufficient to achieve a given (environmental) objective	– Influencing behaviour to realise specific objectives	– Often applied – Effectiveness is socially/politically relevant criterion
Ramsey pricing	Charges/taxes are set at the level that maximises revenues	– Generating revenues	– Often applied, although other approaches (i.e. Baumol pricing) have become more relevant over the last decade(s) – Not in line with internalisation philosophy of the Commission

2.3.3 Use of revenues and earmarking

The introduction of market-based internalisation measures results in additional revenues (unless the burden of taxation is simply shifted). This raises questions regarding the optimal use(s) of those revenues, mostly focussed on the issue whether the revenues should be earmarked (for investments in infrastructure or in environmental mitigation measures).

According to economic theory earmarking of revenues leads, in general, to a loss of efficiency. This is because there is no guarantee that transport or environmental mitigation projects are the most efficient projects available to be financed with the revenues and it may even lead to over-investments in those sectors (CE Delft et al. (2008); (OECD, 2001); (Parry, et al., 2012)). Second, earmarking creates inflexibility (OECD, 2001) as programmes may last longer than is optimal because of bureaucratic or vested interests' obstruction to reform. Third, earmarking of revenues may also lead to distortion of price signals. If revenues are used to (partly) reimburse those responsible for the externality, the initial price incentive (i.e. to change the behaviour of these agents) is partly offset. By a similar reasoning it can be argued that reimbursing those affected by the externality would harm social welfare, as it would lower their incentive to avoid the externality below an efficient level.

On the other hand, earmarking of revenues is often considered as a way to gain public support for the implementation of the internalisation measures (CE Delft et al., (2008); (OECD, 2001); (Ricci, et al., 2006)). If revenues are used to minimize the utility loss experienced by transport users when internalisation measures are introduced, this may increase the acceptability of that reform. For example, the revenues of noise charges on airports can be used to finance a noise isolation programme or revenues from congestion charges may be reinvested in expanding road capacity at specific bottlenecks or in alternative transport solutions, such as improving public transport or providing infrastructure for soft modes. Because of the contribution earmarking can provide to public acceptability, it is widely applied for internalisation measures in transport. In particular, revenues from infrastructure charges are often earmarked to be reinvested in the transport sector.

2.4 Indicators to measure the state of play of internalisation

As indicated in the previous section, the state of play of internalisation is assessed from both the average cost pricing and marginal social cost pricing perspective. In this section, we present both perspectives of the indicators that have been used for this purpose.

2.4.1 Average cost pricing

To assess the extent of internalisation from the perspective of average cost pricing, five types of indicators are used. These indicators are presented in Table 7.

Table 7 - Overview of main indicators for average cost pricing

Cost coverage ratio	Explanation
Overall cost coverage ratio	This ratio compares revenues from all taxes/charges with all external and infrastructure costs.
Overall cost coverage ratio excluding fixed infrastructure costs	This ratio compares revenues from all taxes/charges with all external and variable infrastructure costs (i.e. excluding fixed infrastructure costs).
Variable external and infrastructure cost coverage ratio	This ratio compares revenues from variable taxes/charges with variable external and infrastructure costs.
Overall infrastructure cost coverage ratio	This ratio compares revenues from infrastructure charges with all infrastructure costs.
Variable infrastructure cost coverage ratio	This ratio compares revenues from infrastructure charges with variable infrastructure costs.

The five indicators complement each other in the assessment of the internalisation of external and infrastructure costs and have all their own strengths and weaknesses:

1. *The overall cost coverage ratio* provides a good indication of the extent to which the average transport user of a certain vehicle pays for the average external and infrastructure costs caused by that vehicle category.
2. *The overall cost coverage ratio excluding fixed infrastructure costs* shows to what extent the external and variable infrastructure costs are covered by tax/charge revenues. This indicator is in line with the ambitions of the Commission to realise full internalisation of external costs, including the wear and tear costs (European Commission, 2011a). . This indicator recognises that fixed infrastructure costs are sunk costs¹⁸ and requiring users to pay fully for these costs may result in a (further) underutilisation of existing infrastructure (e.g. for rail transport), which is not optimal for society. Furthermore, there may be socio-economic reasons (e.g. improving of accessibility of rural areas) to provide transport infrastructure ‘for free’ to society.
3. *The variable external and infrastructure cost coverage ratio* shows to what extent - on average - the additional costs caused by an additional kilometre is covered by additional taxes/charges. Actually, this indicator is measuring MSCP, in a simplified way as proposed by the Communication on the Strategy for the internalisation of external costs (EC, 2008) which states that “In general, the marginal costs can be said to correspond to the average of the variable costs”. However, this indicator does not address fixed taxes (and costs) at all, while they play an important role in many countries. Therefore, other indicators (like the first two) should be considered as well.
4. *The overall infrastructure cost coverage ratio* shows to what extent total infrastructure costs are covered by infrastructure charge revenues. This indicator can be used to assess the user-pays principle. However, this assessment is complicated by the fact that infrastructure charges are also used to cover external costs and it is difficult to separate both objectives. Furthermore, it should be mentioned that an overall infrastructure cost coverage ratio above 100% does not mean that transport users do pay too much, as the coverage of external costs is not included in this indicator.
5. *The variable infrastructure cost coverage* shows whether the wear and tear costs (of the entire network) are covered by infrastructure charges. As discussed above, there may be reasons to consider the level of internalisation without the fixed infrastructure costs. Therefore, the assessment of this indicator may provide useful information in addition to the assessment of the overall infrastructure cost coverage ratio.

¹⁸ Cost that has already been incurred and cannot be recovered.

In addition to the five main indicators mentioned in Table 7, two additional indicators for average cost pricing are defined (see Table 8), for which the results are presented in the Annexes report accompanying this study:

1. *The overall external cost coverage ratio* shows to what extent the external costs are covered by tax/charge revenues. This indicator can be used to assess the polluter-pays principle. However, many transport taxes/charges are (mainly) used to cover the infrastructure costs, further complicating how to draw conclusions from these indicators with respect to the polluter-pays principle.
2. *Energy related cost coverage ratio* shows to what extent the energy related external costs (i.e. climate change, WTT emissions) are covered by energy taxes/charges (i.e. fuel taxes, electricity taxes). This ratio may show whether energy related external costs are properly internalised. However, energy related taxes/charges are often used for other objectives as well (financing infrastructure expenditures, generating revenues for the general budget), complicating the interpretation of this ratio.

Table 8 - Overview of additional indicators for average cost pricing

Cost coverage ratio	Explanation
Overall external cost coverage ratio	This ratio compares revenues from all taxes/charges with all external costs.
Energy related cost coverage ratio	This ratio compares revenues from energy taxes/charges with energy-related external costs.

In order to assess the indicators presented in Table 7 and Table 8, the definitions of fixed and variable costs and tax/charge revenues are presented in Section 2.2.

Finally, note that there may be further motivations for taxation, including revenue generation, or benefits to other objectives not assessed here, such as energy efficiency or innovation.

2.4.2 Marginal social cost pricing

To assess the extent of internalisation from the MSCP perspective, we make use of the *marginal cost coverage ratio*. This ratio compares the marginal external and infrastructure costs with the marginal tax/charge revenues¹⁹ for three/four specific situations. In case MSCP is perfectly applied, this ratio will be 100% for all scenarios. Ratios below (above) 100% indicate that marginal taxes/charges may be too low (high) from a MSCP perspective. Large differences in the marginal cost coverage ratios between scenarios indicate that there are options to bring the taxes/charges more in line with the MSCP principles by further differentiating these taxes/charges based on the main cost drivers of the external/infrastructure costs. However, as we only consider a few scenarios, we are not able to assess the marginal cost coverage ratios in a broad range of situations, limiting the number of final conclusions that can be drawn from this analysis for specific vehicle types or road types. For example, we only consider the marginal cost coverage ratio for electric cars driving on a motorway in a rural area. If we find for this scenario that the cost coverage ratio is significantly above 100%, we cannot conclude that electric cars are charged too high.

¹⁹ Marginal taxes/charges are the variable taxes/charges mentioned in Table 5.

The following four marginal cost scenarios are considered:

1. *Representative scenario*: this scenario presents weighted average marginal cost coverage ratios, comparing weighted average marginal external and infrastructure costs with weighted average marginal tax/charge levels. For example, the marginal external air pollution costs for a passenger car are in this scenario equal to the weighted average of the marginal costs for all different types of passenger cars (large and small; petrol, diesel, LPG, electric; in urban areas and in rural areas; etc.). The weighting of both the costs and tax/charge levels has been done based on transport performance data for the various countries. This implies that this scenario presents the actual ‘average’ marginal cost coverage ratios.
2. *High external costs scenario*: this scenario is based on a selection of cost drivers (e.g. vehicle type, type of infrastructure, etc.) that results in relatively high marginal external costs.
3. *Low external cost scenario*: this scenario is based on a selection of cost drivers that results in relatively low marginal external costs.
4. *Very low external cost scenario*: this scenario is based on a selection of cost drivers that results in relatively low marginal external costs. This scenario is mainly applied for vehicle categories where electric propulsion is an appropriate alternative for the combustion engine (i.e. passenger cars, motorcycle, bus, LCV). Furthermore, for maritime transport a very low external cost scenario is used to distinguish between a large container vessel (low external cost scenario) and a large bulk vessel (very low external cost scenario).

Considerations with respect to marginal cost scenarios

When interpreting the results of the marginal cost coverage analyses, the following issues with respect to the marginal cost scenarios should be considered:

- The high and (very) low-cost scenarios considered are sometimes a bit extreme, in order to reflect cases with high or low marginal external cost values. As a consequence, these scenarios are not necessarily reflecting cases that are fully representative of real-world situations. For example, as the very low external cost scenario for passenger cars, we consider electric cars driving on motorways in rural areas. Although this situation occurs in real-life, electric vehicles are expected to primarily operation in urban areas, over shorter distances.
- The scenarios are defined based on the level of external costs. The marginal cost coverage ratios, however, are also driven by marginal infrastructure costs and taxes/charges. Therefore, low marginal cost coverage ratios may be found for low external cost scenarios, if marginal infrastructure costs are relatively high or tax/charge levels relatively low. By the same reasoning it can be explained why marginal cost coverage ratios are sometimes relatively high in high external cost scenarios (i.e. due to relatively low marginal infrastructure costs and/or relatively high tax/charge levels).

A detailed definition of the four marginal cost scenarios is presented in Table 9.

Table 9 - Definition of marginal cost scenarios

	Representative scenario	High external cost scenario	Low external cost scenario	Very low external cost scenario
Road transport				
Passenger car	– Average vehicle – Average daytime/night – Average congestion level – Average road	– Large car – Diesel EURO 3 – CO₂ emissions^a: 176 g/km – Daytime – Congested traffic – Urban road in metropolitan area	– Small car – Petrol EURO 6 – CO₂ emissions^a: 99 g/km – Daytime – Thin traffic – Motorway in rural area	– BEV – Daytime – Thin traffic – Motorway in rural area
Motorcycle	– Average vehicle – Average daytime/night – Average traffic flow – Average road	– Petrol EURO 3 – CO₂ emissions^a: 128 g/km – 4-stroke 250-750 cm³ – Daytime – Dense traffic – Urban road in metropolitan area	– Petrol EURO 3 – CO₂ emissions^a: 100 g/km – 4-stroke 250-750 cm³ – Daytime – Thin traffic – Motorway in rural area	– Electric motorcycle – Daytime – Thin traffic – Motorway in rural area
Bus	– Average vehicle – Average daytime/night – Average traffic flow – Average road	– Standard 15-18 t – Diesel EURO 3 – CO₂ emissions: 1,155 g/km – Daytime – Dense traffic – Urban road in metropolitan area	– Standard 15-18 t – Diesel EURO 6 – CO₂ emissions: 954 g/km – Daytime – Thin traffic – Average road in rural area	– Electric bus – Daytime – Thin traffic – Average road in rural area
Coach	– Average vehicle – Average daytime/night – Average congestion level – Average road	– Standard ≤ 18 t – Diesel EURO 3 – CO₂ emissions: 742 g/km – Daytime – Congested traffic – Urban road in metropolitan area	– Standard ≤ 18 t – Diesel EURO 6 – CO₂ emissions: 583 g/km – Daytime – Thin traffic – Motorway in rural area	
LCV	– Average vehicle – Average daytime/night – Average congestion level – Average road	– Diesel EURO 3 – CO₂ emissions^a: 225 g/km – Daytime – Congested traffic – Urban road in metropolitan area	– Petrol EURO 6 – CO₂ emissions^a: 105 g/km – Daytime – Thin traffic – Motorway in rural area	– BEV – Daytime – Thin traffic – Motorway in rural area
HGV 3.5-7.5 t	– Average vehicle – Average daytime/night – Average congestion level – Average road	– Diesel EURO 3 – CO₂ emissions: 450 g/km – Daytime – Congested traffic – Urban road in metropolitan area	– Diesel EURO 6 – CO₂ emissions: 370 g/km – Daytime – Thin traffic – Motorway in rural area	
HGV 7.5-16 t	– Average vehicle – Average daytime/night – Average congestion level – Average road	– Diesel EURO 3 – CO₂ emissions: 716 g/km – Daytime – Urban road in metropolitan area	– Diesel EURO 6 – CO₂ emissions: 596 g/km – Daytime – Thin traffic – Motorway in rural area	

	Representative scenario	High external cost scenario	Low external cost scenario	Very low external cost scenario
HGV 16-32 t	– Average vehicle – Average daytime/night – Average congestion level – Average road	– Diesel EURO 3 – CO₂ emissions: 875 g/km – Daytime – Congested traffic – Urban road in metropolitan area	– Diesel EURO 6 – CO₂ emissions: 716 g/km – Daytime – Thin traffic – Motorway in rural area	
HGV > 32 t	– Average vehicle – Average daytime/night – Average congestion level – Average road	– Diesel EURO 3 – CO₂ emissions: 1,033 g/km – Daytime – Urban road in metropolitan area	– Diesel EURO 6 – CO₂ emissions: 848 g/km – Daytime – Thin traffic – Motorway in rural area	
Rail transport				
HST	– Average day/night	– Night	– Day	
Passenger electric train	– Average passenger train – Average daytime/night	– Regional train – Daytime	– Intercity train – Daytime	
Passenger diesel train	– Average passenger train – Average daytime/night	– Regional train – Not equipped with EGR/SCR – Daytime	– Intercity train – Equipped with EGR/SCR – Daytime	
Freight electric train	– Average freight train – Average daytime/night	– Short train (bulk) – Daytime – High noise level	– Long train (bulk) – Daytime – Low noise level	
Freight diesel train	– Average freight train – Average daytime/night	– Short train (bulk) – Daytime – High noise level – Not equipped with EGR/SCR	– Long train (bulk) – Daytime – Low noise level – Equipped with EGR/SCR	
IWT				
Freight vessel	– Average vessel	– CEMT II (bulk) – CCR-1	– CEMT Va (bulk) – CCR-2	
Maritime transport				
Freight vessel	–	– Small vessel (container) – Tier 1 – Trip of 500 km	– Large vessel (container) – Tier 2 – Trip of 15,000 km	– Large vessel (bulk)^b – Tier 2 – Trip of 15,000 km
Aviation				
Passenger aircraft	– Average airplane – Average day/night	– Embraer 170 – Short-haul (500 km) – High emission level – High noise class – Night	– Airbus A34-300 – Long-haul (15,000 km) – Low emission level – Low noise class – Daytime	

^a Test cycle CO₂ emissions.

^b As presented in CE Delft, et al. (2019c), the external costs per tonne-kilometre are lower for a large bulk vessel than for a large container vessel. This is due to a higher average load (in tonnes) of bulk vessels.

2.5 Broader context of internalisation

This report mainly discusses the extent by which the external and infrastructure costs of transport are internalised by transport taxes and charges applied in the EU28 Member States, Norway, Switzerland and some non-EU countries. However, as mentioned in Section 2.3.1, other policy instruments (e.g. command-and-control measures, subsidies) may contribute to achieving the objectives of internalisation. In this respect, we particularly focus on the role these policy instruments may have in reducing the external costs of transport²⁰. We do this by discussing in the various mode-specific chapters the main policy instruments (other than taxes and charges²¹) that are applied for that specific transport mode in the EU28 to reduce external costs. We mainly consider EU28 broad policies in this respect, but also some often used national and/or local instruments are considered.

To assess the role of the command-and-control measures and subsidies in the reduction of external costs of transport, we have carried out a thorough literature review, mainly considering EU legislative documents, impact assessments and evaluation studies. Based on the information found, we have briefly described the selected policy instruments. Furthermore, we discussed the market failures that are addressed by these instruments as well as the main interactions with relevant taxes and charges.

In general, several reasons have been identified for applying command-and-control measures and/or subsidies to reduce externalities in addition to or instead of taxes and charges:

- *The international dimension of some of the external costs*; some of the external costs have transboundary impacts (e.g. climate change, air pollution) and therefore addressing them at the EU level has added value. As transport taxes and charges are under Member States competence, they cannot be easily harmonised at the EU level. Using alternative EU-wide instrument may be preferred in such cases.
- *To avoid distortions of the internal market*; as transport taxes and charges differ widely between EU Member States, they may distort the internal market, leading to higher administrative costs. Using EU-wide harmonised instruments may therefore be preferred (in some cases).
- *Better conditions to invest in technologies reducing external costs*; closely related to the previous issue is the fact that EU harmonised policies may provide a broad level playing field, providing vehicle manufacturers (and other industry) the same specifications that should be met by externality reducing technologies/actions at the entire EU. This improves the investment climate for these types of technologies/actions. Furthermore, command-and-control measures may provide some more long-term certainty to investors as they are (perceived) less volatile than tax/charge measures.

²⁰ As discussed in Section 2.3.1, policies like command-and-control measures and subsidies may also contribute to other internalisation objectives, particularly increasing fairness. However, the main contribution these instruments provide in meeting the internalisation objectives is by reducing the external costs of transport. Therefore, we have limited the scope of the analysis of command-and-control measures and subsidies to this role.

²¹ Including ETS (see CE Delft et al. (2019b)).

- *The energy paradox*; vehicle owners do not always invest in fuel-reducing technologies, even if the higher investment costs are fully compensated by lower energy costs. This ‘so-called’ energy paradox may be explained by several factors, including consumer myopia, imperfect information and split incentives (see Section 4.5 for more details). Instruments like fuel-efficiency standards are better equipped to solve the energy paradox than tax/charge measures.
- *Improving information provision to consumers/companies*: instruments like labelling may improve the knowledge of consumers/companies and may indirectly change their behaviour.
- *To address externalities that are not targeted by taxes and charges*: accident costs are currently not (directly) addressed by transport taxes/charges, mainly because it is not straightforward to internalise these costs by tax/charge measures²² (CE Delft et al., (2008)). Therefore, other policy instruments (mainly command-and-control measures) are used to improve transport safety.
- *Lack of social and political support for taxes and charges*: the lack of social and political support for implementing or raising taxes and charges²³ may also be a reason to choose other policy instruments.

In the next chapters, these issues will be discussed in more detail for the specific policy instruments applied for addressing the external costs of the various transport modes.

²² The level of accident costs depends on a complete set of cost drivers (location, time of day, vehicle type, driving behaviour, etc.) for which it is hardly possible to cover them with a tax/charge instrument.

²³ According to Zverinova et al. (2014) lower public acceptance of tax measures may be due to the perception that taxes are not very effective and are considered unfair, raise distributional concerns, or due to a lack of confidence in politicians, and a lack of understanding on how a tax can reduce the externalities.

3 Comparison of transport modes on total/average cost coverage in the EU28

3.1 Introduction

In this chapter we compare the various transport modes with respect to their total/average cost coverage rates. For road, rail and IWT we perform this assessment at the EU28 level, i.e. total/average costs and tax/charge revenues for the EU28 are compared²⁴.

For maritime transport and aviation most cost and revenue figures are not available at the EU28 level. Therefore, we consider total/average costs and tax/charge revenues for the selection of 33 EU28 airports and 34 EU28 seaports.

To compare the total/average cost coverage for the various transport modes, we will make use of the indicators presented in Section 2.4.1, i.e.:

- overall cost coverage ratio (Section 3.2);
- overall cost coverage ratio excluding fixed infrastructure costs (Section 3.3);
- variable external and infrastructure cost coverage ratio (Section 3.4);
- overall infrastructure cost coverage ratio (Section 3.5);
- variable infrastructure costs coverage ratio (Section 3.6).

The definitions applied to distinguish between fixed and variable costs and revenues in the calculation of these cost coverage ratios can be found in Section 2.2 (see Table 3 , Table 4 , and Table 5).

As mentioned above, in this chapter we will discuss the various cost coverage ratios at the EU28 level. However, there may be large differences between EU Member States with respect to these ratios, and even within countries these ratios may differ significantly on different parts of the network (e.g. motorways vs. urban roads and between vehicle types (heavy vs light trucks). Although these differences are not discussed in this chapter, they are considered in the next mode-specific chapters.

The analysis presented in this chapter is mainly focussed on the comparison of external and infrastructure costs on the one hand, and tax and charge revenues/levels on the other hand. Where needed to understand the (differences in) cost coverage ratios, we discuss findings on some of the individual concepts (i.e. external costs, infrastructure costs, tax/charge revenues). For a more detailed discussion on these issues, we refer to the other deliverables published as part of the entire project (see Section 1.1).

²⁴ For some of the total cost coverage ratios, EU27 values are presented in Excel Annex D. These ratios are, in general, well in line with the EU28 cost coverage ratios. Only for aviation, EU27 total cost coverage ratios are significantly below EU28 values, reflecting the relatively high cost coverage ratios of the UK airports considered (i.e. London Heathrow and London Gatwick).

For interpreting the cost coverage concept, it should be clarified that some benefits (such as energy independence) are not quantified, and that there might be also reasons for taxation beyond internalisation.

3.2 Overall cost coverage

A comparison of the total external and infrastructure costs and the total tax and charge revenues for the various transport modes in the EU28 is given in Figure 1. The highest costs are found for road transport (about € 780 billion), with accident costs (€ 279 billion) and infrastructure costs (€ 184 billion) as the main cost categories²⁵. As the total revenues of road transport taxes/charges sum up to € 350 billion, about 45% of the road transport external and infrastructure costs are covered. For rail transport, the total infrastructure and external costs in the EU28 are equal to € 98 billion. The main part of these costs (about 80%) are related to the construction, maintenance and operation of rail infrastructure. About 20% of the total external and infrastructure costs are covered by tax/charge revenues (€ 20 billion). Finally, the total external and infrastructure costs for IWT in the EU28 are about € 6 billion, mainly covering infrastructure costs (about 50%) and air pollution costs (about 33%). As there is only a limited number of relevant taxes/charges levied on IWT in the EU28 (in many countries only port charges are levied), the cost coverage ratio found for IWT is relatively low (about 6%).

As explained in Section 4.1, for maritime transport and aviation no EU28 figures were available. Instead we estimated the total costs and revenues for a selection of maritime ports and airports. The total external and infrastructure costs for the 34 maritime port considered sums up to € 45 billion²⁶. The main part of these costs consists of air pollution costs (about 65%) and costs of GHG emissions (about 23%). As for IWT, only a limited number of tax/charge schemes are in place for maritime transport in the EU28 (often only port charges are levied²⁷), resulting in a low-cost coverage ratio (about 4%). The cost coverage ratio for aviation is significantly higher. The total external and infrastructure costs of about € 47 billion for the 33 selected airports is covered for 30% by the revenues from taxes and charges.

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- ²⁵ Please notice that for road congestion costs the deadweight loss costs are presented in this chapter. As explained in CE Delft et al (2019) these costs only reflect part of the external congestion costs (i.e. the congestion costs that arise due to congestion levels above the economically optimal level). Therefore, the total/average cost coverage ratios presented in this chapter for road transport are (slightly) too high, as they do not reflect all external costs. Please, also notice that congestion/scarcity costs are not considered at all for the other transport modes (due to lack of data).
- ²⁶ Due to lack of data, the uncertainty in the port infrastructure costs estimated is rather large. This should be taken into account when considering the results for maritime transport. See CE Delft et al., (2019) for more details.
- ²⁷ Due to lack of data, the uncertainty in the port charge revenues of maritime transport is rather large. This should be taken into account when considering the results for maritime transport. See CE Delft et al. (2019b)) for more details.

Figure 1 - Total external and infrastructure costs vs. total taxes and charges

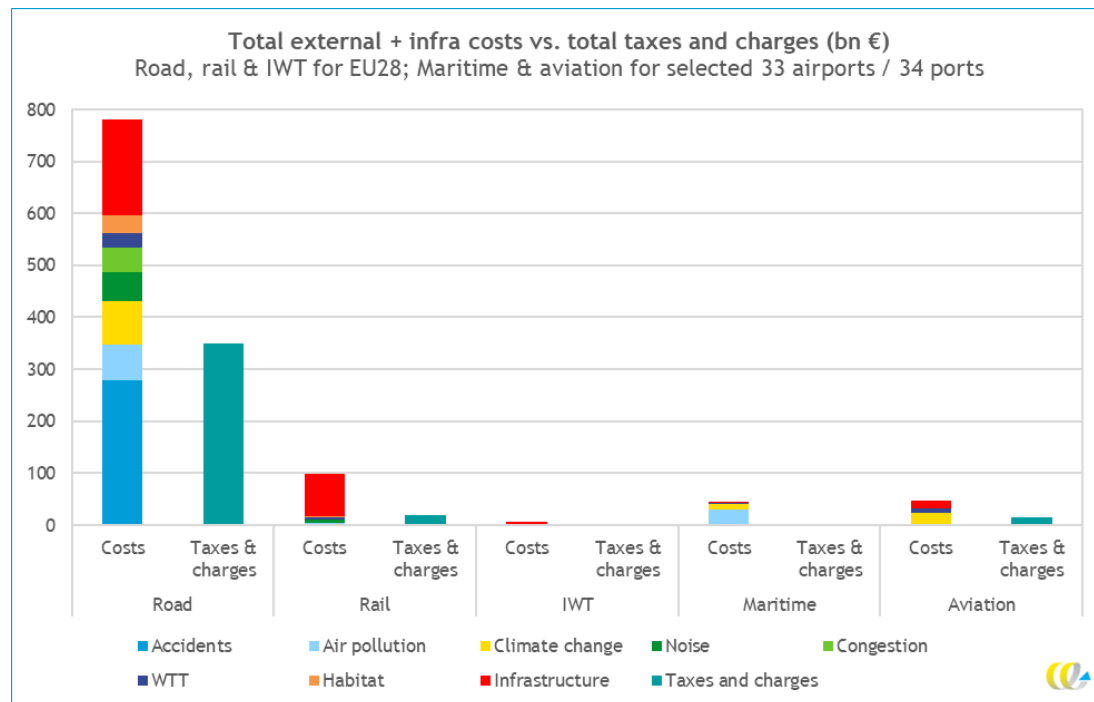
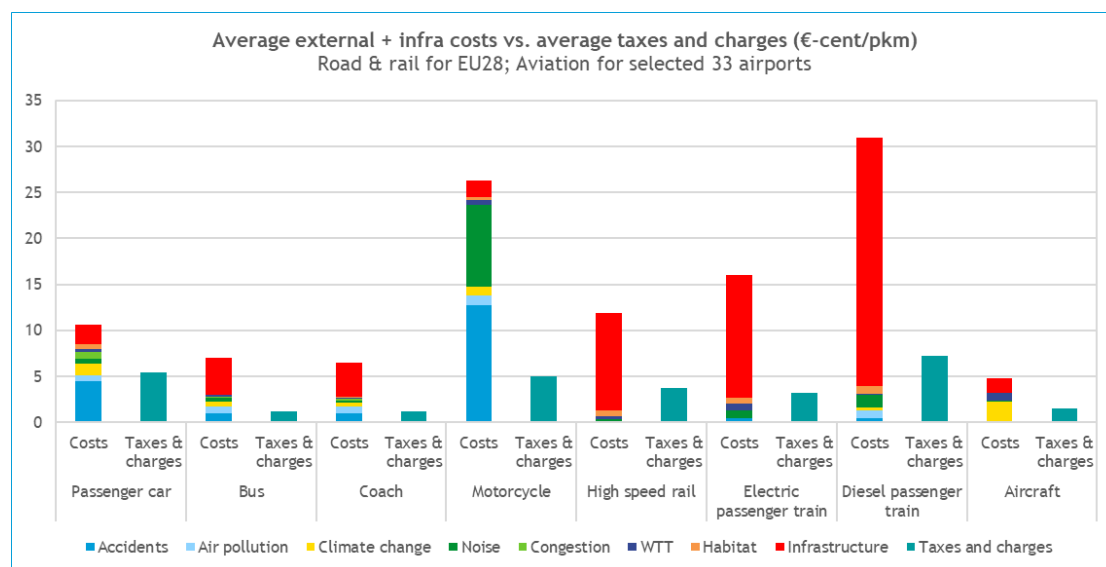


Figure 2 shows a comparison of the average external and infrastructure costs and the average tax/charge revenues for all passenger vehicle types. Comparisons of the results for the various vehicle types should be made very carefully, as they often do not compete on the same market. For example, the average airplane²⁸ operates in a completely different market than the average train²⁹. Preferably, comparisons between transport modes should be made for specific sub-markets (e.g. urban transport, regional transport, transport up to 2,000 km, etc.), considering the costs and taxes/charges that are relevant for the specific vehicle types used on those markets. However, the data available on external and infrastructure costs as well as tax/charge revenues is not detailed enough to make such analyses.

²⁸ I.e. the weighted average of the airplanes used for short-haul, medium-haul and long-haul trips.

²⁹ I.e. the weighted average of regional, national and international trains.

Figure 2 - Average external and infrastructure costs vs. average taxes/charges for passenger transport



The highest average cost coverage ratio is found for passenger cars; the average tax/charge level of about 5.5 €/pkm covers about 51% of the average external and infrastructure costs (about 11 €/pkm). The cost coverage ratios for buses and coaches are significantly lower. For buses, about 17% of the average external and infrastructure costs (about 7 €/pkm) is covered. For coaches, average tax/charge levels cover about 18% of the average costs (which are about 6.5 €/pkm). As shown in Figure 2, this can be explained by the lower tax/charge revenue per passenger-kilometre. These vehicles are in general less taxed than passenger cars (e.g. vehicle taxes per passenger-kilometre are for buses and coaches on average significantly lower than for passenger cars³⁰). The cost coverage ratio for motorcycles is equal to 19%. Although the average tax/charge levels for motorcycles are comparable to those for passenger cars (about 5 €/pkm), the average external plus infrastructure costs are much higher (about 26 €/pkm). This is mainly due to the relatively high noise and accident costs for these vehicles³¹.

For rail transport, the highest average costs are found for diesel passenger trains, followed by electric passenger trains (both conventional and high speed electric trains). These differences in average costs can be mainly explained by differences in occupancy rates³², which directly affects the average costs per passenger-kilometre calculated. Additionally, variance in utilisation of the infrastructure result in differences in average infrastructure

³⁰ As discussed in more detail in CE Delft et al. (2019b), buses and coaches are exempted from purchase taxes in 20 Member States of the EU28. Ownership taxes are levied on buses and coaches in most EU countries, although public transport buses are exempted in some of them (e.g. Belgium, Germany, the Netherlands). Per vehicle, ownership tax levels for buses/coaches are often higher than for passenger cars, although there are some exceptions (e.g. Ireland, Latvia, Malta).

³¹ As discussed in CE Delft et al. (2019c) motorcycles are involved in a relatively high number of accidents, often resulting in victims in the opposing vehicle as well. As a consequence, motorcycles have relatively high average accident costs. As motorcycles produce relatively much noise (compared to other vehicle types) they also contribute significantly to the noise costs caused by road transport.

³² For example, the average number of passengers on diesel trains in the EU28 is 60, while on conventional electric trains this number is equal to 150.

costs. For example, diesel rail infrastructure is - on average - less intensively used than electric rail infrastructure, leading to higher average infrastructure costs for diesel trains³³. The differences in occupancy rates are also an important reason for the differences in average tax/charge levels. Furthermore, the fact that diesel tax levels are - on general - higher than electricity tax levels also contributes to the relatively higher tax/charge levels of diesel trains. The resulting cost coverage ratios for the various types of passenger trains are all in the same range: for high speed trains the ratio is equal to 32%, while for conventional electric and diesel passenger trains these ratios are 20% and 23%. Differences in infrastructure utilisation and the energy taxation (diesel vs. electricity taxes) are the main explanations for this variance in cost coverage ratios.

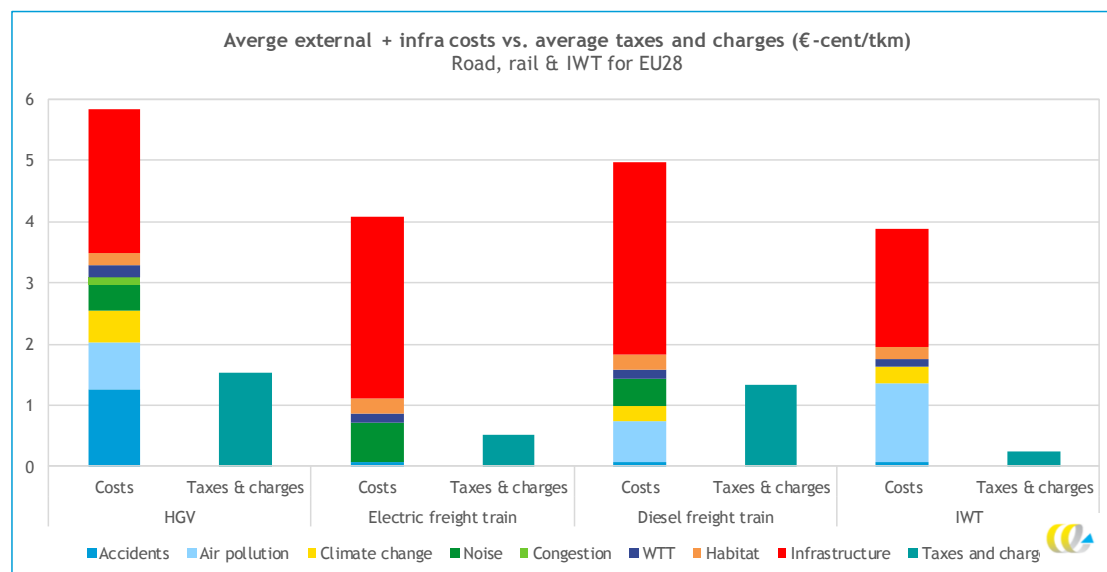
Finally, about 32% of the average external and infrastructure costs of aviation (4.8 €/ct/pkm) are covered by taxes and charges (1.5 €/ct/pkm). However, it should be noticed that this cost coverage ratio covers all flights from the 33 selected airports, including both long-haul and short-haul flights. As aviation only competes with other passenger vehicle categories on the shorter distances, this cost coverage ratio cannot be compared with the ratios found for coaches and passenger trains. For such a comparison, a cost coverage ratio for short-haul flights is required, but - as mentioned before - no data is available to develop it³⁴.

Figure 3 presents the comparison of average external and infrastructure costs and average tax/charge revenues for the various freight vehicle types, with the exception of maritime transport and LCVs (see note below the graph for an explanation). Again, when comparing the results for the various modes, it should be remembered that these modes often compete in different markets.

³³ More specifically, the utilisation rates of rail infrastructure are - on average - lower in countries with high shares of diesel rail transport. Keeping other things constant, this results in higher average infrastructure cost figures for these countries. And as these countries significantly contribute to the total volume of diesel rail transport in the EU28, it also contributes to higher average infrastructure costs at the EU28 level.

³⁴ It can be argued that the costs coverage ratio will probably be lower for short-haul flights than for average flight distances. This is because some of the externalities (e.g. air pollution, noise) are mainly occurring during the LTO cycle and hence are relatively more important for short-haul flights than for long-haul flights. Also the average infrastructure costs will be higher for short-haul flights (as the fixed infrastructure costs are allocated to a lower number of passenger kilometres). Although also the average tax/charge revenues (per passenger kilometre) will probably be higher for short-haul flights, it is expected that the increase in average costs is that high that lower cost coverage ratios would be found for these types of flights.

Figure 3 - Average external and infrastructure costs vs. average taxes/charges for freight transport



Note: For maritime transport no data was available for tonne-kilometres, therefore no comparable average cost and revenue figures could be calculated for this transport mode. LCVs are not included in this graph as well. As LCVs are often used for services related transport (e.g. by plumbers), the average load of vans is relatively low. Therefore, presenting the average infrastructure costs in €/t/km would result in very high and meaningless values. It was possible to estimate the cost coverage ratio for LCVs (based on total cost and revenue values), which is equal to 43%.

As for the passenger vehicle types, the costs far exceed the revenues for all freight vehicle types. For HGVs about 26% of the average external and infrastructure costs (5.8 €/t/km) are covered by the average tax/charge revenues (1.5 €/t/km). For rail transport, the average external and infrastructure costs for diesel freight train exceed the costs for electric freight trains (5.0 €/t/km vs. 4.1 €/t/km). This is because of the higher air pollution and climate change costs caused by diesel freight trains. Part of these higher costs are compensated for by lower average noise costs for diesel trains³⁵, but in the end the average external costs for diesel freight trains are higher than for electric freight trains. At the same time, the average tax/charge levels for diesel freight trains are higher as well, which is mainly explained by the relatively high diesel tax levels compared to electricity tax levels. The average electricity tax level for freight trains in the EU28 is equal to € 0.19 per 1,000 tkm, while the average diesel fuel tax amounts € 5.36 per 1,000 tkm³⁶. These differences in average tax/charge levels are so high, that the cost coverage ratios for diesel freight trains are higher than for electric freight trains (27% vs. 13%).

³⁵ In general, the noise costs per tonne kilometre for a diesel and electric freight train are highly comparable. However, there are a few countries (i.e. Ireland, Latvia, Lithuania and Estonia) where only diesel freight trains are used. As the noise costs of rail transport in these countries are relatively low (number of noise exposed people due to rail traffic is low, probably due to low population densities) this lowers the EU28 average noise costs per tonne kilometre for diesel trains.

³⁶ This significant difference in the EU28 average tax levels can be explained by two factors. First, electricity tax levels applied in EU countries for rail transport are - on average - lower than diesel tax levels. Secondly, in ten Member States of the EU28 rail transport is exempted from electricity taxes, while for diesel taxes only three EU Member States apply such an exemption. For more information, see CE Delft et al. (2019b).

Finally, as mentioned in Figure 1, the cost coverage ratio for inland navigation in the EU28 is only 6%, reflecting the fact that in most countries only a few taxes/charges are levied on this transport mode (e.g. in many countries IWT is fully exempted from fuel taxes and fairway dues), while particularly external costs are relatively high due to high average air pollution costs per tkm³⁷ (which are even higher than for HGVs and freight trains). Also, the average infrastructure costs for IWT are significant, particularly reflecting the considerable fixed infrastructure costs of this mode (see CE Delft et al. (2019a) for a more detailed discussion on this issue).

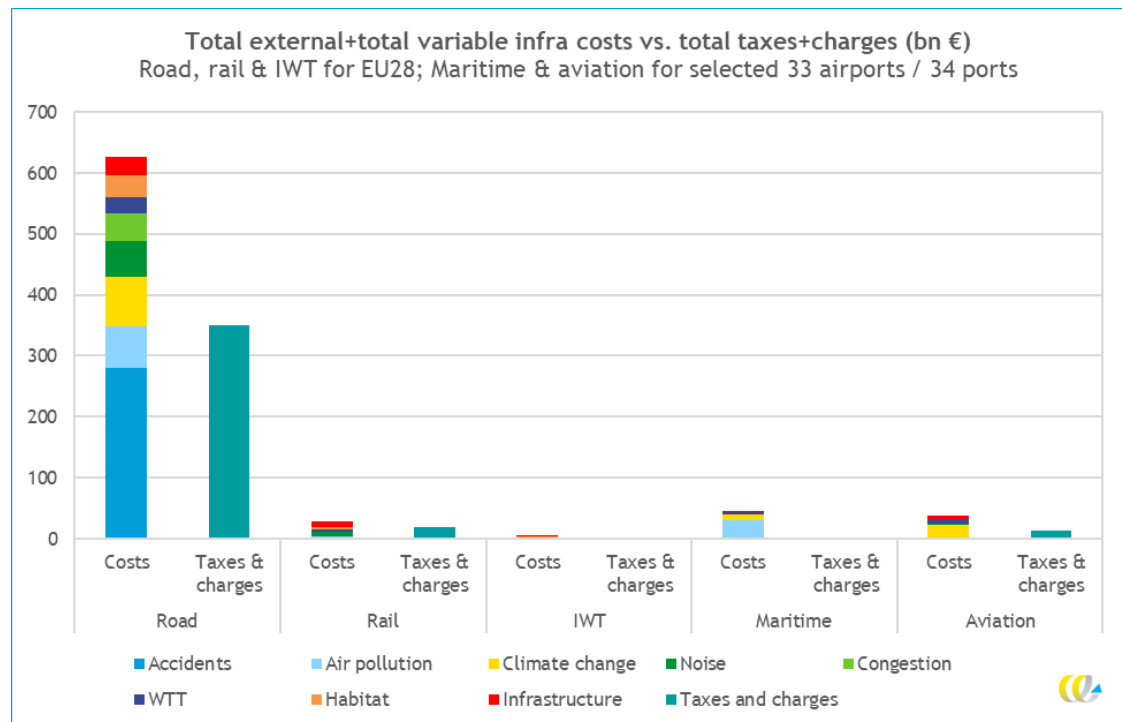
3.3 Overall cost coverage excluding fixed infrastructure costs

In Figure 4, the total external costs and variable infrastructure costs are compared to the total revenues of taxes and charges for the various transport modes. As fixed infrastructure costs are excluded from the analysis, these cost coverage ratios are in general higher than the overall cost coverage ratios. However, there are some main differences between the various transport modes.

The highest coverage ratios for this indicator are found for rail transport (69%), followed by road transport (56%), aviation (37%), IWT (12%) and maritime transport (4%). Particularly for rail transport, this cost coverage ratio is significantly higher than the overall cost coverage ratio for this mode, which is 20%. This can be explained by the relatively high fixed infrastructure costs (particularly investment and renewal costs) for rail transport, which contributes significantly to the total external and infrastructure costs of rail transport (about 70% of the total external and infrastructure costs of rail transport consist of fixed infrastructure costs, while for road transport this is only 20%). The doubling of the cost coverage ratio for IWT (compared to the overall cost coverage ratio) can also be explained by the relatively high share fixed infrastructure costs have in the total external and infrastructure costs (about 46%).

³⁷ Because of the long life cycle of IWT vessels, older vessels with polluting engines stay in-service for long periods.

Figure 4 - Total external and total variable infra costs vs. total taxes and charges



The average external and average variable infrastructure costs of the various passenger vehicle types are compared to the average taxes/charges in Figure 5. As mentioned before, comparisons between vehicle categories should be made carefully, as they do not all compete in the same market.

For the road vehicles the highest cost coverage ratio is again found for passenger cars (63%), followed by the coach (26%), bus (24%) and motorcycle (20%). As mentioned in Section 3.2, the lower cost coverage ratios for buses and coaches compared to passenger cars is mainly explained by the relatively low tax/charge levels for these vehicles. For motorcycles, the relatively high average external costs (particularly accident and noise costs) are the main explanation for the relatively low-cost coverage ratio.

Regarding rail transport, the highest cost coverage ratios are found for high speed trains. For this train category, the average taxes/charges are higher than the average costs, resulting in a cost coverage ratio of 181%. For electric (high speed + conventional trains) and diesel passenger trains the cost coverage ratios are equal to 75% and 97%, respectively. The differences in cost coverage ratios between the various types of trains are mainly explained by differences in tax/charge levels. As was shown in CE Delft et al. (2019b) the access charges (in €/pkm) for high speed trains are in Europe - on average - significantly higher than for conventional passenger trains. This may partly be explained by the fact that in some countries the access charges for conventional (regional) trains may be kept low by subsidising rail infrastructure managers. But because transport subsidies are out of the scope of the study, we have not assessed this issue in detail and therefore we are not able to quantify this aspect. The higher cost coverage ratio for diesel passenger trains compared to electric passenger trains can be explained by differences in energy taxation (diesel taxes are on average higher than electricity taxes). Furthermore, diesel trains are more often used for regional services, for which the access charges are on average lower.

Finally, for aviation this cost coverage ratio is equal to 41%, which is about 9 percentage points higher than the overall cost coverage ratio. Again, it should be noted that the cost coverage ratio for aviation refers to all flights of the 33 selected airports (including short-, medium- and long-haul flights). The cost coverage ratio for short-haul flights is expected to be lower than this average cost coverage ratio.

Figure 5 - Average external and average variable infrastructure costs vs. average taxes/charges for passenger transport

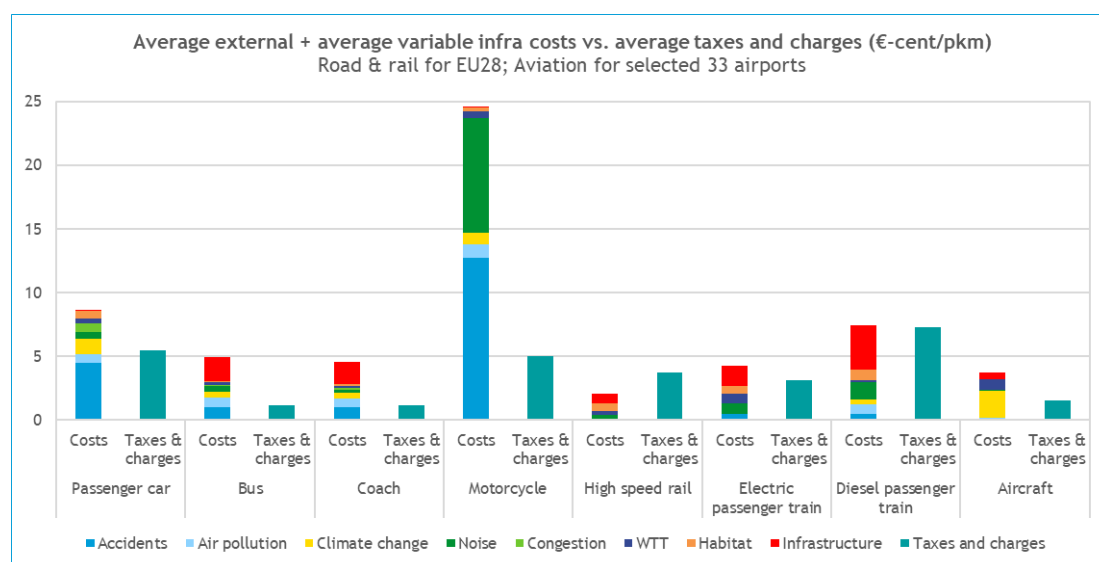
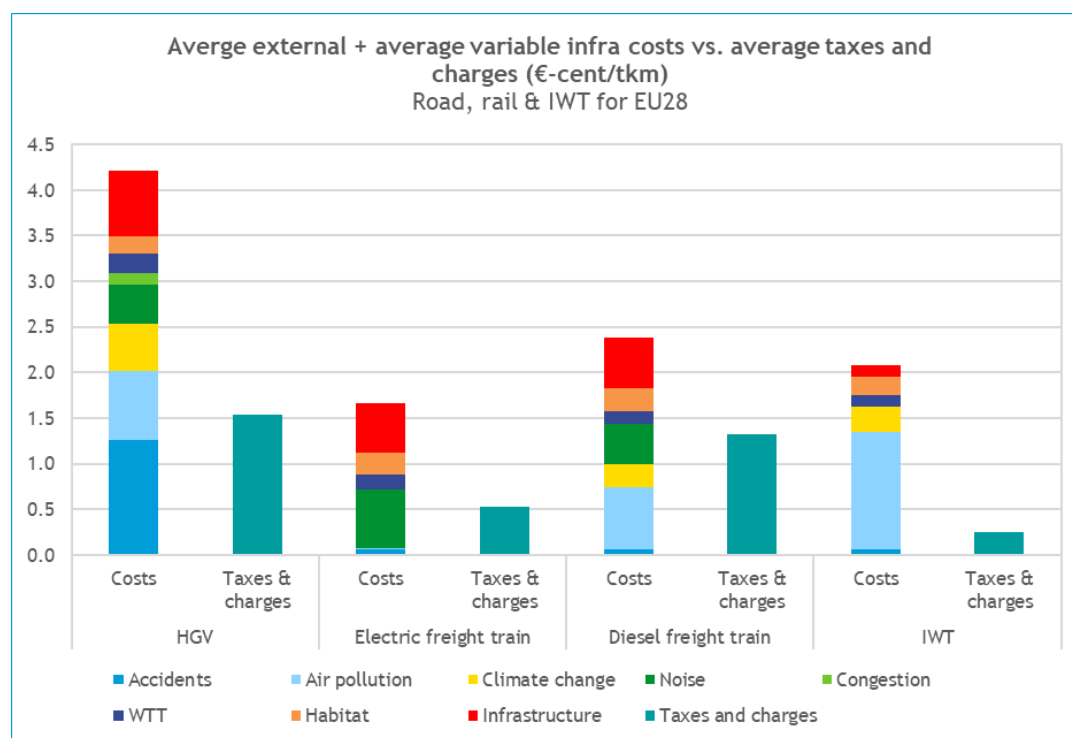


Figure 6 shows the average external costs and variable infrastructure costs as well as the average tax/charge revenues for freight vehicle types. For all vehicle types, the cost coverage ratios are higher than the ratios for overall cost coverage (as fixed infrastructure costs are excluded now). The largest differences are found for rail transport, because for this mode fixed infrastructure cost has the largest share in total external and infrastructure costs.

The highest cost coverage ratio for this indicator is found for diesel trains (56%), followed by HGVs (36%), electric trains (32%) and IWT vessels (12%). As discussed before, the difference in cost coverage ratio between diesel and electric freight trains is mainly explained by differences in energy taxation (EU28 average diesel taxes are much higher than EU28 average electricity taxes).

Figure 6 - Average external and average variable infrastructure costs vs. average taxes/charges for freight transport



Note: For maritime transport no data was available for tonne-kilometres, therefore no comparable average cost and revenue figures could be calculated for this transport mode. LCVs are not included in this graph as well. As LCVs are often used for services related transport (e.g. by plumbers), the average load of vans is relatively low. Therefore, presenting the average infrastructure costs in €/ct/tkm would result in very high and meaningless values. It was possible to estimate the cost coverage ratio for LCVs (based on total cost and revenue values), which is equal to 53%.

3.4 Variable external and infrastructure cost coverage

In Figure 7, a comparison between the variable external and infrastructure costs and the variable tax/charge revenues is made for the various transport modes. For all transport modes, the variable costs exceed the variable tax/charge revenues. The highest cost coverage ratio is found for rail transport: about 79% of the variable external and infrastructure costs (about € 25 billion) is covered by variable taxes/charges (about € 20 billion). This cost coverage ratio is even higher than the overall cost coverage ratio excluding fixed infrastructure costs, as the fixed costs of habitat damage are not included in this indicator³⁸ (and the same taxes/charges are included as all rail tax/charges are considered variable). For road transport in the EU28, about 45% of the variable external and infrastructure costs (€ 592 billion) are covered by variable taxes/charges (€ 269 billion). This ratio is lower than the overall cost coverage ratio excluding fixed infrastructure costs, which can be explained by the fact that the fixed vehicle taxes for road vehicles (e.g. registration taxes, ownership taxes and insurance taxes) are not included. For IWT, about 13% of the variable external and infrastructure costs (about € 3 billion) are covered

³⁸ For rail transport, the contribution of the costs of habitat damage in total external and infrastructure costs is relevant: about 13%. For the other transport modes this contribution is smaller: 9% for IWT, 6% for road transport and no significant contribution for aviation.

by variable taxes/charges. This is slightly higher as for the overall cost coverage ratio excluding fixed infrastructure costs, due to the exclusion of the cost of habitat damage. Finally, for aviation and maritime transport, the cost coverage ratio is equal to the ratio for overall cost coverage excluding fixed infrastructure costs, i.e. 37 and 4% respectively.

Figure 7 - Total variable external and infra costs vs. total variable taxes and charges

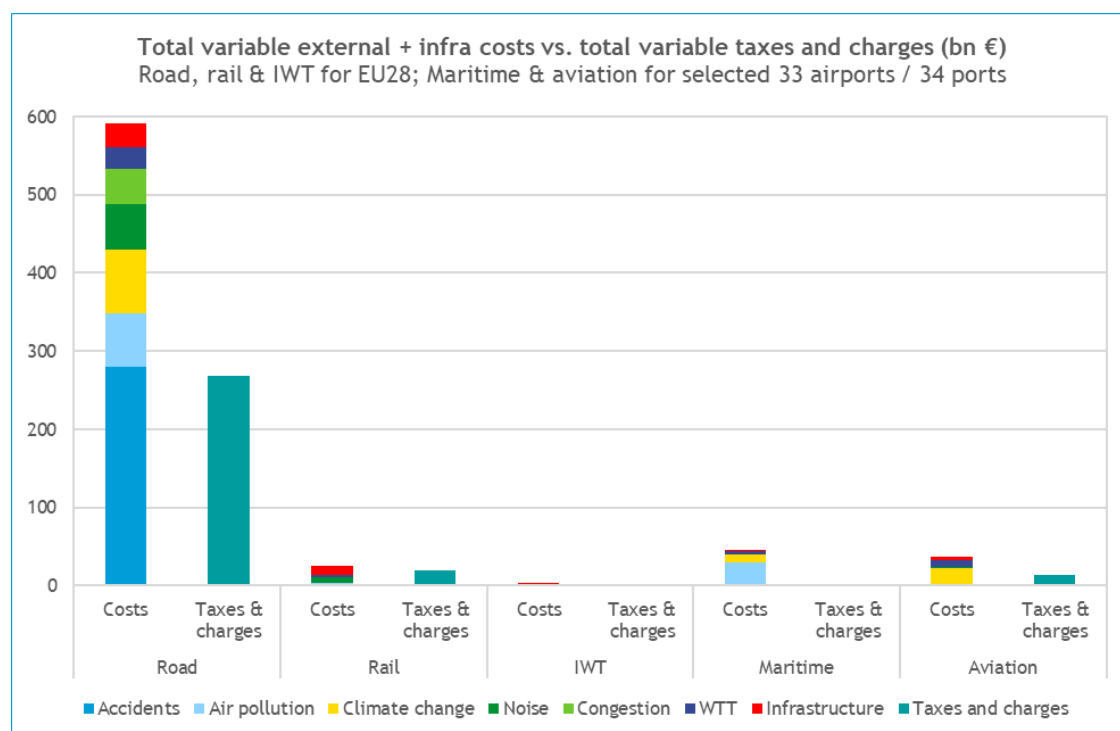


Figure 8 presents the average variable external and infrastructure costs as well as the average variable tax/charge revenues for the various passenger vehicle types. For the road vehicles, particularly the average tax/charges levels are lower as for the previous two indicators, as the fixed vehicle taxes (i.e. registration, ownership and insurance taxes) are not included in this ratio. For that reason, the cost coverage ratio for passenger cars (48%) and motorcycles (15%) is for this indicator even lower as the overall cost coverage ratio. For buses and coaches, the cost coverage ratio is 21 and 23%, which is slightly higher as the overall cost coverage ratio. For these vehicles, excluding the fixed external (habitat damage) and infrastructure costs has a larger impact on the cost coverage ratio than excluding the fixed taxes.

For high speed rail the revenues of variable taxes/charges far exceed the variable costs (i.e. by a factor of 2.5), while for diesel passenger trains revenues are relatively equal to variable costs. For electric passenger trains, this cost coverage ratio is significantly lower (about 86%), which is - as discussed before - mainly due to lower infrastructure access charges compared to high speed trains and lower energy tax levels (compared to diesel trains). As previously discussed, the fixed costs for rail transport are high and all rail taxes/charges are considered variable in this study, so variable cost coverage is higher than total cost coverage.

Finally, the variable external and infrastructure costs of aircraft have 41% of cost coverage by revenues from variable taxes and charges. This ratio is comparable to the total cost coverage ratio excluding fixed infrastructure costs for this vehicle category, which can be explained by the facts that all aviation taxes/charges are considered variable and there are no significant fixed costs of aviation in addition to the fixed infrastructure costs.

Figure 8 - Average variable external and infrastructure costs vs. average variable taxes/charges for passenger transport

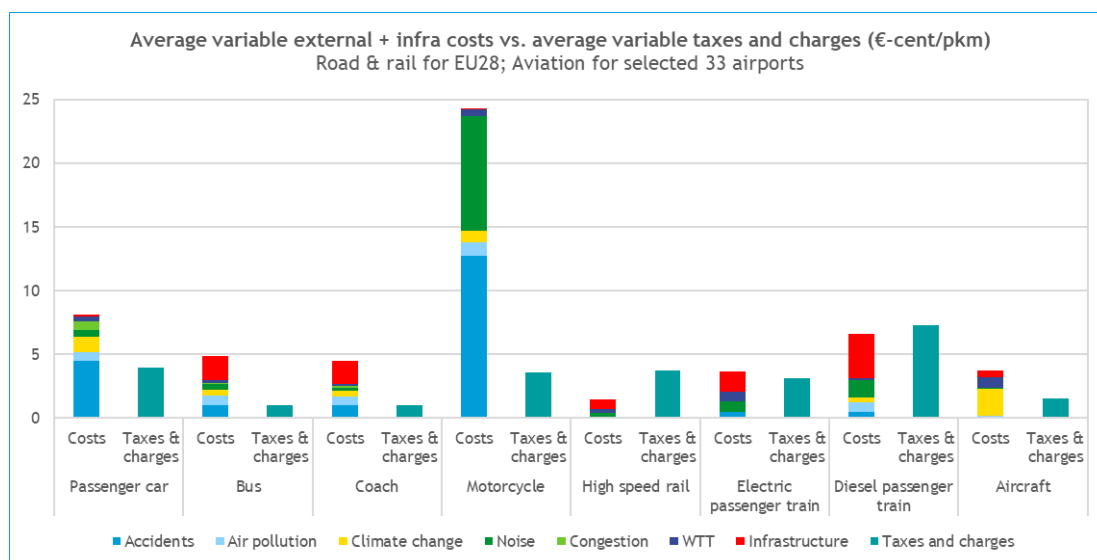
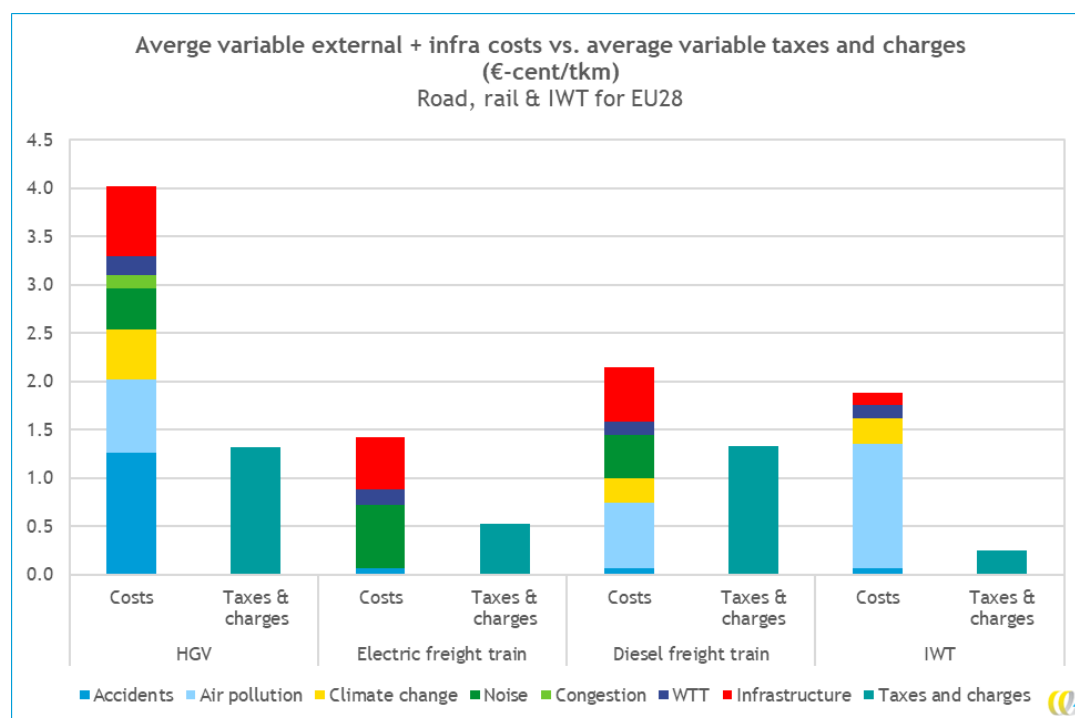


Figure 9 shows that the variable external and infrastructure costs of the various freight vehicle types exceed the revenues from variable taxes/charges levied on these vehicles. The variable cost coverage ratios found for the freight trains and IWT are higher than the cost coverage ratios for the previous two ratios. This can be explained by the fact that all taxes/charges for these vehicles are considered variable in this study (and hence the same taxes/charges are included in all three indicators), while compared to the previous two indicators the fixed habitat damage costs are not included in this indicator. For the HGV, the variable cost coverage ratio is higher as the total cost coverage ratio, but lower than the total cost coverage ratio excluding fixed infrastructure costs. The latter result can be explained by the fact that fixed vehicle taxes (i.e. ownership tax, insurance tax) are not included in this indicator, while they were included in the previous indicator.

The highest variable cost coverage share is found for diesel trains (62%), which is significantly higher than for electric trains (37%). As discussed under total cost coverage, the high fuel tax levels compared to electricity tax levels is the main explanation for this difference. Some 33% of the variable external and infrastructure costs of HGVs are covered by the revenues of variable taxes and charges (i.e. road tolls and fuel taxes), while about 13% of the variable costs of IWT are covered by variable taxes/charges.

Figure 9 - Average variable external and infrastructure costs vs. average variable taxes/charges for freight transport



Note: For maritime transport no data was available for tonne-kilometres, therefore no comparable average cost and revenue figures could be calculated for this transport mode. For LCVs no average costs and revenues (in €-cent per tkm) could be presented. However, it was possible to estimate the cost coverage ratio (based on total costs and revenues), which is equal to 48%.

3.5 Overall infrastructure cost coverage

As shown in Figure 10, the total infrastructure costs exceed the total infrastructure charges for road transport, rail transport, IWT and aviation. Only for maritime transport the total revenues from port charges are in line with the total infrastructure costs. However, as discussed before, due to limited maritime data availability, the uncertainty of both the total infrastructure costs and total port charge revenues for maritime transport is high.

For road transport, about 18% of the total infrastructure costs (€ 184 billion) are covered by the revenues from distance-based and time-based road charges (€ 33 billion).

For rail transport, the rail access charges (€ 17 billion) cover about 21% of the total infrastructure costs (€ 81 billion), while for aviation about 81% of the infrastructure costs (€ 14 billion) are covered by airport charges (€ 11 billion). Finally, the port charges and fairway dues (€ 0.4 billion) cover 12% of the total infrastructure costs of IWT (€ 2.9 billion).

Figure 10 - Total infrastructure costs vs. total infrastructure taxes and charges

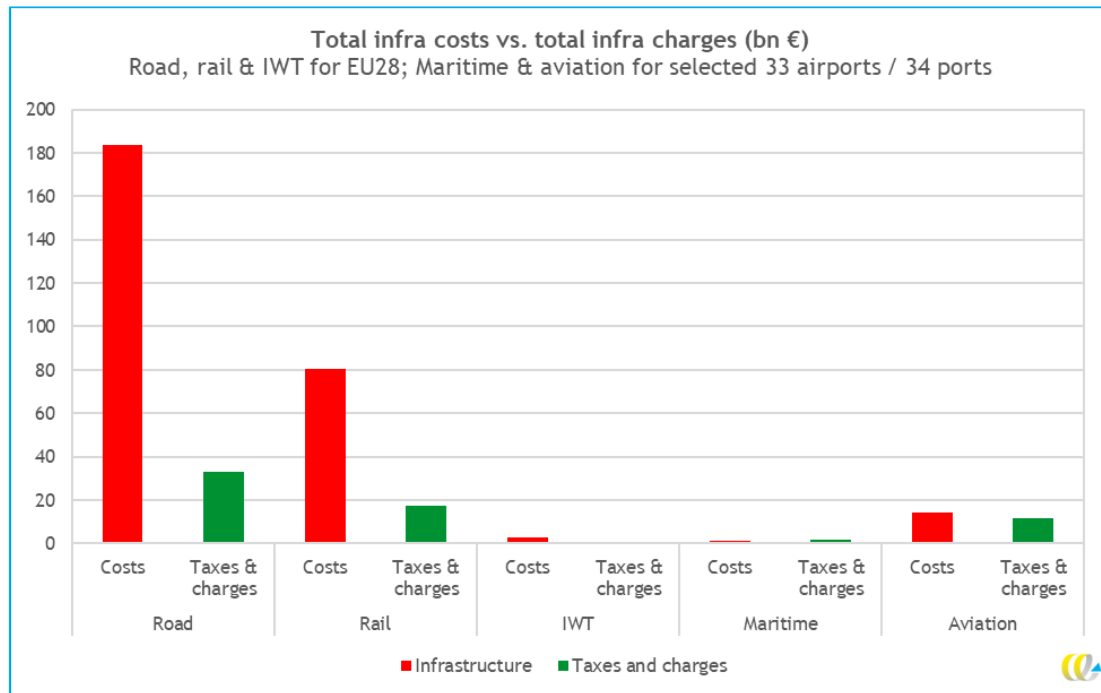


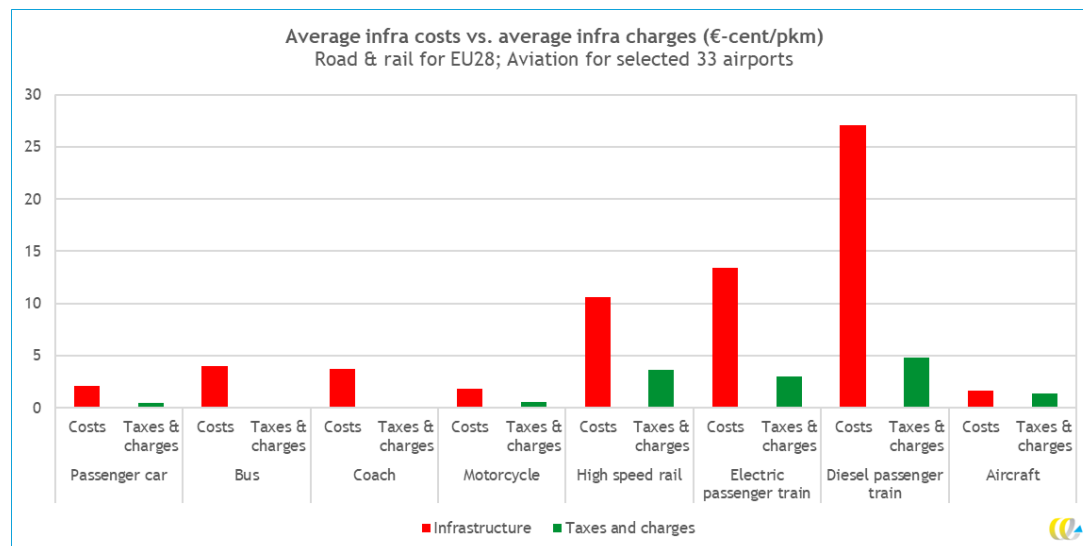
Figure 11 shows that for all passenger vehicle types (except aviation), the total infrastructure costs far exceed the revenues from infrastructure charges. Particularly for buses and coaches only a very small share (about 3%) of the infrastructure costs are covered by infrastructure charges. This is particularly because buses and coaches cause significant wear and tear costs, but also because buses/coaches are exempted from road charges in several European countries (e.g. Germany, The Netherlands, UK). Some 22 and 28% of infrastructure costs for passenger cars and motorcycles respectively are covered by infrastructure charges.

As for rail transport, the highest average infrastructure costs are found for diesel passenger trains, followed by electric trains (both conventional and high speed trains) and high speed trains. The differences in these average costs are mainly explained by differences in occupancy rates and infrastructure utilisation of the various train types. The same reasons explain the relatively high average charge revenues for diesel passenger trains. The relatively high average charge level for high speed trains (compared to conventional electric trains) is due to the higher rail access charges levied on high speed trains in many European countries³⁹. The highest overall infrastructure cost coverage ratio is found for high speed trains (34%), while this rate is about 23% for electric (both conventional and high speed) and 18% for diesel passenger trains. These differences in cost coverage ratios can be explained by the differences in infrastructure costs and infrastructure charge levels discussed before.

³⁹ As discussed in Section 3.3, these higher rail access charges for high speed trains compared to conventional trains may partly be explained by the fact that mark ups are charged to high speed operators for the use of infrastructures, while subsidies are provided to rail infrastructure managers to keep the access charges for conventional (regional) trains low.

Finally, the infrastructure cost coverage ratio for passenger aircraft is 82%, indicating that the aviation-related infrastructure costs are largely paid for by the air passengers.

Figure 11 - Average infrastructure costs vs. average infrastructure taxes/charges for passenger transport

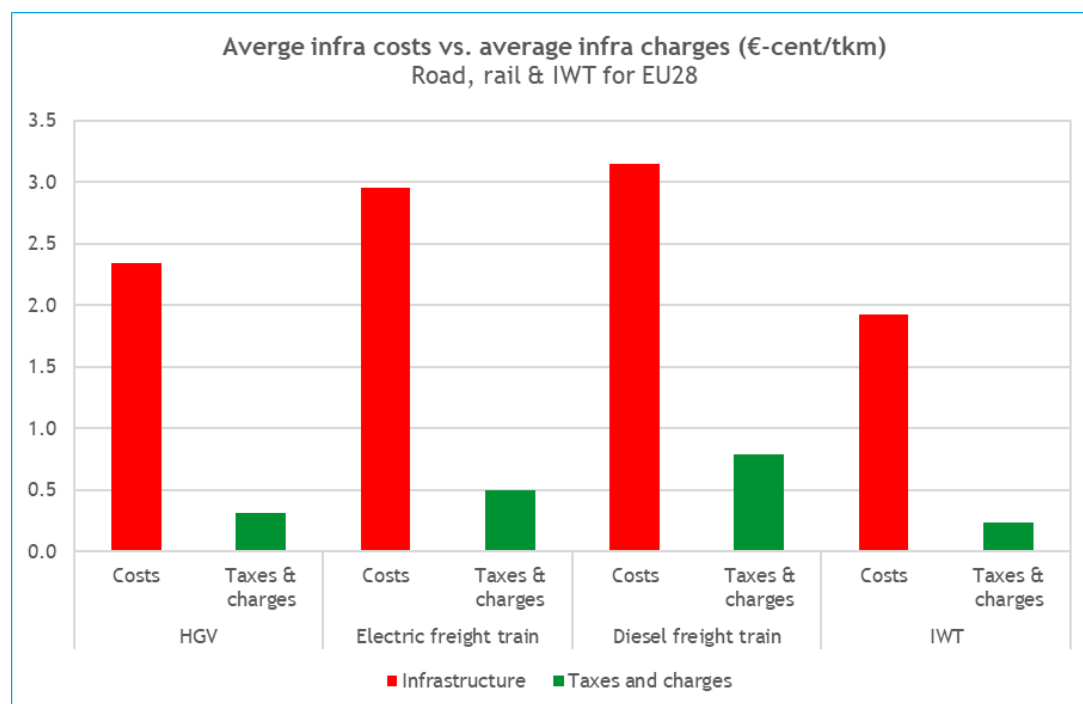


As with passenger vehicles, the total infrastructure costs caused by the freight vehicle types exceed the infrastructure charges levied on these vehicles (see Figure 12). For HGVs, we find that about 13% of the total infrastructure costs are covered by distance-based or time-based road charges. The fact that infrastructure charges for HGVs are (mainly) applied on motorways, while a significant part of the infrastructure costs are associated to non-motorways. Also the road charge levels levied are - in general - insufficient to cover for all infrastructure costs (including fixed costs).

For rail transport, the average infrastructure costs for diesel freight trains are slightly higher as for electric freight trains. As explained in CE Delft et al. (2019a) this is because the load factors for diesel trains are - on average - slightly lower than for electric trains. Furthermore, lower levels of utilisation of the rail network by diesel trains may also contribute to the higher average infrastructure costs. The higher average infrastructure charge levels for diesel trains may also partly be explained by the slightly lower load factors for these trains. But a more important explanation for the higher average access charges for diesel trains is that in countries where all rail freight transport is performed by diesel trains (i.e. Estonia, Ireland, Latvia and Lithuania) the rail access charges are - on average - relatively high. As these countries are responsible for about 10% of the freight train-kilometres in the EU28, this results in a higher average access charge level for diesel freight trains in the EU28. This fact is also the main explanation for the higher EU28 overall infrastructure cost coverage ratio found for diesel trains (about 25%) than for electric trains (17%).

Finally, as mentioned above, the overall infrastructure cost coverage for IWT vessels is equal to 12%.

Figure 12 - Average infrastructure costs vs. average infrastructure taxes/charges for freight transport



Note: For maritime transport no data was available for tonne-kilometres, therefore no comparable average cost and revenue figures could be calculated for this transport mode. For LCVs no average costs and revenues (in €-cent per tkm) could be presented. However, it was possible to estimate the cost coverage ratio (based on total costs and revenues), which is equal to 11%.

3.6 Variable infrastructure cost coverage

As shown in Figure 13, the variable infrastructure costs (i.e. only wear and tear costs) are fully covered for all transport modes. The highest cost coverage ratio is found for maritime transport, with revenues from port charges that exceed variable infrastructure costs by a factor of 46. This high-cost coverage ratio can be explained by the relatively low share of variable costs in total infrastructure costs (which is lower than for the other modes). However, as mentioned before, the uncertainty in the infrastructure cost and tax/charge revenue estimates for maritime transport is high and hence this result should be interpreted carefully.

For aviation, the infrastructure charges exceed the variable infrastructure costs by a factor of 2.5, indicating that the airport charges cover more than just the variable infrastructure costs, but also part of the capital expenditures. It should be mentioned, however, that the share of variable cost in the total infrastructure costs of airports is rather uncertain (see CE Delft et al., (2019a)) and hence that this conclusion should be considered carefully.

For IWT and rail transport the infrastructure charges exceed the variable infrastructure costs by a factor of 1.8 and 1.6, respectively. Finally, for road transport, the total revenues from infrastructure charges are in the same range as the variable infrastructure costs (i.e. a cost coverage ratio of about 1).

It is important to note that external costs and fixed infrastructure costs are not included here. In other words, while these graphs show that users are overcompensating variable infrastructure costs, the previous analysis shows that the opposite is true if we consider all external costs and infrastructure costs.

Figure 13 - Total variable infrastructure costs vs. total infrastructure charges

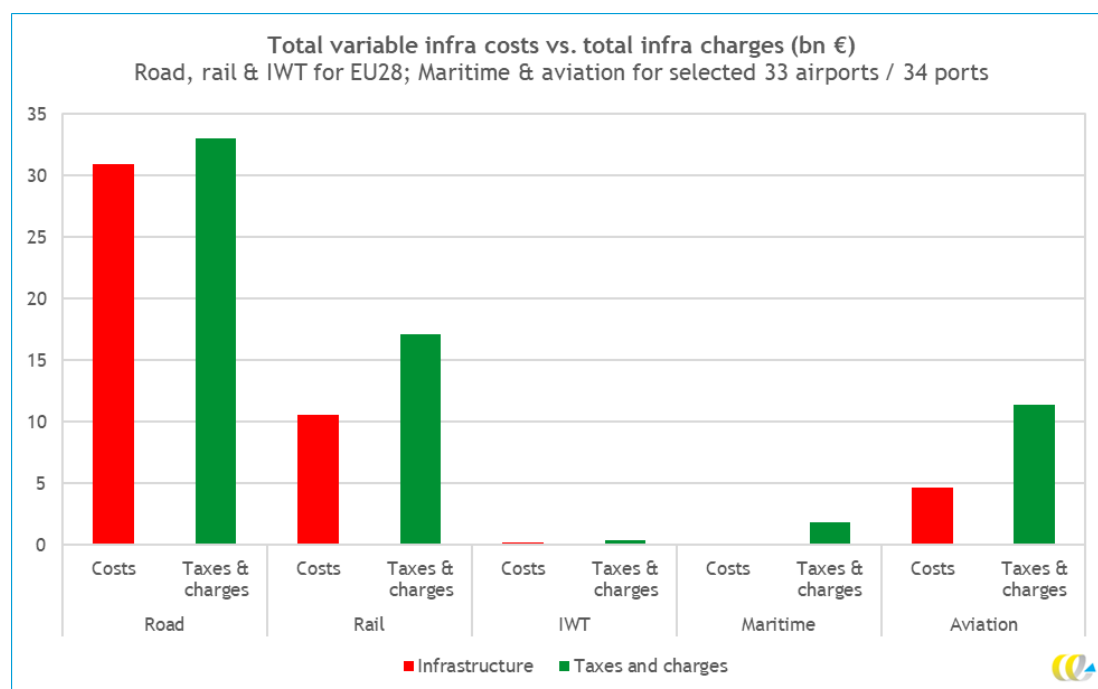
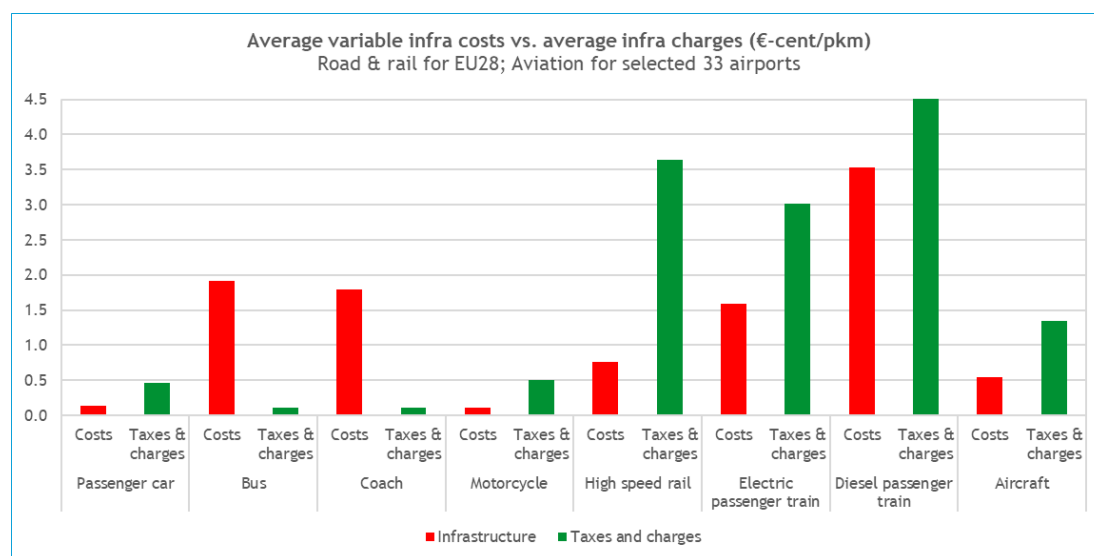


Figure 14 compares, for the various passenger vehicle types, the average variable infrastructure costs with the total revenues from infrastructure charges. For most vehicle types the infrastructure charges far exceed the variable infrastructure costs. The exceptions are buses and coaches. Because of the high wear and tear costs caused by these vehicles and the - on average - relatively limited scope of road charges for these vehicles, only about 5% of the variable infrastructure costs are covered by infrastructure charges. For passenger cars and motorcycles, the infrastructure charges exceed the variable infrastructure costs by a factor 3.5 and 4.7 respectively, as light duty vehicles have limited impact on variable infrastructure costs.

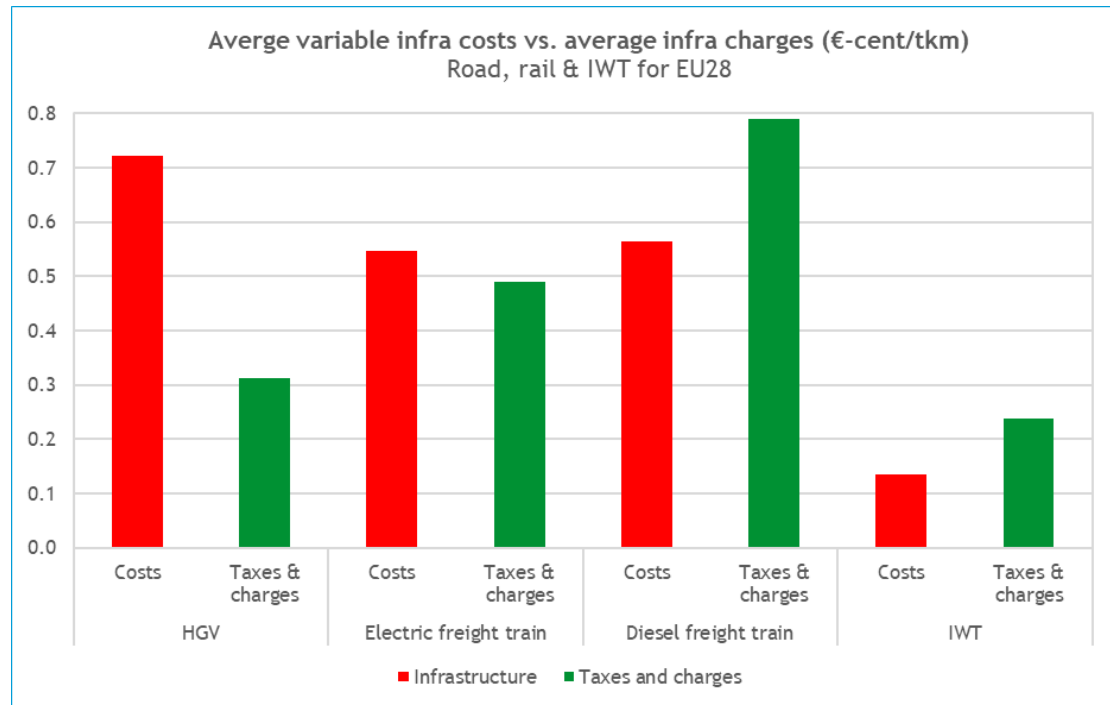
As shown in Figure 14, rail infrastructure access charges seem to cover the variable rail infrastructure costs for all electric and for diesel passenger trains (cost coverage ratio of about 1.9 and 1.4 respectively), reflecting the marginal cost pricing principle gradually applied for these charges in European countries. For high speed trains, significantly higher access charges (marginal costs plus mark ups) are applied in many European countries, resulting in revenues that far exceed the variable infrastructure costs.

Figure 14 - Average variable infrastructure costs vs. average infrastructure taxes/charges for passenger transport



Finally, the average variable infrastructure costs and revenues from infrastructure charges for the freight vehicle types are presented in Figure 15. For HGVs, the variable infrastructure costs exceed the revenues from road charges (cost coverage ratio of 43%), mainly because of the relatively high wear and tear costs caused by this vehicle category and, with the exemption of a few Member States, the limited scope of distance-based tolling. For rail transport, the variable infrastructure costs of diesel trains are covered by the infrastructure charge revenues (cost coverage ratio of 140%), while for electric trains this is not the case (cost coverage ratio of 90%). As mentioned in the previous section, this can be explained by the higher EU28 average access charge levels for diesel trains, which is particularly due to the relatively high access charges applied in EU Member States where all rail freight transport is performed by diesel trains. Finally, as mentioned before, the revenues from infrastructure charges for IWT exceed the variable infrastructure costs for this mode by about a factor of 1.8.

Figure 15 - Average variable infrastructure costs vs. average infrastructure taxes/charges for freight transport



Note: For maritime transport no data was available for tonne-kilometres, therefore no comparable average cost and revenue figures could be calculated for this transport mode. For LCVs no average costs and revenues (in €-cent per tkm) could be presented. However, it was possible to estimate the cost coverage ratio (based on total costs and revenues), which is equal to 153%.

4 Road transport

4.1 Introduction

This chapter provides the analyses of average cost and marginal social cost coverage for road passenger and freight transport. In addition, Section 4.5 provides an analysis of the non-pricing measures introduced across Europe that also impact road externalities.

Average cost coverage ratio results are provided in the following order:

- overall cost coverage ratio;
- overall cost coverage ratio excluding fixed infrastructure costs;
- variable external and infrastructure cost coverage ratio;
- overall infrastructure cost coverage ratio;
- variable infrastructure cost coverage ratio.

Table 10 in Section 2.4.1 provides a summary of the cost coverage ratios presented throughout the average cost coverage analysis. Table 10 provides a summary of the costs and charges used to inform the cost coverage ratios for road transport, split by type between fixed and variable. It is worth noting that fixed taxes and charges do not solely respond to fixed costs in the scenarios presented⁴⁰.

Table 10 - Overview of the costs, taxes and charges used for road cost coverage ratios

Type of comparison	Infrastructure costs	External costs	Taxes and charges
Overall average	All infrastructure costs	All external costs	All taxes and charges
Fixed	All enhancement costs and traffic independent part of O&M and renewal costs	Habitat	Vehicle taxes (registration and circulation taxes), insurance taxes
Variable ⁴¹	Traffic dependent part of O&M and renewal costs	Accidents, air pollution, climate, noise, congestion, WTT	Fuel/energy taxes, infrastructure charges (i.e. road tolls, vignettes, urban road charges, and tolls for bridges and tunnels)

As detailed in Section 2.4.2, marginal cost coverage ratios for road transport are estimated for up to four scenarios: high external cost scenario; representative scenario; low external cost scenario and very low external cost scenario. The reference vehicles used in these scenarios come from those in the related report, “Transport Taxes and Charges in Europe” (CE Delft, 2019b). For the representative scenario, the costs and revenues presented are equal to the average variable costs and revenues, representing the weighted averages of actual real-world conditions/situations. For example, the ‘average road’ is the weighted average of urban roads, motorways and other roads (weighted with transport performance data).

⁴⁰ For clarification, vehicle taxes are not introduced to primarily tackle habitat costs.

⁴¹ The variable infrastructure cost coverage ratio only considers taxes and charges relating to road infrastructure (i.e. it excludes fuel/energy taxes).

The data underpinning the cost coverage ratios for road transport comes from a selection of sources, described in detail in Section 1.3.

A key robustness issue which affects road transport is the disparity between the principles used to calculate some of the cost data (territoriality principle) and transport performance data (nationality principle). As vehicle-kilometres travelled by all vehicles in a country are greater than the vehicle-kilometres travelled by vehicles registered in centrally-located countries, and smaller in peripheral countries, the data may be unrepresentative. This is even more important for road freight, where the difference in activity according to the two approaches can be very significant. This disparity in approaches to calculate average cost data and transport performance data is particularly relevant for infrastructure costs, accident costs, noise costs, congestion costs and costs of habitat damage. For the other cost categories - air pollution, climate change, WTT emissions - a bottom-up approach is used to estimate the cost figures⁴², and hence both the transport performance and cost data are based on the nationality principle. With respect to tax/charge revenues, all figures presented are based on the nationality principle (See CE Delft et al. (2019b) for more details) and hence no disparity issues with transport performance data exist. More information on this issue can be found in Section 1.3.

4.2 Average cost-based internalisation

4.2.1 Road passenger transport

Overall cost coverage ratio

The overall cost coverage ratio provides an insight into total cost recovery, determining whether external and infrastructure costs are internalised by total tax and charge revenues. This cost coverage is related to Figure 1 and Figure 2, presented in Section 3.2, which outline the costs and taxes used to inform the total and average cost coverage ratios.

Figure 16 displays the overall cost coverage for road passenger transport across all modes (i.e. passenger car, motorcycle, bus, coach)⁴³. The blue line represents 100% cost coverage, where all external and infrastructure costs are internalised. The EU28 average cost is €ct 10.70 per pkm and the EU28 average revenue is €ct 5.01 per pkm. Average costs range from €ct 6.81 per pkm to €ct 21.81 per pkm, with Japan bearing the highest average costs in the sample (which, along with Missouri's high average costs, extend beyond the x-axis displayed in the magnified subset).

Austria bears the highest average costs across EU28 Member States, reporting the highest average infrastructure costs, due to relatively high infrastructure expenditures on motorways. In addition, high average infrastructure costs in Austria are linked to complex road networks, higher expenditure on winter maintenance and maintenance of a high-quality road network. In addition, Austria also experiences the highest average external accident costs for passenger cars in the EU28 and accident costs provide the greatest contribution towards overall average external costs for road passenger transport across the

⁴² The transport performance data (based on nationality principle) is used as starting point in this approach. These performance data is multiplied with emissions factors in order to calculate the total GHG and air pollutant emissions (which are monetarised using relevant cost indicators). Hence, in this approach both the transport performance data and cost data is based on the nationality principle.

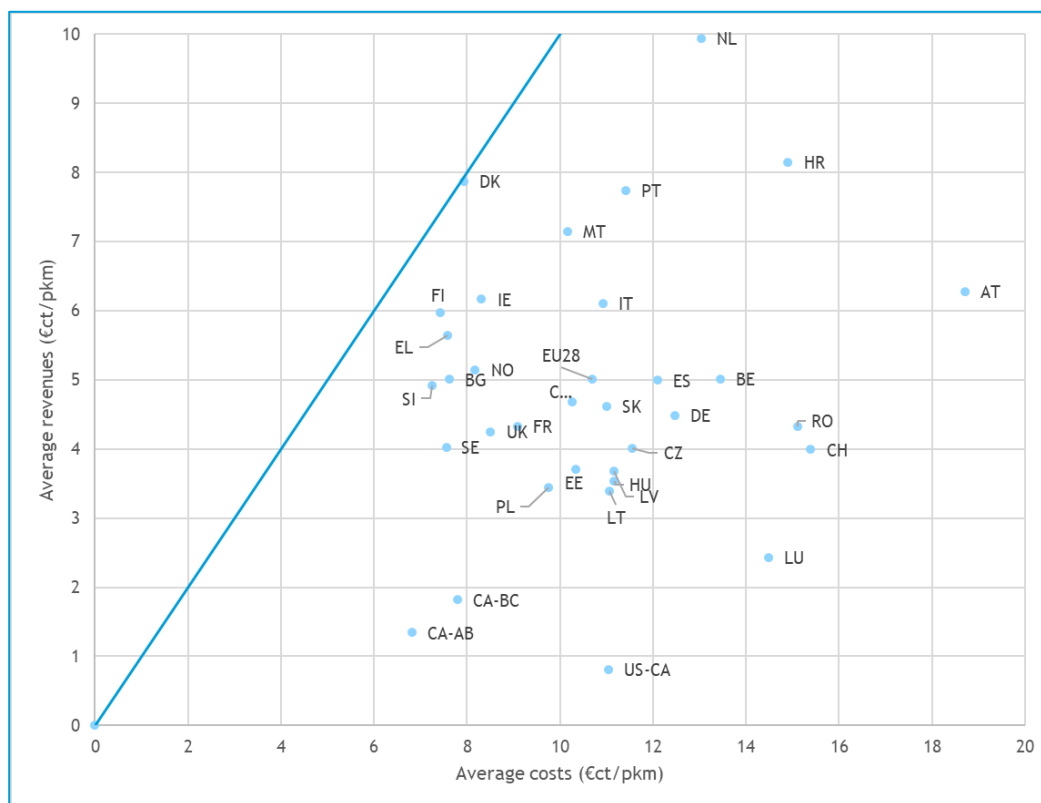
⁴³ Cost coverage by vehicle type is included in a separate Excel deliverable, Annex E.

EU28 (CE Delft, 2019c). The relatively high accident costs in Austria (compared to other countries) are primarily linked to transit traffic, which is not considered when estimating the average accident risk. The VSL in Austria is relatively high (as GDP in Austria is high) as well and hence, contributes to high average accident costs. However, there are countries with even higher VSL (e.g. Switzerland, Ireland, Luxembourg).

The high average costs in Austria are followed closely by Romania and Croatia, which is expected as these countries bear the next highest average external accident costs for passenger cars, as well as relatively high average infrastructure costs for all road passenger transport modes. In contrast, Finland, Slovenia and Sweden bear much lower average costs, under €ct 8 per pkm. This is due to relatively low average infrastructure costs for road passenger transport (below € 21 per 1,000 pkm) and relatively low average external accident costs. In addition, the three countries have lower than average air pollution costs and noise costs, whilst Slovenia has the lowest average congestion costs for passenger cars and buses in the EU28.

Across Europe, the range of average revenues is less extensive than the range of average costs. However, the Netherlands, Portugal, Croatia and Denmark generate higher average revenues than most of the EU28 Member States. For the Netherlands, this is linked to a combination of revenues derived from fuel excise duty and ownership tax, as well as smaller contributions from revenues generated by VAT on taxes, purchase tax and insurance tax. The average revenues are relatively high in Croatia due to particularly high fuel taxes and high average road tolls (PPS corrected). The high average revenues in Portugal are primarily attributed to fuel excise duty, which is expected to be due to the relatively high tax on petrol (corrected for PPS), as well as road tolls. Average revenues are particularly high for motorcycles in Portugal, due to relatively high road toll rates, which are not reduced for motorcycles, as is the case for most other Member States. In Denmark, the high average revenues are comprised of a combination of taxes and charges; however, vehicle ownership tax contributes most significantly to overall average revenues for passenger cars, buses and coaches.

Figure 16 - Overall cost coverage for road passenger transport in the EU28, Switzerland, Norway, the US, Canada and Japan (magnified subset)



None of the sample countries internalise all external and infrastructure costs associated with road passenger transport. However, Denmark reaches a cost coverage ratio of 99%, primarily by applying the highest purchase taxes for passenger vehicles in Europe. Looking at reference vehicles used for this study, purchase taxes for Euro 6 buses and coaches exceed € 120,000 per vehicle, whilst Euro 6 passenger cars face purchase taxes between € 5,438 and € 26,665 per vehicle, depending on fuel-efficiency and fuel type (PPS corrected).

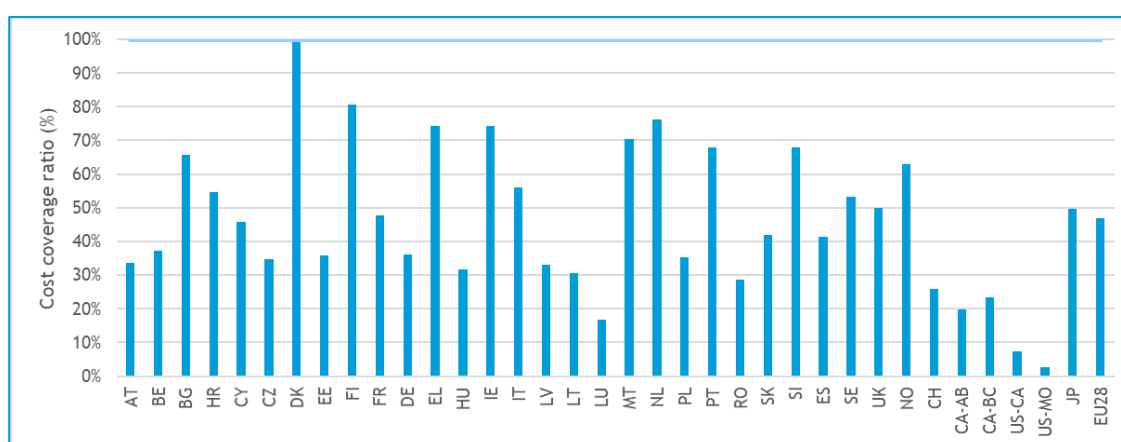
As seen in Figure 17, there is significant variation in cost coverage across the EU28, from 17% in Luxembourg to 99% in Denmark. The high-cost coverage in Denmark is primarily linked to the previously mentioned high average revenues, as well as the relatively low average costs (linked to low average external accident and air pollution costs). The Netherlands and Finland report cost coverages of 76 and 81% respectively, for the same reasons. Ireland achieves a relatively high-cost coverage of 74%. This is linked to a combination of relatively low average infrastructure costs and relatively low average accident costs across passenger transport. In addition, Ireland generates relatively high average revenues, which are primarily linked to a combination of fuel, purchase and ownership tax revenues for passenger car, as well as VAT on taxes.

The low-cost coverage in Luxembourg is primarily linked to the relatively limited number of taxes and charges applied to road transport, as well as relatively low fuel taxes for general and business use (CE Delft, 2019b). Furthermore, Luxembourg has the highest average external air pollution, congestion and well-to-tank costs in the EU28. The primary reason

for the high air pollution and WTT costs in Luxembourg are due to high-cost factors, linked to high income levels and relatively high population density in Luxembourg.

In addition, the low-cost coverage ratios in Lithuania and Romania are due to relatively high average costs. In Romania, this is linked to relatively high road infrastructure investment as a proportion of GDP, and is also caused by inefficiencies in the planning and construction phase (CE Delft, 2019a). In addition, Romania also bears relatively high accident and noise costs for passenger transport. In Lithuania, the low-cost coverage is linked to relatively high road infrastructure O&M expenditures as a share of GDP (ibid). Lithuania also has a limited number of taxes in place, with no ownership, purchase or insurance tax or distance-based road charges.

Figure 17 - Overall cost coverage ratio for road passenger transport in the EU28, Switzerland, Norway the US, Canada and Japan



Overall cost coverage ratio excluding fixed infrastructure costs

The overall cost coverage excluding fixed infrastructure costs displays the extent to which all external costs and variable infrastructure costs are internalised by all taxes and charges. Variable infrastructure costs refer to all traffic-dependent renewal and maintenance costs. This cost coverage ratio is related to Figures Figure 5 and Figure 6 presented in Section 3.3, which outline the costs and taxes used to inform the total and average cost coverage ratios excluding fixed infrastructure costs.

Figure 18 displays the varied spread of average costs and average revenues, with five EU Member States achieving complete cost internalisation. Japan and Missouri are not captured by the graph, due to their respective high average revenues and high average costs, which extend beyond the bounds of Figure 18. Austria bears the highest average costs in the EU of €ct 14.34 per pkm. The high average costs are linked to the aforementioned relatively high accident costs and high variable infrastructure costs, due to complex, high-quality road networks which require winter maintenance. After Austria, Luxembourg and Belgium bear the highest average costs. The high average costs in Luxembourg are primarily attributed to the high average external air pollution, congestion and well-to-tank costs linked to road passenger transport.

Similarly, in Belgium, high average costs are attributed to the relatively high average external costs. In particular, Belgium bears the highest average external congestion costs and noise costs across EU Member States. However, it is likely that the high average costs in

Luxembourg are influenced by the differing scopes used for cost data and transport performance data. The vehicle-kilometres travelled by all vehicles in Luxembourg are likely to be much greater than the vehicle-kilometres travelled by vehicles registered in Luxembourg. Therefore, the data may be unrepresentative, as the transport performance data used to estimate average costs may be too low, as it is based on the nationality principle, whilst cost data is based on the territoriality principle.

The highest average revenues in the EU28 are generated by the Netherlands (€ct 9.94 per pkm), followed by Croatia, Portugal and Denmark. Refer to the discussion under the overall cost coverage ratio for explanations of high average revenues in these countries.

Figure 18 - Overall cost coverage excluding fixed infrastructure costs for road passenger transport in the EU28, Switzerland, Norway, the US, Canada and Japan (magnified subset)

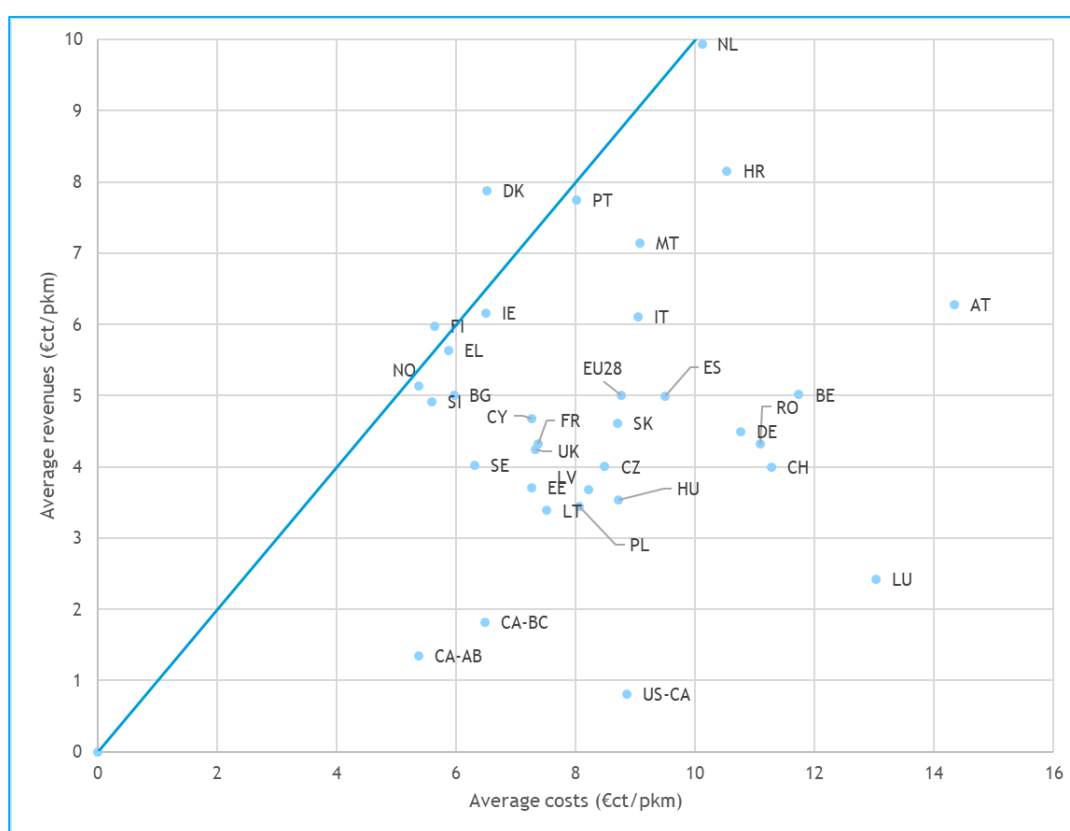


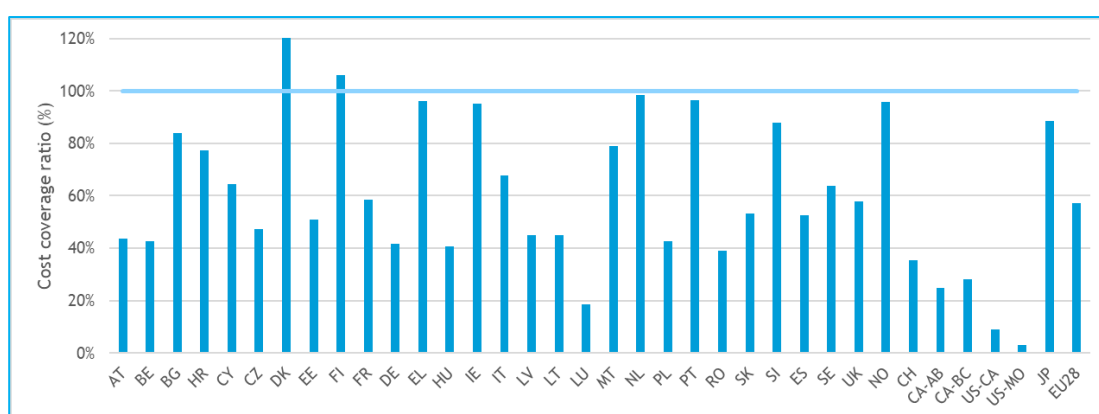
Figure 19 displays the overall cost coverage ratio excluding fixed infrastructure costs, where the majority of countries do not recoup average external costs and average variable infrastructure costs. As with overall cost coverage, Denmark has the highest cost coverage ratio of 121%, followed closely by Finland, Portugal and Norway. Denmark's high-cost coverage is due to relatively high vehicle purchase tax revenues, alongside relatively low average external accident and air pollution costs.

The high-cost coverage ratio in Portugal is linked to relatively high fuel excise duty revenues, attributed to the relatively high tax on petrol (corrected for PPS), as well as road tolls. The high-cost coverage in Finland is linked to the relatively low average accident, air pollution and noise costs associated with road passenger transport. In Finland, variable

expenditure levels per kilometre of road network are relatively low as well, as the majority of the variable expenditures are spent on a small proportion of the road network (CE Delft, 2019a). The low costs in Finland are combined with relatively high average revenues from a variety of sources, primarily generated by fuel taxes. In Norway, complete cost coverage is achieved through a combination of bearing the lowest average costs (linked to relatively low average external accident and climate costs) and high purchase taxes for fuel-inefficient vehicles.

Luxembourg displays the lowest cost coverage amongst EU Member States, followed by Romania, Hungary and Germany. The explanations for the low-cost coverage in Luxembourg and Romania reflect the justifications provided for the overall cost coverage ratio. The low-cost coverages in Germany and Hungary are attributed to a combination of relatively high average costs and relatively low average revenues. In Germany, the low average revenues are linked to a lack of infrastructure charging and purchase taxes and relatively low average revenues sourced from ownership taxes, relative to other EU28 Member States. In Hungary, low average revenues are linked to the lack of distance-based road tolls and relatively low revenues generated by insurance, ownership and vehicle purchase taxes. The relatively high average costs in Germany and Hungary are primarily linked to high average external accident costs.

Figure 19 - Overall cost coverage ratio excluding fixed infrastructure costs for road passenger transport in the EU28, Switzerland, Norway, the US, Canada and Japan



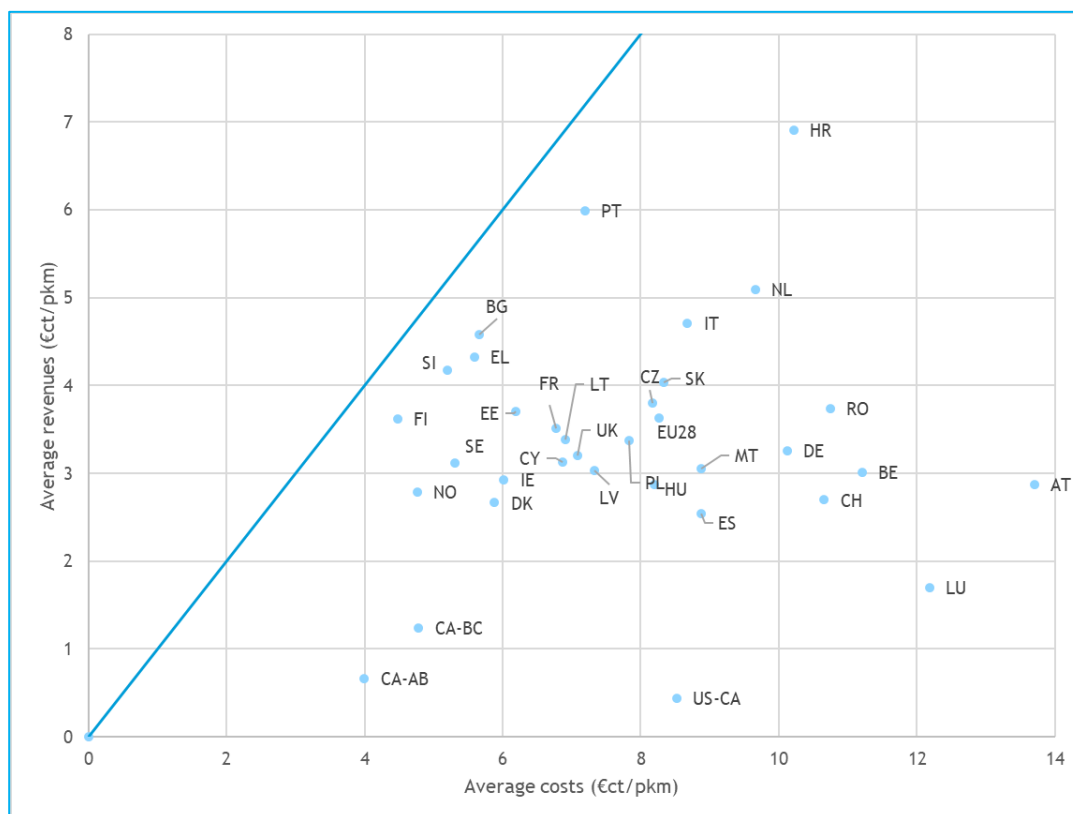
Variable external and infrastructure cost coverage ratio

The variable external and infrastructure cost coverage displays the extent to which additional costs caused by increasing the use of the road networks are internalised by variable taxes and charges (i.e. fuel/energy taxes, infrastructure charges). Figure 7 and Figure 8 under Section 3.4 provide an overview of the total and average variable external and infrastructure cost coverage ratio.

Figure 20 displays the spread of average variable costs and average variable revenues, highlighting that none of the sample countries completely internalise total variable costs. Japan and Missouri are not captured by the graph, due to their respective high average revenues and high average costs, which extend beyond the bounds of Figure 20. Luxembourg and Austria bear the highest average variable costs in the EU28, linked to the reasons mentioned under the overall cost coverage ratio.

The EU28 average revenue is €ct 3.63 per pkm, with Croatia and Portugal generating the highest average revenues in the EU. The justification for high average revenues in these countries is previously outlined under the coverage cost coverage ratio.

Figure 20 - Variable external and infrastructure cost coverage for road passenger transport in the EU28, Switzerland, Norway, the US, Canada and Japan (magnified subset)



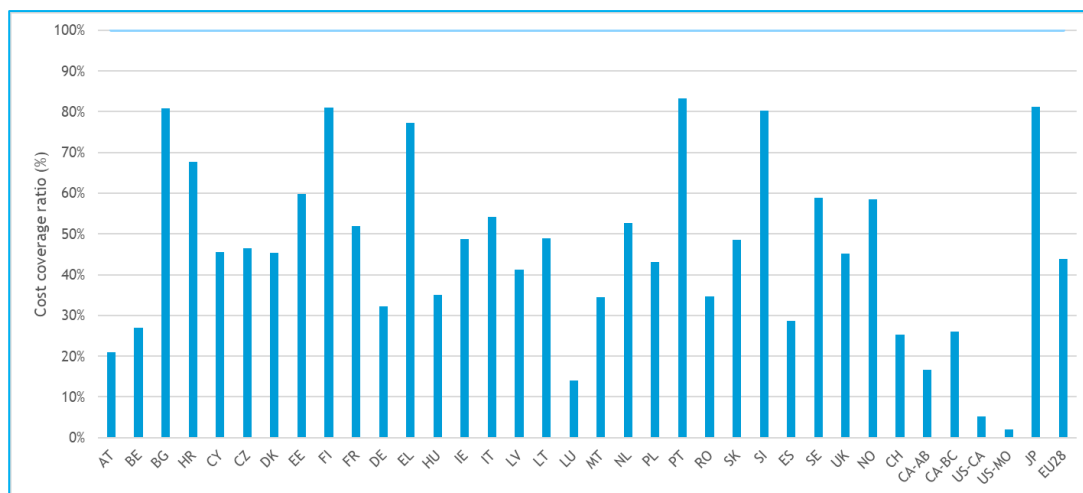
As depicted in Figure 21, the EU28 average variable cost coverage is 44%. Portugal achieves the highest cost coverage ratio of 83%. This relatively high-cost coverage ratio is likely to be linked to the aforementioned high average revenues Portugal generates from road tolls and fuel taxes. In addition, Portugal also bears relatively low average external air pollution and well-to-tank costs.

Bulgaria and Finland achieve the second highest cost coverage ratios of 81%. In Slovenia, the cost coverage ratio is 80%. In Bulgaria, this is primarily linked to high (PPS adjusted) revenues from fuel excise duty for passenger cars, buses and coaches. In Finland and Slovenia, the relatively high-cost coverage is somewhat linked to moderate average revenues, which are primarily attributed to fuel taxes. However, both countries display some of the lowest average external costs in the EU, which contribute to their high-cost coverage ratios. Specifically, both countries bear low average external accident, air pollution and noise costs. Despite the transit traffic and geographical bottlenecks, Slovenia also bears particularly low average external congestion costs for road passenger transport. Despite congestion on motorways over the summer months, congestion costs for passenger cars remain relatively low on motorways per vkm over the course of the year.

Greece and Croatia also achieve relatively high-cost coverage ratios of 77% and 68% respectively. The high-cost coverage in Greece is linked to relatively low average costs, bearing some of the lowest average external accident, air pollution and well-to-tank costs in the EU28. This is complemented by relatively high petrol tax levels, which comprise the majority of the average revenues for road passenger vehicles. In Croatia, the previously mentioned fuel taxes and road toll revenues contribute to the relatively high-cost coverage. In contrast to Greece; however, Croatia bears relatively high average costs, due to relatively high average external accident and climate costs and relatively high average variable infrastructure costs.

Luxembourg reports the lowest cost coverage in the EU28 of 14%. The low-cost coverage is primarily linked to the relatively limited number of taxes and charges applied to road transport, as previously mentioned in the overall cost coverage ratio (CE Delft, 2019b). Furthermore, Luxembourg has the highest average external air pollution, congestion and well-to-tank costs in the EU28. Austria also reports a relatively low-cost coverage ratio (21%), which is likely to be linked to high average external accident costs, in contrast to relatively low average variable revenues (a large proportion of its average revenues derive from ownership taxes for passenger cars and motorcycles, which are not considered under this cost coverage ratio). As discussed first under the overall cost coverage ratio, the low ratios observed for Luxembourg and Austria may be linked to the robustness issues with the data, as both countries have significant transit traffic.

Figure 21 - Variable external and infrastructure cost coverage ratio for road passenger transport in the EU28, Switzerland, Norway, the US, Canada and Japan



Overall infrastructure cost coverage ratio

The overall infrastructure cost coverage ratio provides an insight into infrastructure cost recovery, determining whether average infrastructure costs (investments, renewal costs and O&M costs) are internalised by average infrastructure charge revenues. This is related to Figure 10 and Figure 11 from Section 3.5, which outline the costs, taxes and charges used to inform the total and average infrastructure cost coverage ratios.

Figure 22 displays the overall infrastructure cost coverage for road passenger transport across all modes (i.e. passenger car, motorcycle, bus, coach). The EU28 average cost is €ct 2.24 per pkm and the EU28 average revenue is €ct 0.43 per pkm. There are a few

countries, such as Japan (extends outside the x-axis of the magnified subset), where average costs (€ct 11.21 per pkm) are significantly higher than the EU28 average costs. This is linked to high investments in road infrastructure, high infrastructure costs per kilometre of the network and low-road utilisation in Japan, relative to the majority of EU Member States (CE Delft, 2019a).

Austria bears the highest average costs in the EU28 (€ct 5.42 per pkm). As mentioned before, this is likely to be linked to the high road infrastructure complexity in Austria, as well as the need for winter maintenance. In the EU, Portugal and Croatia generate the highest average revenues. The average revenues are relatively high in Croatia, due to relatively high average road toll levels applied on the charged network. The high average revenues in Portugal are attributed to the distance-based road charge levied on all motorways.

Many Member States (i.e. Luxembourg, Estonia, Cyprus, Finland) do not apply road charges to passenger transport, and subsequently, report no average revenues. Some of these countries, however, do apply some local pricing schemes (e.g. Germany employs a toll on Herrentunnel and Warnowtunnel, Latvia enforces an urban pricing scheme in Jurmala and Malta operates an urban road-pricing scheme in Valetta). As the average revenues from these infrastructure charges are negligible, they are not considered in this study.

Figure 22 - Overall infrastructure cost coverage for road passenger transport in the EU28, Switzerland, Norway, the US, Canada and Japan (magnified subset⁴⁴)

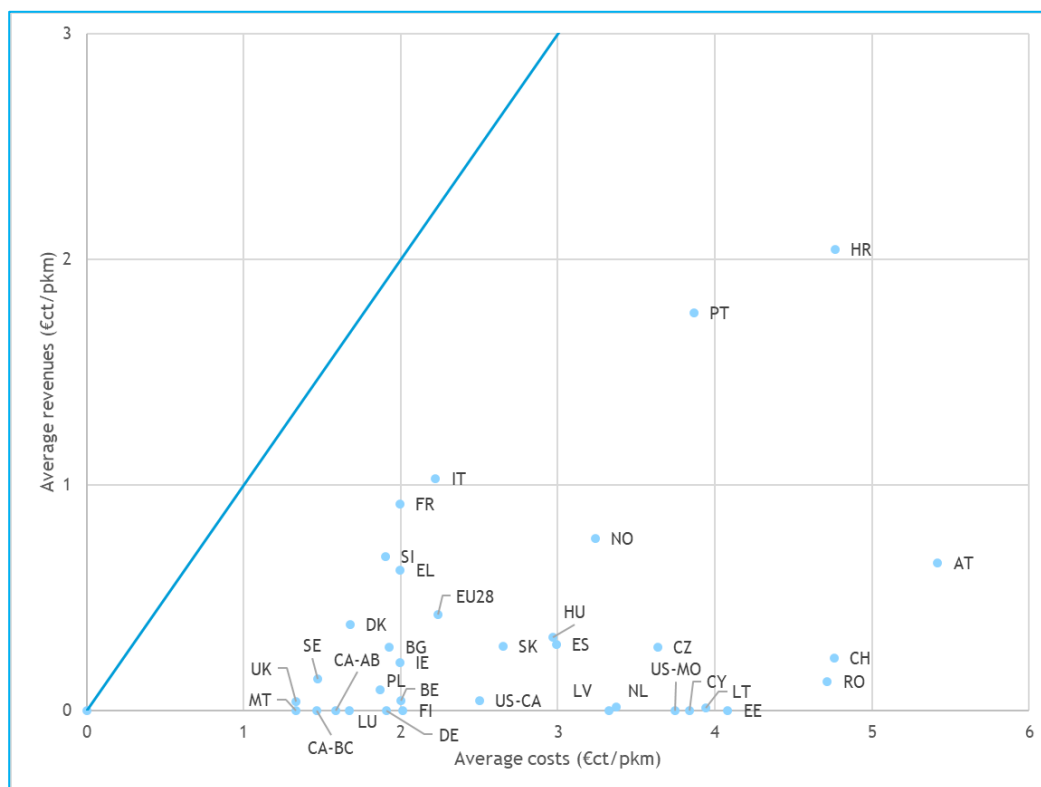


Figure 23 displays the infrastructure cost coverage ratio for overall road passenger transport. The EU28 average infrastructure cost coverage is 19%, highlighting the generally low recuperation of average infrastructure costs by EU Member States. The highest cost coverage ratios are found in countries with large-scale distance-based road charging schemes for passenger transport vehicles, primarily applied to motorways (e.g. Portugal, Italy and France⁴⁵). Countries that apply time-based road charges (e.g. Austria, Czech Republic, Hungary and Switzerland) achieve intermediate cost coverage ratios.

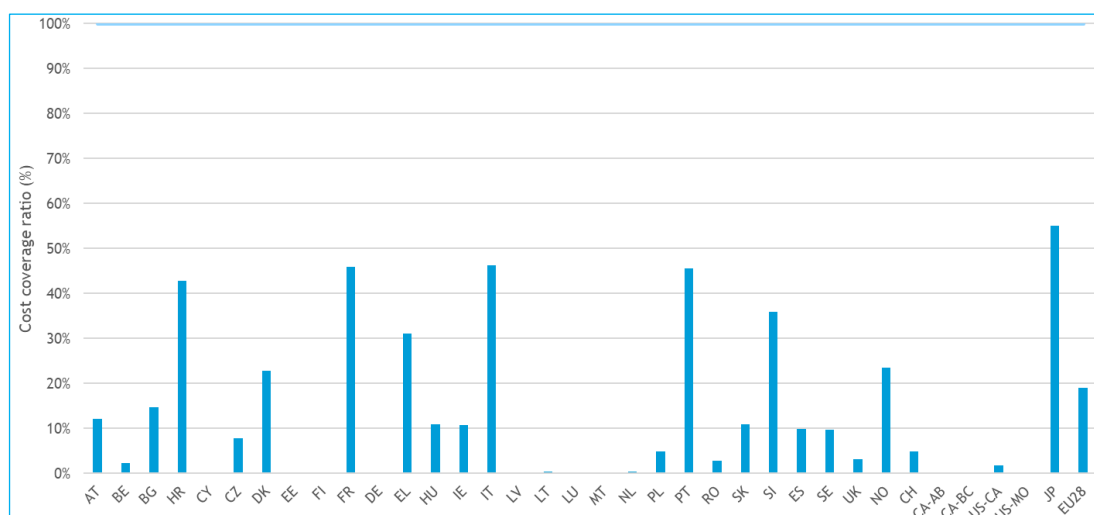
The aforementioned absence of road charges for passenger vehicles in a number of countries (e.g. Cyprus, Estonia and Finland) results in these countries reporting zero cost coverage. It is worth noting that, although Denmark does not impose a road toll or vignette on the interurban network, it achieves a cost coverage of 23%, which is primarily due to relatively low average external and infrastructure costs. In addition, the revenues generated by bridge tolls also contribute. Similarly, Sweden also achieves a cost coverage ratio of 10%, despite a lack of road tolls or vignettes. This is due to the urban charging schemes operating in Stockholm and Gothenburg, which apply to passenger cars, buses

⁴⁴ A zoomed-in version of the graphs has been presented, to provide a detailed view of the range of values. Therefore, some outliers are not captured in the 'magnified subset', although these values are described in the analysis.

⁴⁵ Some of these countries (i.e. France, Italy) do even enforce additional charges on specific sections for passenger vehicles. Charges are levied at the tunnels of Monte Bianco (cross-border Italy-France), Gran San Bernardo (cross-border Italy-Switzerland) and Frejus (cross-border Italy-France). Milan also has an urban pricing system in place during peak hours Monday to Friday.

(14 tonnes and under) and coaches, as well as the bridge tolls in operation at Sundsvallsfjarden and Motalaviken.

Figure 23 - Overall infrastructure cost coverage ratio for road passenger transport in the EU28, Switzerland, Norway, the US, Canada and Japan



Variable infrastructure cost coverage ratio

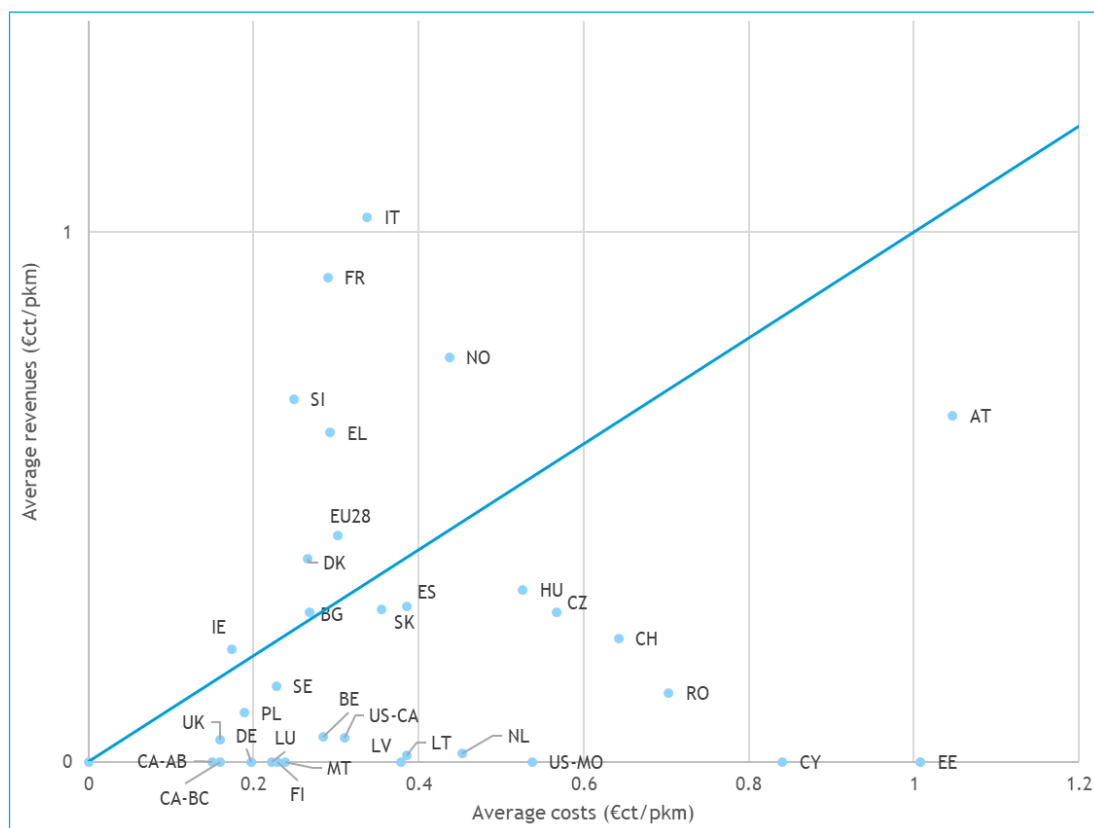
The variable infrastructure cost coverage ratio provides an insight into infrastructure cost recovery, determining whether variable infrastructure costs are internalised by revenues from infrastructure charges. It measures the extent to which additional infrastructure costs, caused by an additional kilometre travelled, are covered by infrastructure charges.

This section assesses the variable infrastructure cost coverage outlined in Figure 13 and Figure 14 in Section 3.6, which outline the costs and taxes used to inform the total and average variable infrastructure cost coverage ratios. Table 10 in Section 4.1 provides a summary of the variable infrastructure costs and variable taxes considered.

Figure 24 displays the variable infrastructure cost coverage for road passenger transport across all vehicle types. Both average costs and average revenues vary between countries. The EU28 average cost is €ct 0.30 per pkm and the EU28 average revenue is €ct 0.43 per pkm. Austria bears the highest average costs in the EU28 (€ct 1.05 per pkm), followed closely by Estonia (€ct 1.01 per pkm). Austria's high average variable infrastructure cost is due to the high network complexity in Austria (e.g. many tunnels) (CE Delft, 2019a).

Croatia and Portugal generate the highest average revenues in the EU28 (€ct 2.04 and €ct 1.76 per pkm respectively), which exceed the bounds of the magnified subset shown in Figure 24.

Figure 24 - Variable infrastructure cost coverage for road passenger transport in the EU28, Switzerland, Norway, the US, Canada and Japan (magnified subset)

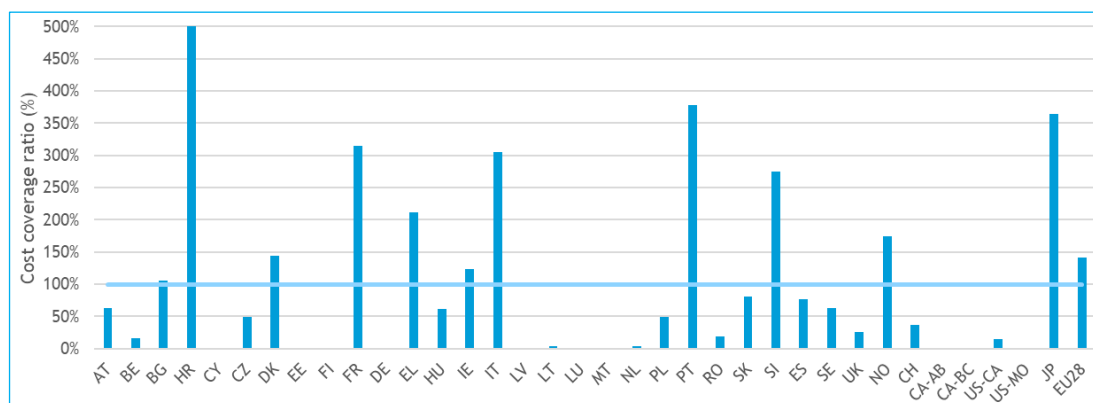


As displayed by Figure 25, the EU28 average variable infrastructure cost coverage ratio is 142%. The cost coverage ratios of Croatia and Portugal extend beyond the visible y-axis of Figure 19, which is magnified to provide a detailed view of the range of values. Croatia achieves the highest cost coverage ratio of 513%, followed by a number of other European countries which have applied distance-based road charging schemes. Croatia's high-cost coverage is linked to relatively high distance-based road charges on motorways for all vehicles. Portugal also achieves a high-cost coverage ratio of 377%, which is linked to high average revenues, associated with its distance-based toll levied on all motorways.

Italy, Greece, France and Slovenia also achieve high-cost coverages of 304%, 212%, 315% and 275% respectively. In France, the high-cost coverage is linked to the high toll placed on passenger vehicles. In Greece, the high average revenues are linked to the distance-based toll. Italy enforces a road toll, tolls at the tunnel crossings between country borders and an urban road pricing scheme in Milan. In Slovenia, high cost coverage is linked to the combination of a vignette on cars and motorcycles, and the road toll placed on buses. The toll placed on the use of the Karavanke road tunnel also provides some contribution to average revenues. The high average revenues in these four countries are complemented by relatively low average variable infrastructure costs. Denmark also achieves complete cost coverage of 145%. Although Denmark does not implement a road toll or vignette for passenger vehicles, it does charge all passenger vehicle types for use of the Storebælt and Øresund bridges. In addition to these bridge tolls, the variable infrastructure costs in Denmark for passenger vehicles are low, relative to many other Member States.

Several EU Member States (Cyprus, Estonia, Finland, Latvia, Luxembourg, Malta, Germany) have a 0% cost coverage. Refer to the overall infrastructure cost coverage ratio for justifications of the lack of cost coverage in these countries.

Figure 25 - Variable infrastructure cost coverage ratio for road passenger transport in the EU28, Switzerland, Norway, the US, Canada and Japan



4.2.2 Road freight transport

Overall cost coverage ratio

As presented for road passenger transport, the overall cost coverage ratio examines the capacity of all taxes and charges to reach cost recovery against infrastructure and external costs. Only HGV data is presented here, as most LCVs are used for services, rather than for goods delivery. Therefore, LCV costs and revenues are not representative of the way LCVs are used, and therefore, would distort the freight data⁴⁶.

As displayed by Figure 26, none of the sample countries reaches complete cost internalisation for road freight. The majority of average costs and average revenues are clustered around the EU28 average of €ct 5.83 per tkm (average costs) and €ct 1.53 per tkm (average revenues). However, Switzerland, Japan and Missouri bear particularly high average costs of €ct 14.42 per tkm, €ct 18.64 per tkm and €ct 24.80 per tkm respectively; and therefore, extend beyond the range of the magnified subset.

Croatia (€ct 2.69 per tkm) and the Czech Republic (€ct 2.66 per tkm) achieve the highest average revenues in the EU28. In Croatia, this is linked to the relatively high distance-based road charge on motorways for all vehicles. It is also linked to high average revenues derived from fuel excise duty. In the Czech Republic, it is primarily linked to high average revenues from fuel taxes, as well as the distance-based road toll for vehicles exceeding 3.5 tonnes.

Luxembourg generates the lowest average revenues in the EU28, followed by Spain and Estonia. The low average revenues in Luxembourg are attributed to relatively low average fuel tax levels, as well as relatively low-road charge levels for HGVS (only the Eurovignette is required for HGVS over 12 tonnes). In Estonia, the majority of average revenue is linked to fuel taxes, as Estonia does not have infrastructure road charges. Minimal revenues are

⁴⁶ However, the EU28 average cost coverage for LCVs could be estimated (based on total cost and revenue values), as 36%.

also generated by ownership tax, because of relatively low tax levels. In Spain, the relatively low diesel taxes are the main explanation for the low average revenues found for HGVs.

Figure 26 - Overall cost coverage for road freight transport in the EU28, Switzerland, Norway, the US, Canada and Japan (magnified subset)

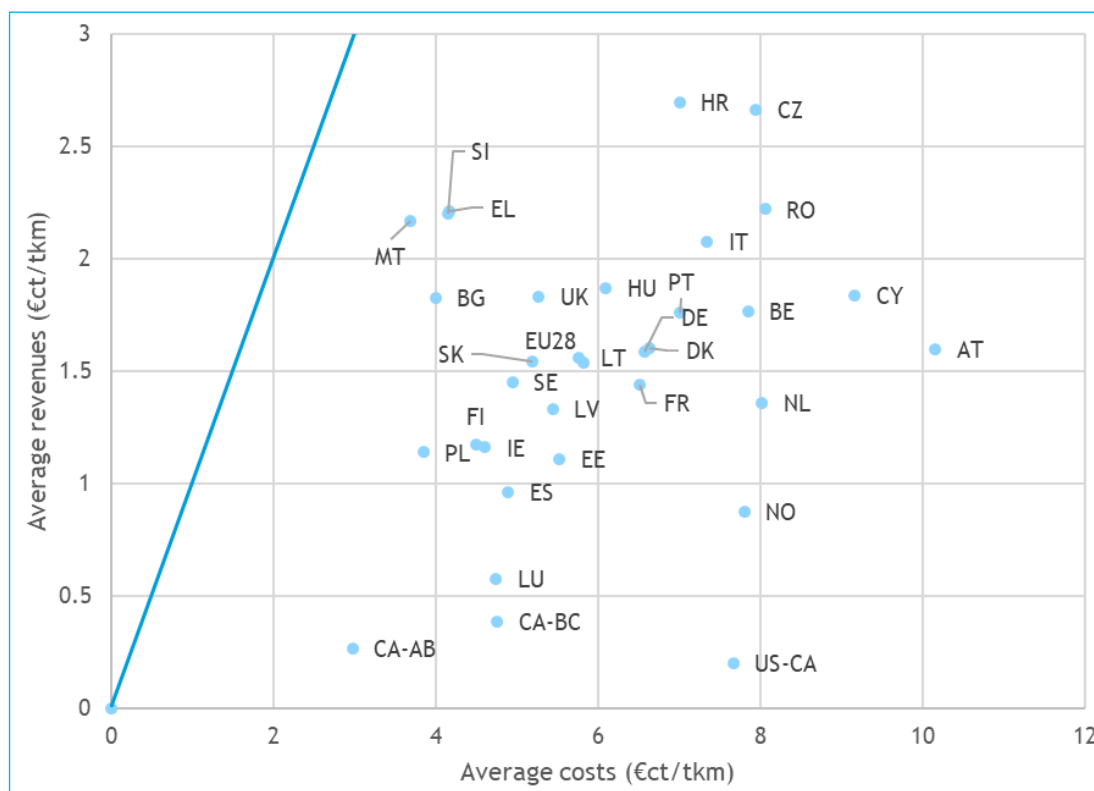
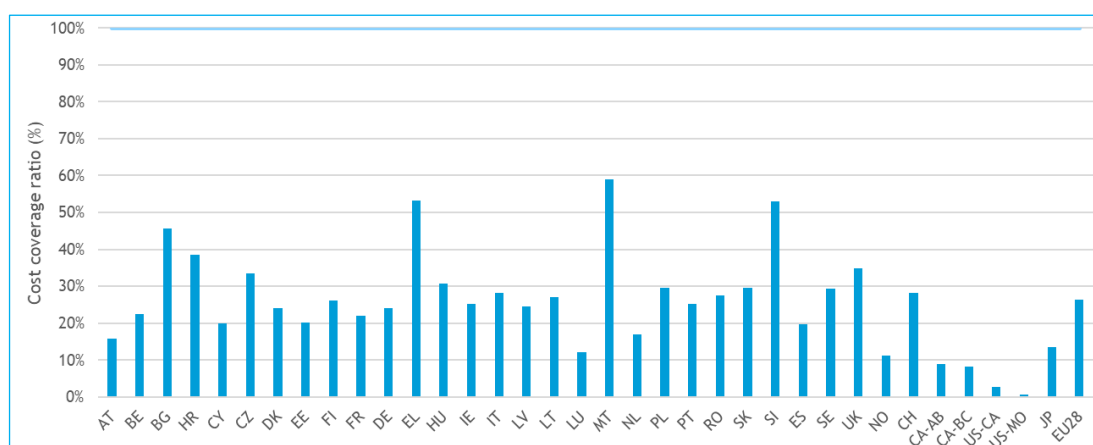


Figure 27 highlights the lack of complete cost internalisation, with Malta achieving the highest cost coverage ratio of 59%. This relatively high-cost coverage is linked to the tax on vehicle ownership for HGVs and vehicle insurance tax (11% of the insurance premium). Furthermore, despite relatively high average external accident costs, relatively low average external air pollution and noise costs, and infrastructure costs result in Malta bearing the second-lowest average costs in the sample, leaving relatively minimal costs to cover. The cost coverage ratios are also relatively high in Greece, Slovenia and Bulgaria. Slovenia's relatively high-cost coverage (53%) is linked to the high distance-based charges on HGVs. For example, Euro 3 truck trailers over 32 tonnes are charged the highest (€ 0.62 per km, PPS corrected), and relatively high tolls are also placed on the remaining weight categories. In addition, HGVs are linked to relatively low average infrastructure and external costs and Slovenia generates relatively high revenues from fuel taxes.

The majority of average revenue generated in Bulgaria is linked to fuel excise duty, on account of relatively high diesel taxes. In addition, the relatively high time-based road charge for HGVs over 32 tonnes (€ 1,436.71 per vehicle per year, PPS corrected) also contributes to average revenues. In Greece, the relatively high average revenues are linked to a combination of fuel tax revenue and relatively high vehicle ownership taxes on HGVs.

The EU28 cost coverage average is only 26%, and with countries showing lower cost coverage such as the Netherlands, this is linked to a combination of high average costs and relatively low average revenues. The high average infrastructure costs, as well as high external accident and air pollution costs, attributed to HGVs in Austria result in a relatively low-cost coverage of 16%, in spite of the country enforcing one of the highest road tolls for truck trailers (and generating relatively high average revenues). In Luxembourg, the low-cost coverage of 12% is linked to relatively low average revenues generated by fuel taxes and the Eurovignette.

Figure 27 - Overall cost coverage ratio for road freight transport in the EU28, Switzerland, Norway, the US, Canada and Japan



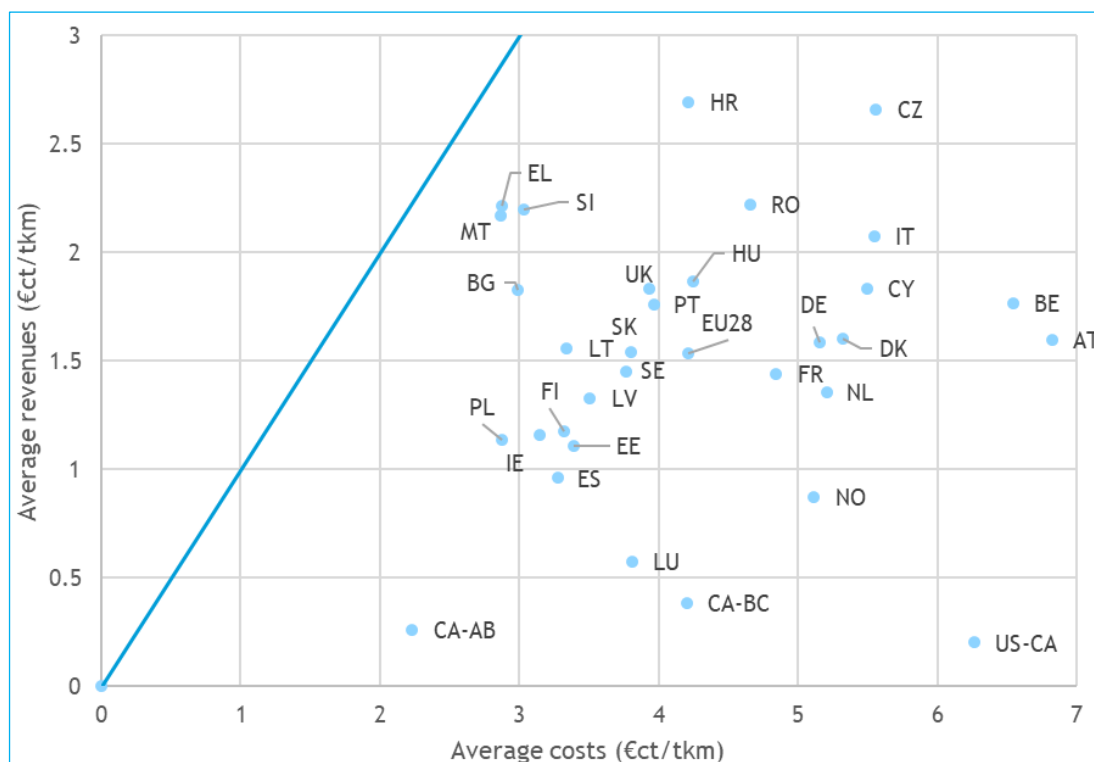
Overall cost coverage ratio excluding fixed infrastructure costs

The overall cost coverage excluding fixed infrastructure costs for road freight transport is displayed in Figure 28. The spread of average revenues is compact, with Switzerland's average revenue of €ct 4.07 per tkm not displayed within the magnified subset. Japan and Missouri are also excluded from the magnified subset, due to high average costs.

Croatia and the Czech Republic generate the highest average revenues amongst EU28 countries of €ct 2.69 per tkm and €ct 2.66 per tkm respectively. This is due to the reasons discussed under the overall cost coverage ratio. In contrast, the lowest average revenues are reported for Luxembourg (€ct 0.58 per tkm), echoing the reasons discussed under the overall cost coverage ratio.

The highest average costs in the EU28 are linked to Austria (€ct 6.82 per tkm), due to the previously mentioned high accident costs, as well as bearing the highest variable infrastructure costs in the EU28. In addition, Malta bears the lowest average costs of €ct 2.87 per tkm, linked to the country having some of the lowest average accident and air pollution costs in the EU28.

Figure 28 - Overall cost coverage excluding fixed infrastructure costs for road freight transport in the EU28, Switzerland, Norway, the US, Canada and Japan (magnified subset)

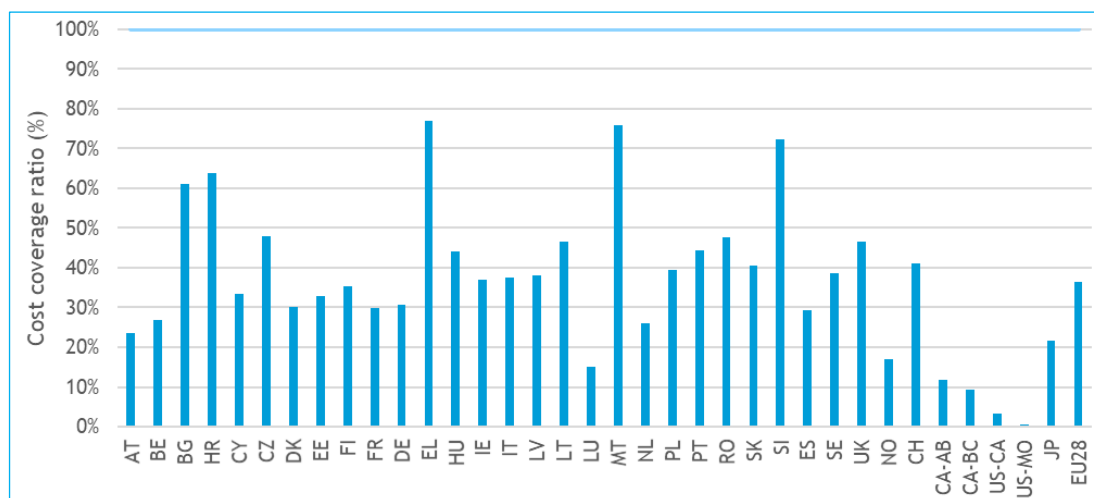


As with overall cost coverage, none of the countries reach 100% cost coverage with this indicator, as displayed in Figure 29⁴⁷. Some EU28 Member States, such as Greece, Malta and Slovenia, come close to achieving cost internalisation. This is linked to the combination of relatively low average costs, alongside relatively high average revenues. In Malta, Slovenia and Greece, relatively high average revenues are linked to high fuel taxes. In Slovenia, high distance-based charges for HGVs also contribute to high average revenues and in Greece, ownership tax revenues are also significant. The lowest cost coverage experienced by EU Member States is for Luxembourg and Norway, followed by Austria and the Netherlands. For Austria, this is primarily linked to high average costs and relatively low moderate revenues. For the Netherlands and Norway, this is due to a combination of high average costs and relatively low average revenues. While Luxembourg has relatively low average costs, it also has the lowest average revenues in the EU28.

The data robustness issue with Austria was discussed above. Belgium also has high transit traffic, so the mismatch in the scope of the transport performance data and other data used to construct the cost coverage ratio also affects it.

⁴⁷ The EU28 average for LCV cost coverage was estimated at 44%.

Figure 29 - Overall cost coverage ratio excluding fixed infrastructure costs for road freight transport in the EU28, Switzerland, Norway the US, Canada and Japan



Variable external and infrastructure cost coverage ratio

This variable cost coverage ratio displays the extent to which additional road freight transport costs are covered by pricing measures. The EU28 average cost is €ct 4.02 per tkm and the EU28 average revenue is €ct 1.32 per tkm. However, Switzerland, Japan and Missouri experience much higher average costs, with all three regions existing outside the visible range on Figure 30.

The highest average costs in the EU28 are reported by Austria (€ct 6.63 per tkm) and Belgium (€ct 6.38 per tkm). The reasons for high average costs for these countries are previously discussed under the overall cost coverage ratio excluding fixed infrastructure costs.

Malta and Greece bear the lowest average costs of €ct 2.71 per tkm and €ct 2.77 per tkm respectively. This is due to Malta having the second lowest average external costs for HGVs (€ct 2.3 per tkm), followed closely by Greece (€ct 2.4 per tkm). Croatia generates the highest average revenues in the EU28, mirroring the results under the overall cost coverage ratio and overall cost coverage ratio excluding fixed infrastructure costs.

Figure 30 - Variable external and infrastructure cost coverage for road freight transport in the EU28, Switzerland, Norway, the US, Canada and Japan (magnified subset)

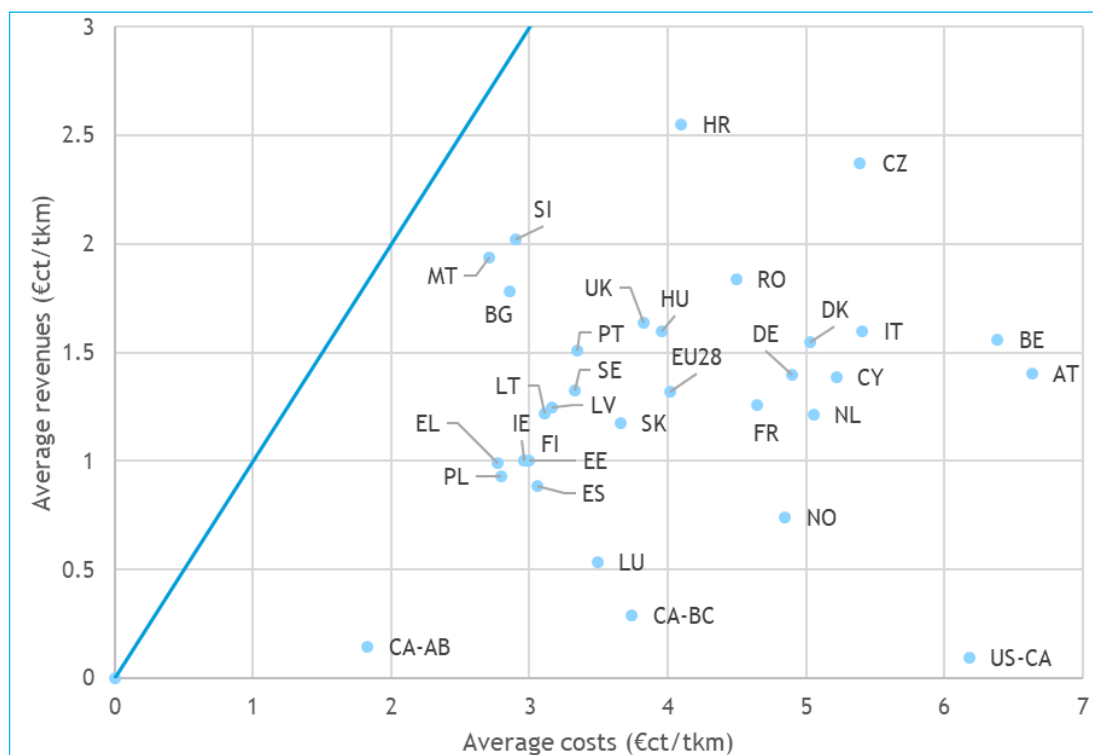
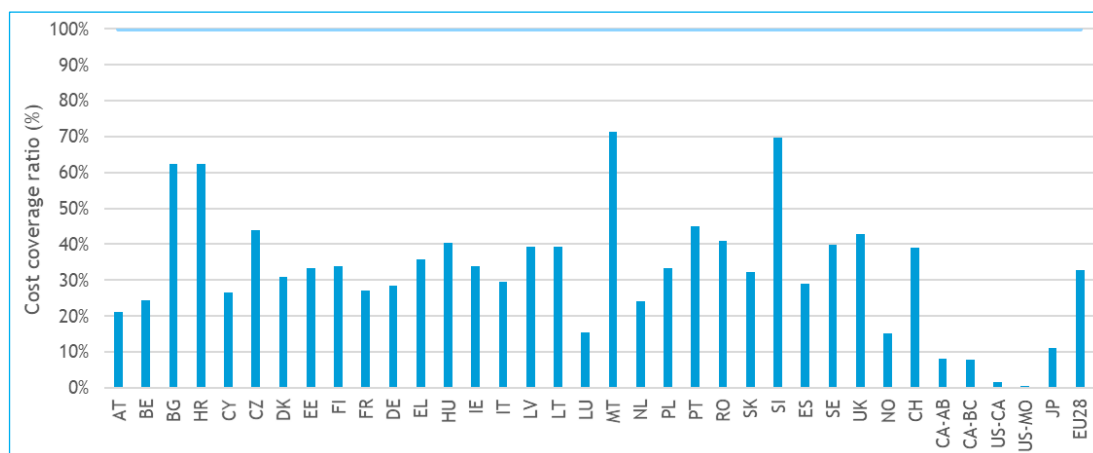


Figure 31 shows that none of the EU28 Member States reach 100% cost coverage. Only Malta achieves a cost coverage higher than 70%. Malta's higher cost coverage is associated with the combination of low average costs and high average revenues. These are primarily linked to high fuel tax revenues, whilst the low average costs are due to relatively low average accident, air pollution and noise costs. Bulgaria, Croatia and Slovenia also achieve relatively high-cost coverage, due to previously mentioned low average costs combined with charges targeting road freight transport. This can partially be explained by Slovenia and Croatia charging some of the highest distance-based tolls for HGVs, as well as relatively high fuel tax levels. Although Austria also has a high toll in place, high average costs (due to infrastructure costs and accident costs) result in relatively low-cost recovery. Bulgaria achieves cost coverage of 62%, primarily due to high (PPS adjusted) fuel tax levels, as well as a high vignette prices for HGVs and tolls operating on some bridges (although the contribution of toll revenues is relatively low).

Despite this, the EU28 average is relatively low, at 33%⁴⁸. Luxembourg has the lowest cost coverage ratio of 15% in the EU, linked the previously mentioned low fuel tax levels. The result of Luxembourg may also be impacted by the data robustness issue linked to the differing scope of transport performance data against other data used in the ratio, due to a high amount of transit traffic through the country.

⁴⁸ The EU28 average for LCV cost coverage was estimated at 39%.

Figure 31 - Overall total variable cost coverage ratio for road freight transport in the EU28, Switzerland, Norway, the US, Canada and Japan

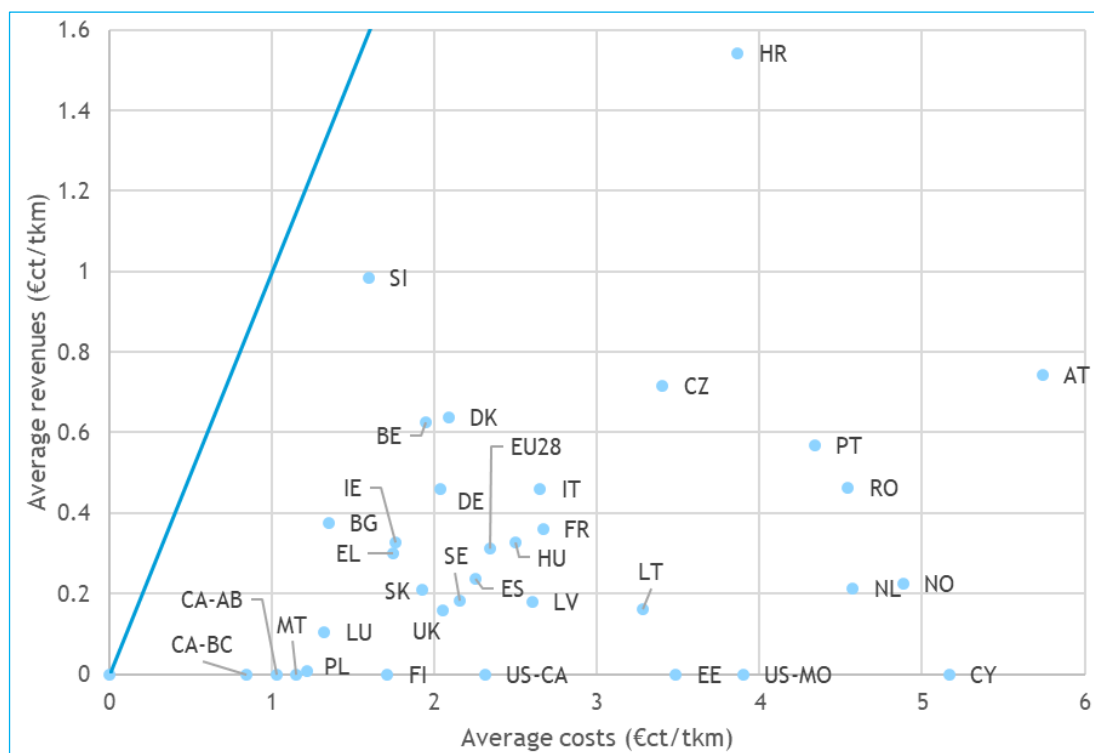


Overall infrastructure cost coverage ratio

This section reviews infrastructure cost recovery for freight transport, comparing infrastructure costs against infrastructure charges. It will examine the same infrastructure costs and infrastructure charges considered in road passenger transport. Figure 32 displays the overall infrastructure cost coverage for freight transport, incorporating costs for HGVs only.

Average infrastructure costs tend to exceed average revenues generated by infrastructure charges, with none of the sample countries achieving full cost internalisation. The EU28 average revenue is €ct 0.31 per tkm and the EU28 average cost is €ct 2.34 per tkm. Japan has the highest average costs, followed closely by Switzerland (which extend beyond Figure 32). Cyprus and Austria bear the highest average costs in the EU, which for Austria is linked to the high road network complexity (many bridges and tunnels). For Cyprus, the relatively high average costs are linked to a combination of relatively high infrastructure costs per kilometre of road network and relatively low utilisation rates of roads (CE Delft, 2019a). In contrast, Malta and Poland bear the lowest average costs in the EU, which is likely to be linked to low costs per kilometre of road network. Malta, Cyprus, Estonia and Finland report no average revenues, which is unsurprising as none of these countries enforce road infrastructure charging (except for the urban pricing scheme in Valetta, Malta). The UK, Poland and Luxembourg also generate relatively low average revenues. The low average revenues in Poland are linked to relatively low revenues generated by the distance-based toll, despite the relatively high charge. This could be linked to the fact that only a small proportion of vkms is being covered by the toll on HGVs operating on motorways in Poland. The UK enforces the London congestion charge, M6 toll and HGV road user levy rates, but yet generates relatively low average revenues from infrastructure charges. Croatia, on the other hand, generates the highest average revenues amongst EU28 Member States. This is linked to the previously mentioned high levels of revenue generated by the high distance-based toll for HGVs.

Figure 32 - Overall infrastructure cost coverage for road freight transport in the EU28, Switzerland, Norway, the US, Canada and Japan (magnified subset)

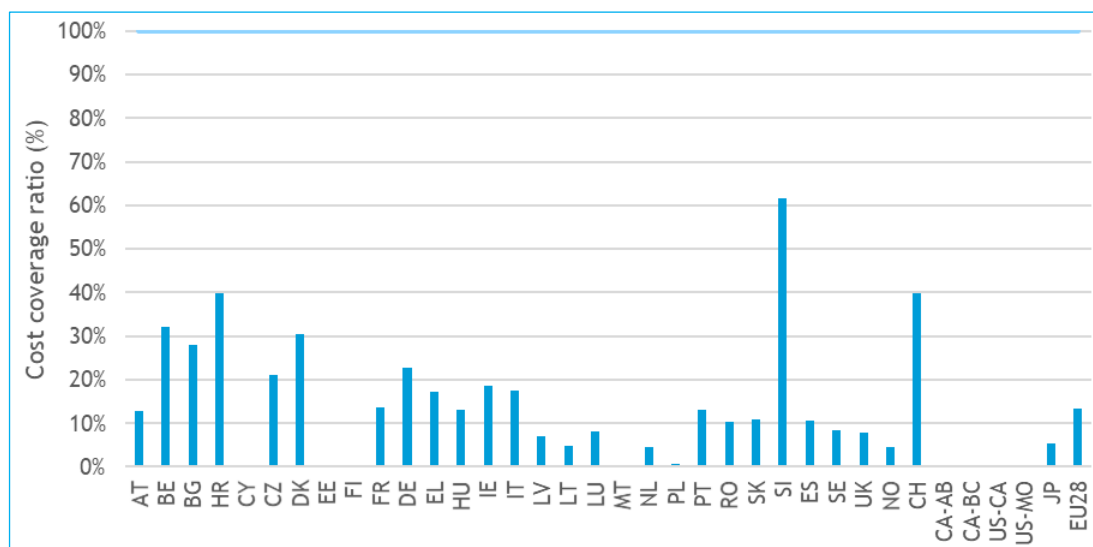


Slovenia has the highest cost coverage ratio of 62%, which is expected to be due to the high distance-based charges, particularly on older trucks (e.g. the charge level for a Euro 3 truck trailers over 32 tonnes equals € 0.62 per km, PPS corrected), only exceeded by Switzerland's charge. Therefore, Switzerland also experiences a relatively high-cost coverage of 40%.

As displayed in Figure 33, the EU28 average cost coverage ratio is 13%, highlighting the low total infrastructure cost coverage across EU Member States⁴⁹. In Austria, the high average costs causing low-cost recovery. This outweighs the relatively high average revenues generated by the distance-based road charge for HGVs. This ratio, however, may be impacted by the previously discussed data robustness issue linked to Austria and other states with high transit traffic. In the Netherlands, the lack of cost coverage is due to a lack of distance-based road charges for HGVs. Similarly, Estonia, Malta, Cyprus and Finland achieve 0% cost coverage due to the previously mentioned absence of distance-based and time-based road charges for HGVs. Lithuania also reports low-cost coverage of 5%, which is linked to a combination of relatively high average infrastructure costs and relatively low average revenues, despite the high vignette. Although some countries that have implemented a distance-based HGV toll achieve higher cost coverage, the relationship does not hold across all countries, as Japan, Hungary and Austria have some of the highest distance-based tolls for HGVs, yet achieve relatively moderate cost coverage because of their high infrastructure costs.

⁴⁹ The EU28 average for LCV cost coverage was estimated at 12%.

Figure 33 - Overall infrastructure cost coverage ratio for road freight transport in the EU28, Switzerland, Norway, the US, Canada and Japan



Variable infrastructure cost coverage ratio

Figure 34 displays the variable infrastructure cost coverage for HGVs⁵⁰. The EU28 average costs are €ct 0.72 per tkm and EU28 average revenues are €ct 0.31 per tkm. Switzerland, which extends beyond the magnified subset, bears the highest average costs (€ct 3.03 per tkm) and the highest average revenues in the sample (€ct 2.99 per tkm). In the EU28, Austria bears the highest average costs, which is linked to the previously mentioned high costs per kilometre of road network. In addition, high average variable infrastructure costs in Austria are also linked to the high network complexity.

Although the majority of countries do not completely internalise their variable infrastructure costs, some EU28 Member States (Slovenia, Croatia, Bulgaria and Ireland) reach complete cost coverage. In Croatia, this is linked to the high distance-based toll for HGVs, which results in Croatia generating the highest average revenues in the EU28. In Slovenia, cost coverage is also linked to high average revenues generated by the road toll and the toll enforced for use of Karavanke road tunnel (although this contributes less significantly than the road toll). Ireland has a relatively moderate charge of € 0.17 per km (PPS corrected) for truck trailers operating on motorways, but combined with some of the lowest average variable infrastructure costs for HGVs, achieves complete cost coverage of 108%. Bulgaria achieves complete cost coverage of 111%, which is primarily linked to low variable infrastructure costs, as the time-based road charge does not generate particularly high average revenues.

⁵⁰ The EU28 average for LCV cost coverage was estimated at 177%.

Figure 34 - Variable infrastructure cost coverage for road freight transport in the EU28, Switzerland, Norway, the US, Canada and Japan (magnified subset)

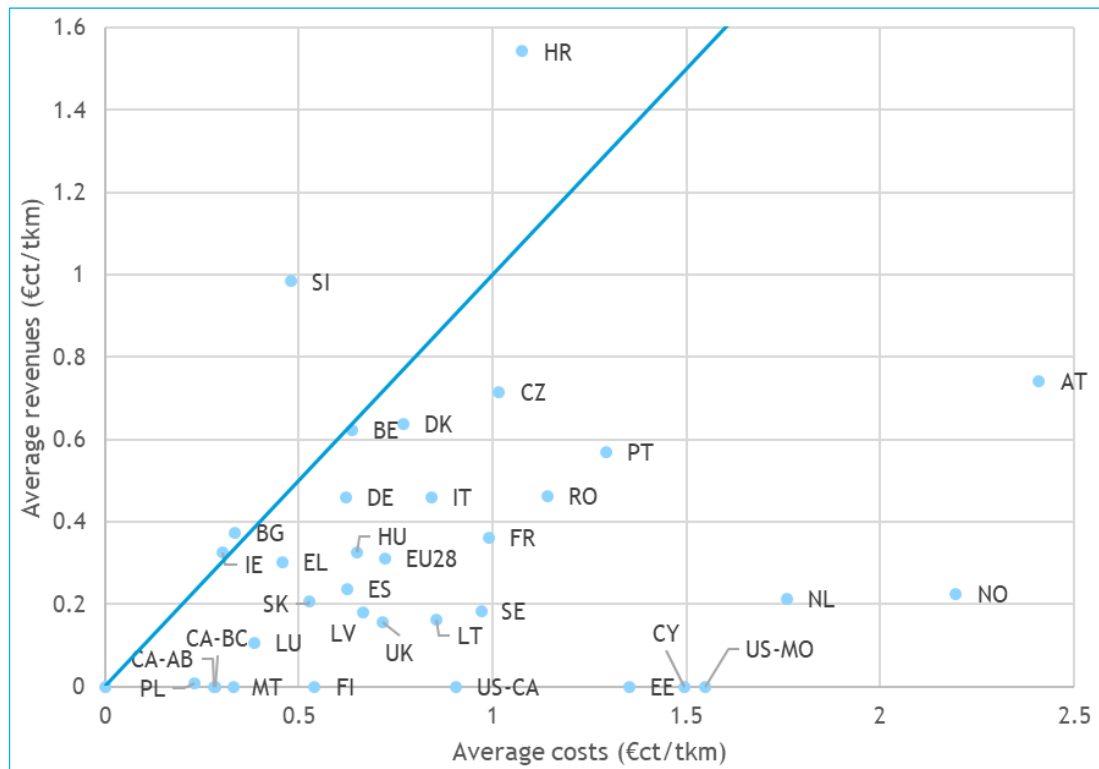
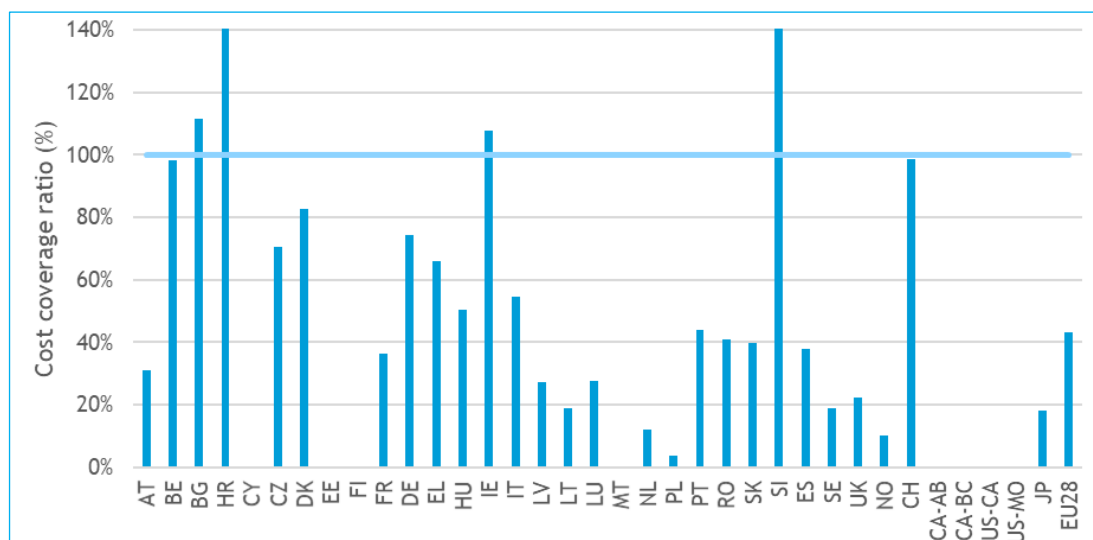


Figure 35 displays the complete cost internalisation achieved by Croatia, Slovenia, Bulgaria and Ireland. Croatia and Slovenia achieve cost coverages of 143% and 206% respectively, which both extend beyond the y-axis of Figure 35 and are linked to previously mentioned high average revenues. Cyprus, Estonia, Finland and Malta do not generate any charge revenues, mirroring the results under the overall infrastructure cost coverage ratio. As previously mentioned, this is due to the lack of distance-based or time-based road charges in place for HGVs in these countries. Denmark achieves a relatively high-cost coverage of 83%, despite only implementing a relatively low vignette and tolls on the Storebælt and Øresund bridges. In contrast, countries such as Austria, the Czech Republic and France, with high distance-based tolls in place, achieve lower cost coverages. This is largely linked to the higher average variable infrastructure costs borne by these countries, relative to Denmark.

Figure 35 - Variable infrastructure cost coverage ratio for road freight transport in the EU28, Switzerland, Norway, the US, Canada and Japan



4.3 Marginal social cost-based internalisation

The marginal cost coverage ratios for road transport compare marginal external and infrastructure costs with marginal tax and charge revenues for up to four scenarios by vehicle type: high external cost scenario; representative scenario; low external cost scenario and a very low external cost scenario. In all of these scenarios, the sample covers the EU28, Norway and Switzerland. Details of the representative scenario are presented in Section 2.4.2, which explains the construction of the scenarios, highlighting the definition of the ‘average vehicle’ and the other factors considered.

For passenger transport, passenger cars, buses and coaches are covered by the analysis and are presented separately below. For road freight transport, LCVs and four types of HGV (split by weight category) are examined.

As previously presented in Section 2.4.2, there are a number of key attributes of marginal cost coverage scenarios to consider when analysing the results.

Considerations with respect to marginal cost scenarios

When interpreting the results of the marginal cost coverage analyses, the following issues with respect to the marginal cost scenarios should be considered:

- The high and (very) low-cost scenarios considered are sometimes a bit extreme, in order to reflect cases with high or low marginal external cost values. As a consequence, these scenarios are not necessarily reflecting cases that are fully representative of real-world situations.
- The scenarios are defined based on the level of external costs. The marginal cost coverage ratios, however, are also driven by marginal infrastructure costs and taxes/charges. Therefore, low marginal cost coverage ratios may be found for low external cost scenarios, if marginal infrastructure costs are relatively high and/or tax/charge levels relatively low.

4.3.1 Passenger Car

The conditions applied in high external cost, representative, low external cost and very low external cost scenarios for passenger cars are shown in Table 11. It is important to note that the low and very low external cost scenarios are highly stylised. In addition, the very low external cost scenario does not reflect tax breaks on the purchase of BEVs implemented in several Member States, as fixed taxes are not considered under marginal social cost-based internalisation.

Table 11 - Marginal social cost scenarios - passenger car

	High external cost scenario	Representative scenario	Low external cost scenario	Very low external cost scenario
Scenario description	– Diesel EURO 3 – CO₂ emissions: 176 g/km – Daytime – Congested traffic – Large SUV – Urban road in metropolitan area	– Average vehicle – Average daytime/night – Average congestion level – Average road	– Petrol EURO 6 – CO₂ emissions: 99 g/km – Daytime – Thin traffic – Small car – Motorway in rural area	– BEV – Daytime – Thin traffic – Motorway in rural area
Externality description	– AP*: Metropolitan area - urban road – CC**: Urban – Noise: Urban, day, dense – WTT***: Urban	– Take average values for all cost categories except: • Accidents: Rural • Noise: Suburban, day, thin	– AP: Rural motorway – CC: Motorway – Noise: Rural, day, thin – WTT: Motorway	– AP: Rural motorway – CC: Motorway – Noise: Rural, day, thin – WTT: Motorway

*AP = Air Pollution; **CC = Climate Change; ***WTT = Well-To-Tank.

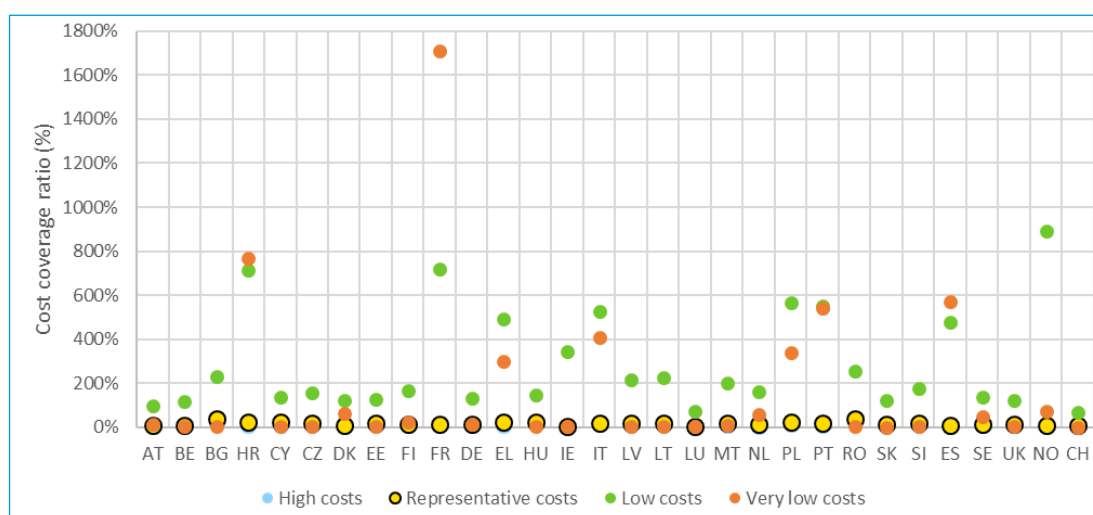
Figure 36 displays the spread of cost coverage ratios under each scenario, while Figure 37 provides a more detailed view of the core range of values. We present Figure 36 as an example of the complete spread; with later vehicle type sections only presenting the magnified subset.

Under the **high external cost scenario**, the cost coverages range from 2% (Luxembourg) to 21% (Romania). Bulgaria (19%), Poland (14%) and Romania (21%) achieve the highest cost coverage ratios. Romania bears the lowest marginal costs and the highest marginal revenues, with the lowest marginal external congestion costs for passenger cars. The high marginal tax revenues are primarily related to relatively high fuel tax levels, linked to the high petrol and diesel taxes, when PPS corrected (CE Delft, 2019b). Bulgaria also has some of the highest marginal revenues, combined with some of the lowest marginal costs. Again, this is linked to relatively low marginal congestion costs, as well as relatively low accident costs. The high marginal revenues are primarily linked to high fuel tax levels. Finally, Poland generates high marginal revenues, linked primarily to fuel taxes, and the country's relatively low marginal costs are linked to the country also bearing some of the lowest marginal congestion costs for passenger cars.

The countries with the lowest cost coverage ratios are Switzerland (4%), Norway (4%), Ireland (3%) and Luxembourg (2%). Luxembourg bears the highest marginal costs and lowest marginal revenues across the EU28. Luxembourg's high marginal costs are linked to the country having the highest marginal congestion costs for passenger cars at € 905.40 per 1,000 pkm, as well as the highest marginal air pollution costs. The relatively low marginal revenues are mainly linked to relatively low fuel taxes, when adjusted for PPS.

The low-cost coverage in Ireland is linked to relatively low fuel taxes, as well as bearing the second-highest marginal congestion costs, after Luxembourg. The low-cost coverage in Norway and Switzerland can be linked to relatively high marginal air pollution and congestion costs. Switzerland also bears the highest marginal noise costs under the high external cost scenario. Both Norway and Switzerland also generate relatively low marginal revenues, linked to relatively low fuel taxes.

Figure 36 - Passenger car marginal cost coverage ratios for the EU28, Norway and Switzerland



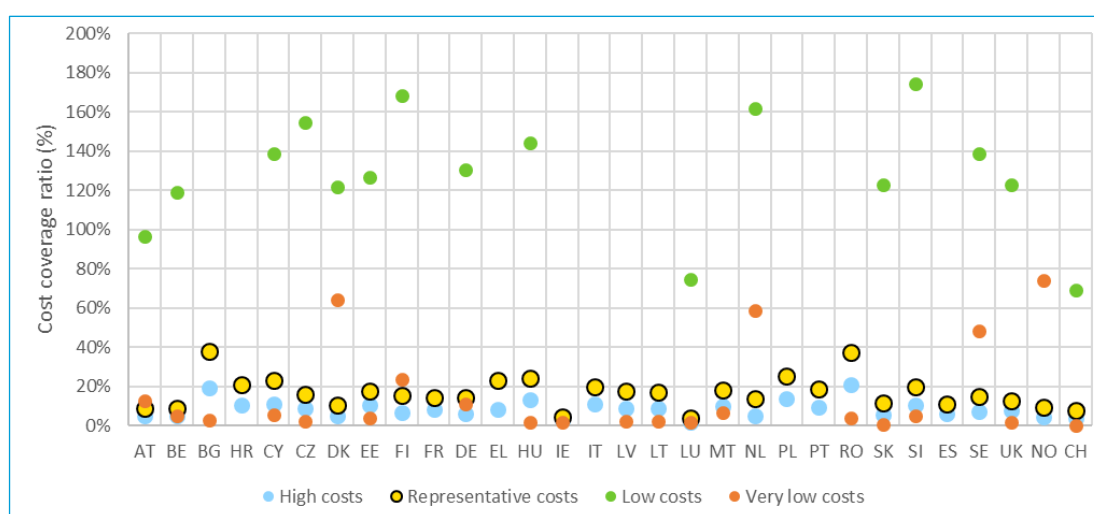
Under the **representative scenario**, Luxembourg achieves the lowest cost coverage of 4%, whilst Bulgaria achieves the highest cost coverage of 38%. There is not a significant difference between the high external cost and representative scenarios, particularly in terms of the marginal revenues generated. However, a significant reduction in marginal accident costs, attributed to the assumption of rural accident levels under the representative scenario, contributes to lower marginal costs for the majority of countries. In fact, for Bulgaria, marginal revenues remain constant, yet the great reduction in marginal accident costs results in cost coverage doubling from 19% under the high external cost scenario to 38% under the representative scenario.

Under the **low external cost scenario**, only three out of 30 countries do not achieve complete cost internalisation. This implies that taxes and charges are not well aligned to marginal costs in the high or low external cost scenarios; however, in the case of Luxembourg (which has the lowest cost coverage), the result may be linked to the disparity in the scope of transport performance data and revenue/cost data. Under the low external cost scenario, the range of values shifts greatly, with a minimum of 69% (Switzerland) and a maximum of 890% (Norway). The high-cost coverage for Norway is linked to it imposing the highest distance-based road charge for efficient Euro 6 petrol cars operating on motorways in the EU28, as well as revenues generated from fuel taxes.

Under the **very low external cost scenario**, the majority of countries do not achieve complete cost coverage. The great range of cost coverage ratios reflect the preferential toll rates a number of countries implement to encourage the uptake of BEVs. In addition, electricity taxes for household use are relatively low across the sample countries. The electricity taxes are highest in Denmark (€ 0.12 per KWh) and the Netherlands (€ 0.11 per KWh), which both have moderate cost coverage ratios of 64% and 59% respectively.

The minimum cost coverage reported is 0% (Switzerland) and the maximum reached is 1,710% (France). The high-cost coverage in France is linked to high toll rates, as France enforces the highest toll on motorways for EVs in the EU28 of € 0.10 per km (exc. VAT)⁵¹. In addition, the electricity tax in France is one of the highest in the EU28 (PPS corrected). Further to high marginal revenues, the marginal well-to-tank costs are some of the lowest in the sample, as most electricity in France is produced by nuclear power. The 0% cost coverage in Switzerland is linked to the lack of electricity tax, resulting in no revenue collection. Although a low vignette is in place in Switzerland, which includes BEVs, the lack of revenues is perhaps unsurprising, due to the unlikely nature that BEVs engage in long motorway trips. The majority of countries do not cover costs in this scenario, as the primary aim is to incentivise the purchase of BEVs through low tax rates and tax exemptions, leading to 16 countries experiencing less than 10% cost coverage.

Figure 37 - Passenger car marginal cost coverage ratios for the EU28, Norway and Switzerland (magnified subset)



Conclusions

Under the low external cost scenario, almost all of the Member States achieve complete cost coverage, with the exception of Austria and Luxembourg. This is expected, as revenues from motorway charges accrue, whilst external costs are relatively minimal. In contrast, under the high external cost scenario, complete cost coverage is not achieved by any of the EU Member States, which is largely linked to the high congestion costs in urban areas, which result in relatively low-cost coverage. Under the very low external cost scenario, there is great disparity in cost coverage, due to the varying incentive levels which Member States have enforced to encourage the uptake of EVs. The large variance in marginal cost coverage ratios also reflects the difficulties in applying pure marginal social cost pricing in real life,

⁵¹ France offer a tax break to individuals purchasing EVs which, being fixed, is not considered here.

due to the distinctions between the underlying conditions assumed in the different scenarios.

4.3.2 Motorcycle

Due to the inconsistency of data available for motorcycles across Member States, the marginal cost-based internalisation is not reported for this vehicle type.

4.3.3 Bus

The conditions used in high external cost, representative, low external cost and very-low external cost scenarios for buses are shown in Table 12. As with passenger cars, it is important to note that the low and very low external cost scenarios are highly stylised, and as such, may not reflect real-life scenarios. In addition, tax breaks encouraging the uptake of electric buses are not considered here, as they are fixed, rather than variable.

Table 12 - Marginal social cost scenarios - bus

	High external cost scenario	Representative scenario	Low external cost scenario	Very low external cost scenario
Scenario description	– Diesel EURO 3 – CO₂ emissions: 1,155 g/km – Daytime – Standard 15-18t – Dense traffic – Urban road in metropolitan area	– Average vehicle – Average daytime/night – Average traffic flow – Average road	– Diesel EURO 6 – CO₂ emissions: 954 g/km – Daytime – Standard 15-18t – Thin traffic – Average road	– Electric bus - medium – Daytime – Thin traffic – Average road
Externality description	– AP[*]: Metropolitan area - urban road – CC^{**}: Urban – Noise: Urban, day, dense – WTT^{***}: Urban	– Take average values for all cost categories except: • Accidents: Rural • Noise: Suburban, day, thin	– AP: Rural area - rural road – CC: Other road – Noise: Rural, day, thin – WTT: Other road	– AP: Rural area - rural road – CC: Other road – Noise: Rural, day, thin – WTT: Motorway

*AP = Air Pollution; **CC = Climate Change; *** WTT = Well-To-Tank.

Figure 38 shows the spread of cost coverage ratios for each scenario, focusing on a range which encapsulates the majority of ratios.

Under the **high external cost scenario**, the range extends from 3% (Luxembourg) to 21% (Bulgaria). Reflecting the marginal cost coverage of passenger cars, Bulgaria (21%) and Romania (16%) achieve the highest cost coverage under a high external cost scenario. Bulgaria's high-cost coverage is linked to relatively high fuel tax levels, combined with bearing the lowest marginal congestion costs. In addition, Bulgaria bears relatively low marginal accident, air pollution and well-to-tank costs. Romania generates the highest marginal revenues under this scenario, linked to fuel tax revenues, which primarily contribute to the relatively high-cost coverage, as marginal costs are relatively moderate compared to other Member States.

Austria (4%), Luxembourg (3%) and Norway (4%) have the lowest cost coverage ratios, which can be explained by a combination of high marginal costs and low marginal revenues.

The relatively low marginal revenues are linked to relatively low fuel taxes, when adjusted for PPS. In addition, Luxembourg bears the highest marginal congestion costs in the EU28 for buses, as well as the highest marginal air pollution and well-to-tank costs. However, as mentioned previously, it is important to note the potential impact of variations in the scope of data, between the territoriality principle and the nationality principle. This data issue would particularly affect results from Austria and Luxembourg, who have high through-traffic. The low-cost coverage in Norway can be linked to relatively high marginal air pollution and congestion costs, combined with relatively low fuel taxes. Norway also bears higher marginal accident costs than all EU28 Member States. Although Norway has implemented an urban road pricing system in several cities (Bergen, Kristiansand, Namsos, Nord-Jaeren, Oslo, Tonsberg) marginal revenue levels remain low.

In the representative scenario, the cost coverage ratio range extends from 5% (Norway) to 41% (Bulgaria), following a similar pattern of performance to the high external cost scenario. There is a cluster of 11 countries within 2 percentage points of the sample average. Again, Austria (6%), Luxembourg (7%) and Norway (5%) display the lowest cost coverage. In contrast, Bulgaria (41%), Malta (29%) and Poland (32%) achieve relatively high-cost coverage. Similar to passenger cars, the reduction in marginal revenues is not particularly large; however, the reduction in marginal costs is significant. In the case of Bulgaria, marginal noise and congestion costs for buses fall dramatically, whilst marginal accident, air pollution and climate costs also fall considerably. Malta and Poland experience a similarly significant reduction in marginal noise and congestion costs.

Under the low external cost scenario, there is increasing variation. Cost coverage ranges from 12% (Switzerland) to 143% (France). In four countries, the cost coverage is particularly high: France (143%), Greece (134%), Poland (139%) and Portugal (137%). The high-cost coverage in France is linked to a combination of high marginal revenues, derived primarily from fuel taxes, and relatively low marginal costs. The low marginal costs for France are linked to relatively low marginal accident and air pollution costs. In addition, according to transport performance data, buses do not use motorways in France. Therefore, no marginal infrastructure costs were reported, which also contributes to the low marginal cost experienced for bus transport in France.

Greece, Poland and Portugal also display a combination of relatively low marginal costs and relatively high marginal revenues, with the majority of tax revenues derived from fuel taxes. Greece and Portugal have some of the lowest marginal accident and well-to-tank costs in the EU28. The countries with the lowest cost coverage ratios are Denmark (18%), Finland (13%), Luxembourg (14%) and Switzerland (12%). This is generally due to relatively high marginal costs and relatively low marginal revenues.

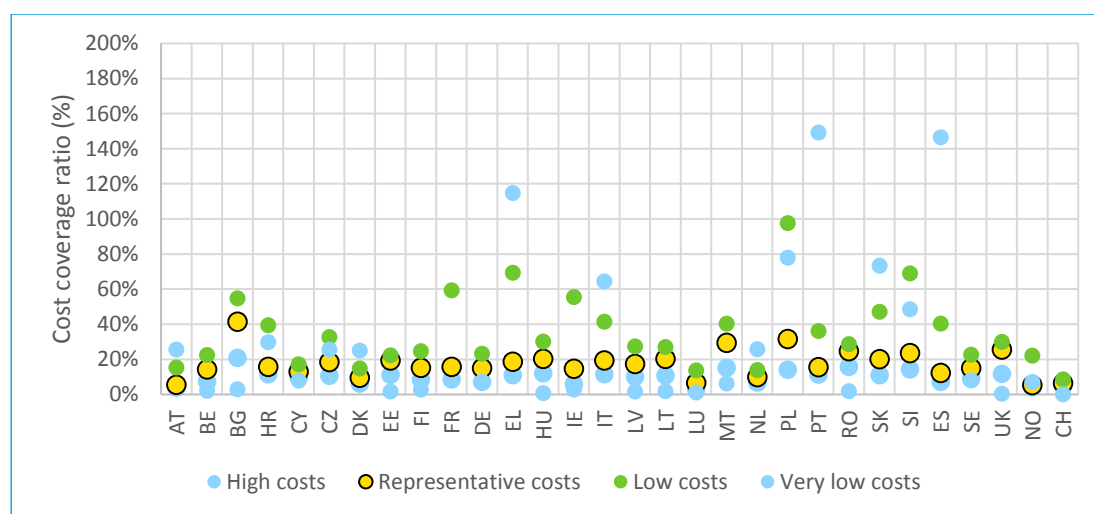
Under the very low external cost scenario, the range is extensive, with Switzerland displaying 0% cost coverage, whilst France experiences a cost coverage of 798%, which extends beyond the y-axis of the magnified subset. This highlights the relative disparities in attempts to incentivise electric vehicle use, which under this stylised scenario, refer to electricity taxes and preferential tolls for electric buses. The high-cost coverage in France is linked to the high electricity tax in France (PPS corrected). Further to high marginal revenues, the marginal well-to-tank costs are some of the lowest in the sample, as most electricity in France is produced by nuclear power.

The 0% cost coverage in Switzerland is linked to the lack of electricity tax, resulting in no revenue collection. The majority of countries do not completely cover costs in this scenario, as the primary aim is to incentivise the purchase of BEVs through low tax rates and tax exemptions, leading to seventeen countries experiencing less than 10% cost coverage.

Conclusions

The marginal social cost-based internalisation assessment for buses shares similarities with passenger cars. Under the high external cost scenario, complete cost coverage is not achieved by any of the EU Member States. For the majority of Member States, a lack of complete cost coverage is linked to the combination of high congestion costs, relatively low fuel taxes and a lack of (or low) infrastructure charging within urban areas. Under the very low external cost scenario, there is great disparity in cost coverage, due to the varying incentive levels which Member States have enforced to encourage the uptake of EVs. The large variance in marginal cost coverage ratios also reflects the difficulties in applying pure marginal social cost pricing.

Figure 38 - Bus marginal cost coverage ratios for the EU28, Norway and Switzerland (magnified subset)



4.3.4 Coach

The conditions applied in the high external, representative and low external cost scenarios for coaches are shown in Table 13.

Table 13 - Marginal social cost scenarios - coach

	High external cost scenario	Representative scenario	Low external cost scenario
Scenario description	– Diesel EURO 3 – CO₂ emissions: 742 g/km – Standard <=18 t – Daytime – Congested traffic – Urban road in metropolitan area	– Average vehicle – Average daytime/night – Average congestion level – Average road	– Diesel EURO 6 – CO₂ emissions: 583 g/km – Standard <=18 t – Daytime – Thin traffic – Motorway in rural area
Externality description	– AP*: Metropolitan area - urban road – CC**: Urban – Noise: Urban, day, dense – WTT***: Urban		– AP: Rural motorway – CC: Motorway – Noise: Rural, day, thin – WTT: Motorway

*AP = Air Pollution; **CC = Climate Change; *** WTT = Well-To-Tank.

Figure 39 shows the spread of cost coverage ratios under each scenario, focused on the range where the majority of ratios lie.

For coaches, the **high external cost scenario** exhibits a range of 3% (Luxembourg) to 25% (Bulgaria). Bulgaria is the only country to exceed 20% cost coverage. Bulgaria bears the lowest marginal costs in the sample, reporting relatively low marginal accident, air pollution and well-to-tank costs. Bulgaria also bears the lowest marginal congestion costs in the sample. The relatively high marginal revenues are linked to the high fuel tax levels.

Due to a combination of low marginal revenues and high marginal costs, Austria (4%), Luxembourg (3%), the Netherlands (8%), Norway (5%) and Switzerland (5%) have the lowest cost coverage. The relatively low marginal revenues are linked to relatively low fuel taxes, when adjusted for PPS. The justification for the low-cost coverages in these countries reflect the reasons provided for buses.

The low-cost coverage in Norway can be linked to relatively high marginal air pollution costs, combined with relatively low fuel taxes. Norway also bears the highest marginal accident costs in the EU. Austria, Switzerland, Norway and the Netherlands incur some of the highest marginal infrastructure costs for coaches, due to relatively high infrastructure costs per kilometre road network (CE Delft, 2019a).

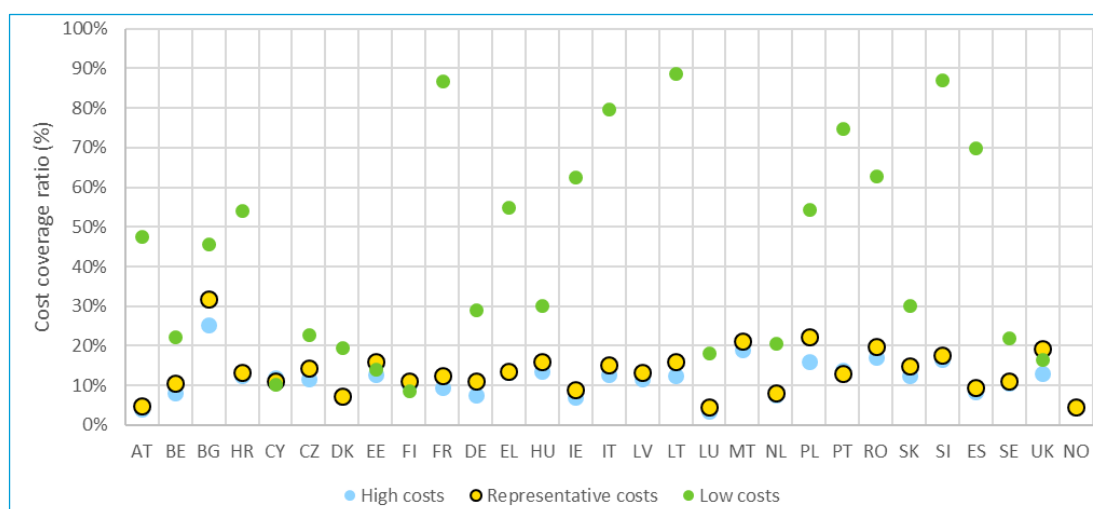
As shown in Figure 39, the **representative scenario** follows a similar pattern to the high external cost scenario. The same countries sit at the maximum and minimum, with Luxembourg achieving 4% cost coverage and Bulgaria achieving 32%. For both the high-cost and representative scenarios, low-cost coverage prevails, suggesting that tax and charge levels are not well aligned to marginal costs incurred by coach transport.

There is more significant change under the **low external cost scenario**, where coaches are considered to be operating on uncongested motorways. The cost coverage range extends from 8% (Switzerland) to 143% (Latvia) in the EU28, although Norway achieves a higher cost coverage of 153%. The high-cost coverage ratio for Latvia is due to no marginal infrastructure costs being available for coaches on motorways. Malta is not considered under this scenario, due to the absence of motorways in the country. In the EU28, only Latvia achieves complete cost coverage. This can be explained by relatively high diesel taxes, combined with relatively low marginal costs for coaches (CE Delft, 2019a).

Conclusions

The marginal social cost-based internalisation assessment for coaches shares some similarities with passenger cars and buses, where the low external cost scenario delivers the highest cost coverage for the majority of Member States. However, only Malta and Latvia achieve complete cost internalisation (and for Latvia, as explained above this is due to there being no marginal infrastructure costs due to no data being available for coaches on motorways). This suggests that generally, taxes are not well aligned to marginal costs for coaches under any of the scenarios assessed.

Figure 39 - Coach marginal cost coverage ratios for the EU28, Norway and Switzerland (magnified subset)



4.3.5 Light Commercial Vehicle

The conditions applied in high external cost, representative, low external cost and very low external cost scenarios for Light Commercial Vehicles (LCVs) are shown in Table 14. As with passenger cars and buses, it is important to note the stylised nature of the low and very low external cost scenarios, which may not reflect real-life scenarios.

Table 14 - Marginal social cost scenarios - LCV

	High external cost scenario	Representative scenario	Low external cost scenario	Very low external cost scenario
Scenario description	– Diesel EURO 3 – CO₂ emissions: 225 g/km – Daytime – Congested traffic – Urban road in metropolitan area	– Average vehicle – Average daytime/night – Average congestion level – Average road	– Petrol EURO 6 – CO₂ emissions: 105 g/km – Daytime – Thin traffic – Motorway in rural area	– BEV – Daytime – Thin traffic – Motorway in rural area
Externality description	– AP*: Metropolitan area - urban road – CC**: Urban – Noise: Urban, day, dense – WTT***: Urban	– Take average values for all cost categories except: • Accidents: rural • Noise: suburban, day, thin	– AP: Rural motorway – CC: Motorway – Noise: Rural, day, thin – WTT: Motorway	– AP: Rural motorway – CC: Motorway – Noise: Rural, day, thin – WTT: Motorway

*AP = Air Pollution; **CC = Climate Change; ***WTT = Well-To-Tank.

Figure 40 shows the spread of cost coverage ratios for each scenario.

Under the **high external cost scenario**, the cost coverage exhibits a narrow range of 1% (Luxembourg) to 11% (Bulgaria). Bulgaria's higher cost coverage is likely to be linked to the relatively high fuel taxes, as well as bearing the lowest marginal congestion costs.

In the **representative scenario**, the cost coverage extends over a slightly larger range of 4% (Luxembourg) to 34% (Greece). Luxembourg has the lowest cost coverage under the high external cost and representative scenario, due to relatively low fuel tax levels, in comparison to other EU Member States. The high costs for LCVs in Luxembourg mirror the discussions under the road passenger vehicles. Under the representative scenario, Bulgaria (30%), Greece (34%) and Romania (30%) achieve the highest cost coverage ratios. Romania enforces the highest fuel tax level on diesel, when PPS corrected, which explains the higher than average cost coverage. In addition, Romania has the largest network subject to time-based road tolls on LCVs, at € 630 per vehicle per year, when PPS corrected. The relatively high-cost coverage in Greece is attributed to the comparably high petrol taxes and associated high marginal revenues. Greece also bears some of the lowest marginal air pollution and congestion costs in the EU28.

In the **low external cost scenario**, Luxembourg has the lowest cost coverage of the sample (69%), whilst Croatia achieves the highest (1,106%). However, it is also possible that variations in the scope of the data used in this study result in distorted effects for countries with high transit traffic such as Luxembourg. Croatia generates the highest marginal revenues, which may be linked to relatively high petrol tax levels. In addition, Croatia applies the highest distance-based toll levels for LCVs in the EU28, which partially

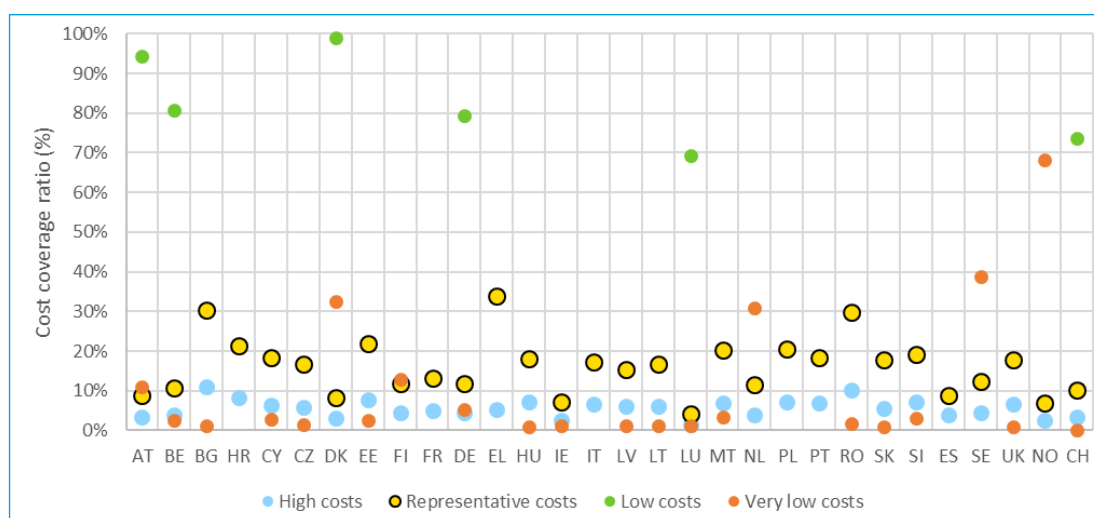
contribute to higher marginal revenues. France (828%), Ireland (632%), Poland (660%) and Norway (783%) also achieve high-cost coverages. All of these countries enforce relatively high distance-based tolls for petrol LCVs, leading to higher cost coverage ratios. However, for all of these Member States, fuel taxes contribute a greater proportion to revenue generation. The generally high-cost coverage levels suggest that tax and charge levels exceed marginal costs, under a low external cost scenario.

Under the **very low external cost scenario**, the average charge collection is likely to be similar to passenger cars. However, the cost coverage is lower for the majority of Member States. This is driven by significantly higher marginal external costs compared to passenger cars, with marginal revenues that are insufficient to recover costs to the same level as passenger cars. Switzerland's cost coverage ratio is 0%, as with passenger cars and buses, and France's cost coverage ratio is the highest at 1,205%. The high-cost coverage in France is linked to high marginal revenues, as France enforces one of the highest distance-based tolls on electric LCVs and charges one of the highest electricity taxes in the EU28 (PPS corrected). Further to high marginal revenues, the marginal well-to-tank costs are some of the lowest in the sample, as most electricity in France is produced by nuclear power.

Conclusions

The conclusions for LCVs mirror the conclusions outlined for passenger car transport. Under the low external cost scenario, the majority of Member States achieve complete cost coverage, due to a combination of motorway charge revenues and relatively low external costs. Under the high external cost scenario, complete cost coverage is not achieved (due to the setup of the scenario, which is defined by high congestion costs in urban areas, where vehicles are often exempt from road tolls). The varying cost coverages under the very low external cost scenario are expected due to the varying electricity taxes and toll rates employed by Member States to encourage EV uptake. The large variance in marginal cost coverage ratios also reflects the difficulties in applying pure marginal social cost pricing.

Figure 40 - LCV marginal cost coverage ratios for the EU28, Norway and Switzerland (magnified subset)



4.3.6 Heavy Goods Vehicle 3.5-7.5 t

The conditions applied in high-cost, average and low external cost scenarios for Heavy Goods Vehicles (HGVs) weighing between 3.5-7.5 t are shown in Table 15.

Table 15 - Marginal social cost scenarios - HGV 3.5-7.5 t

	High external cost scenario	Representative scenario	Low external cost scenario
Scenario description	– Diesel EURO 3 – CO₂ emissions: 450 g/km – Daytime – Congested traffic – Urban road in metropolitan area	– Average vehicle – Average daytime/night – Average congestion level – Average road	– Diesel EURO 6 – CO₂ emissions: 370 g/km – Daytime – Thin traffic – Motorway in rural area
Externality description	– AP*: Metropolitan area - urban road – CC**: Urban – Noise: Urban, day, dense – WTT***: Urban	– Take average values for all cost categories except: • Accidents - rural • Noise: suburban, day, thin	– AP: Rural motorway – CC: Motorway – Noise: Rural, day, thin – WTT: Motorway

*AP = Air Pollution; **CC = Climate Change; ***WTT = Well-To-Tank.

Figure 41 shows the marginal cost coverage for the three scenarios for HGVs weighing between 3.5 and 7.5 tonnes.

For the **high external cost scenario**, there is significant variation in the ratios, extending between 4% (Luxembourg) and 40% (Estonia). The high-cost coverage in Estonia is linked to a combination of bearing the lowest marginal costs in the EU28, alongside generating one of the highest marginal tax/charge levels. The low marginal costs are primarily linked to Estonia having the lowest marginal air pollution costs by a significant margin relative to other EU Member States. The higher average revenues are linked to the relatively high fuel taxes. The low level of cost coverage in Luxembourg is linked to having the second-lowest diesel tax level in Europe (PPS corrected). Luxembourg also bears the highest marginal air pollution cost for HGVs, which further contributes to the low-cost coverage. However, results for Luxembourg, a high transit country, may be affected by disparities in the coverage of transport performance and other data used in the study (national versus territoriality principle).

Under the **representative scenario**, the cost coverage ranges from 17% (Luxembourg) to 112% (Romania). The high-cost coverage in Romania is linked to the relatively high fuel tax levels, whilst the low-cost coverage in Luxembourg reflects the aforementioned reasons and data caveat under the high external cost scenario.

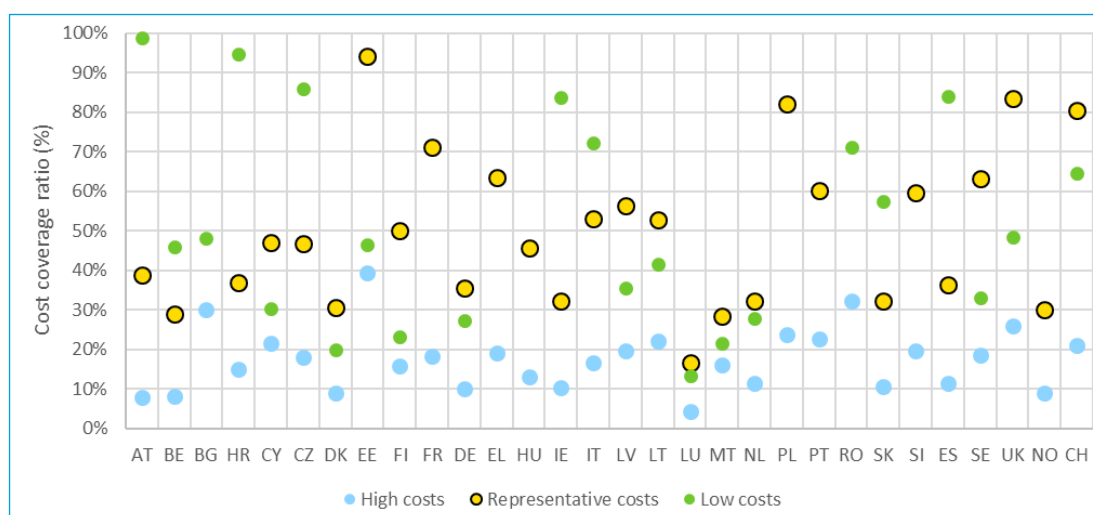
Under the **low external cost scenario**, the cost coverage ranges from 13% (Luxembourg) to 214% (France). Luxembourg has the lowest cost coverage in all scenarios, driven in part by low marginal revenues, which are consistently the lowest in each scenario. This is due to a lack of road infrastructure charging for this HGV weight category, as well as the low diesel taxes across vehicle types. The 214% cost coverage achieved by France is the highest in the sample, which is linked to relatively high fuel tax levels and the high distance-based toll levels for Euro 6 trucks.

Seven countries reach complete cost coverage under the low external cost scenario, which extend beyond the y-axis of the magnified subset. These are France (214%), Greece (126%), Hungary (118%), Poland (148%), Portugal (102%), Slovenia (116%) and Norway (147%). These countries bear marginal costs close to the sample average of €ct 62 per tkm, but all of the countries generate relatively high marginal revenues from fuel taxes and distance-based charging schemes.

Conclusions

The marginal social cost-based internalisation assessment for HGVs (3.5-7.5 t) shares similarities with coaches. The representative and low external cost scenario achieve the highest cost coverages. However, the majority of Member States do not achieve complete cost internalisation under these scenarios. This suggests that taxes are not well aligned to marginal costs for HGVs (3.5-7.5 t) under any of the scenarios assessed. However, it is important to note the potential impact of variations in the scope of data, between the territoriality principle and the nationality principle, which affects the robustness of cost data for a number of Member States with high through-traffic or for whose national fleet's activity out of the national border is significant

Figure 41 - HGV 3.5-7.5 t marginal cost coverage ratios for the EU28, Norway and Switzerland (magnified subset)



4.3.7 Heavy Goods Vehicle 7.5-16 t

The conditions applied in high-cost, average and low external cost scenarios for Heavy Goods Vehicles (HGVs) weighing between 7.5-16 t are shown in Table 16.

Table 16 - Marginal social cost scenarios - HGV 7.5-16 t

	High external cost scenario	Representative scenario	Low external cost scenario
Scenario description	– Diesel EURO 3 – Rigid 7.5-12 t – CO₂ emissions: 716 g/km – Daytime – Congested traffic – Urban road in metropolitan area	– Average vehicle – Average daytime/night – Average congestion level – Average road	– Diesel EURO 6 – Rigid 7.5-12 t – CO₂ emissions: 596 g/km – Daytime – Thin traffic – Motorway in rural area
Externality description	– AP*: Metropolitan area - urban road – CC**: Urban – Noise: Urban, day, dense – WTT***: Urban	– Take average values for all cost categories except: • Accidents: rural • Noise: suburban, day, thin	– AP: Rural motorway – CC: Motorway – Noise: Rural, day, thin – WTT: Motorway

*AP = Air Pollution; **CC = Climate Change; *** WTT = Well-To-Tank.

Figure 42 shows the marginal cost coverage for the three cost scenarios for HGVs weighing between 7.5-16 t.

In the **high external cost scenario**, the cost coverage ranges from 8% (Luxembourg) to 73% (Estonia). Variation in this scenario follows a similar pattern to the scenario for 3.5-7.5 t HGVs, with Luxembourg achieving the lowest cost coverage.

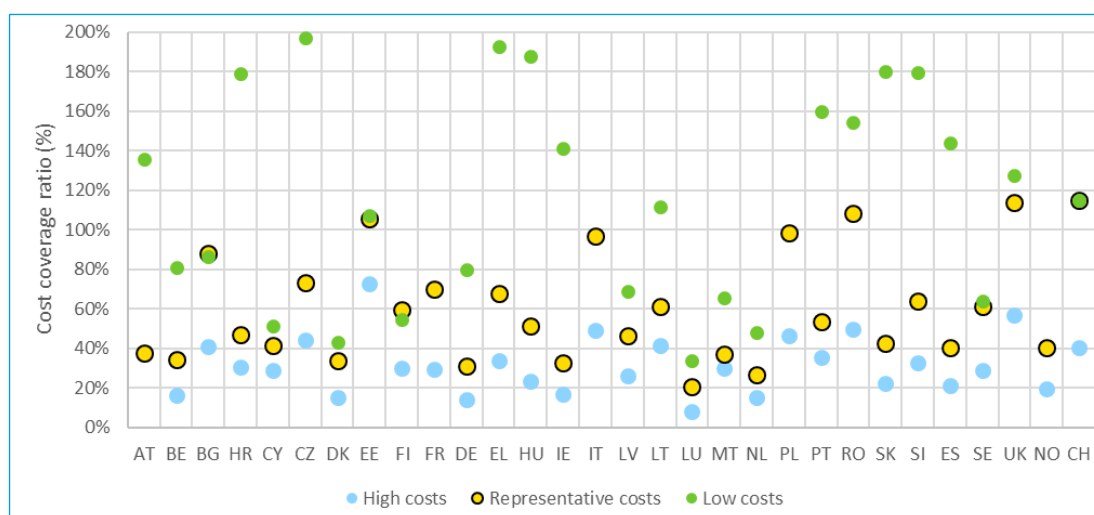
In the **representative scenario**, the cost coverage ranges from 21% (Luxembourg) to 114% (UK) within the EU28. Estonia (105%), Romania (108%), the UK (114%) and Switzerland (115%) achieve complete cost internalisation, generating relatively high marginal revenues compared to other sample countries. The revenues are primarily linked to the high fuel tax levels levied in these countries, when PPS adjusted.

Under the **low external cost scenario**, Norway has the highest cost coverage of 311%, primarily due to relatively high marginal revenues, generated through a combination of relatively high distance-based road charges for medium trucks and fuel taxes. Other countries with cost coverage ratios significantly higher than the average include France (283%), Poland (239%) and Portugal (160%), which is likely to be strongly linked to relatively high fuel taxes and the high distance-based tolls for HGVs operating in these countries. Countries with cost coverage ratios exceeding 200% extend beyond the y-axis of the magnified subset. As with road passenger vehicles, low external cost scenarios tend to generate higher revenue than necessary to cover marginal costs.

Conclusions

The marginal social cost-based internalisation assessment for HGVs (7.5-16 t) shares similarities with other modes considered. The low external cost scenario displays great disparity in cost coverage. Under the representative scenario, a number of countries also achieve complete cost coverage. However, none of the countries achieve complete cost coverage under the high external cost scenario. As previously mentioned, the large variance in marginal cost coverage ratios also reflects the difficulties in applying pure marginal social cost pricing. The analysis provides a first indication that the current structure of the marginal road taxes and charges is reflecting the main cost drivers of marginal costs only to a limited extent. However, it is important to note the potential impact of variations in the scope of data, between the territoriality principle and the nationality principle, which affects the robustness of cost data for a number of Member States with high through-traffic or for whose national fleet's activity out of the national border is significant .

Figure 42 - HGV 7.5-16 t marginal cost coverage ratios for the EU28, Norway and Switzerland (magnified subset)



4.3.8 Heavy Goods Vehicle 16-32 t

The conditions applied for high-cost, average and low external cost scenarios for Heavy Goods Vehicles (HGVs) weighing between 16-32 t are shown in Table 17.

Table 17 - Marginal social cost scenarios - HGV 16-32 t

	High external cost scenario	Representative scenario	Low external cost scenario
Scenario description	– Diesel EURO 3 – Rigid 20-26t – CO₂ emissions: 875 g/km – Daytime – Congested traffic – Urban road in metropolitan area	– Average vehicle – Average daytime/night – Average congestion level – Average road	– Diesel EURO 6 – Rigid 20-26t – CO₂ emissions: 716 g/km – Daytime – Thin traffic – Motorway in rural area
Externality description	– AP[*]: Metropolitan area - urban road – CC^{**}: Urban – Noise: Urban, day, dense – WTT^{***}: Urban	– Take average values for all cost categories except: • Accidents: rural • Noise: suburban, day, thin	– AP: Rural motorway – CC: Motorway – Noise: Rural, day, thin – WTT: Motorway

*AP = Air Pollution; **CC = Climate Change; ***WTT = Well-To-Tank.

The marginal cost coverage ratios for the three scenarios are displayed by Figure 43.

Under the **high external cost scenario**, Bulgaria, Estonia and the UK achieve relatively high-cost coverage ratios of 65%, 50% and 49% respectively. Bulgaria and Estonia incur lower than average marginal costs from HGVs of this size and collect comparatively high revenues. Estonia bears some of the lowest marginal accident and air pollution costs, whilst Bulgaria bears the lowest marginal congestion cost in the EU28. The UK generates the highest marginal revenues in the EU28, although marginal costs are relatively moderate. The UK, Bulgaria and Estonia all impose relatively high fuel taxes. Luxembourg, as before, achieves the lowest cost coverage of the sample at 9%. Again, it is likely that this is linked to relatively low diesel tax levels as well the data coverage issue discussed previously.

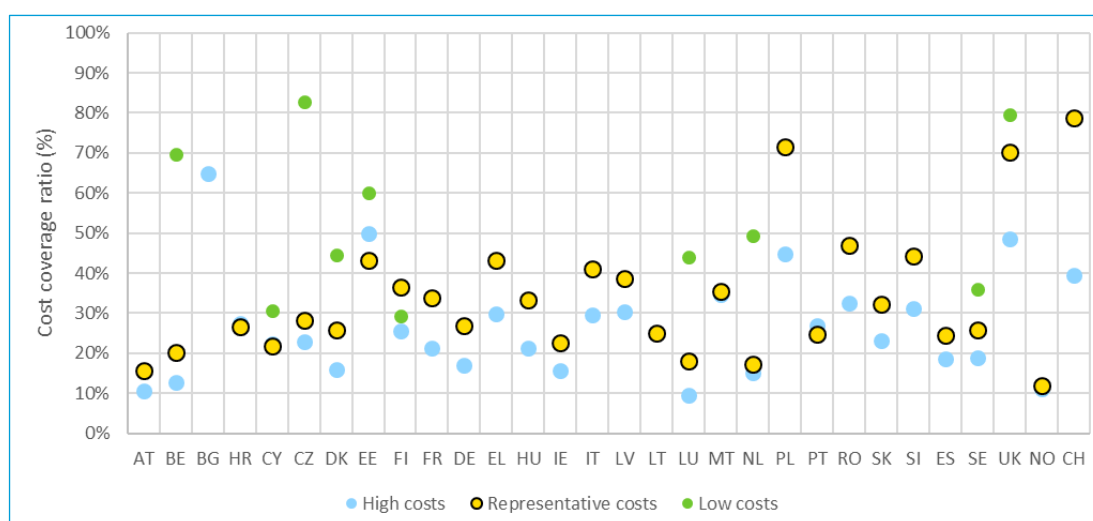
For the **representative scenario**, Norway achieves the lowest cost coverage (12%) and Bulgaria achieves the highest cost coverage (103%). Switzerland generates the highest marginal revenues in this scenario, which is primarily linked to fuel tax revenues. The high-cost coverage is Bulgaria is linked to the previously mentioned high fuel tax revenues.

Under the **low external cost scenario**, there is a general upward trend in cost coverage compared to other scenarios. Norway had the lowest cost coverage in the representative scenario (12%), yet under the low external cost scenario, the country achieves the highest cost coverage (230%). This is likely to be linked to Norway's road-based toll for efficient HGVs, as well as a reduction in marginal air pollution costs under a low external cost scenario. Finland reports the lowest cost coverage (29%) in the sample, which is explained by the absence of distance-based road tolls and vignettes and relatively high marginal infrastructure costs.

Conclusions

The marginal social cost-based internalisation assessment for HGVs (16-32t) shares similarities with other modes considered. The low external cost scenario displays great disparity in cost coverage. None of the countries achieve complete cost coverage under the high external cost scenario, despite countries, such as Bulgaria, enforcing high diesel taxes (PPS corrected). However, it is important to note the potential impact of variations in the scope of data, between the territoriality principle and the nationality principle, which affects the robustness of cost data for a number of Member States with high through-traffic or for whose national fleet's activity out of the national border is significant.

Figure 43 - HGV 16-32 t marginal cost coverage ratios for the EU28, Norway and Switzerland (magnified subset)



4.3.9 Heavy Goods Vehicle >32 t

The conditions applied in high-cost, average and low external cost scenarios for Heavy Goods Vehicles (HGVs) weighing over 32 t are shown Table 18.

Table 18 - Marginal social cost scenarios - HGV >32 t

	High external cost scenario	Representative scenario	Low external cost scenario
Scenario description	– Diesel EURO 3 – Articulated 34-40 t – CO₂ emissions: 1,033 g/km – Daytime – Congested traffic – Urban road in metropolitan area	– Average vehicle – Average daytime/night – Average congestion level – Average road	– Diesel EURO 6 – Articulated 34-40 t – CO₂ emissions: 848 g/km – Daytime – Thin traffic – Motorway in rural area
Externality description	– AP*: Metropolitan area - urban road – CC*: Urban – Noise: Urban, day, dense – WTT***: Urban	– Take average values for all cost categories except: • Accidents: rural • Noise: suburban, day, thin	– AP: Rural motorway – CC: Motorway – Noise: Rural, day, thin – WTT: Motorway

*AP = Air Pollution; **CC = Climate Change; ***WTT = Well-toTank.

Figure 44 shows the marginal cost coverage ratios for HGVs over 32 tonnes for the three scenarios discussed.

In the **high external cost scenario**, the cost coverage ranges from a minimum of 11% (Austria) to a maximum of 49% (Poland), between which there is an even spread of countries. The relatively high-cost coverage in Poland is due to relatively high fuel taxes, relatively low marginal congestion costs and the lowest marginal infrastructure costs, whilst the relatively low-cost coverage in Austria is due to particularly high marginal infrastructure costs for HGVs in this weight category in urban areas, as well as one of the highest marginal air pollution costs. In addition, Austria generates relatively low marginal revenues, due to comparably low fuel taxes. On the other hand, the results for high transit countries such as Austria may be affected by the scope of the data coverage in this study, as discussed earlier (territorial versus national principle).

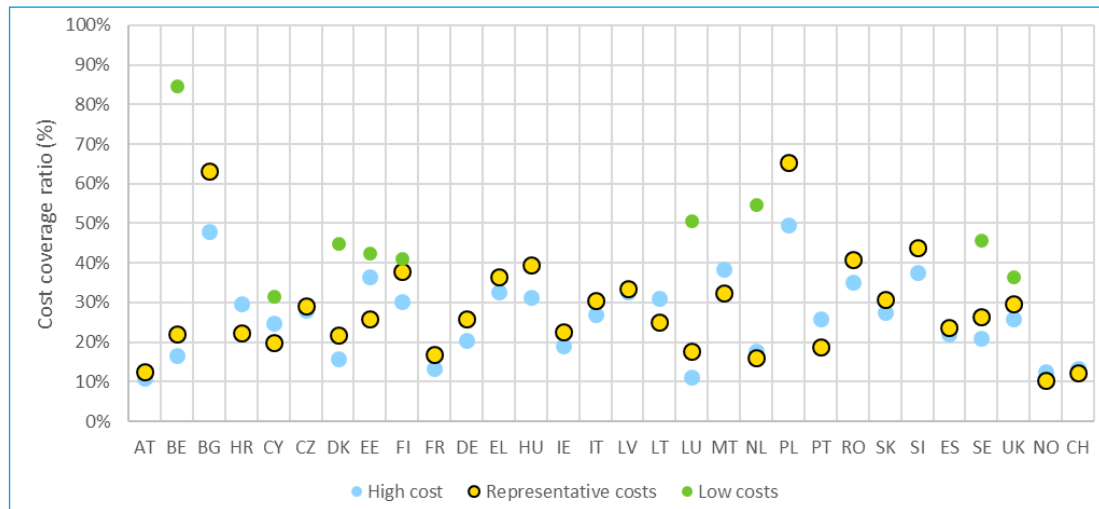
There is a small upward trend for the majority of countries under the **representative scenario**. Countries with more notable changes include Bulgaria (63%) and Poland (65%), experiencing their highest cost coverage ratios under this scenario, linked to aforementioned marginal tax revenues. Norway (10%), Austria (12%) and Switzerland (12%) report the lowest cost coverage, which is largely driven by these countries bearing high marginal infrastructure costs for HGVs, due to relatively high infrastructure costs per kilometre road network (CE Delft, 2019a). Austria's results, however may be particularly affected by the scope of the data used for this study.

More significant changes in cost coverage are observed under the **low external cost scenario**. The cost coverage ranges from a minimum of 32% (Cyprus) to a maximum of 301% (Hungary). Some 21 out of the 30 sample countries achieve complete cost coverage, extending beyond the scope of the magnified subset. Hungary (301%) and Slovenia (238%) achieve particularly high-cost coverage, due to their relative large distance-based toll schemes for HGVs and fuel tax revenues. Cyprus reports the lowest cost coverage, due to a combination of high marginal costs, primarily caused by bearing the largest marginal infrastructure costs in the EU28.

Conclusions

The marginal social cost-based internalisation assessment for HGVs (>32 t) shares similarities with other modes considered. The low external cost scenario achieves the highest cost coverages, due to revenues accruing from motorway tolls. Under the representative and high external cost scenarios, none of the countries achieve complete cost coverage. As previously mentioned, the large variance in marginal cost coverage ratios also reflects the difficulties in applying pure marginal social cost pricing. It is important to note the potential impact of variations in the scope of data, between the territoriality principle and the nationality principle, which affects the robustness of cost data for a number of Member States with high through-traffic or for whose national fleet's activity out of the national border is significant. The analysis provides a first indication that the current structure of the marginal road taxes and charges is reflecting the main cost drivers of marginal costs but only to a limited extent.

Figure 44 - HGV >32 t marginal cost coverage ratios for the EU28, Norway and Switzerland (magnified subset)

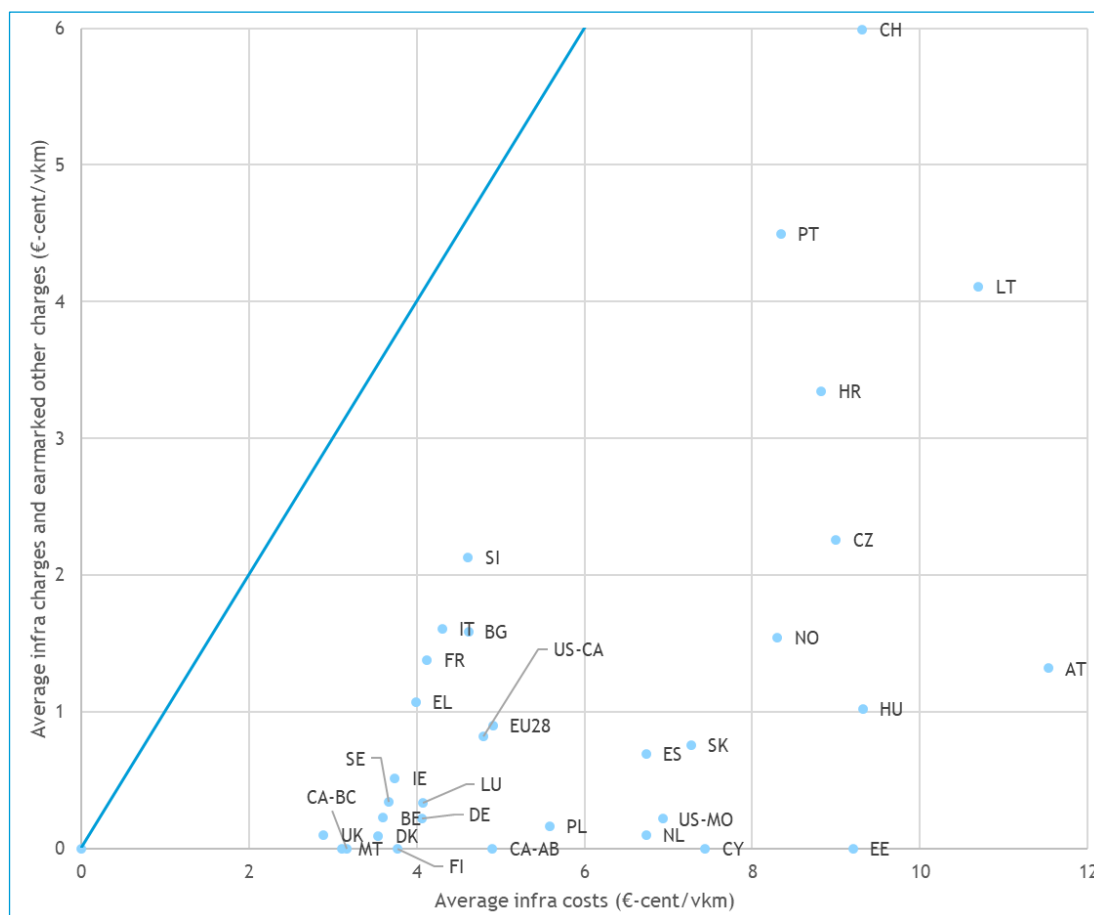


4.4 Average infrastructure cost coverage and earmarking

This section considers the average infrastructure cost coverage and earmarking of taxes for road passenger and freight transport. Earmarking refers to the reservation of tax revenues for road infrastructure costs, rather than the accumulation of revenues in a general budget. Revenues from infrastructure charges are considered as well as earmarked revenue from other taxes. This differs from Section 5.1, due to the combined assessment of passenger and freight transport and the inclusion of infrastructure charges and earmarked taxes and charges. Note that unlike the average cost coverage ratios presented earlier in this chapter, these refer to vkms rather than pkms/tkms.

Figure 45 highlights the spread of average costs and average revenues. The EU28 average infrastructure costs are €ct 4.91 per vkm, whilst EU28 average infrastructure earmarked charge revenues are €ct 0.90 per vkm. Although the majority of average infrastructure costs are clustered between €ct 2 per vkm and €ct 10 per vkm, Japan, Romania, Austria and Lithuania fall outside this range (Japan and Romania extend beyond the x-axis of the magnified subset). Romania and Austria display high average infrastructure costs, as we discussed before.

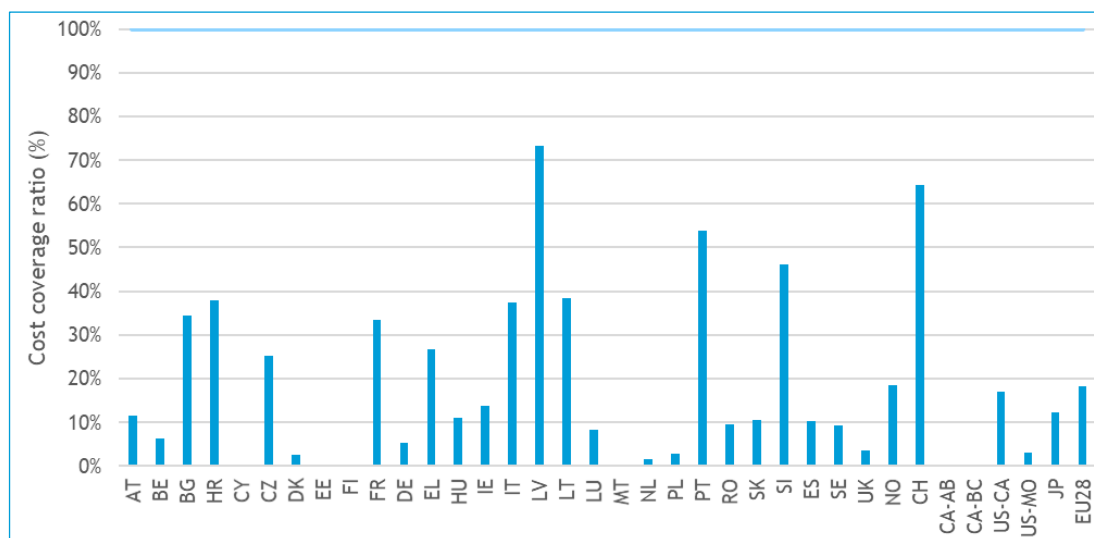
Figure 45 - Overall average infrastructure cost coverage and earmarking for road passenger and freight transport in the EU28, Switzerland, Norway, the US, Canada and Japan (magnified subset)



As displayed by Figure 46, Latvia comes the closest to achieving complete cost coverage, with a cost coverage of 73%, with Switzerland achieving the second-highest cost coverage of 64%. Although for most sample countries, only 0-25% of road transport charges are earmarked, in Latvia and Switzerland, 60% and 80% are earmarked respectively. Therefore, the high average revenues and associated high-cost coverage are expected. The primary reason for the larger proportion of revenues earmarked is that fuel taxes in these countries are earmarked for transport infrastructure expenditure. As fuel taxes comprise the majority of total tax revenues, this results in a significant proportion of earmarked revenues for infrastructure in these countries (CE Delft, 2019b).

Several countries and provinces (Cyprus, Estonia, Finland, Malta, Alberta and British Columbia) achieved 0% cost coverage, with €0 average infrastructure charges and earmarked charges. In the majority of these locations, no earmarking of revenues occurs. In addition, all of these locations lack the implementation of either distance-based or time-based road charges for road freight and passenger vehicles, limiting the capacity to internalise infrastructure costs. Therefore, the lack of cost coverage is to be expected. The EU28 average cost coverage is 18%.

Figure 46 - Overall average infrastructure cost coverage and earmarking ratio for road passenger and freight transport in the EU28, Switzerland, Norway, the US, Canada and Japan



4.5 Broader context of internalisation of the external costs of road transport

In the previous sections the role of taxes and charges in the internalisation of the external and infrastructure costs of road transport is discussed. As discussed in Section 2.5, also other instruments (i.e. command-and-control measures, subsidies) can be used to meet the objectives of internalisation. In this section, we discuss the role of these policy instruments in the reduction of the main external costs (i.e. climate change, air pollution, noise, accidents and congestion) of road transport.

4.5.1 Climate change

In addition to road taxes and charges implemented by countries, there are several other policies that supports the mitigation of CO₂ emissions in the EU. Most relevant instruments at the EU level are the CO₂ regulation of vehicles, car labelling, the clean vehicle directive, the alternative fuels infrastructure directive, and the Fuel Quality and Renewable Energy Directives. At the national/local level, particularly incentive programmes to stimulate the uptake of zero or low emission vehicles are relevant.

CO₂ standards and regulation for cars, LDV and HGV

A cornerstone of the European climate change policy for the transport sector is the CO₂ regulation of vehicles. In 2009, CO₂ performance standards for passenger cars were introduced. Mandatory targets for the average fleet CO₂ emissions of passenger cars newly registered in the EU of 130 g/km in 2014 and 95 g/km in 2021 were set (Regulation 443/2009). In 2011, CO₂ standards for vans (Regulation 510/2011) were introduced as well (targets: 175 g/km in 2017 and 147 g/km in 2020). Both the performance standards for passenger cars and vans are combined with specific mechanisms for zero and low emission vehicles, in order to accelerate their market uptake. In December 2018, the European Parliament and the Council reached a political agreement, provisionally agreeing on stricter new CO₂ emission standards for new passenger cars and vans: 37.5% and 31% lower in 2030 compared to 2021 (European Parliament, 2019).

In February 2019, the European Parliament and the Council reached a political agreement, provisionally agreeing on a legislative proposal of the European Commission for CO₂ emissions standards for heavy-duty vehicles (HDVs) (EC, 2018b). The agreement sets targets for average CO₂ emissions from new HDVs of 15% reduction in 2025 and at least 30% reduction in 2030, both compared to 2019 levels. The standards are first introduced for large lorries only, while the scope will be extended to other heavy duty vehicles (i.e. small lorries, buses, coaches) in due course. Like the CO₂ regulation for passenger cars and vans, the proposed legislation for HDVs does include a specific mechanism to provide additional incentives for zero- and low-emission vehicles.

CO₂ performance standards effectively complements the use of road transport taxes and charges in mitigating CO₂ emissions. First of all, these standards are more effective instruments to address the so-called energy paradox, i.e. consumers/companies do not purchase a fuel-efficient vehicle even if the higher investment costs are fully compensated by lower energy costs. European Commission (2018a) shows, for example, that a large number of readily available fuel saving technologies are not widely deployed in the market, even though they would result in net savings from the user perspective. This energy paradox may be explained by various factors, including consumer myopia⁵² and imperfect information⁵³ for vehicle buyers, barriers to financing options⁵⁴, and the existence of split incentives⁵⁵ (European Commission, 2007). Although CO₂ differentiated purchase/registration taxes may address some of these issues, it can only partly solve the energy paradox and hence applying CO₂ performance standards seems a more effective option to deal with this market failure. Secondly, as road transport tax schemes do differ widely between European countries, they do contribute to the emergence of barriers to the single market (i.e. fragmentation of the market) (Ricardo ; TEPR, 2015a). This would harm manufacturers and component suppliers, as different national schemes have different specifications leading to different demands on the industry. By introducing harmonised EU-wide CO₂ performance standards, more (regulatory) certainty is given to the industry, such that large investments in fuel-efficient technologies can be done and economies of scale can be achieved. At the same time, CO₂ differentiated road transport taxes and charges may support the demand for fuel-efficient vehicles, which contributes to meet the CO₂ performance standards in a cost-efficient way. Finally, it should be considered that road transport taxes and charges may stimulate - in addition to the purchase of a more fuel-efficient vehicle - other CO₂ reducing behavioural actions (e.g. reducing transport demand) as well. This complements the CO₂ performance standards, increasing the effectiveness of the overall CO₂ policy package.

⁵² Consumers (both private consumers and companies) do often not take the life-time savings from improved fuel efficiency into account, but only the savings for small number of years (3 to 5 years).

⁵³ Buyers of new vehicles have less accurate information than manufacturers about the potential performance of fuel-saving technologies. Because of this uncertainty, buyers may attach a risk premium to investing in new technologies and give a relatively larger weight to immediate costs than future savings.

⁵⁴ Particularly for buyers of HDVs, financing barriers may exist for investments in fuel-efficient vehicles. As banks do not factor in fuel efficiency as part of their lending criteria, it will become more complicated to finance vehicle purchased with relatively high upfront costs.

⁵⁵ This refers to the situation that the buyer of a fuel-efficient vehicle is not the one (fully) benefitting from the fuel savings achieved with that vehicle. This may be the case if the owner of the vehicle is not its operator (e.g. due to leasing constructions) or when fuel provisions are used in transport contracts, implying that the operator's costs do not change with fuel consumption.

Car labelling Directive

The ‘car labelling Directive’ (Directive 1999/94/EC) aims to inform consumers on the fuel-efficiency and CO₂ emissions of new cars, in order to help them to buy or lease cars that use less fuel and emit less CO₂. To achieve this objective, this Directive requires that EU Member States ensure that relevant information on these issues is provided to consumers, among other things by a label showing a car’s fuel-efficiency and CO₂ emissions.

As a demand-side policy, the directive is a complementary measure to help car manufacturers to meet their specific CO₂ emission standards, particularly as this instrument directly addresses the lack of knowledge of consumers on the fuel-efficiency and CO₂ emissions of new cars. In this perspective, there may be synergies between this instrument and national fiscal measures, as is also concluded by Ricardo and TEPR (2015c). For example, for France they find that the introduction of a car label has resulted in a clear increase in the rate of CO₂ emission reductions, which accelerated further with the introduction of the bonus-malus regime (which was linked to the equivalent label classes). For some other countries (e.g. UK, Denmark), Ricardo and TEPR (2015c) found that the labels may have raised consumer awareness or improved their knowledge on CO₂ related taxation measures. However, it should be noted that this link between car labels and tax measures is only found for a small number of countries.

Clean Vehicle Directive

The Directive on the Promotion of Clean and Energy Efficient Road Transport Vehicles (also known as the Clean Vehicle Directive, Directive 2009/33/EC) requires that energy and environmental impacts linked to the operation of vehicles over their whole lifetime are taken into account in public procurement of all road transport vehicles⁵⁶. Energy and environmental impacts to be included are a least energy consumption, CO₂ emissions, and emissions of the air pollutants NO_x, NMHC and particulate matter. The aim of the Directive is to ensure a level of demand for clean and energy-efficient road transport vehicles that is sufficiently substantial to encourage manufacturers to invest in these types of vehicles. In February 2019, the European Parliament provisionally agreed to revise the current version of the Clean Vehicle Directive (European Parliament, 2019). This reform sets out minimum procurement targets for clean light-duty vehicles, trucks and buses for 2025 and 2030, new definitions of a ‘clean vehicle’⁵⁷, and an extension of the scope of the Directive to a wider range of services (e.g. postal and parcel delivery services, public road transport services, etc.).

Like the car labelling, the Clean Vehicle Directive can be regarded a demand-side policy supporting the achievement of the European CO₂ emission targets for new vehicles. Although the direct contribution of public procurement to increasing the market for clean and fuel-efficient vehicles is considered small, there may be some indirect effects as public procurement can contribute to raising awareness about environmental issues amongst citizens and it may support public authorities in taking leadership by acting as an example to consumers and businesses. The adoption of clean and fuel-efficient vehicles may also send signals to industry that there is a market for these vehicles and it can therefore help to stimulate industry to innovate.

⁵⁶ Two options are offered to meet the requirements: including energy and environmental impacts as award criteria in the purchasing procedure, or setting technical specifications for energy and environmental performance.

⁵⁷ The definition of a clean light-duty vehicle is based on CO₂ standards, while the definition of clean heavy-duty vehicles is based on the use of alternative fuels.

As indicated by Ricardo and TEPR (2015b), the Clean Vehicle Directive complements the use of (CO₂ differentiated) road transport taxes and charges. Both types of instruments aim to stimulate the demand for fuel-efficient vehicles. Particularly for buses, this Directive may have a significant added value to national taxation measures. On the one hand, because most of the buses are purchased in procurement procedures, and on the other hand as vehicle taxes for buses in many countries are relatively low (CE Delft et al., (2019b)).

Alternative fuel infrastructure directive

The large-scale market introduction of alternative fuels is held back by three main barriers: high (investment) cost of vehicles, a low level of consumer acceptance, and lack of recharging and refuelling stations. To address the third type of barrier, the European Parliament and Council adopted in 2014 Directive 2014/94/EC on the deployment of Alternative Fuels Infrastructure. This Directive requires the EU Member States to provide a minimum infrastructure for alternative fuels (i.e. electricity, Liquid Natural Gas (LNG), Compressed Natural Gas (CNG) and hydrogen) and to develop national frameworks to do so. Furthermore, Member States have to apply common technical specifications for recharging and refuelling infrastructure and to ensure that clear user information is available.

This Directive is implemented to address several market failures hampering the deployment of alternative fuel infrastructure and, consequently, alternative fuelled vehicles (European Commission, 2013a). First, by requiring a minimum infrastructure for alternative fuels it reduces coordination⁵⁸ and first-mover⁵⁹ issues, both hampering the deployment of recharging/refuelling infrastructure. Secondly, the Directive also addresses the lack of common standards on alternative fuels infrastructure, reducing the fragmentation of the market and hence increase opportunities to realise economies of scale. Both market failures cannot be addressed by transport taxes and charges. Therefore, the Alternative fuel infrastructure directive complements tax and charge schemes stimulating the uptake of alternative fuelled vehicles in order to reduce road transport's CO₂ emissions.

Fuel Quality Directive and Renewable Energy Directive

The Fuel Quality Directive (FQD) (Directive 2009/30/EC) requires a reduction of the greenhouse gas intensity of transport fuels by at least 6% in 2020, to be achieved by using less CO₂ intense fuels (e.g. biofuels, electricity, less carbon intense fossil fuels and renewable fuels of non-biological origin) and reducing the CO₂ emissions at the extraction stage of fossil fuel feedstocks. The Renewable Energy Directive (RED) (Directive 2009/28/EC) sets a target for each Member State of a 10% share of renewable energy in transport by 2020. In the recast of the RED (RED 2), a target of a 14% share of renewable energy in transport in 2030 has been set. Additionally, the RED together with the FQD, regulates the sustainability of biofuels, among other things by limiting the use Member States are allowed to make of biofuels with indirect land use effects.

⁵⁸ The coordination issue refers to the 'chicken and egg' problem: investors do not invest in alternative fuels infrastructure as there is insufficient consumer demand, and consumers do not invest in alternative fuelled vehicles due to a lack of a dedicated infrastructure. This problem generates uncertainty on the business case and hence hinders the deployment of this infrastructure

⁵⁹ The first-mover issue refers to investors' fear for free-riding by competitor investors if they finance open-access recharging/refuelling infrastructure. They have to make large upfront investments in a situation with uncertain payback times, while market players who will enter the market at a later stage when the demand for the marketed product consolidates, can (partly) benefit from the investments done by the first-mover. This risk discourages first movers' investments.

The FQD and RED complements the other EU policies to mitigate road transport CO₂ emissions as it targets the GHG intensity and type of transport fuels, while most of the other measures are addressing fuel-efficient vehicles. In parallel with the CO₂ regulation for vehicles, the regulation of fuels supports the harmonisation of the internal market, providing certainty to (alternative) fuel producers/suppliers to implement large-scale investments. In this way, the FQD and RED complements any national road transport tax schemes targeting the uptake of renewable energy.

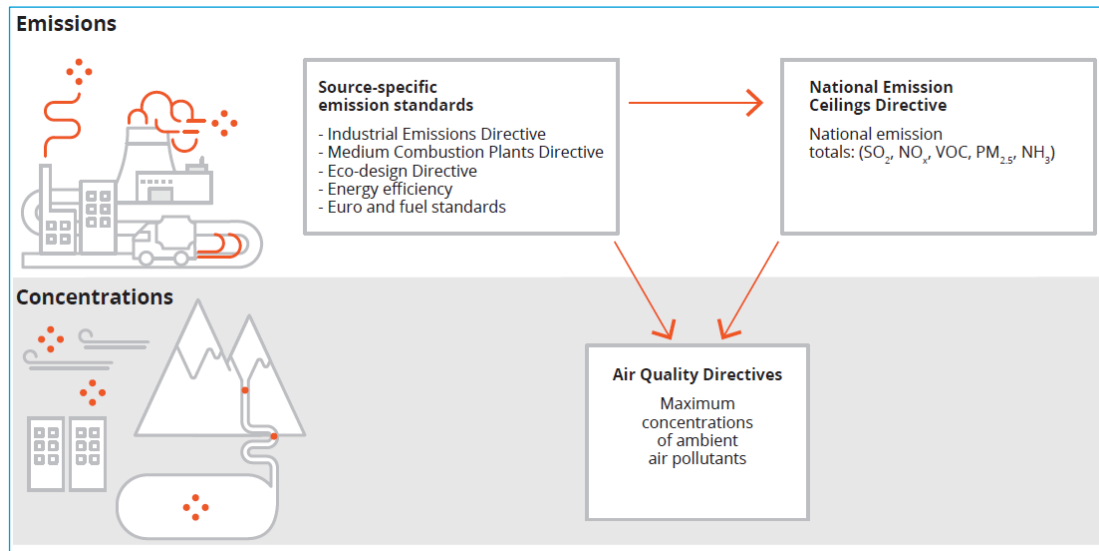
National incentives to support zero or low emission vehicles

At the national/local level, a wide range of policy instruments (in addition to tax measures) are implemented to stimulate the purchase of zero or low emission vehicles. In several European countries, direct subsidies (often in addition to exemptions of road transport taxes/charges) are provided for the purchase of these vehicles. For example, Germany provided in 2016 an environmental bonus of € 4,000 for full electric and fuel cell vehicles and € 3,000 for plug-in hybrid and range-extended electric vehicles (ACEA, 2018). In addition to direct subsidies, other instruments like access to bus lanes (e.g. Norway) and priority parking to electric cars (e.g. Netherlands, Spain) are used. All these measures complement road transport tax measures aimed to support the uptake of zero or low emission vehicles.

4.5.2 Air pollution

There are three types of legislation regarding air pollution, which are illustrated in Figure 47. Source specific emission standards, the National Emission Ceilings Directive (NECD) and Air Quality Directives. There are two main EU instruments dealing with overall air pollution. The first is the EU Ambient Air Quality Directive (Directive 2008/50/EC), which sets EU air-quality standards for ground level ozone, PM, nitrogen oxides, dangerous heavy metals and a number of other pollutants. The second is the National Emissions Ceilings Directive (Directive 2016/2284), which caps overall emissions of sulphur dioxide, nitrogen oxides, ammonia and volatile organic compounds (VOC). These overall air pollution instruments, that together set a general framework for air quality policy in Europe, are supplemented by the Euro standards, which limit the pollutants at the vehicle level. Additionally, the **Fuel Quality Directive**, **Clean Vehicle Directive** and the **Directive on the deployment of alternative fuels infrastructure** also contributes to the reduction of air pollutant emissions of road transport. These three Directives have been discussed in detail in the previous section. Finally, several national initiatives to tackle air pollution of road transport are applied in the EU. Some relevant ones are discussed below.

Figure 47 - EU clean air policy - the policy framework (source: EEA, 2018)



Air Quality Directive on Ambient Air Quality

The Ambient Air Quality Directives (Directive 2008/50/EC) defines ambient air quality standards which require the Member States to adopt and implement air quality plans and meet the standards in order to protect human health and the environment. The standards are defined as maximum concentration levels that cannot be exceeded for a certain number of times per year and maximum average concentration levels. Air pollution is a cross boundary challenge for which in the market no obvious stakeholders are responsible. National emission ceilings do not ensure local air quality as the distribution of emissions can be very uneven. Therefore, maximum local air concentration levels are needed to ensure local air quality. The AAQD can be perceived by local authorities or national governments as an incentive for introducing (local) tax/charge policies. The other way around, pricing instruments for road transport may provide an important contribution to meeting the air concentration limits set by the AAQD.

National Emission Ceilings Directive

The National Emission Ceilings (NEC) Directive (Directive 2016/2284) sets national total emission reduction targets and requires Member States to develop National Air Pollution Control Programmes by 2019 in order to comply with their emission reduction commitments. Air pollution ignores national borders and can be carried very long distances by the wind, so it needs to be tackled through co-operation at European, international and global level. National road transport taxes and charges may be used as a means to achieve a reduction in air pollutants.

Euro standards

The European emission standards define the acceptable limits for exhaust emissions of new vehicles sold in the EU Member States. The emission standards are defined in a series of European Union directives staging the progressive introduction of increasingly stringent standards. The Euro standards were first introduced in 1992 (Euro 1 for passenger cars) and the most recent standard is the Euro 6/VI standard. The Euro standards are currently in place for light-duty (cars, vans) and heavy-duty vehicles (lorries, buses), and for non-road

mobile machinery. The standards apply for the pollutants: nitrogen oxides (NO_x), total hydrocarbon (THC), non-methane hydrocarbons (NMHC), carbon monoxide (CO) and particulate matter (PM).

Euro standards have set an increasingly stricter and challenging targets for maximum exhaust emissions levels. This created a level playing field in which all manufactures had to meet the same standards, which has driven innovation towards technologies that reduce pollutants. This supply-push for innovation has driving down the costs of meeting the standards (Newbery, 2017). Furthermore, the EU scope of the standards well align with the international dimension of air pollution (European Commission, 2008).

Classification of air pollutant emission levels of vehicles provide information to consumers and can help them to decide to buy a 'cleaner vehicle'. The euro standards are an instrument that can be combined with national pricing policies to stimulate cleaner vehicles. For example, in Germany, the HGV kilometre charging system differentiates to Euro classes. As discussed in CE Delft et al. (2019b) differentiations to euro standards are also sometimes applied in registration and ownership taxes in the EU28.

National incentives to support clean vehicles

At the national/local level, a wide range of policy instruments (in addition to tax/charge measures) are applied to stimulate the purchase/use of clean road vehicles. Some examples of such instruments are:

- *Low emission zones (LEZs)*: in fourteen European countries LEZ are applied in (some) cities, restricting the operation of older, polluting vehicles (Dieselnet, 2019). In some cases (e.g. London, Milan), these LEZs are combined with charging schemes
- *Subsidised public transport*: public transport in the EU is often subsidised (Ecologic; CE Delft; TU Dresden, 2006). There may be several reasons to provide subsidies (or public services obligations) to public transport, including the reduction of the environmental impact of transport.
- *Air pollution emergency schemes (smog alerts)*: many European countries (e.g. Belgium, Czech Republic, Finland, France, Hungary, Luxembourg, Poland, Slovakia, UK) and individual cities/regions (e.g. Graz, Stuttgart, Lombardy, Catalonia) apply air pollution emergency schemes in order to inform the public and undertake measures in case of a smog episode (Wiesen, 2017). Short-term actions applied for transport include lower speed limits, increased supply of public transport, public transport temporarily free of charge, restrictions on use of private cars (odd-even rationing policy), etc.
- *Promotion of car sharing*: local authorities (e.g. London, several Italian cities) support car sharing in several ways, including the provision of parking spaces, allow use of reserved bus lanes, free access to low emission zones, etc. (BCS, 2012).
- *Different incentives to support electric vehicles*: see Section 4.5.1 for more details.

All these instruments may complement national tax/charge policies for road transport. In case of LEZs that are combined with urban road charging schemes, this complementarity is very clear, but also the other instruments contribute to the same objectives as the road taxes/charges applied to reduce air pollutant emissions.

4.5.3 Noise

The general framework to address the issue of road noise in Europe is provided by the Environmental Noise Directive. In addition, EU regulations are applied to regulate vehicle noise and tyres. With respect to the rolling noise of tyres, the EU has also introduced a specific labelling scheme. Finally, several noise abatement measures are applied at the national and local level. All these instruments are discussed below.

Environmental Noise Directive

The main aim of the Environmental Noise Directive (END) (Directive 2002/49/EC) is to provide a common basis for tackling the noise problem across the EU. The objectives include monitoring the environmental problem by requiring Member States to draw up 'strategic noise maps' for major roads, railways, airports and agglomerations, using harmonised noise indicators. Local authorities need to prepare action plans to ensure local noise quality. Member States have to report on strategic noise maps, the status of limit values that they enforce and send action plans to the Commission.

The END provides a common approach for the assessment of environmental noise and thus contributes to the comparability of noise exposure data between various jurisdictions or across time. The Directive ensures collection of adequately harmonised and standardised data at EU level and therefore attributes to the mapping of evidence of population exposure to noise. The END reduces differences in which transport and industry infrastructure operators across the EU address the noise they produce and attributes to a level playing field across the EU in which they can operate and compete. Furthermore, the Directive contributes to better-informed EU policy-making, by providing complete and comparable data at EU level to policy makers responsible for noise-at-source legislation (European Commission, 2016b). Information provision through END helped raise public awareness and put environmental noise on the policy agenda.

Vehicle noise regulation

The vehicle noise regulation (Regulation 540/2014) establishes the administrative and technical requirements for the EU type-approval of all new motorised vehicles with regard to their sound level, and of replacement silencing systems. The regulation prescribes the test conditions for noise measurements for stationary vehicles and for vehicles in motion. Furthermore, the regulation sets limit values for measured sound levels emitted from new vehicles depending on the vehicle category (Schwela, 2017).

This regulation creates a level playing field for OEMs as all vehicles have to satisfy the same standards and has promoted research towards decreasing noise (European Parliament, 2014c). With respect to the latter issue, the clear framework including timeframe provided by the regulation supports innovation and investments in noise reducing technologies. The harmonised approach provided by the regulation is also in line with the international dimension of the issue, as EU registered vehicles are often used in several countries. As the current road transport taxes and charges do not apply differentiations to the noise emissions of vehicles (CE Delft et al., (2019b)), the vehicle noise standards effectively complement them in stimulating the supply of more silent vehicles.

Noise regulation with respect to tyres

The noise emission of tyres is regulated since 2001 by Regulation 2001/43. In 2009 a tightening of limit values by about 2 to 5 dB was introduced by EC Regulation 661/2009 (the type-approval requirements for vehicles) and ECE Regulation R117.02 (MBBM Group, 2014).

The regulation facilitates a smooth functioning of the internal market and ensures that when setting tyre-rolling noise requirements, tyres are designed to take into account parameters relating to safety and environment (European Parliament, 2001). The standards that are set by the regulation ensure that all manufacturers are bound by the same requirements, such that they will be able to incorporate the design standards into their products, reducing administrative costs. The harmonised approach also provides reliable investment conditions, incentivising investments in tyres with lower rolling noise levels and

reducing associated costs. As for vehicle noise regulation, the tyre regulation complements the current road transport taxes and charges implemented in EU Member States, as the latter do not provide incentives to apply low rolling-noise tyres.

Tyre labelling

The European Tyre Labelling Regulation (EC/1222/2009) introduces labelling requirements including information on the fuel-efficiency, wet grip and external rolling noise of tyres. The aim of the regulation is to increase the safety and the environmental and economic efficiency of road transport by promoting fuel-efficient and safe tyres with low noise levels (ERTMA, 2019).

This regulation addresses the lack of knowledge of vehicle owners with respect to differences in rolling-noise levels of tyres. By providing this information by using labels, it allows end-users to make more informed choices when purchasing tyres by considering this information along with other factors normally considered during the purchasing decision process (European Parliament, 2014c). The tyre labels also allow national governments to introduce incentives for choosing energy efficient, safe or silent tyres (e.g. by differentiating taxes/charges based on these labels), but no examples are known of implementing these policies.

National measures for noise abatement

Besides EU Directives and Regulations, many local/national policies are implemented for road noise abatement. Some examples are:

- Infrastructure measures, such as low-noise road pavement or noise barriers.
 - Traffic management, such as lower speed limits and improved traffic planning.
- An example is the London Lorry Control Scheme, which is designed to help minimise noise pollution from lorries in residential areas (ISINNOVA ; PwC, 2017).

Quiet Zones: A new concept in the context of Low Emission Zones is the Quite zone (Q-zone): an area where a low level of traffic noise is guaranteed by the reservation of access only to low noise vehicles. An experiment is the Naples quiet zone which was researched in the FP7 CityHush project on Acoustically Green Road Vehicles and CityAreas.

4.5.4 Accidents

Road safety is at the EU level regulated by command-and-control measures, mainly by setting (minimum) safety standards or requirements⁶⁰. Also, at the national, regional and local level, certain command-and-control measures are applied. These are supplemented by “soft measures” such as investment support and awareness raising activities. The main safety measures at the EU and national level, part of the EU Policy Orientations on Road Safety 2011-2020⁶¹, are briefly discussed below.

⁶⁰ This section lists a number of important pieces of legislation, however many more exist. A complete list of EU road safety policies can be found at https://ec.europa.eu/transport/road_safety/specialist/policy_en

⁶¹ See: https://ec.europa.eu/transport/road_safety/sites/roadsafety/files/pdf/road_safety_citizen/road_safety_citizen_100924_en.pdf An outline of a Road Safety Policy Framework 2021-2030 along with a Strategic Action Plan on Road Safety have been adopted in May 2018 (https://ec.europa.eu/transport/modes/road/news/2018-05-17-europe-on-the-move-3_en).



Road transport taxes and charges are not directly⁶² linked to external accident costs. Therefore, there is no interaction between any of the measures discussed below and the pricing instruments covered in the previous sections.

Vehicle regulations

The vehicle regulation on type-approval requirements sets out the safety and environmental requirements that motor vehicles have to comply with before being placed on the EU market. The EU Type Approval system is mandatory for all categories of motor vehicles and their trailers (European Parliament, 2018a). There are also separate regulations that regulate seat belts, tyres, ABS, blind spot mirrors.

Vehicle inspection: periodic and roadside inspection

The Directive on the periodic technical inspection of motor vehicles and their trailers (Directive 2014/45/EC) covers passenger cars, trucks, buses, heavy-trailers, motorcycles and speed tractors, and defines the items to be tested during the roadworthiness test, the test methods, and the defects and their assessment (CITA, 2014). The Directive also introduces minimum requirements for testing facilities, the training of inspectors and the supervising bodies. The objective is to strengthen controls on many safety issues such as brakes, tires, steering, lighting, equipment and pollution levels. The Road Side Inspection Directive (2014/47/EC) provides common rules for the technical roadside inspection of trucks, buses, heavy-trailers and speed tractors. The overall goal is that the number of initial roadside inspections carried out per year corresponds to a least 5% of the number of trucks, buses and heavy trailers registered in the Member States. To this end, each Member State is required to conduct a number of initial roadside inspections in proportion to the total number of vehicles concerned registered in its territory.

These Directives impose harmonised strict controls for motor vehicles and their trailers to ensure that they are kept in a safe and environmentally acceptable condition throughout their lifetime. The Directives complement Regulations and Directives that introduce standards concerning safety measures, but also greenhouse gas emissions, air pollution and noise.

Driving licenses

The revised Driving Licence Directive (Directive 2006/126/EC) entered into force in 2013 and provides harmonised EU-wide rules on driving licences with the objective to facilitate greater freedom of movement to EU drivers, reduce the possibility of driving licence fraud and improve road safety in Europe. The Directive introduces the New Union Model Licence, harmonises administrative validity periods, driving licence categories and driving examiners. Furthermore, an EU driving licence network (RESPER) was established.

⁶² There may be indirect links, as taxes/charges may affect the demand for road transport and hence the size (and composition of the) traffic flow on roads. The latter may affect the total accident costs of road transport (e.g. an increase of the number of vehicles will result in more accidents, assuming a constant accident risk). Implementation of road charges may also lead to a shift of traffic from the charged part of the road network to the uncharged part. As the accident risk on the latter is higher than on the charged part, this may result in more traffic accidents and hence higher accident costs.

Professional drivers: training, working conditions, tachograph & speed limiters

There are several Directives and Regulations that affects professional drivers:

- Training: Directive 2003/59/EC: initial qualification and periodic training of drivers of certain road vehicles for the carriage of goods or passengers.
- Working conditions:
 - Directive 2002/15/EC on the organisation of the working time of persons performing mobile road transport activities.
 - Regulation (EC) No 561/2006 on the harmonisation of certain social legislation relating to road transport=
- Tachograph and speed limiters: Regulation 68/2009 on the technical requirements of recording equipment in road transport and Directive 2002/85/EC on the installation and use of speed limitation devices for certain categories of motor vehicles.

All these Directives and Regulations ensure fair competition in the commercial transport of goods market and a high level of professionalism in the sector, contributing to road safety.

Road infrastructure safety

The Road Infrastructure Safety Management Directive (2008/96/EC) obliges Member States to take safety considerations into account at the design, planning and operation stage of important European roads by carrying out safety impact assessments, audits and inspections.⁶³ The Tunnel Safety Directive (2004/54/EC) lays down EU minimum safety requirements for tunnels to ensure that they are adequate for the volume of traffic and have emergency exits to prevent them from becoming death traps in an accident.

National/local safety measures

Additional to the EU Regulations and Directives, national and local safety measures are also implemented in all Member States. For example, there are regulations regarding driving under influence (alcohol, drugs), speed limits, infrastructure measures such as roundabouts, design of roads and urban areas, pedestrian crossings, traffic lights, etc.

4.5.5 Congestion

Road congestion in the EU is mainly addressed by national measures, including traffic management measures, modal shift policies and investments in the road infrastructure. At the EU level, the TEN-T policy may contribute to reducing congestion levels by co-financing the development of additional road network capacity, addressing important bottlenecks in the road infrastructure or improving/enhancing rail infrastructure in order to stimulate a modal shift to rail transport. Both the instruments at the EU and national level are discussed in more detail below.

TEN-T Policy

The Trans-European Transport Network (TEN-T) is a European Commission policy directed towards the implementation and development of a Europe-wide network of roads, railway lines, inland waterways, maritime shipping routes, ports, airports and rail-road terminals (European Commission, 2019c).

⁶³ A revision provisionally agreed by the co-legislators in February 2019 extends the scope of the Directive from the TEN-T network to primary roads, introduces new 'network-wide safety assessments' and improves the follow-up and transparency of procedures.

The infrastructure development of the trans-European transport network is closely linked with the implementation and further advancement of EU transport policy.

The TEN-T policy reinforces the network approach, thereby establishing a coherent basis for the identification of projects and for service provision in line with relevant European objectives. The policy sets standards for all the network, which integrate EU legislation in force and lead the way infrastructure-wise to achieving key policy objectives. Through the new core network corridor approach, TEN-T advances sustainable transport solutions which lead the process towards the achievement of the European Union's long-term transport policy objectives (meeting future mobility needs while ensuring resource efficiency and reducing carbon emissions).

The TEN-T policy may contribute to tackling road congestion in the EU by providing financial support to increasing road capacity or removing important infrastructural bottlenecks along the main European corridors. Furthermore, financial support to improve the rail network in the EU may increase the attractiveness of rail transport resulting in a shift of transport from (congested) roads to rail. The corridor approach adopted in the TEN-T Regulation intended to 'coordinate different projects on a transnational basis and synchronise the development of the corridor. Such a coordinated, transnational approach is unlikely to be adequately addressed by Member State action alone. Unnecessary complexity and duplication of efforts can be avoided by applying the same or coordinating the procedures across the border with a view to maximise synergies and reap the benefits of a European approach. This way, infrastructure projects under TEN-T are not confronted with a multitude of national procedures, differing requirements and regulatory fragmentation (European Commission, 2018c).

As a supply side measure, the TEN-T projects complement the demand-driven road charging schemes. Furthermore, the revenues from road charging schemes may be used to finance road infrastructure projects, in addition to the funding received from the TEN-T project.

National/regional/local policies on mitigating congestion

National policies on congestion reduction are often aimed at corridors and bottlenecks, focusing on creating more capacity on the national road network for growing transport demand. For international or EU relevant corridors an overlap with the TEN-T policy exists, as Member States have to contribute a share of the investment themselves. Regional and local transport management systems focusing on congestion include modal shift policies (by promoting public transport or active modes) and local traffic management systems.

5 Rail transport

5.1 Introduction

This chapter discusses the resulting average and marginal cost coverage ratios of rail passenger and freight transport.

Average cost-based internalisation results are discussed in Sections 5.2.1 and 5.2.2, as follows:

- overall cost coverage ratio;
- overall cost coverage ratio excluding fixed infrastructure costs;
- variable external and infrastructure cost coverage ratio;
- overall infrastructure cost coverage ratio;
- variable infrastructure cost coverage ratio.

Table 19 shows the categories of costs (i.e., infrastructure and external) and revenues (i.e., taxes and charges) which are used to calculate the ratios. They are also distinguished with respect to their nature, namely if they are fixed or variable components.

Table 19 - Costs and revenues used for rail mode cost coverage ratios

Type of comparison	Infrastructure costs	External costs	Taxes and charges
Overall average	All infrastructure costs	All external costs	All taxes and charges
Fixed	All investments and traffic independent part of O&M and renewal costs	Habitat	None
Variable	Traffic dependent part of O&M and renewal costs	Accidents, air pollution, climate, noise and WTT	Infrastructure access charges, electricity taxes, fuel taxes and ETS

Marginal cost coverage ratios of rail passenger and freight modes are presented in Section 6.3 according to three external cost scenarios, namely high, representative and low⁶⁴. These are illustrated in Table 20. The reference rail vehicles used in these scenarios come from those of the study, “Transport Taxes and Charges in Europe” (CE Delft, 2019b).

It is worth remarking that for the representative scenarios, costs and revenues are the result of calculations of the average infrastructure and external costs⁶⁵, representing the weighted averages of the actual real-world conditions/situations. This means that the representative scenario may not lie in the middle of the high and low external cost scenarios.

Furthermore, to define the scenarios, some cost drivers have been identified for the various types of externalities (i.e., type of train and time of the day). These cost drivers, however, do not always affect the various externalities in the same way. This may explain why in some cases higher values for specific externalities are found in the low external cost scenario than in the high external cost scenario (or vice versa).

⁶⁴ The very low external cost scenario is not applicable for rail transport.

⁶⁵ Marginal costs of the representative scenarios are often equal to the variable part of the average costs.

Table 20 - Definition of rail marginal cost scenarios

Reference rail vehicle	High external cost	Representative	Low external cost
HST	Night	Average daytime/night	Day
Passenger electric train	Regional train Daytime	Average passenger train Average daytime/night	Intercity train Daytime
Passenger diesel train	Regional train Not equipped with EGR/SCR Daytime	Average passenger train Average daytime/night	Intercity Equipped with EGR/SCR Daytime
Freight electric train	Short train (bulk) Daytime High noise level	Average freight train Average daytime/night	Long train (bulk) Daytime Low noise level
Freight diesel train	Short train (bulk) Daytime High noise level Not equipped with EGR/SCR	Average freight train Average daytime/night	Long train (bulk) Daytime Low noise level Equipped with EGR/SCR

5.2 Average cost-based internalisation

For the purpose of this study, the revenues from infrastructure access charges have been estimated assuming a “minimum access package⁶⁶”, which considers only the cost components actually charged to a typical train for utilising a railway line. Other charges that a train undertaking may pay to the infrastructure manager, for example, ancillary services at stations and depots, are excluded.

It is also worth noting that infrastructure access charges may incorporate public subsidies. This implies that the average revenues could be gross of these subsidies and not a net value. This may impact on the level of infrastructure charges for some train types and explain the differences between countries. As noted in the report on transport taxes and charges (see Section 1.3.5) (CE Delft, 2019b), the treatment of subsidies is out of the scope of the analysis, because data availability on subsidies is poor and a large number of subsidy and PSO schemes exist, both at national and regional/local level⁶⁷.

⁶⁶ Infrastructure access charges are related to three cost components, namely (i) direct costs of a train run related to wear and tear and electric supply charges, (ii) mark ups up to full costs depending on an ability of a market segment to it and (iii) other charges such as reservation and environmental charges.

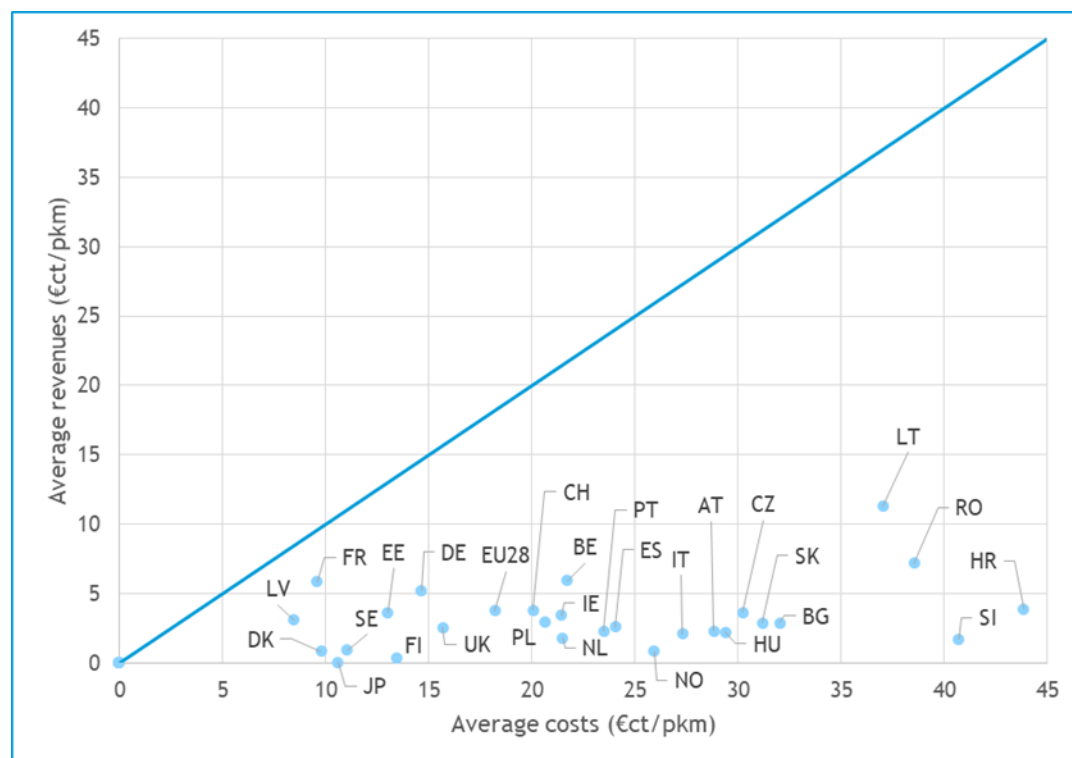
⁶⁷ Also subsidies to tariffs paid by the users are not in the scope of this analysis.

5.2.1 Rail passenger transport

Overall cost coverage ratio

Figure 48 shows the spread of the overall cost coverage, which compares the average revenues from all internalisation measures⁶⁸ against all external and infrastructure costs⁶⁹.

Figure 48 - Spread of overall total cost coverage - Rail passenger transport (magnified subset)



Note: Cyprus and Malta do not have operating rail networks. Data is not available for California and Missouri.

The average revenues from all internalisation measures are low relative to the total external and infrastructure costs across all the countries covered by this study. This basically depends on the high share of the average infrastructure costs of the rail networks, which at EU28 level is equal to 85% of the total average cost (i.e., €ct 15.4 out of €ct 18.2 per pkm; or € 17.2 out of € 20.4 per train-km). The average revenues from infrastructure access charges do not cover the average infrastructure cost (particularly the fixed part of it). The revenues from the other internalisation measures are negligible, because the

⁶⁸ Revenues from all internalisation measures consider: fuel excises, electricity taxes, infrastructure access charges, infrastructure access charges of specific part of the infrastructure (for countries where this is applicable) and ETS.

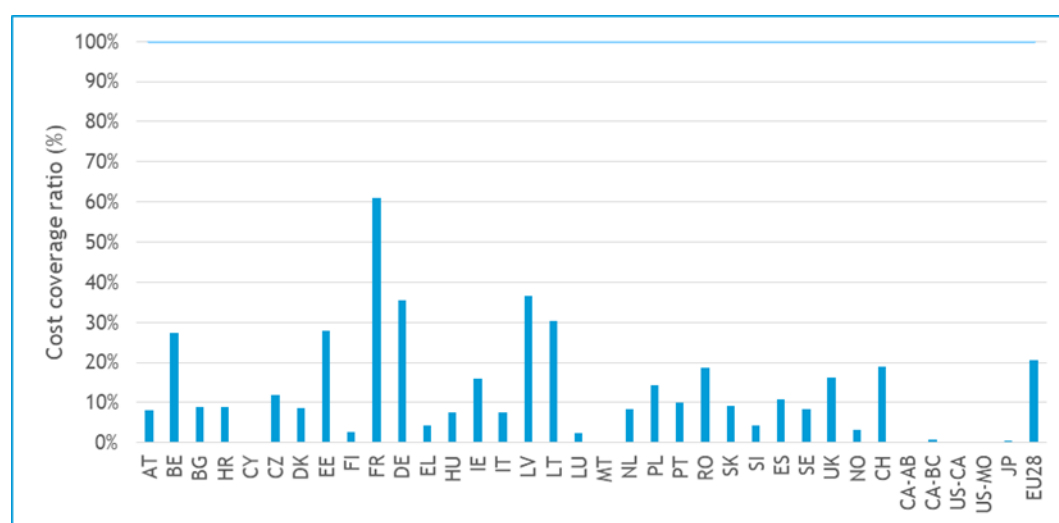
⁶⁹ External costs consider: accidents, air pollution, climate change, noise, WTT and habitat. Figures on congestion costs (or scarcity costs) are not available for this mode.

external costs related to emissions of air pollutants and noise still have little consideration across European infrastructure access charges schemes⁷⁰.

Another pattern shown in the figure above is that the average total costs vary widely between countries, with the minimum found for Latvia (i.e., €ct 8.5 per pkm) and the maximum for Greece and Luxembourg (i.e., €ct 74.4 and €ct 130.6 per pkm respectively), which extend beyond the x-axis displayed in the magnified subset. On the other hand, the maximum average total revenue only amounts to €ct 11.3 per pkm for Lithuania. This outcome is mainly driven by the average infrastructure costs which are rather high in a country with low activity, given the significant fixed infrastructure costs, as explained later in the chapter.

Figure 49 shows the total cost coverage ratio. At EU28 level, the total cost coverage ratio is found equal to 21%. France, Latvia, Germany, and Lithuania are found with the highest ratios above the average (i.e., 61%, 36%, 35% and 30%, respectively). For France and Germany, the result depends on the high value found for the total revenues from all internalisation measures. For Latvia and Lithuania, the result depends on the high infrastructure access charges and revenues from fuel taxes. On the other hand, Finland, Greece, Luxembourg and Slovenia present the lowest ratios (i.e., 3%, 4%, 2% and 4%, respectively), which depend on the low value of the infrastructure access charges and revenues found from all internalisation measures.

Figure 49 - Overall total cost coverage ratio - Rail passenger transport



Note: Cyprus and Malta do not have operating rail networks. Data is not available for California and Missouri.

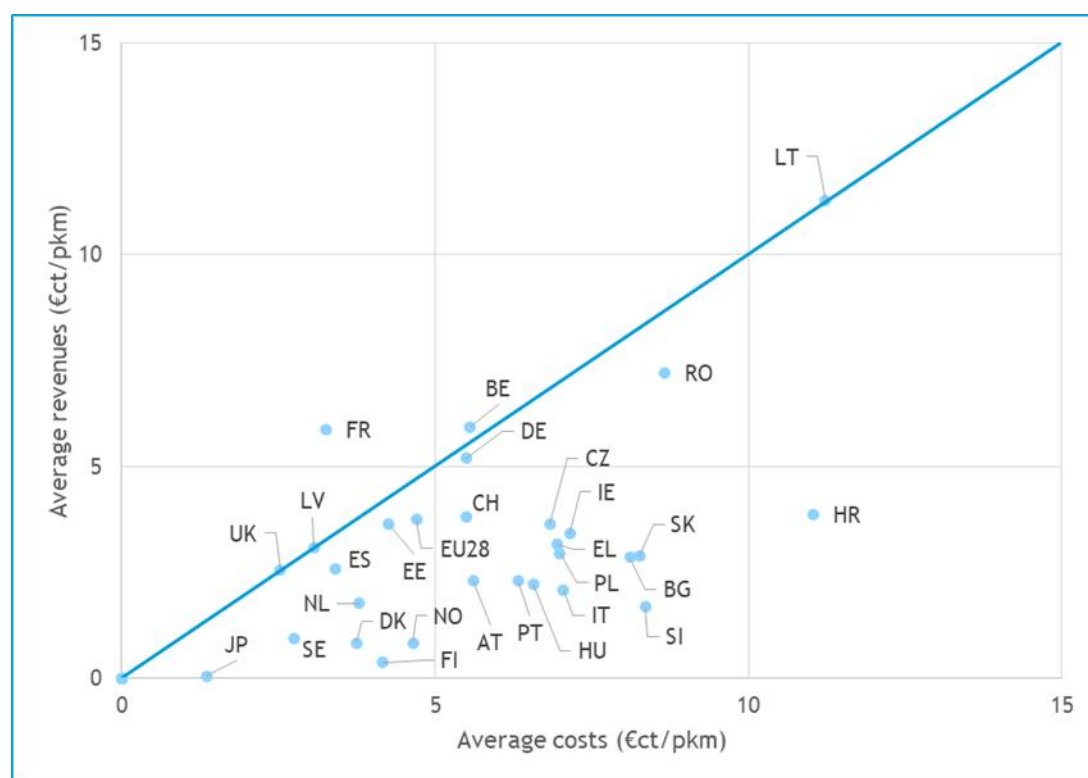
⁷⁰ In this respect, it is also worth reminding that (i) Belgium, Hungary, Norway and Sweden do not charge fuel excise duties and (ii) in 12 European countries an electricity tax on rail transport activities is, neither not levied at all, or under a regime of exemption. As far as infrastructure access charges are concerned, the current schemes give little consideration to the external costs. 4 Member States only charge for the external costs related to local emissions. In Sweden an emission charge is levied on diesel-engine locomotives and multiple-unit trains, while in Austria, Germany and the Netherlands a differentiation with respect to brakes noise emission is applied to infrastructure access charges levied to freight trains. Eventually, also Switzerland applies a similar noise differentiation.

For Norway and Switzerland, the cost coverage ratios are 3 and 19%, respectively. It is worth reminding that, for Norway, low infrastructure access charges have been introduced in 2017 with the purpose to prevent perturbations of the circulation. The access charges are calculated with respect to the social marginal cost approach to stimulate a modal shift to railway from other transport modes⁷¹.

Overall cost coverage ratio excluding fixed infrastructure costs

Figure 50 shows the spread of the total cost coverage with variable infrastructure costs, which compares the average revenues from all internalisation measures against all average external and average variable infrastructure costs⁷².

Figure 50 - Spread of overall total cost coverage with variable infrastructure costs - Rail passenger transport (magnified subset)



Note: Cyprus and Malta do not have operating rail networks. Data is not available for California and Missouri.

At EU28 level, the average external and variable infrastructure cost is found €ct 4.7 per pkm (i.e., € 5.3 per train-km). The average revenue at EU28 level is found equal to €ct 3.8 per pkm (i.e., € 4.2 per train-km).

The overall spread shows that both average costs and revenues vary widely across the Member States. The minimum cost is found for the UK (i.e., €ct 2.5 per pkm) and the maximum for Lithuania (i.e., €ct 11.2 per pkm). Regarding the average revenues, Finland

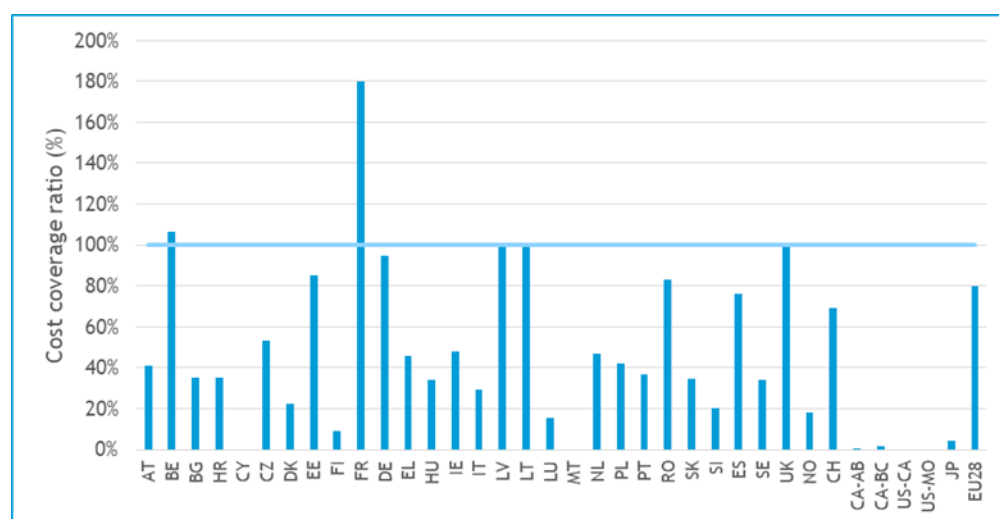
⁷¹ See IRG-Rail (2015b) and IRG-Rail (2017).

⁷² The variable infrastructure costs consist of the traffic-dependent part of the renewal and O&M costs.

shows the minimum value (i.e., €ct 0.4 per pkm) and again Lithuania the maximum (i.e., €ct 11.3 per pkm), respectively. Luxembourg can be considered as an outlier, being outside the region of the graph displaying the magnified subset, and also shows a very high average cost (i.e., €ct 20.0 per pkm) compared to relatively low revenues (i.e., €ct 3.1 per pkm). Norway and Switzerland show average costs relatively in line with the EU28 level (i.e., €ct 4.7 and 5.5 per pkm, respectively). As regards the average revenues, Switzerland is slightly above the EU28 level (i.e., €ct 3.8 per pkm), while Norway is found below (i.e., €ct 0.8 per pkm), for the same reason explained in the section above.

Figure 51 shows the cost coverage ratios, where the average at EU28 level is found equal to 80%. The EU28 cost coverage ratio is now four times higher with respect to the EU28 cost coverage ratio presented in Figure 58 (i.e., 20.6%) and which compares revenues from all internalisation measures with all external and infrastructure costs. This illustrates the large contribution that fixed infrastructure costs have in total external and infrastructure costs of rail transport. The full cost coverage is achieved for Belgium, France, Latvia, Lithuania and the UK, which basically depends on the high infrastructure access charges found for conventional passenger trains.

Figure 51 - Overall total cost coverage with variable infrastructure costs ratio - Rail passenger transport



Note: Cyprus and Malta do not have operating rail networks. Data is not available for California and Missouri.

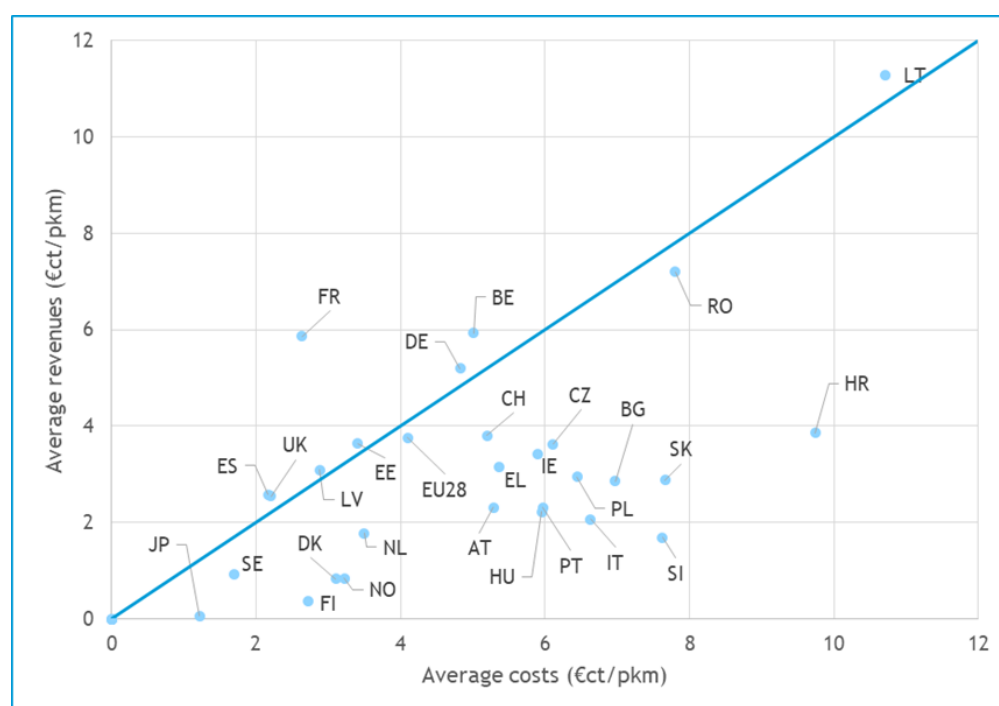
Variable external and infrastructure cost coverage ratio

Figure 52 shows the spread of total variable cost coverage, comparing the average revenues from variable taxes and charges against the variable external and infrastructure costs. Variable taxes and charges include infrastructure access charges, ETS, and fuel/energy taxes. Variable external costs consider all categories except habitat costs, and variable infrastructure costs cover O&M and renewal costs that depend on traffic levels. The overall picture is similar to the one presented in the subsection above, with the same average variable revenues and variable infrastructure costs, but lower external costs, having excluded the habitat external costs.

At EU28 level, the average external and O&M cost is now €ct 4.1 per pkm (i.e., € 4.6 per train-km), compared to the previous €ct 3.8 per pkm (i.e., € 4.2 per train-km). The spread has basically moved to the left-hand side of the plan. Alongside with previously noted Belgium, France, Latvia, Lithuania and the UK, now 3 more Member States are in the region of the plan where the average revenues are higher than the average costs (i.e., Estonia, Germany and Spain). Luxembourg can be considered as an outlier, being outside the region of the graph displaying the magnified subset (i.e., €ct 19.2 per pkm).

For the other countries, the reduction of the average cost is more significant for Norway, which is now equal to €ct 3.2 per pkm, compared to € ct 4.7per pkm. The average cost of Switzerland is found relatively unchanged (i.e., €ct 5.2 per pkm, compared to €ct 5.5 per pkm).

Figure 52 - Spread of overall total variable cost coverage - Rail passenger transport

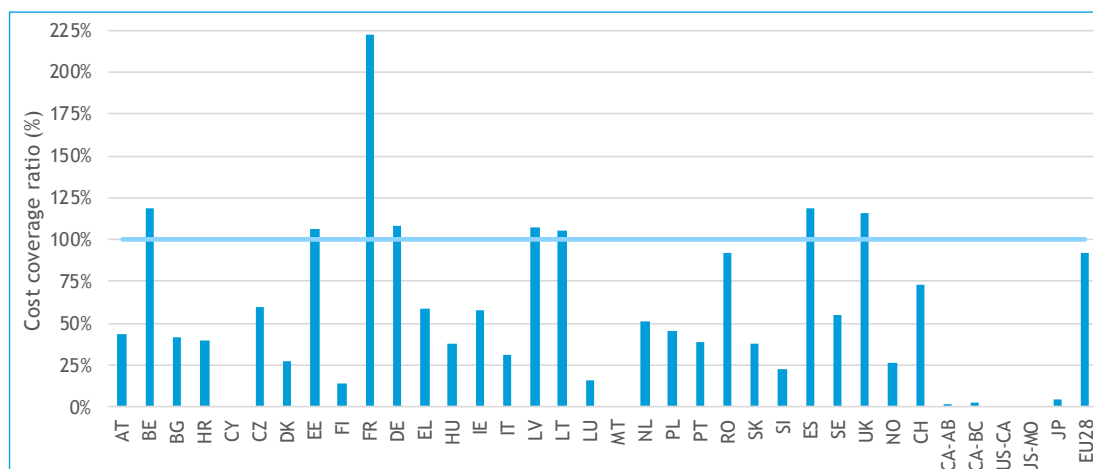


Note: Cyprus and Malta do not have operating rail networks. Data is not available for California and Missouri.

Figure 53 shows the overall total variable cost coverage ratio. At EU28 level, the overall level of cost coverage attained under this indicator is now higher than that found under the overall total cost coverage with O&M costs (i.e., 92% against 80%).

The trends are also similar to those presented in the previous subsection.

Figure 53 - Overall total variable cost coverage ratio - Rail passenger transport



Note: Cyprus and Malta do not have operating rail networks. Data is not available for California and Missouri.

Overall infrastructure cost coverage ratio

Figure 54 shows the spread of overall infrastructure cost coverage for rail passenger transport, comparing revenues from infrastructure access charges against all infrastructure costs. The infrastructure costs have been allocated to train types by using costs drivers identified from a literature review and which are presented in Table 21⁷³.

Table 21 - Cost drivers for allocation of rail infrastructure costs to train types

Cost category	Cost driver
Enhancement costs	100% capacity related: Allocated to passenger and freight trains based on train-kilometres. - Costs related to high speed lines are fully allocated to high speed trains.
Renewal costs	Variable costs allocated based on tonne km (both for passenger and freight trains). Fixed costs area allocated based on train-km.
Maintenance costs	- Variable costs are partially (50%) allocated based on train-km and partially (50%) based on tonne-km. - Fixed costs are fully allocated based on train-km.
Operational costs	Fully allocated on train-km.

The diagonal in Figure 54, which indicates the full cost coverage, is never achieved, because all infrastructure costs markedly outweigh the average revenues.

At EU28 level, the average infrastructure cost of passenger trains is €ct 15.4 per pkm (i.e., € 17.2 per train-km). In general, the highest average infrastructure cost for passenger trains are estimated for countries with relatively high network costs and associated with small networks or low transport performance. Greece and Luxembourg are outliers in this respect, being beyond the x-axis displayed in the magnified subset (i.e., €ct 70.0 and €ct 124.6 per pkm, respectively). On the other hand, the higher transport performance on the

⁷³ This study does not take into account the different costs of a diesel and an electrified rail line, but the cost of the overall rail network, which are allocated to electric and diesel trains based on the cost drivers mentioned in Table 21. See also section 4.3 of CE Delft (2019a).

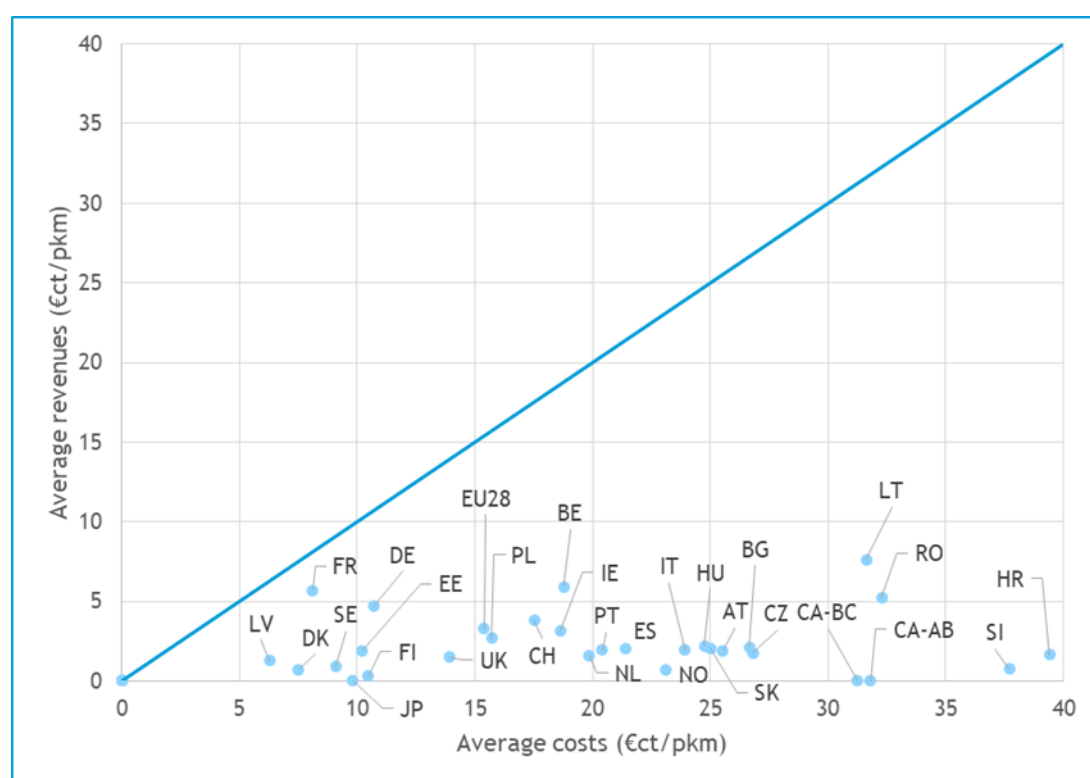
rail networks of France and Germany (including significant market shares of high speed trains) can explain a lower average infrastructure cost (i.e., €ct 8.1 and 10.7 per pkm).

For non-EU countries, Japan is the only country below the EU28 average (i.e., €ct 9.8 per pkm), Switzerland is relatively close (i.e., €ct 17.5 per pkm) and Norway found higher (i.e., €ct 23.1 per pkm).

The average revenue at EU28 level from infrastructure access charges is €ct 3.3 per pkm. The highest average revenues are found for Belgium, France, Lithuania and Romania, which could be influenced by the relatively high infrastructure access charges of these countries (i.e., €ct 5.9, 5.7, 7.6 and 5.2 per pkm, respectively).

For non-EU countries, Norway and Switzerland, where they are found lower and higher than the EU28 average (i.e., €ct 0.7 and 3.8 per pkm, respectively).

Figure 54 - Spread of overall infrastructure cost coverage - Rail passenger transport (magnified subset)



Note: Cyprus and Malta do not have operating rail networks. Data is not available for California and Missouri.

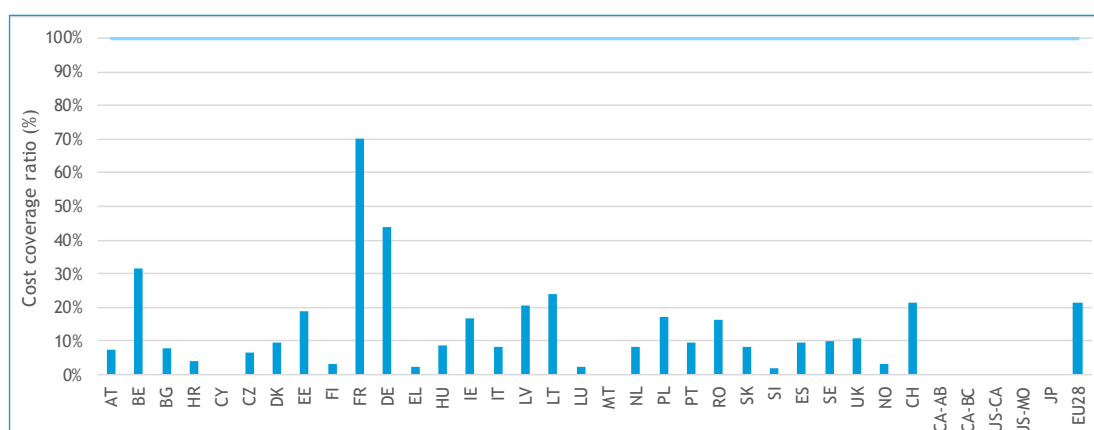
Figure 55 shows the infrastructure costs coverage ratios, which at EU28 level is found equal to 21%.

Only four Member States are above the average. The three Baltic States are relatively close, being in the 19%-24% interval. Belgium, France and Germany have an even higher cost coverage ratio (i.e., 31%, 70% and 44%, respectively), which could depend on the relatively high access charges levied by the national infrastructure managers on passenger trains⁷⁴. On the other hand, Croatia, Finland, Greece, Luxembourg and Slovenia show the lowest cost coverage ratios, being in the 2%-4% interval. This result depends on the low level found of revenues from infrastructure access charges.

It is worth noting that, in general for the Member States, the infrastructure access charges schemes are based (at least partially) on the principle of marginal cost pricing. This may explain why the average revenues are always found significantly lower than the average cost, and hence below the line of full cost coverage.

For non-EU countries the cost coverage of Norway is very low (i.e., 3%). As previously noted regarding the overall total cost coverage ratio, infrastructure access charges have been just introduced in 2017 to prevent perturbations of the circulation and are calculated with respect to the social marginal cost, in order to stimulate a modal shift to railway from other transport modes⁷⁵. Eventually, infrastructure access charges for passenger trains are applied to rail undertakings in California and Japan, but the data either cannot be disclosed for confidentiality reasons or is not available.

Figure 55 - Overall infrastructure cost coverage ratio - Rail passenger transport



Note: Cyprus and Malta do not have operating rail networks. Data is not available for California and Missouri.

Variable infrastructure cost coverage ratio

Figure 56 presents the spread of variable infrastructure cost coverage, comparing revenues from infrastructure access charges with the estimations of the variable infrastructure costs (i.e., the variable part of renewal and maintenance costs).

⁷⁴ For Belgium, the infrastructure access charges levied to high speed trains are very high (i.e., € 20.32 per train-km), but the limited transport activity of this type of train contributes to a small share of the total revenues (i.e., 8%). For France, the infrastructure access charges of high speed trains are the lowest amongst the countries providing this type of service (i.e., € 5.79 per train-km), but the very high transport activity of this type of service allows for generating some 48% of the total revenues from infrastructure access charges.

⁷⁵ See Footnote 71.

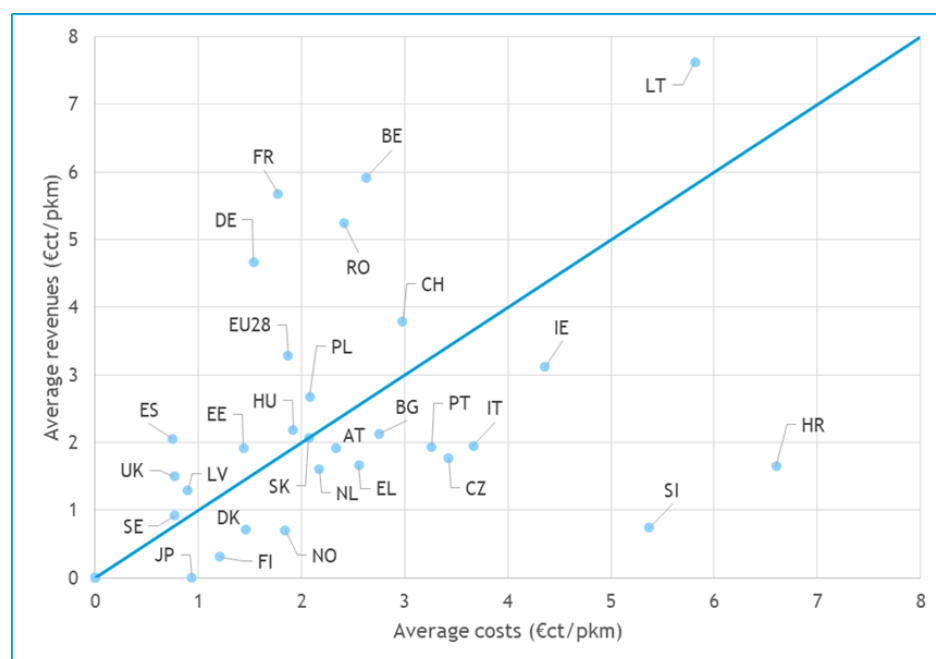
The average revenues do not change with respect to the infrastructure access charges revenues considered in the subsection above. On the other hand, the magnitude of the average costs significantly reduces not considering the fixed cost components (i.e., construction, fixed renewal, operational and fixed maintenance). This implies that the overall spread has moved to the left, showing a relatively balanced distribution around the diagonal of full cost coverage.

At EU28 level, the average variable infrastructure cost is equal to €ct 1.87 per pkm, which is around (i) 12% of the average of all infrastructure costs (i.e., €ct 15.4 per pkm) and (ii) 175% of the average revenue from infrastructure access charges (i.e., €ct 3.3 per pkm). This indicates that the variable infrastructure cost components allocated to passenger trains are, in general, internalised by the average revenues from infrastructure access charges.

For seventeen Member States the average variable infrastructure cost is found above the EU28 average, especially for Croatia, Lithuania and Luxembourg, and the latter extends beyond the x-axis displayed in the magnified subset (i.e., €ct 14.0 per pkm). On the other hand, the average variable infrastructure cost is found lower in Latvia, Spain, Sweden and the United Kingdom.

For non-EU countries, the average variable infrastructure cost of Norway is found close to the average at EU28 level (i.e., €ct 1.8 per pkm), while for Switzerland is higher (i.e., €ct 3.0 per pkm).

Figure 56 - Spread of overall variable infrastructure cost coverage - Rail passenger transport



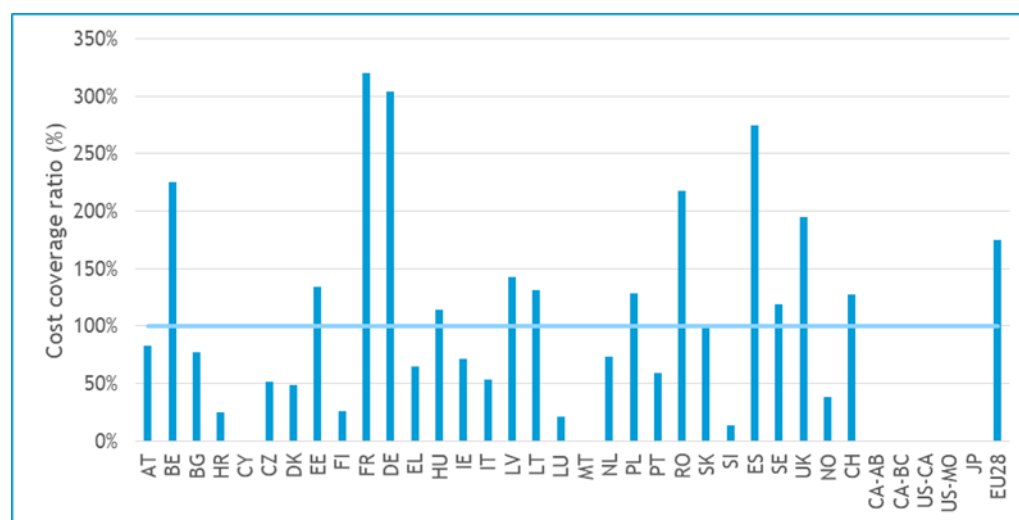
Note: Cyprus and Malta do not have operating rail networks. Data is not available for US and Canada.

Figure 57 shows the corresponding variable infrastructure cost coverage ratios. As noted above, they are found to be higher in respect to the previous subsection, because the revenues are unchanged in the numerator and only variable cost components are considered in the denominator.

At EU28 level, the cost coverage ratio is found equal to 175%. Amongst the Member States, 12 have the average revenues higher than full cost coverage ratio. Notably, they are significantly higher for Belgium, France, Germany, Romania, Spain and the United Kingdom⁷⁶. Croatia, Finland, Luxembourg and Slovenia have a cost coverage ratio that is significantly low, because of the high average variable infrastructure cost.

For non-EU countries, the cost coverage ratio of Norway is very low (i.e., 38%), while for Switzerland it is higher, but relatively comparable to that at EU28 level (i.e., 127%).

Figure 57 - Overall variable infrastructure cost coverage ratio - Rail passenger transport



Note: Cyprus and Malta do not have operating rail networks. Data is not available for US and Canada.

⁷⁶ Except for Romania, all the other countries have high speed networks with infrastructure access charges calculated to cover the higher fixed costs of such networks. This also (partly) explain why these countries scores high at the other indicators.

5.2.2 Rail freight transport

Overall cost coverage ratio

Figure 58 shows the spread of the overall cost coverage, comparing average revenues from all internalisation measures⁷⁷ against all external and infrastructure costs⁷⁸.

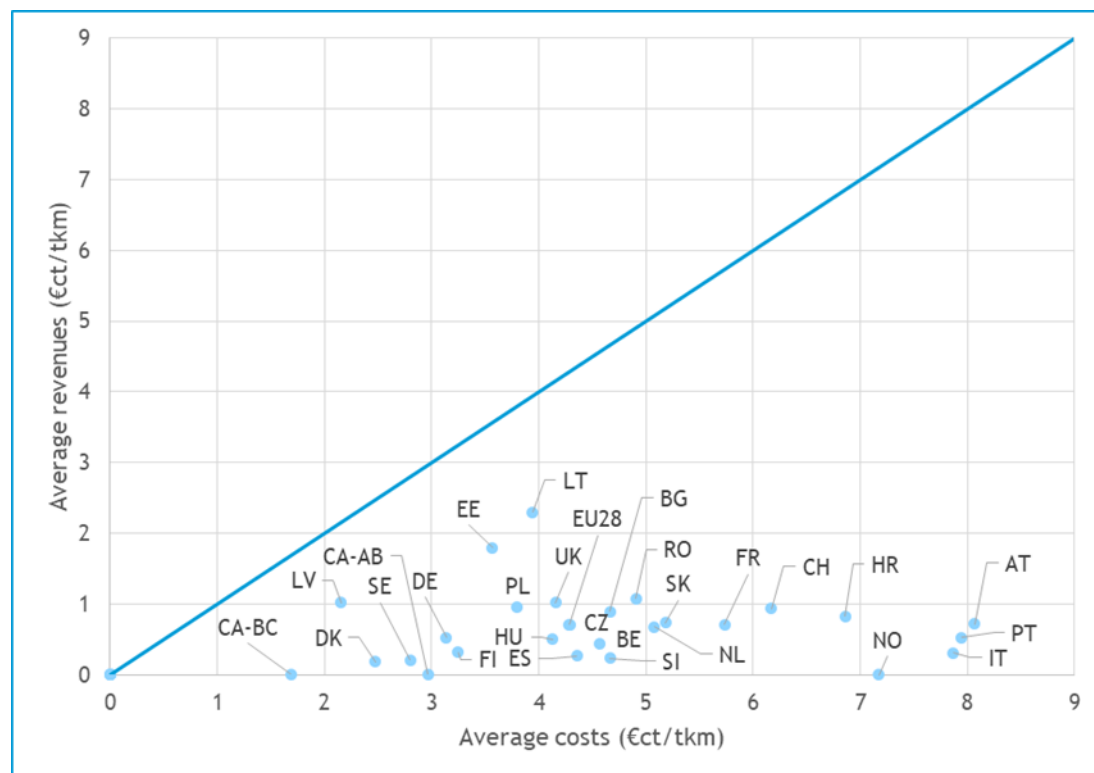
As found for rail passenger transport, the average revenues from all internalisation measures levied to rail freight transport are very low relative to total average external and infrastructure costs, across all countries. This result depends on the high share of the average infrastructure costs of railway networks, which at EU28 level is equal to around 70% of the total external and infrastructure costs (i.e., €ct 3.0 against €ct 4.3 per tkm, or € 15.7 against € 22.5 per train-km). For freight trains, the average revenues from infrastructure access charges do not cover the average infrastructure costs and the revenues from other internalisation measures are negligible.

Another pattern shown in the figure is that average total costs vary widely between countries, with the minimum found for Latvia (i.e., €ct 2.2 per tkm) and the maximum for Luxembourg (i.e., €ct 26.1 per tkm), which along with Ireland and Greece (i.e., €ct 12.5 and €ct 19.8 per tkm, respectively), extends beyond the x-axis displayed in the magnified subset. The outcome found for Luxembourg, Greece and Ireland depends on the low transport performance of this train type at country level.

⁷⁷ Revenues from all internalisation measures consider: fuel excise, electricity tax, infrastructure access charges, infrastructure access charges of specific part of the infrastructure (for countries where applicable) and ETS.

⁷⁸ External costs consider the following categories: accidents, air pollution, climate change, noise, WTT and habitat. As regards the infrastructure costs, the average costs are assumed. Congestion cost is not applicable for this transport mode.

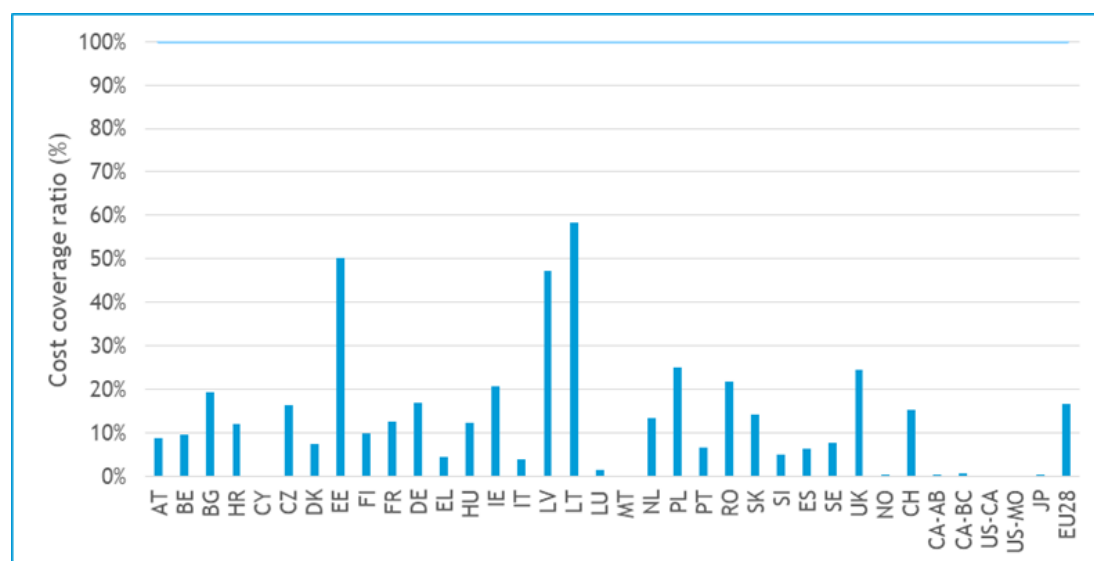
Figure 58 - Spread of overall total cost coverage - Rail freight transport



Note: Cyprus and Malta do not have operating rail networks. Data is not available for California and Missouri.

Figure 59 shows the total cost coverage ratio. At EU28 level, the total cost coverage ratio is equal to 17%. The three Baltic states, alongside with Poland and Romania, show higher cost coverage ratios, which depend on the relatively high access charges levied by the infrastructure managers. For the other countries, the average at EU28 level is close to that found for Switzerland (i.e., 15%).

Figure 59 - Overall total cost coverage ratio - Rail freight transport



Note: Cyprus and Malta do not have operating rail networks. Data is not available for California and Missouri.

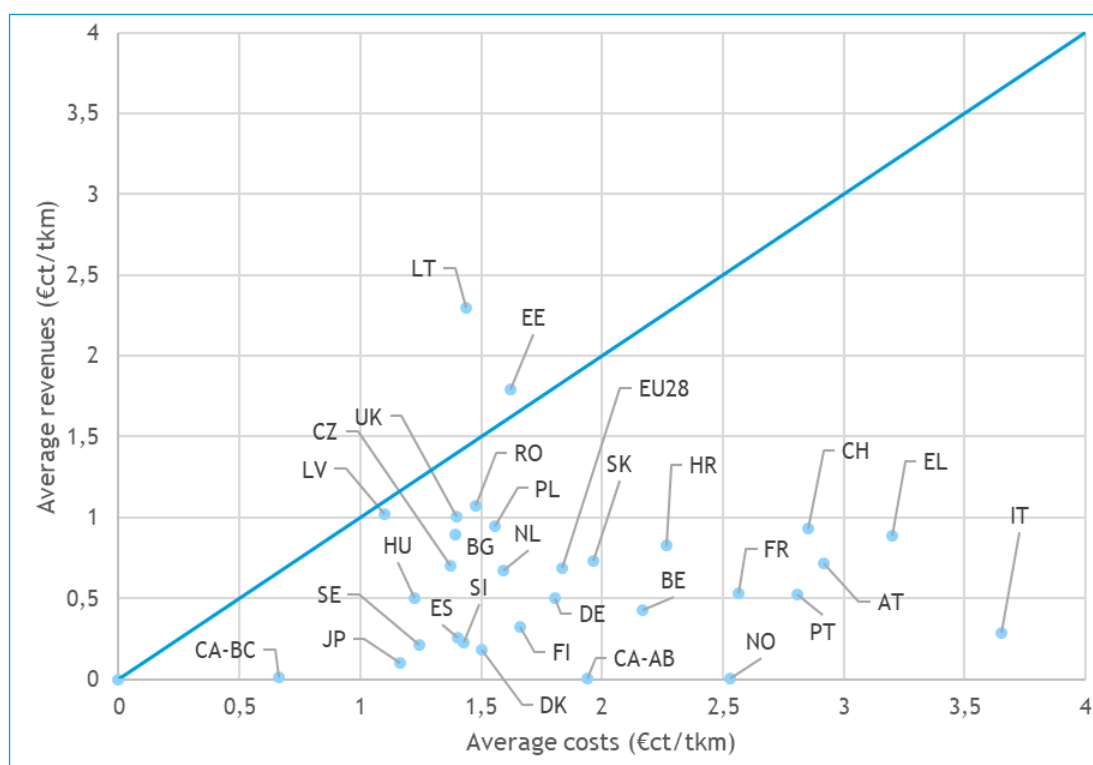
Overall cost coverage ratio excluding fixed infrastructure costs

Figure 60 shows the spread of total cost coverage with variable infrastructure costs, measuring average revenues from all internalisation measures against all average external and variable infrastructure costs⁷⁹ allocated to rail freight transport.

At EU28 level, the average external and variable infrastructure cost is €ct 1.8 per tkm (i.e., € 9.6 per train-km) and the average revenue is found equal to €ct 0.7 per tkm (i.e., € 3.7 per train-km). The spread of the magnified subset shows that both average costs and revenues vary in a relatively wide interval. The minimum cost is found for Latvia (i.e., €ct 1.1 per tkm) and the maximum for Italy (i.e., €ct 3.7 per tkm). Regarding the average revenues, Denmark shows the minimum value (i.e., €ct 0.2 per tkm) and Lithuania the maximum (i.e., €ct 2.3 per tkm). Ireland and Luxembourg can be considered as outliers, with average costs equal to €ct 6.2 per tkm and €ct 6.6 per tkm, respectively, being beyond the x-axis displayed in the magnified subset.

For the other countries, Switzerland shows a higher average cost compared to the EU28 level (i.e., €ct 2.9 per tkm). The average revenue of Switzerland is slightly above that found at EU28 level (i.e., €ct 0.9 per tkm).

Figure 60 - Spread of overall total cost coverage with O&M costs - Rail freight transport (magnified subset)

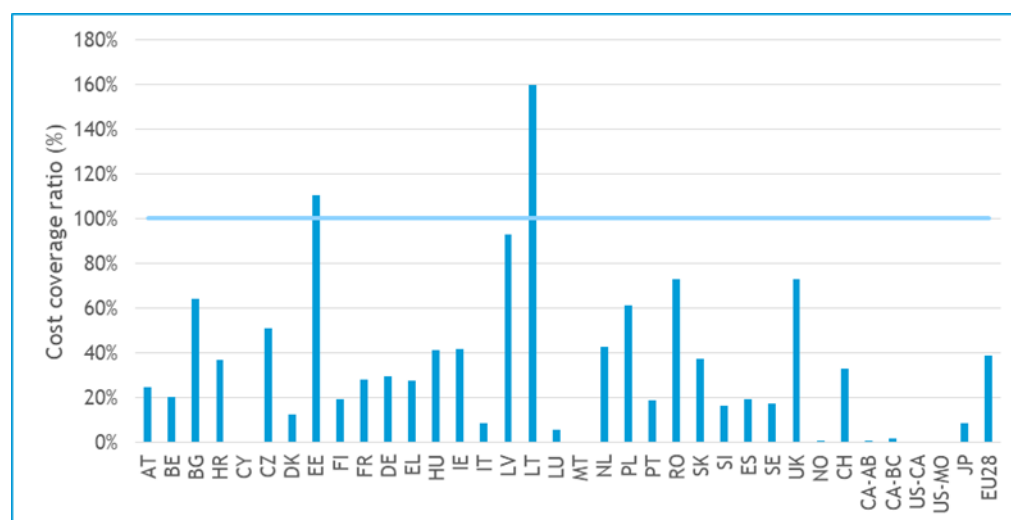


Note: Cyprus and Malta do not have operating rail networks. Data is not available for California and Missouri.

⁷⁹ Variable infrastructure costs consist of the traffic-dependent renewal and O&M costs.

Figure 61 shows the cost coverage ratios, where the average at EU28 level is found equal to 37%. The full cost coverage ratio is achieved only by Estonia and Lithuania, while Latvia is below, but relatively close. Denmark, Italy, Luxembourg and Slovenia show the lowest cost coverage ratios for this train type, being in the interval 5-16%. This depends on the low access charges level found for these countries. As explained for passenger transport, this basically depends on the high infrastructure access charges found for freight trains. For the other countries, Switzerland shows a cost coverage ratio relatively close to that found at EU28 level and equal to 33%.

Figure 61 - Overall cost coverage ratio excluding fixed infrastructure costs - Rail freight transport



Note: Cyprus and Malta do not have operating rail networks. Data is not available for California and Missouri.

Variable external and infrastructure cost coverage ratio

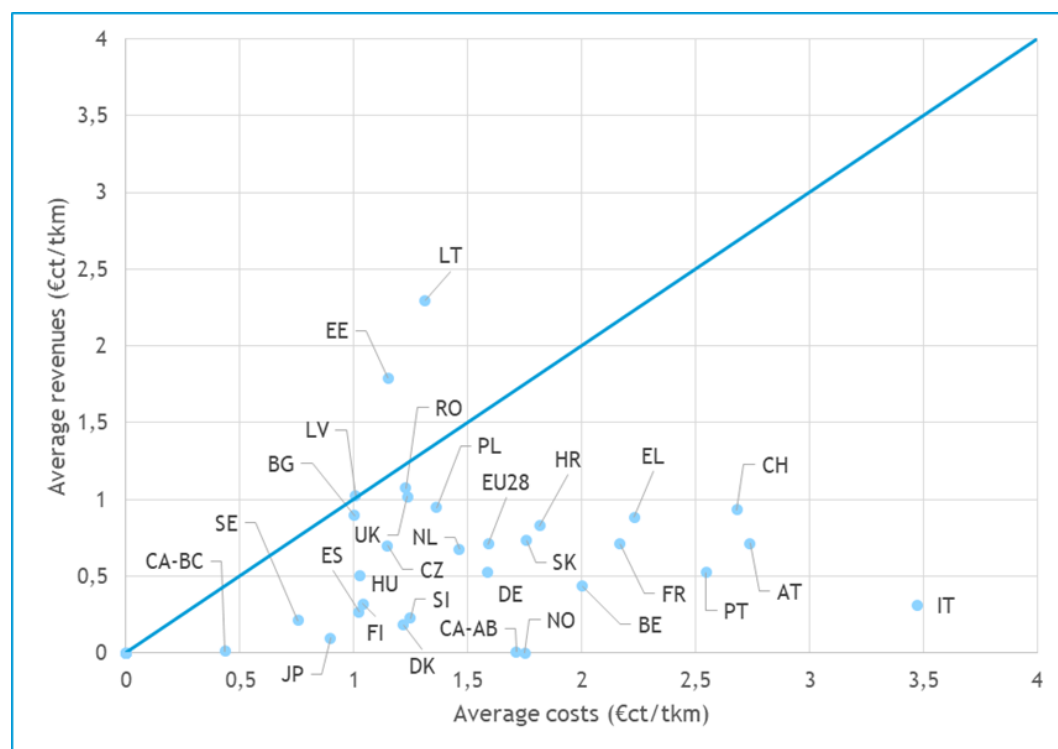
Figure 62 shows the spread of the variable cost coverage, comparing revenues from variable taxes and charges against variable external and infrastructure costs. Variable taxes and charges cover infrastructure access charges, ETS, and fuel/energy taxes. Variable external costs are all those except for habitat costs, while variable infrastructure costs cover O&M and renewal costs dependent on traffic levels.

The overall picture is similar to the one presented in the subsection above, with the same average variable revenues and variable infrastructure costs, but lower external costs, having excluded the average habitat external cost. This implies that the spread has moved to the left-hand side of the costs/revenues graph.

At EU28 level, the average external and O&M cost is now €ct 1.6 per tkm compared to the previous €ct 1.8 per tkm. Alongside with previously noted Estonia and Lithuania, now only Latvia has moved to the region of the plan where the average revenues are higher than the average costs. Because of the exclusion of the habitat cost, on average at EU28 level, the variable external cost is €ct 0.2 per tkm lower. The highest reductions are noted for Greece and Ireland (i.e., €ct 1.0 and 1.4 per tkm, respectively). Luxembourg can be considered an outlier, showing a slightly lower outcome compared to the previous one (i.e., €ct 6.2 against €ct 6.6 per tkm) and still extending beyond the x-axis displayed in the magnified subset.

For the non-EU countries, the reduction of the average cost is more significant for Norway, which is now equal to €ct 1.7 per tkm against €ct 2.5 per tkm. The average cost of Switzerland is relatively unchanged (i.e., €ct 2.7 per pkm against €ct 2.9 per tkm).

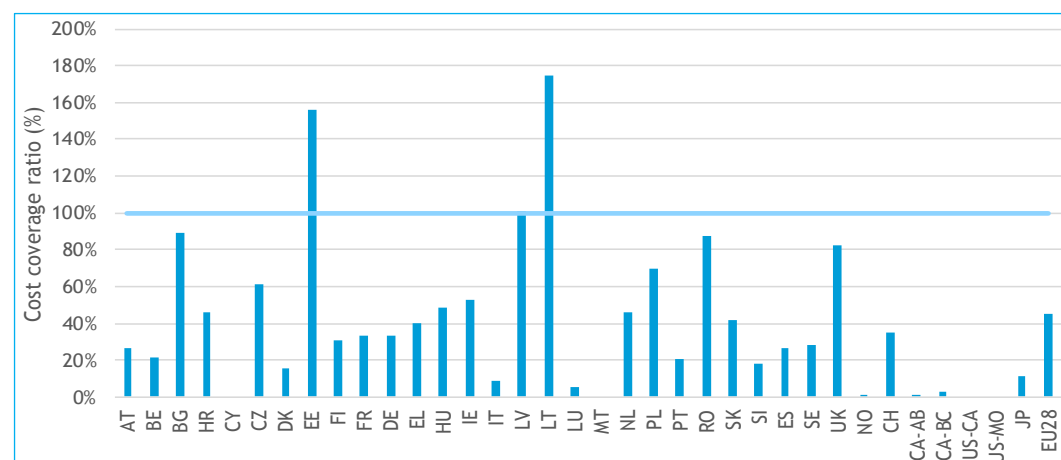
Figure 62 - Overall spread of variable cost coverage - Rail freight transport (magnified subset)



Note: Cyprus and Malta do not have operating rail networks. Data is not available for California and Missouri.

Figure 63 shows the overall total variable cost coverage ratio. At EU28 level, the overall level of cost coverage attained under this indicator is slightly higher than that found under the overall total cost coverage with variable infrastructure costs (i.e., 45% against 37%).

Figure 63 - Overall total variable cost coverage ratio - Rail freight transport



Note: Cyprus and Malta do not have operating rail networks. Data is not available for California and Missouri.

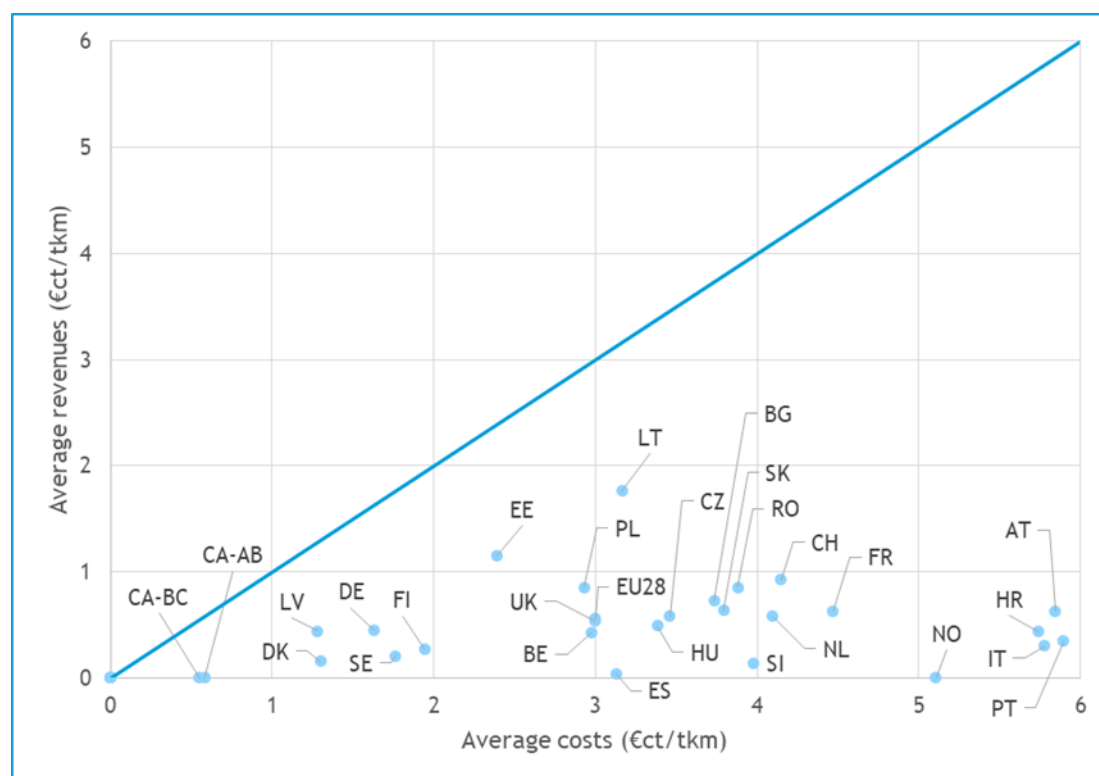
Overall infrastructure cost coverage ratio

Figure 64 shows the spread of overall infrastructure cost coverage for rail freight transport, comparing average revenues from infrastructure access charges⁸⁰ against all average infrastructure costs.

At EU28 level, the average infrastructure cost of freight trains is found equal to €ct 3.0 per tkm (i.e., € 15.7 per train-km). As for passenger trains, in general, the highest average infrastructure costs of freight trains are estimated for countries with relatively high network costs and associated with small networks or limited transport activity. This is the case for Greece, Ireland and Luxembourg, which extend beyond the x-axis displayed in the magnified set (i.e., €ct 17.3, €ct 7.8 and €ct 22.5 per tkm, respectively). For non-EU countries, Switzerland and Norway are relatively close to the EU28 average (i.e., €ct 4.1 and 5.1 per tkm).

The average revenue from infrastructure access charges is found equal to €ct 0.6 per tkm (i.e., € 2.8 per train-km). The highest average revenues are found for Ireland and Lithuania, which depends on the relatively high infrastructure access charges levied (i.e., €ct 2.4 and €ct 1.8 per tkm, respectively). For non-EU countries, values of the average revenues are available for Switzerland only, where they are found higher than the EU28 average (i.e., €ct 0.9 per tkm). In Norway, freight rail undertakings are not charged for network usage to stimulate modal shift from other modes to railway⁸¹.

Figure 64 - Spread of overall infrastructure cost coverage - Rail freight transport (magnified subset)



Note: Cyprus and Malta do not have operating rail networks. Data is not available for California and Missouri.

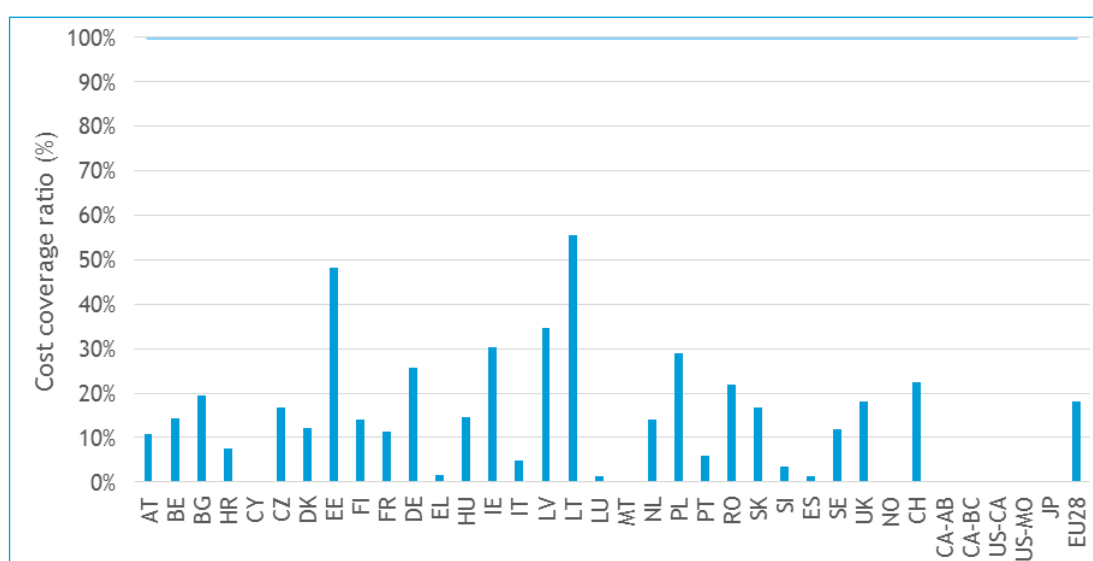
⁸⁰ For countries where necessary, access charges on specific parts of the infrastructure have been considered.

⁸¹ IRG-Rail (2015).

Figure 65 shows the infrastructure cost coverage ratios. At EU28 level, the infrastructure cost coverage ratio is found equal to 19% and 8 Member States only are found above this value. Notably, the Baltic States are significantly above the average, being in the 35%-56% interval and this depends on the relatively high access charges levied by the infrastructure managers. For non-EU countries, the cost coverage of Switzerland is relatively close to that found at EU28 level (i.e., 22%).

As discussed for passenger rail mode, in general for the Member States, the infrastructure access charges schemes are based (at least partially) on the principle of marginal cost pricing. Again, this explains why the average revenues are significantly lower than the average costs, and hence below the diagonal of full cost coverage.

Figure 65 - Overall infrastructure cost coverage ratio - Rail freight transport



Note: Cyprus and Malta do not have operating rail networks. Data is not available for California and Missouri.

Variable infrastructure cost coverage ratio

Figure 66 presents the spread of variable infrastructure cost coverage, comparing average revenues from infrastructure access charges against the estimations of the variable average infrastructure costs (i.e., the variable part of renewal and maintenance costs).

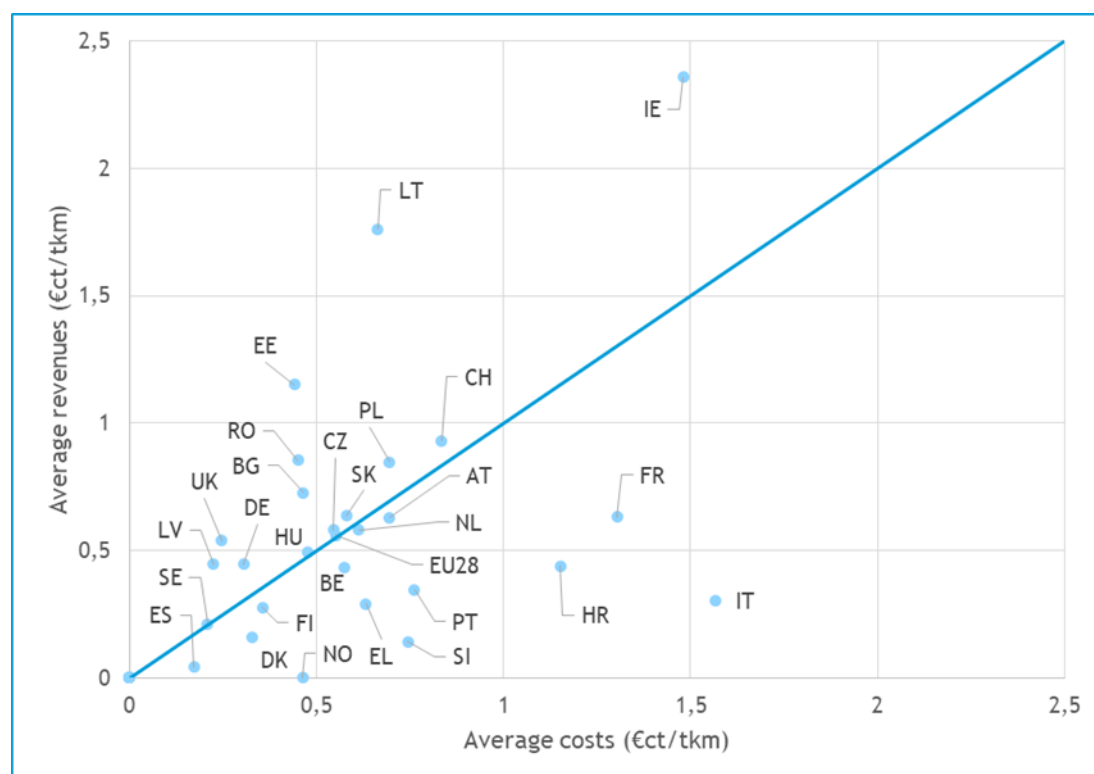
The average revenues do not change with respect to the revenues considered in the subsection above. The magnitude of the average cost changes not having considered the fixed cost components for this ratio (i.e., enhancement, fixed renewal, operational and fixed maintenance). This implies that the spread has moved to the left-hand side of the graph and it is now relatively balanced around the diagonal of full cost coverage.

At EU28 level, the average variable cost is equal to €ct 0.55 per tkm (i.e., € 2.9 per train-km), which is around (i) 18% of the average of all infrastructure cost (i.e., €ct 3.0 per tkm, or € 15.7 per train-km) and (ii) 99% of the average revenue from infrastructure access charges (i.e., €ct 0.56 per tkm, or € 2.9 per train-km). This means that for freight trains, the average variable infrastructure costs allocated to these train types are also balanced by the average revenues from infrastructure access charges.

For 14 Member States the average variable infrastructure cost is found above the EU28 level and higher especially in France, Ireland, Italy and Luxembourg, which extends beyond the x-axis displayed in the magnified subset (i.e., €ct 3.1 per tkm). On the other hand, the average variable infrastructure cost is found low in Denmark, Germany, Latvia, Spain, Sweden and the United Kingdom.

For non-EU countries, the average variable infrastructure cost of Switzerland is higher than that found at EU28 level (i.e., €ct 0.8 per tkm, or € 3.7 per train-km).

Figure 66 - Spread of overall variable infrastructure cost coverage - Rail freight transport (magnified subset)



Note: Cyprus and Malta do not have operating rail networks. Data is not available for US and Canada.

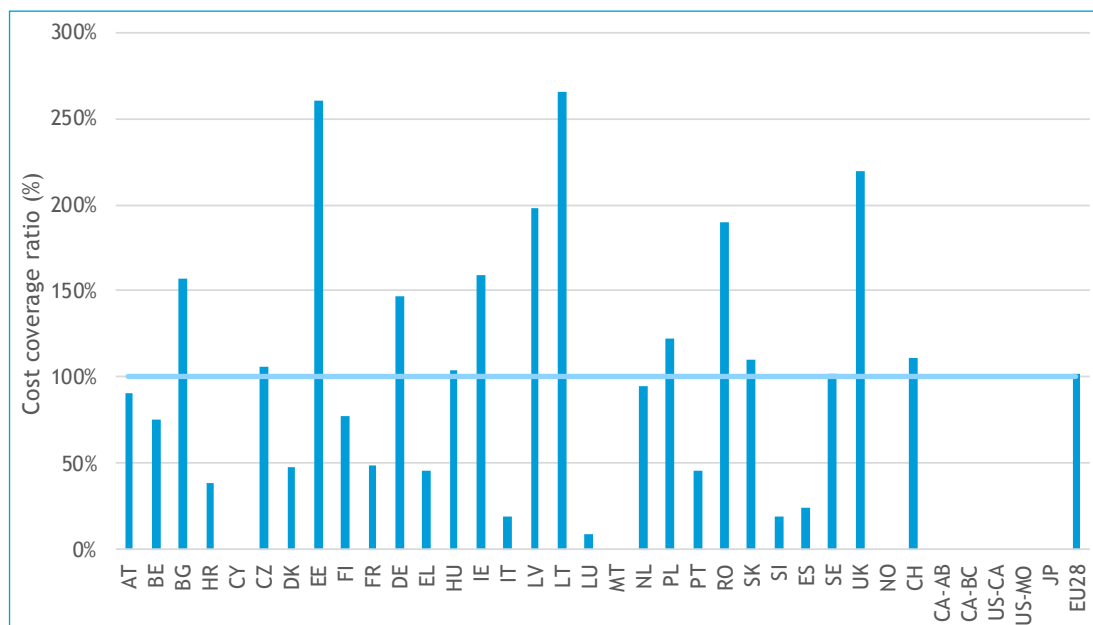
Figure 67 shows the corresponding variable infrastructure cost coverage ratios. As previously discussed, they are higher now because the average revenues are unchanged in the numerator and only variable cost components are in the denominator.

At EU28 level, the cost coverage ratio is found equal to 102%. Amongst the Member States, 13 are found having average revenues higher than average variable infrastructure costs. Notably, they are significantly higher for the Baltic States, Romania and the United Kingdom⁸². The cost coverage ratio remains low for Italy, Luxembourg, Slovenia and Spain.

⁸² For the Baltic States, the infrastructure access charges are found high, which is explained by the higher permitted axle-loads, allowing for trains of 3,000 tonnes on average (AECOM, 2011). The charging level could reflect a higher cost-recovery objective of these countries (see also OECD-IFT, 2008). For Romania, until recently, the access charges were much higher for freight than for passengers, partly because the State was unable to pay for the full cost of Public Service Compensation for passenger services and the freight rail

For non-EU countries, the cost coverage ratio of Switzerland is relatively comparable to that at EU28 level (i.e., 112%).

Figure 67 - Overall variable infrastructure cost coverage ratio - Rail freight transport



Note: Cyprus and Malta do not have operating rail networks.

5.3 Marginal social cost-based internalisation

This section presents the ratio of the marginal external⁸³ and infrastructure costs with the marginal tax/charge revenues for three scenarios, which differ with respect to the level of external average costs (i.e. high, representative and low) and hence by the main cost drivers of the external costs⁸⁴.

As previously presented in Section 2.4.2, there are a number of key attributes of marginal cost coverage scenarios to consider when analysing the results.

undertaking cross-subsidised these services (Romania, 2013). For UK, the charging scheme is based on marginal cost, but freight rail undertakings, carrying certain type of commodities are charged to some of the infrastructure manager fixed costs.

⁸³ Marginal external costs considered are: accidents, air pollution, climate change, noise and WTT. Estimates on congestion cost (i.e. scarcity costs) are not available for this transport mode.

⁸⁴ The scenarios developed also assume a differentiation with respect to the time of the day to consider if a train type runs by night or daytime. Such differentiation applies to infrastructure access charges in some Member States and may depend on the actual level of capacity of the network. The differentiation by time of the day also involves the external costs of noise emissions, which generates a different level of disturbance to the affected population living nearby railway lines.

Considerations with respect to marginal cost scenarios

When interpreting the results of the marginal cost coverage analyses, the following issues with respect to the marginal cost scenarios should be considered:

- The high and low-cost scenarios considered are sometimes a bit extreme, in order to reflect cases with high or low marginal external cost values. As a consequence, these scenarios are not necessarily reflecting cases that are fully representative of real-world situations.
- The scenarios are defined based on the level of external costs. The marginal cost coverage ratios, however, are also driven by marginal infrastructure costs and taxes/charges. Therefore, low marginal cost coverage ratios may be found for low external cost scenarios, if marginal infrastructure costs are relatively high or tax/charge levels relatively low.

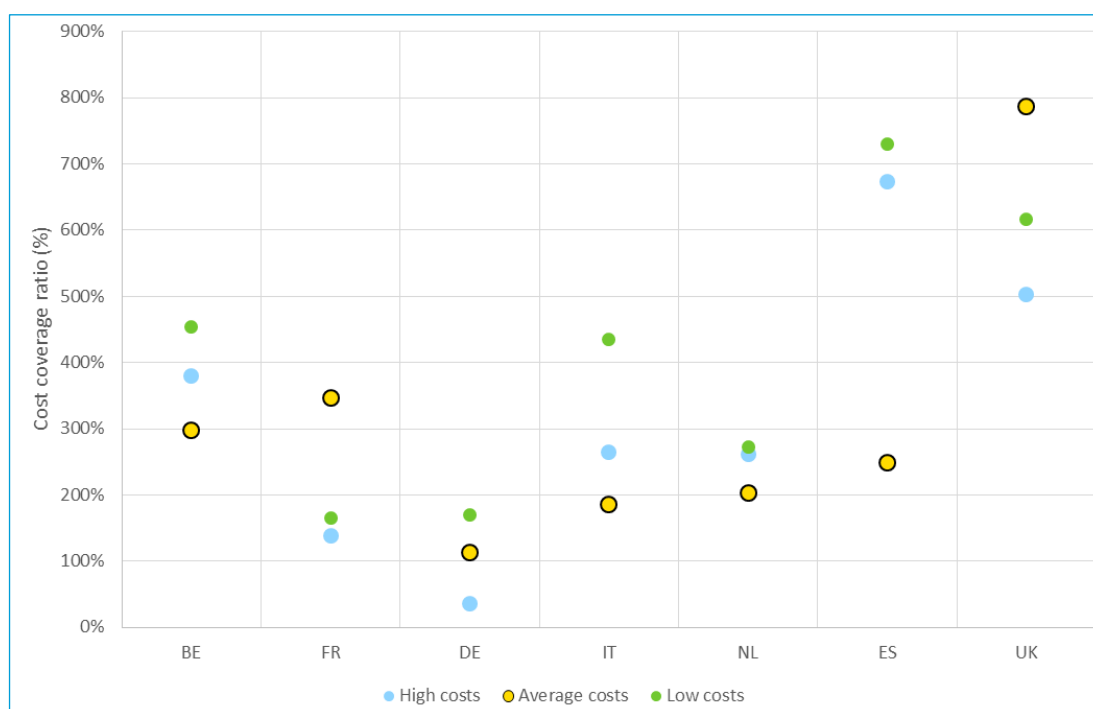
5.3.1 High Speed Train

For high speed trains the marginal cost scenarios are distinguished with respect to the time of the day, by assuming (i) a night situation for the high external cost scenario, (ii) an average daytime/night for the representative scenario and (iii) a daytime situation for the low external cost scenario.

Figure 68 shows the marginal cost coverage ratio for the countries where high speed trains are operated. The full marginal cost coverage threshold is achieved across all countries, except for Germany when the high external cost scenario is assumed.

The relatively large variance in marginal cost ratios for the three scenarios found for most countries illustrates the difficulties to implement pure marginal social cost pricing. The marginal taxes/charges do not perfectly reflect the marginal costs in all cases.

Figure 68 - Marginal cost coverage ratio - High speed train

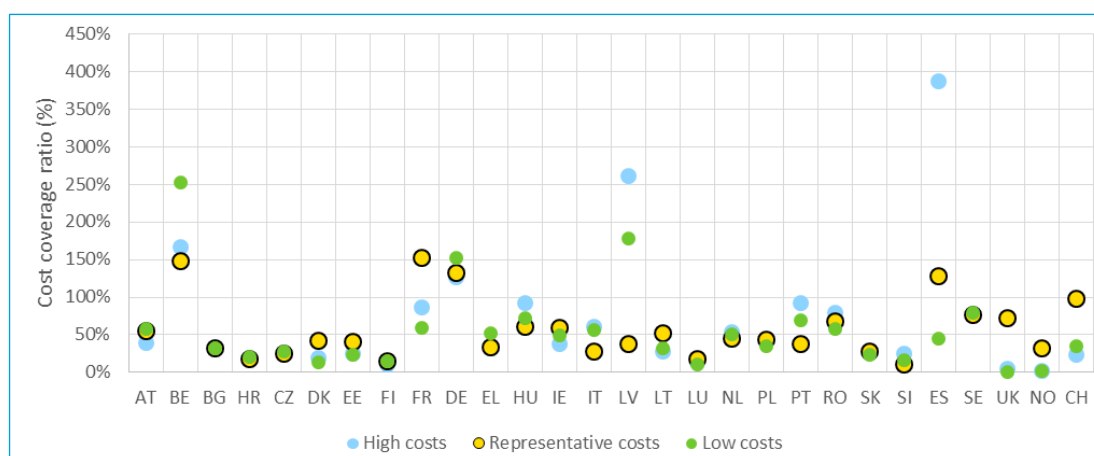


5.3.2 Passenger electric train

For passenger electric trains the marginal external cost scenarios are distinguished with respect to type of trains and time of the day, by assuming (i) a regional train in a daytime situation for the high external cost scenario, (ii) an average passenger train and daytime/night for the representative scenario and (iii) an intercity train in a daytime situation for the low external cost scenario.

Figure 69 shows the marginal cost coverage ratios for this train type, which are found below the threshold of full cost coverage for almost all the situations assumed. With some distinctions regarding the external cost scenario assumed, Belgium, France, Germany, Latvia, and Spain are exceptions in this respect. In many countries, however, the marginal cost coverage ratios are broadly constant over the scenarios, indicating that the access charges in these countries show some relevant aspects of marginal social cost pricing. This can be explained by the fact that access charges in these countries are calculated with respect to marginal infrastructure costs.

Figure 69 - Marginal cost coverage ratio - Passenger electric train



Note: Cyprus and Malta do not have operating rail networks.

5.3.3 Passenger Diesel Train

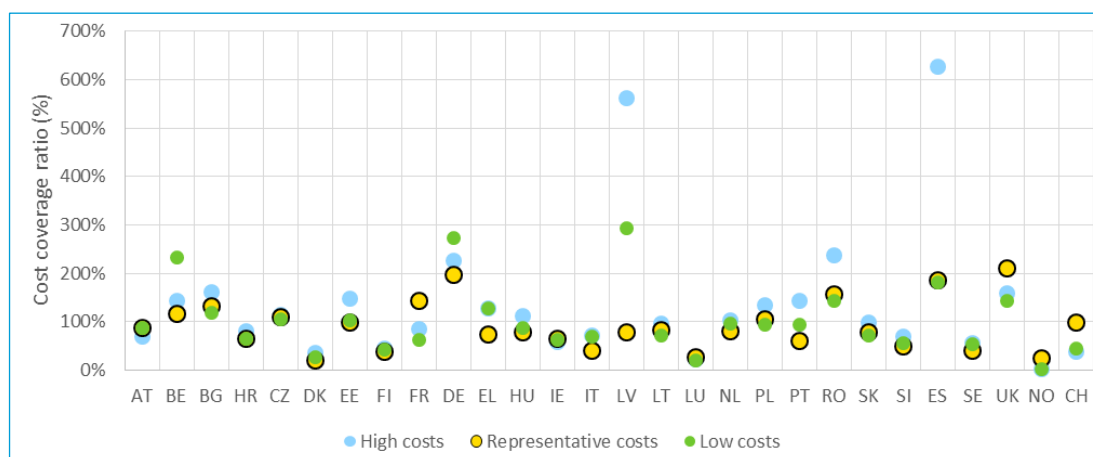
For passenger diesel trains, the marginal external cost scenarios are distinguished with respect to type of train, emission control technology (i.e., EGR/SCR⁸⁵) and time of the day, by assuming (i) a regional train not equipped with EGR/SCR in a daytime situation for the high external cost scenario, (ii) an average passenger train and day/night time for the representative scenario and (iii) an intercity train equipped with EGR/SCR in a daytime situation for the low external cost scenario.

Figure 70 shows the marginal cost coverage ratios for this train type. The marginal external costs are generally higher compared to those found for the electric trains and basically because of the introduction of air pollution and climate change cost components. Despite this, the number of countries where the marginal revenue (per pkm) is higher than the marginal cost is increased. This can be explained by the fuel tax, which is on average higher

⁸⁵ Exhaust Gas Recirculation and Selective Catalytic Reduction, respectively.

than the electricity tax charged to rail transport. Notably, for Belgium, Bulgaria, the Czech Republic, Germany, Romania, Spain and the UK this occurs across all assumed scenarios. As for passenger electric trains, it is shown that the marginal cost coverage ratios are rather constant over the scenarios, indicating that the access charges are calculating with (some) respect to marginal social cost pricing.

Figure 70 - Marginal cost coverage ratio - Passenger diesel train



Note: Cyprus and Malta do not have operating rail networks.

5.3.4 Freight electric train

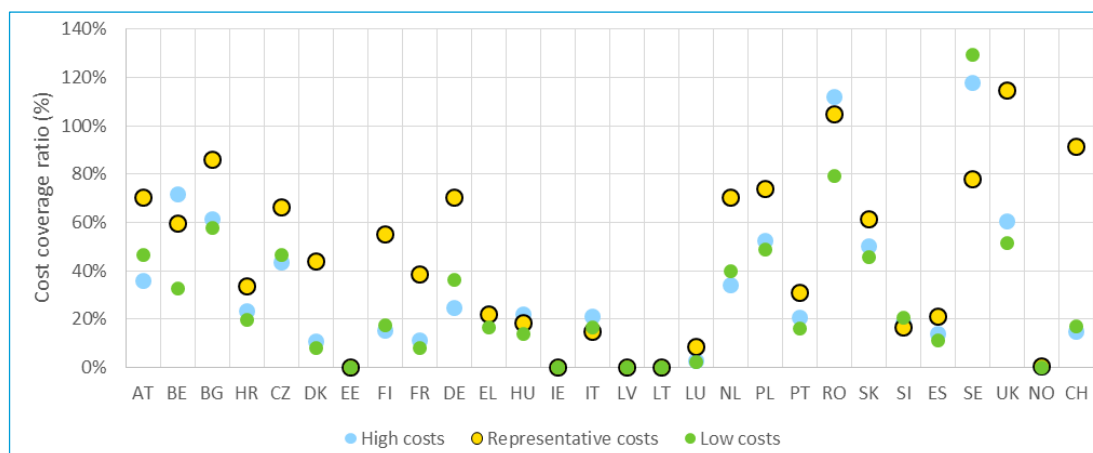
For freight electric trains, the marginal external cost scenarios are distinguished with respect to type of train, time of the day and noise emission level by assuming (i) a short freight train (bulk) in a daytime situation and with high noise level for the high external cost scenario, (ii) an average freight train and day/night time for the representative scenario and (iii) a long freight train (bulk) in a daytime situation and with low noise level for the low external cost scenario.

Figure 71 shows the marginal cost coverage ratios for this train type. In general, the marginal external costs are found higher than the marginal revenues across all countries and cost scenarios, with the few exceptions of Romania, Sweden and the United Kingdom.

It is worth reminding that cost drivers do not always affect the various externalities in the same way. This can explain the variability of the results found across the three scenarios developed, which are higher for the representative case, compared to the other two scenarios for most countries. This seems to be the result of rather high access charges in this scenario compared to the others. Furthermore, marginal cost coverage ratios are rather close over the high and low-cost scenarios, which suggests that the access charges are calculate with (some) respect to marginal social cost pricing.

For the low external cost scenario, the cost coverage ratios are generally lower compared to the other two. This can depend on the lower external costs of noise for this scenario and the lower revenue per tkm due to the higher load of the long bulk freight trains.

Figure 71 - Marginal cost coverage ratio - Freight electric train



Note: Cyprus and Malta do not have operating rail networks.

5.3.5 Freight diesel train

For freight diesel trains, the marginal cost scenarios are distinguished with respect to type of train, time of the day, noise emission level and emission control technology (i.e., EGR/SCR⁸⁶) by assuming (i) a short freight train (bulk) in a daytime situation, with high noise level and equipped with EGR/SCR for the high external cost scenario, (ii) an average freight train and day/night time for the representative scenario and (iii) a long freight train (bulk) in a daytime situation, with low noise level and equipped with EGR/SCR for the low external cost scenario.

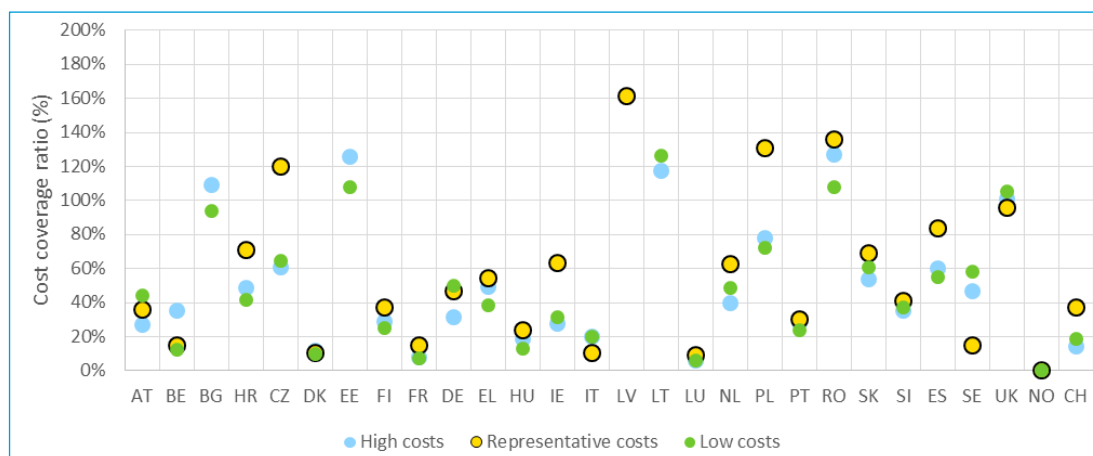
Figure 72 shows the marginal cost coverage ratios for this train type. For the high and low external cost scenarios, the marginal external costs are generally lower than marginal revenues. With respect to the freight electric trains, the distribution of the outcomes is relatively comparable, although the marginal external cost is higher (because of the introduction of air pollution and climate change cost components) and the marginal revenue is also found to have increased (due to the high fuel tax found per tkm⁸⁷). Exceptions are Estonia, Latvia, Lithuania and Romania, which show ratios higher than the full cost coverage ratio and basically because of the high level of fuel tax found for these countries.

As far as the representative scenario is concerned, the marginal costs are higher than the marginal revenues and the differences between the values are found generally increased when compared to the high and low external cost scenarios (see Figure 73). This depends on the way the marginal external costs and revenues from taxes have been assumed for this case. In particular, the external costs of air pollution are significantly higher and the level of fuel taxation is lower when compared to the values assumed for low and high external cost scenarios. The results at country level are fairly comparable against the other two scenarios analysed in terms of cost coverage ratio, being just Bulgaria and Poland added to the previously noted countries above the full cost coverage ratio.

⁸⁶ Cited above.

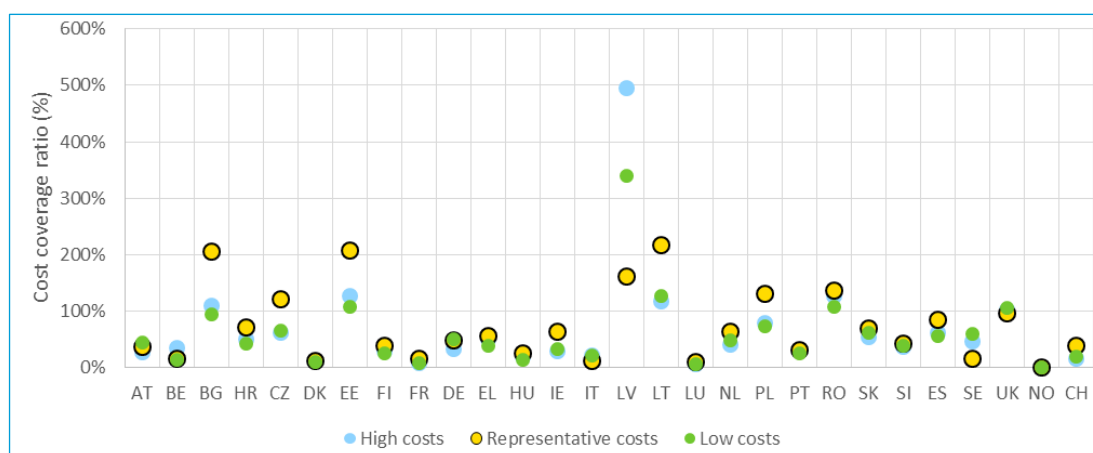
⁸⁷ With the exception of Belgium, Hungary and Sweden where a fuel tax is not charged.

Figure 72 - Marginal cost coverage ratio - Freight diesel train (magnified subset)



Note: Cyprus and Malta do not have operating rail networks.

Figure 73 - Marginal cost coverage ratio - Freight diesel train



Note: Cyprus and Malta do not have operating rail networks.

5.4 Average infrastructure cost coverage and earmarking

With respect to the infrastructure cost coverage, rail access charges provide the bulk of the revenues. As a common approach prevails across the countries covered by this study, these revenues are typically earmarked to cover part of the infrastructure costs borne (i.e., investment, maintenance and network management). No specific evidence was found for earmarked revenues from other electricity charges or fuel taxes in rail transport⁸⁸.

Therefore, no additional graphs have been developed to discuss the earmarking issue, in addition to the graphs already presented in the section of the overall total infrastructure cost coverage.

⁸⁸ See also Section 4.4.3 of deliverable of Task A4 on Transport taxes and charges in Europe.

5.5 Broader context of internalisation of the external costs of rail transport

In the previous sections the role of taxes and charges in the internalisation of the external and infrastructure costs of rail transport is discussed. As discussed in Section 2.5 also other instruments (i.e. command-and-control measures, subsidies) can be used to meet the objectives of internalisation. In this section, we discuss the role of these policy instruments in the reduction of the main external costs (i.e. climate change, air pollution, noise, and accidents) of rail transport.

5.5.1 Climate change

GHG emissions of rail transport are mainly addressed by the EU ETS (electric trains) and fuel taxes (diesel trains). In addition to these market-based instruments, there are also some other relevant EU policies affecting the GHG emissions of rail transport. First, the **Renewable Energy Directive** sets targets for the share of renewable energy used in transport, including rail transport. As explained in Section 4.5.1, this instrument complements fuel taxes (and other price instruments) by targeting the uptake of renewable energy. Furthermore, the **TEN-T policy** (see Section 4.5.5 for more information on TEN-T policy) also incentivise the electrification of rail infrastructure for the core TEN-T network. For example, great western mainline electrification in the United Kingdom was partly co-funded by the EU, as well as a part of the Latvian railway network.

5.5.2 Air pollution

As mentioned in Section 4.5.2 the general framework for air quality in Europe is established in the **Air Quality Directive** (introducing ambient air quality standards for the protection of human health) and the **National Emission Ceilings Directive** (see Section 4.5.2 for a discussion on these two Directives). As part of meeting the targets set by these two Directives the EU has implemented **emission standards** for diesel locomotives and railcars. This was done in 2004, when the European Parliament adopted Directive 2004/26/EC setting for the first time emission standards for diesel locomotives and railcars. Two stages (Stage IIIA and IIIB) of emission limit values were set for these vehicles, covering NO_x, particular matter, carbon monoxide and hydrocarbons. All new locomotives and railcars had to meet the stage IIIA standards by 1 January 2016, while the stage IIIB standards became effective from 1 January 2012. The non-road Mobile Machinery Regulation, adopted by the Council and the European Parliament in 2016, introduced updated emission standards becoming effective from 2021 for locomotives and railcars (Regulation 2016/1628).

The introduction of emission standards for diesel locomotives and railcars at the EU level is in line with the transnational nature of air pollution (European Commission, 2014b). The effects of air pollution are not limited to the local level and cross-border pollution can make national solutions (including national tax/charge measures) ineffective. Addressing rail diesel emissions by national (tax/charge) instruments may potentially result in a wide range of different regimes hampering the proper functioning of the internal market. Therefore, a harmonised approach at the European level by applying emission standards may be preferred. Such a harmonised approach may also result in a lower administrative and financial burden for manufacturers active on more than one market. Furthermore, it may provide in advance clear and comprehensive information on future emission limit values, providing manufacturers with appropriate period of time and certainty to pursue the requisite technical developments. Finally, as the emission standards only affect new rail vehicles and the renewal rate of these vehicles is rather low, national tax/charge instruments that provide an incentive to retrofitting existing rail vehicles may effectively complement the emission standards.

5.5.3 Noise

The general framework on environmental noise management is set by the **Environmental Noise Directive** (Directive 2002/49/EC), which requires Member States to regularly map noise (including around large airports), provide information to the public and provide action plans to prevent or reduce exposure to environmental noise. A more detailed discussion on the Environmental Noise Directive can be found in Section 4.5.3.

In addition to the general framework on environmental noise management, specific rail noise emission limits are applied in the EU. Furthermore, at the national level a broad range of rail noise abatement measures are applied. Both types of measures are discussed in more detail below.

Rail noise emission limits

Railway rolling stock has been required to meet certain noise emission limits since 2006. This obligation, applicable only to newly built wagons, is part of the Railway Interoperability Directive (Directive 2016/797), through a technical specification for interoperability (TSI) on noise. This technical specification was adopted in 2005 and amended several times. The most recent specification is given by Regulation 1304/2014 (European Commission, 2014a) and sets noise limits for stationary, starting and pass-by noise, as well as noise limits for the level in the driver's cab. The pass-by noise limits for wagons are such that wagons equipped with cast iron brake blocks (mostly used in the current fleet) cannot comply with the limits (UIC, 2016). This provides an incentive to apply composite blocks that have far better noise performance (8 to 12 dB).

The noise emission limits for new wagons are complemented by the (noise differentiated) rail track access charges which provide incentives to retrofit old wagons with 'silent' breaks by replacing cast iron blocks with composite braking blocks. Such charges are in place in the Netherlands, Germany, Austria and Switzerland. This may have significant added value to the noise emission limits as the renewal rate of the freight wagon fleet is rather slow (about 2-3% per year), such that it will take a long time before the noise limits will become effective for the main part of the fleet (European Commission, 2015a).

National rail noise abatement programmes

At the national level, many EU Member States apply abatement programmes to reduce the negative impacts of rail noise. In general, two types of abatement measures can be distinguished: at the propagation path (e.g. by setting up barriers) or at the receiver (e.g. by installing insulation measures) (UIC, 2016). For example, Austria has built 850 kilometres of noise barriers at a rail network of about 5,000 kilometres. In Germany, a large scale noise abatement programme was launched in 1999 in order to reduce the perceived noise levels by half by 2020 (Deutsche Bahn, 2019). By the end of 2017 noise abatement measures were installed on nearly 1,700 kilometres of rail track. In Denmark, noise insulation projects have been carried out along all main railway lines in the country, financing part of the costs that house owners had to make to insulate their houses (the financial contribution made depended on the noise level measures) (Lillelund, K and Kristensen, S, 2016). All these national noise abatement measures complement noise emission limits as set by Noise TSI and noise differentiated rail infrastructure charges, particularly as these measures can be targeted at specific locations/dwellings with high noise levels, while noise emission limits and noise charges have (often) a more general scope. Furthermore, the abatement

measures can guarantee that noise levels will be reduced below certain thresholds, ensuring that healthy living conditions are realised.

5.5.4 Rail safety

Rail safety in the EU is mainly regulated by command-and-control measures. The main ones implemented at the EU level are discussed below.

Rail taxes and charges are not directly linked to external accident costs. Therefore, there is no interaction between any of the measures discussed below and the pricing instruments covered in the previous sections.

Railway Safety Directive

In 2004, the Railway Safety Directive (RSD) 2004/49/EC was adopted to create a common European regulatory framework for safety and to define the tasks and responsibilities related to a safety management system (SMS). The Directive provides harmonised methods to be applied to the actors in the Union rail system and the national safety authorities, on monitoring, conformity assessment, supervision and risk evaluation and assessment. Directive 2004/49/EC was complemented by Directive 2008/57/EC (interoperability) and 2008/68/EC (inland transport of dangerous goods). The Safety Directive 2016/798/EU (recast) introduces the “single safety certificate” valid within the area of operation of the railway undertaking concerned and assigns a central role to the EU Agency for Railways (ERA) responsible for the certification of international train operators and their vehicles in issuing such certificates. This new regime should make the EU rail system more effective and efficient by reducing administrative burdens for railway undertakings.

The RSD harmonises the regulatory structure in the Member States, defines responsibilities between the actors in the Union rail system, develops common safety targets (‘CSTs’) and common safety methods (‘CSMs’) thus removing the need for national rules. The RSD also sets out the principles for issuing, renewing, amending and restricting or revoking safety certificates and authorisations and requires a national safety authority and an accident and incident investigating body for each MS. Finally, the RSD defines common principles for the management, regulation and supervision of railway safety.

The Directive applies to the entire EU rail system as well as to ‘tram-trains’ as so far as they operate on national rail infrastructure, but not to local public transport systems or privately owned railway infrastructure (GRB, 2019).

Certification of train drivers

Directive 2007/59/EC on the certification of train drivers specifies conditions and procedures for the certification of train drivers operating rolling stock on the railway system of the EU. It also specifies the tasks of competent authorities in the Member States, train drivers, and their employers, i.e. railway undertakings and infrastructure managers. The main objective of the directive is to facilitate the mobility of train drivers in the context of the increasing opening of the railway market while at least maintaining the current safety levels and generally for licences and complementary certificates to be recognised by all railway sector stakeholders.

Technical specification for interoperability relating to ‘operation and traffic management’ (OPE TSI)

Regulation 2015/995⁸⁹ concerning the technical specification for interoperability for the subsystem, operation and traffic management is targeted at the procedures and related equipment enabling a coherent operation of the various structural subsystems, during both normal and degraded operation, including in particular train composition and train driving, traffic planning and management. Implementation of the TSI and conformity with the relevant points of that TSI, should be determined in accordance with an implementation plan that each Member State is required to draft and update for the lines for which it is responsible.

Shift2Rail Joint Undertaking

The Shift2Rail Joint Undertaking (S2R JU) is a public private partnership in the rail sector, which pursues research and innovation activities in support of the achievement of the Single European Railway Area and aims to improve the attractiveness, competitiveness and safety of the European rail system (European Commission, 2013d).

Revitalising the railways is a key goal of the EU’s transport policy (European Commission, 2014d). Modernising the sector – notably through the introduction of new technologies – is essential, if rail is to be able to compete successfully with other modes of transport and on potentially profitable markets: in particular, long-distance container transport for freight, and high speed international services for passengers. Shift2Rail fosters the introduction of better trains to the market (quieter, more comfortable, more dependable, etc.), which operate on an innovative rail network infrastructure reliably from the first day of service introduction, at a lower life-cycle cost, with more capacity to cope with growing passenger and freight mobility demand. Shift2Rail also contributes to the paradigm for the modal shift to attract users to rail. For EU passengers, this represents more travel options, more comfort and improved punctuality. For freight forwarder/shippers, rail freight offers a more cost-effective, punctual and traceable shipment option. For example some of the cross-cutting activities under the Shift2Rail programme aim at (1) linking energy and sustainability actions with existing initiatives outside Shift2Rail, in order to align understanding and positions from railways and energy stakeholders; (2) developing future methods for predicting overall noise and vibration performance at system level, with proper ranking and characterisation of each contributing source, so as to include different combinations of entire vehicles and infrastructure, and to optimise cost-benefit scenarios as well as exposure and comfort.

⁸⁹ An amending Decision 2012/757/EU.

6 Inland waterway transport

6.1 Introduction

This chapter discusses the resulting average and marginal cost coverage ratios for inland waterway transport for 16 EU countries (those with IWT activity) and Switzerland. Average cost coverage ratio results are discussed in the following order:

- overall cost coverage ratio;
- overall cost coverage ratio excluding fixed infrastructure costs;
- variable external and infrastructure cost coverage ratio;
- overall infrastructure cost coverage ratio;
- variable infrastructure cost coverage ratio.

In addition, Section 6.4 will provide broader context of the non-pricing measures introduced across Europe that also impact inland waterway externalities.

Table 22 shows the categories of revenues, taxes/charges, and external costs considered for each ratio.

Table 22 - Costs and revenues used for different inland waterway cost coverage ratios

Type of comparison	Infrastructure costs	External costs	Taxes and charges
Overall average	All infrastructure costs.	All external costs.	All taxes and charges.
Fixed	All investments and traffic independent part of O&M and renewal costs.	Habitat	
Variable	Traffic dependent part of O&M and renewal costs (estimated).	Accidents, air pollution, climate, WTT.	Fuel taxes, port charges, fairway dues, dues for locks and bridges, water pollution charges.

The data underpinning the cost coverage ratios for IWT transport comes from a selection of sources, described in detail in Section 1.3.

Regarding taxes and charges, fairway dues are only collected in seven countries (CE Delft, 2019b). Only in Belgium and Poland there are special dues for locks and bridges.

Marginal cost coverage ratios for IWT freight vessels are estimated for three scenarios - high-cost, average cost, and low cost. These are defined in Table 23. The reference vehicles used in these scenarios come from those in the related report, “Transport Taxes and Charges in Europe” (CE Delft, 2019b).

For the representative scenario, the costs and revenues presented are equal to the average variable costs and revenues, representing the weighted averages of the actual real-world conditions/situations. This means that the average in the representative scenario may not lie in the middle of the high-cost and low external cost scenario.

Table 23 - Definition of inland waterway marginal cost scenarios

	High external cost scenario	Representative scenario	Low external cost scenario
Freight IWT vessels	CEMT II (bulk) CCR-1	Average vessel	CEMT Va (bulk) CCR-2

6.2 Average cost-based internalisation

Overall cost coverage ratio

The overall cost coverage ratio compares revenues from all taxes and charges with all external and infrastructure costs. For inland waterways specifically, the allocation of infrastructure costs to freight vessels has been done on the basis of Dutch parameters after a literature review on existing estimates and 60% of variable infrastructure costs are allocated to freight vessels (CE Delft, 2019a). In addition, the allocation of variable infrastructure costs has been estimated using literature and Dutch values, adjusting for different utilisation rates between countries (ranging from 0.05 to 15% of infrastructure costs). It shows the extent to which these costs are internalised by pricing measures. Figure 74 depicts the large range of average costs borne by Member States, with the majority falling between €ct 1.4 per tkm and €ct 5.5 per tkm, with a cluster around the sample average of €ct 3.9 per tkm. While Switzerland is the only country to internalise all external and infrastructure costs associated with IWT, the country's navigable waterways are very limited.

As a result of their very low utilisation of inland waterways, Poland, Finland, Italy and the Czech Republic exceed the range of average costs, with costs over €ct 60 per tkm (beyond the range shown in the magnified figure). For these countries the resulting average fixed infrastructure costs are therefore extremely high.

France, Belgium, the Netherlands, and Germany (countries with a higher utilisation of inland waterways), have costs that are clustered near the sample average. This is true for both external and infrastructure costs. On the other hand, Romania (another country in the group with higher IWT utilisation) has a much lower cost than the sample average (€ct 1.59 per tkms) as a result of low average infrastructure costs.

The majority of countries' average revenues do not exceed €ct 0.65 per tkm. Out of the five countries with the highest IWT utilisation, revenues for France (€ct 0.07 per tkm) and the Netherlands (€ct 0.06 per tkm) are far below the sample average of €ct 0.25 per tkm. In contrast, revenues for Belgium (€ct 0.21 per tkm), Germany (€ct 0.32 per tkm) and Romania (€ct 0.35 per tkm) are either near or above the sample average. This can partly be explained by Belgium's dues for locks and bridges and the Netherlands' lack of fairway dues. In addition, Germany has high levels of port charge revenues compared to the other countries in the sample, and it also charges fairway dues. Romania also has relatively high port charge revenues compared to traffic on its network, and like Germany, these revenues are supplemented by fairway dues. About 73% of the revenues in Romania are port charges and in Germany 78% are port charges.

Figure 74 - IWT spread of overall cost coverage for sample of 16 EEA countries (magnified subset)

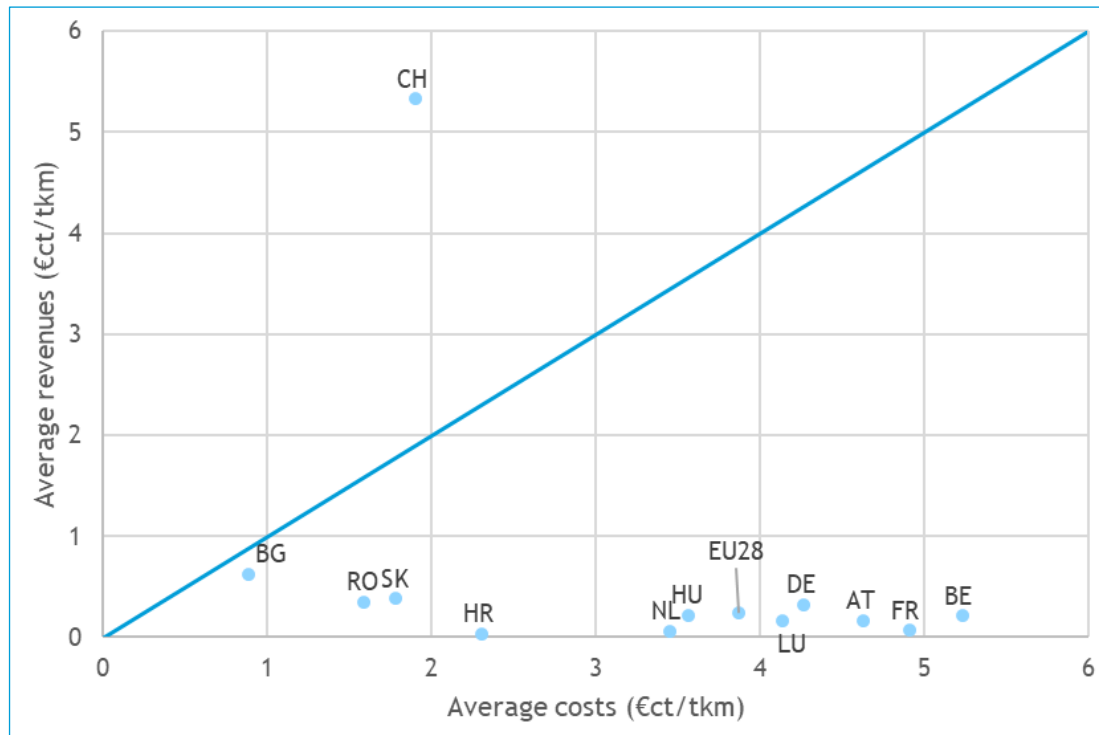
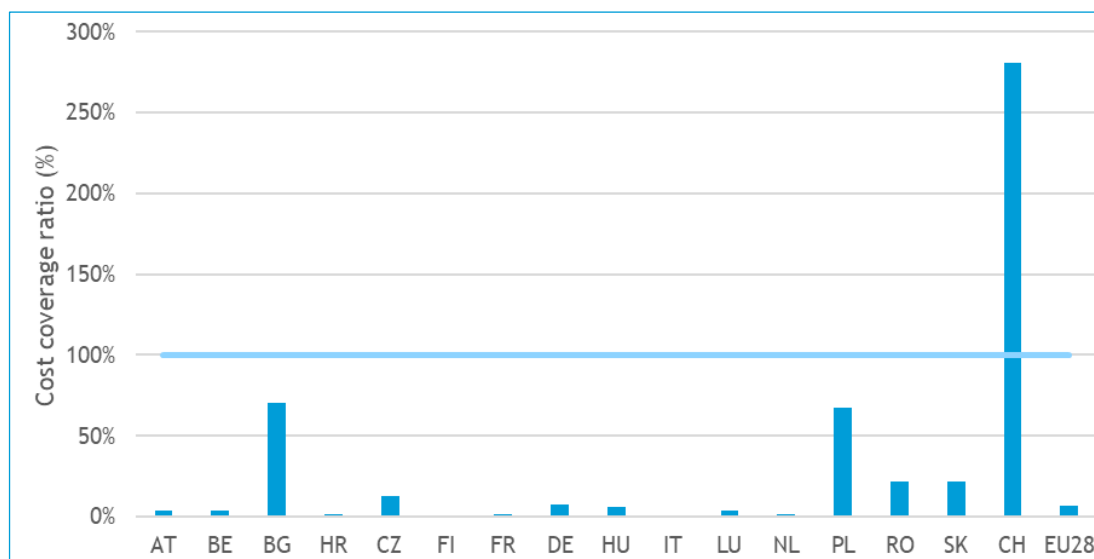


Figure 75 shows the spread of overall cost coverage ratios. As expected, countries with small inland waterway networks have a higher cost coverage (Switzerland, Poland, Bulgaria). This is due to port charges being allocated to a relatively low number of tonne of goods per km, resulting in high average revenues.

The five countries with the highest utilisation of inland waterways have cost coverage ratios ranging between 1% (France) and 22% (Romania), and in range with the sample average of 6%.

Figure 75 - IWT overall cost coverage ratio for sample of 16 EEA countries



Overall cost coverage ratio excluding fixed infrastructure costs

The overall cost coverage ratio excluding fixed infrastructure costs displays the extent to which external and variable infrastructure costs are internalised by taxes and charges. The main difference between this indicator and the overall cost coverage is that only variable infrastructure costs are included in this calculation and for this reason, patterns are similar to those shown in the overall cost coverage section. As a result, this section will focus on the results for costs and the cost coverage ratios (since revenues are the same).

Figure 76 shows the spread of this ratio among sample countries. The Czech Republic and Poland both have high costs and revenues that fall outside of the magnified subset displayed. The figure shows that most countries' costs cluster between €ct 1.3 per tkm and €ct 2.6 per tkm, near the sample average cost of €ct 2.08 per tkm.

Countries with the highest utilisation of inland waterways (France, Belgium, the Netherlands, Germany and Romania) mostly fall within range of the sample average, except for Romania, with lower costs of €ct 1.32 per tkm. This is due to lower variable external costs and variable infrastructure costs for Romania compared to the other countries with high utilisation of inland waterways.

Figure 76 - IWT spread of total cost coverage ratio with variable infrastructure costs for sample of 16 EEA countries (magnified subset)

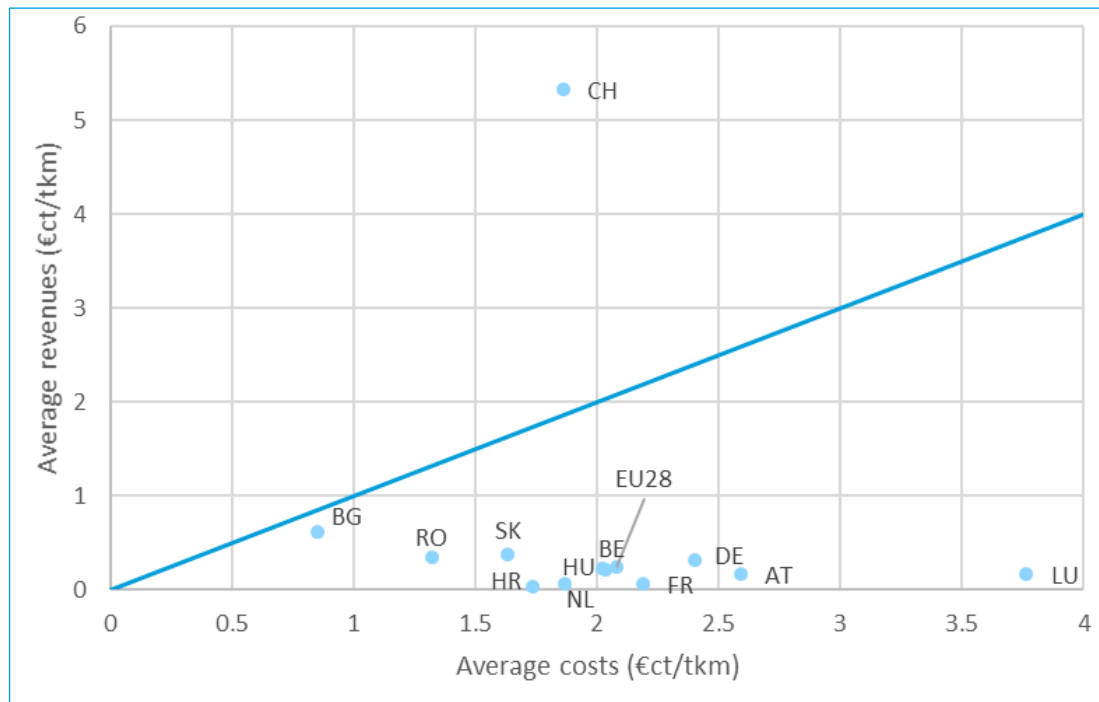
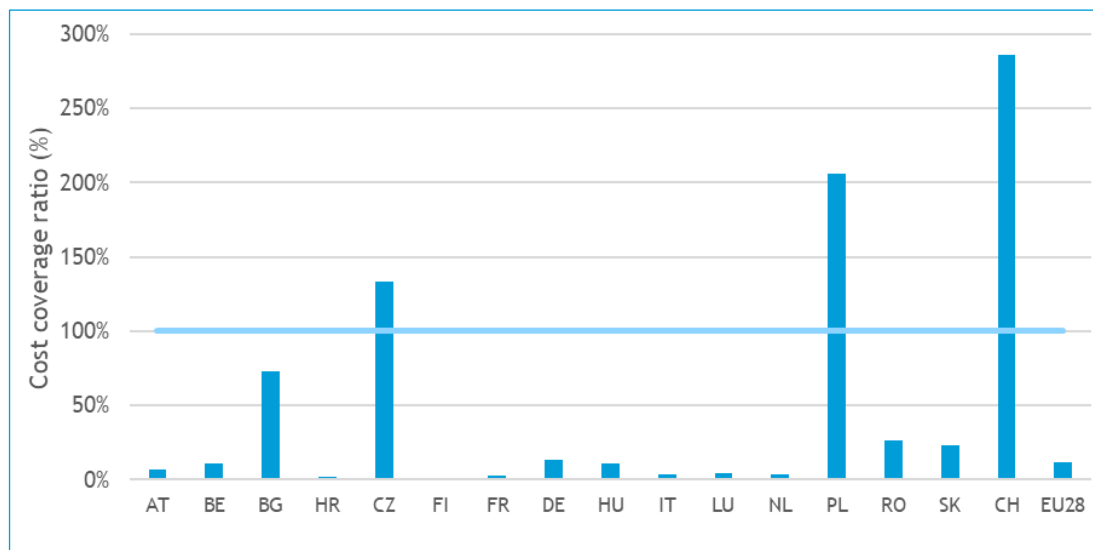


Figure 77 displays the total cost coverage ratio with variable infrastructure costs. Most countries do not cover costs and 12 countries have cost coverage ratios less than 15%. Cost coverage ratios for the countries with the highest utilisation of the inland waterway network range from 3% (France and the Netherlands) to 27% (Romania), within range of the overall sample average of 12%.

Figure 77 - IWT overall cost coverage ratio excluding fixed infrastructure costs for sample of 16 EEA countries



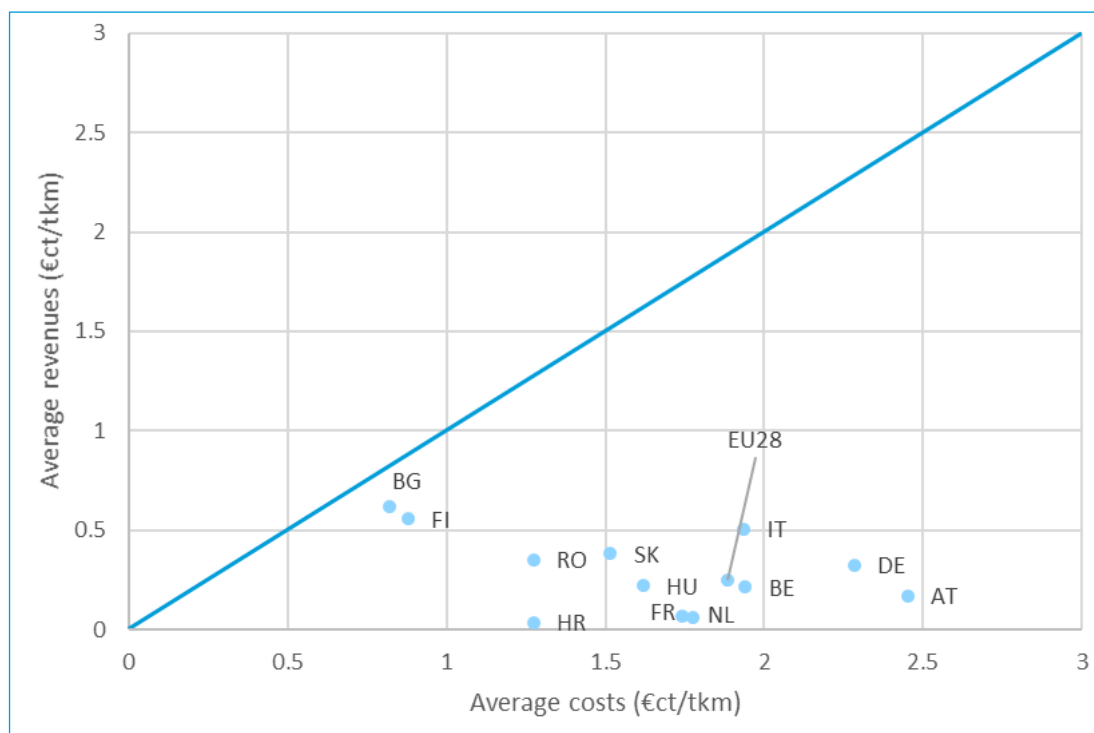
Variable external and infrastructure cost coverage ratio

This ratio displays the extent to which additional costs caused by additional usage of the network are covered by variable taxes/charges. The data is depicted in Figure 78 which shows revenues from variable taxes/charges with variable external and infrastructure costs. External variable costs are all costs except habitat costs, which are fixed. The definition of variable infrastructure costs was covered in the above section, while all IWT taxes and charges can be considered variable.

To summarise, the main difference between this indicator and the overall cost coverage ratio excluding fixed infrastructure costs is that now habitat costs are excluded. Since these are small changes, the resulting trends and patterns are similar to those covered under the overall cost coverage with variable infrastructure costs.

There is a large amount of variation in average variable costs. While there is a cluster of countries around the sample average that falls at €ct 1.9 per tkm, the range stretches from €0.8 per tkm to €ct 2.4 per tkm. Poland, Switzerland and the Czech Republic are outside the range of the magnified subset shown. The countries with the highest utilisation of inland waterways have costs ranging from €ct 1.27 per tkm (Romania) to €ct 1.93 per tkm (Belgium), within range of the sample average.

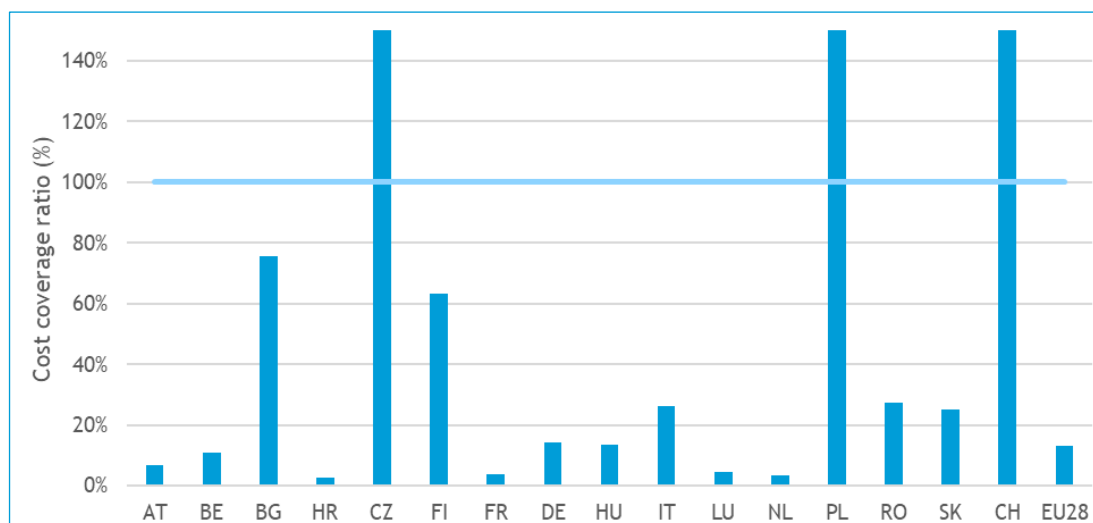
Figure 78 - IWT spread of overall total variable cost coverage costs for sample of 16 EEA countries (magnified subset)



For the majority of countries, revenues from variable taxes and charges are insufficient to cover variable external and variable infrastructure costs. Figure 79 shows that the sample average cost coverage ratio is 13%, only marginally higher than the cost coverage under the overall total cost coverage with variable infrastructure costs indicator. Some countries have extremely high-cost coverage ratios outside the range shown in the figure.

For countries with high inland waterway utilisation, cost coverage ratios range from 3% (the Netherlands) to 27% (Romania), comparable to the sample average and similar to those under the overall total cost coverage ratio with variable infrastructure costs.

Figure 79 - IWT overall total variable cost coverage ratios costs for sample of 16 EEA countries



Overall infrastructure cost coverage ratio

The overall infrastructure cost coverage ratio describes the extent of infrastructure cost recovery by assessing whether infrastructure costs are effectively internalised by revenues from infrastructure charges. Figure 80 displays the overall infrastructure cost coverage for inland waterway transport (IWT). Countries falling outside the magnified subset are the Czech Republic, Italy and Poland. These are all countries with low utilisation of inland waterways. Notably, Italy recovers no infrastructure revenues in our dataset, and this is because the port of Mantova shows no revenues from port charges according to the balance sheets of the port operator.

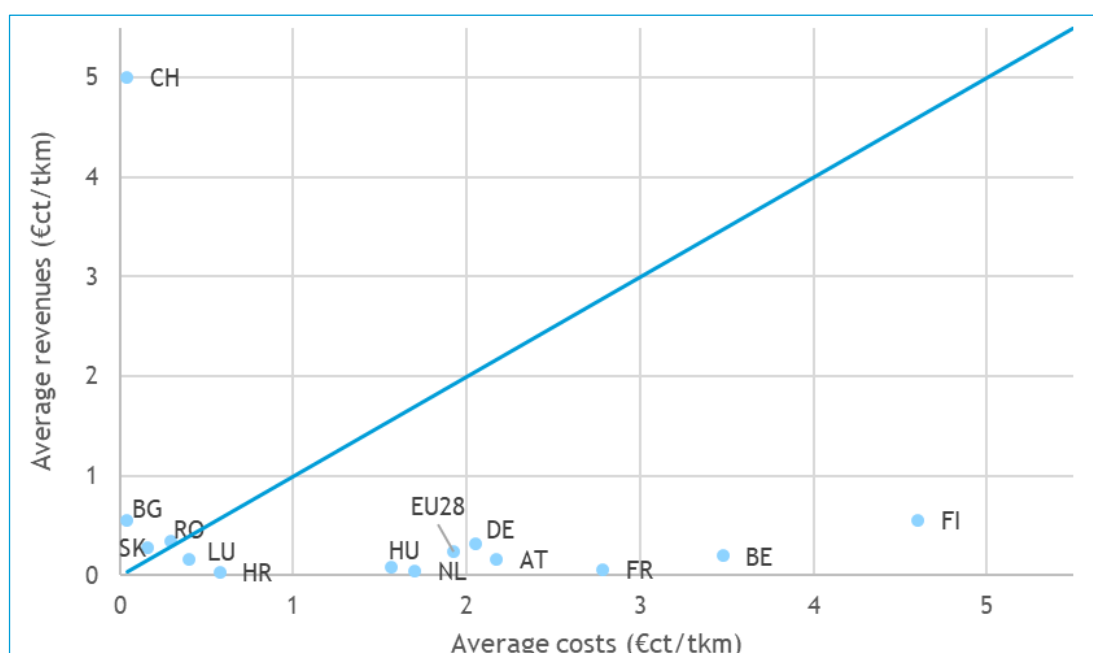
In general, the average revenues in the EEA countries do not exceed €ct 0.55 per tkm, however, there is significant variation in the average costs. Within the scope of the magnified figure, Finland, another country with low utilisation of inland waterways is an outlier on costs. The sample average for infrastructure costs is €ct 1.92 per tkm. Both Germany and the Netherlands have costs around this average at €ct 2.0 per tkm and €ct 1.7 per tkm, respectively.

Belgium and France, countries with high utilisation of inland waterways, have significantly higher average costs of €ct 3.48 per tkm and €ct 2.79 per tkm, respectively. France has lower usage of inland waterways compared to the Netherlands and Belgium, which explains the country's higher than average infrastructure costs. On the other hand, Belgium has high usage of inland waterways, but a higher share of canals than Germany, which explains the country's higher costs compared to Germany. Belgium also has higher costs compared with the Netherlands because only 1% of infrastructure costs for IWT in Belgium is allocated to maritime transport. In contrast, for the Netherlands, 20% of renewal and O&M costs are allocated to maritime transport (CE Delft, 2019a).

In contrast, Romania, another country with high utilisation, has significantly lower average costs of €ct 0.29 per tkm. This is partly due to maritime traffic on the country's network (with 22.84% of costs allocated to maritime transport). It also has lower levels of annual O&M expenditures compared to other countries with high utilisation of their networks.

Average infrastructure revenues in the sample are €ct 0.24 per tkm. Countries with high utilisation of inland waterways (Belgium, Germany, Romania) have revenues around this average, with the notable exception of France (€ct 0.07 per tkm) and the Netherlands (€ct 0.05 per tkm). Unlike Belgium, Germany, Romania, and France, the Netherlands does not charge fairway dues, which explains lower average infrastructure revenues. For France, there was no available data on fairway dues, an important source of infrastructure revenue, so the low result for France is likely due to the unavailability of this data.

Figure 80 - IWT overall infrastructure cost coverage ratio for coverage for sample of 16 EEA countries (magnified subset)



As shown Figure 81, there is a large variation in cost coverage ratios. The majority of countries have low infrastructure cost recovery, with ten only partially internalising costs. The figure is capped at 200% cost coverage, but countries exceeding this are Bulgaria (1,290%) and Switzerland (12,075%). While the cost coverage for Bulgaria and Switzerland is exceedingly high, the data underlying this ratio has been verified. For example, for Switzerland, there is a small network (5 kilometres only) but the Port of Basel collects port charges. Most of the traffic to/from Switzerland is done on German waterways. Aside from Switzerland and Bulgaria, other countries with low utilisation of the network have high-cost coverage - Poland and Slovakia.

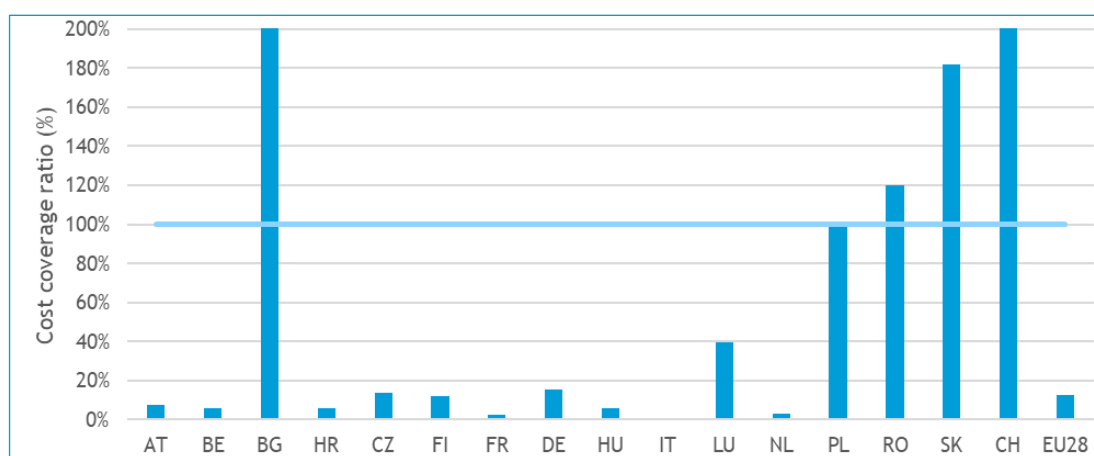
Some of the lowest cost recovery rates, such as Belgium (5.7%) and the Netherlands (3%), can be explained by the countries' relatively large inland waterway network (CE Delft, 2019a), resulting in significant infrastructure costs. Both Belgium and the Netherlands invest a high share of their GDP in inland waterways compared to other EU countries. Each invest over 0.04% of GDP in IWT, whereas the 14 other countries in the sample invest less than 0.01% of their GDP. Additionally, in the Netherlands no fairway dues are levied on IWT (as discussed above), while in Belgium only on a small part of the network fairway dues are charged. As a consequence, the infrastructure charge revenues are mainly coming from port charges in both countries. Combined with the relatively high infrastructure costs, this results in relatively low-cost coverage ratios.

France has the lowest cost coverage ratio (2%) in the sample, although it is one of the countries with relatively high utilisation of inland waterways. As discussed above, France has high costs and low revenues, though it is likely that revenues, in particular those in the form of fairway dues, were underestimated through our data collection exercise. In practice the cost coverage ratio is expected to be higher.

Germany, another country with greater utilisation of inland waterways has a cost coverage ratio of 16%. Overall this is low but higher than the sample average of 12%. This is (partly) explained by the fairway dues applied on several German inland waterways, resulting in higher average revenues than in some of the other countries.

Romania, the final country with higher utilisation of inland waterways, has an infrastructure cost coverage ratio of 120%. This is a result of low infrastructure costs, as discussed in the analysis of the preceding figure.

Figure 81 - IWT infrastructure cost coverage ratio for sample of 16 EEA countries



Variable infrastructure cost coverage ratio

This cost coverage ratio provides additional insight into infrastructure cost recovery, determining whether variable infrastructure costs are internalised by revenues from variable infrastructure charges. It measures the extent to which additional costs caused by an additional tkm of utilisation are covered by additional infrastructure charges.

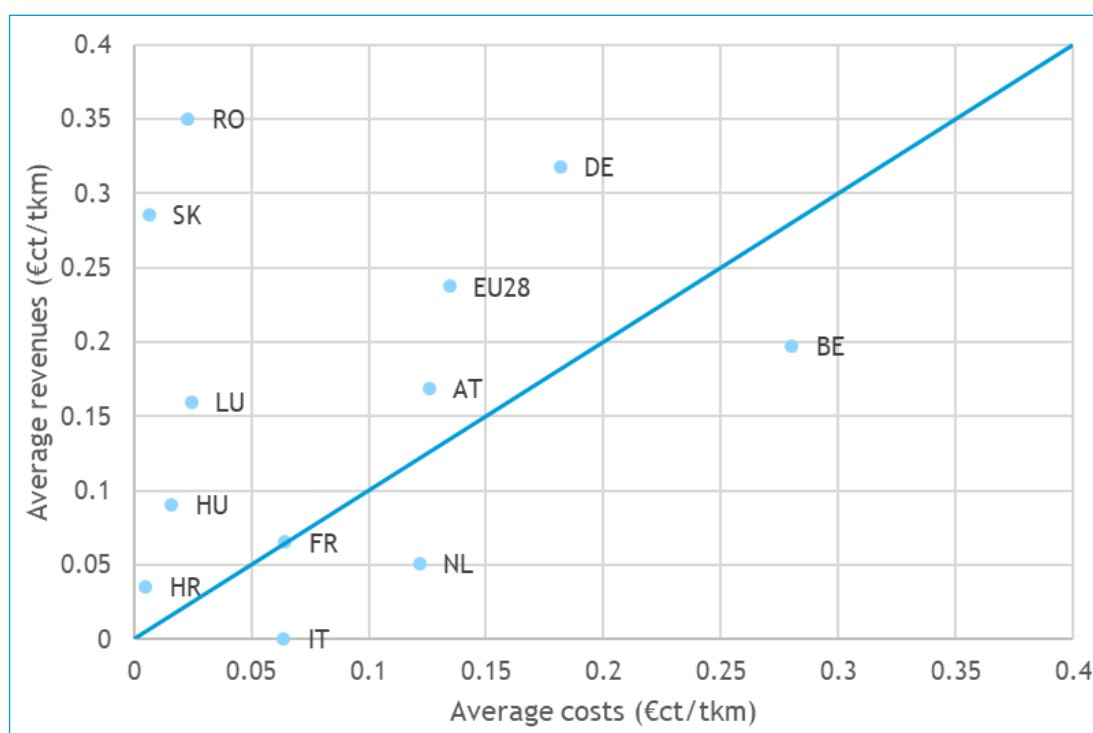
As discussed in the introduction to this chapter, variable IWT infrastructure cost data is not readily available from national accounts, except the Netherlands (CE Delft, 2019a). The cost data for the remaining countries were therefore estimated from the Dutch figures, with adjustments made for the utilisation of a countries' IWT network and total spending on infrastructure.

Figure 82 shows a magnified subset of variable infrastructure cost coverage for IWT, comparing revenues from infrastructure charges with variable infrastructure costs. Revenues included here are raised from port charges, fairway dues, and dues for locks and bridges. Several countries with higher average revenues are outside the scale of the figure - Bulgaria, the Czech Republic, Finland, Poland, and Switzerland. These are all countries with relatively low usage of their inland waterway networks.

The sample average variable infrastructure cost is €ct 0.13 per tkm. Of the five countries with significant usage of their inland waterways, notable deviations from the average are Belgium (€ct 0.28 per tkm), France (€ct 0.06 per tkm), and Romania (€ct 0.02 per tkm). The low infrastructure costs for all three countries were explained under the overall infrastructure cost coverage ratio. In addition, only 3.4% of infrastructure costs for France were categorised as variable, compared to the benchmark 15% for the Netherlands.

Within the sample, the average variable infrastructure revenue is €ct 0.24 per tkm. Of the countries with higher network utilisation, the Netherlands and France have significantly lower than average revenues of €ct 0.05 per tkm and €ct 0.07 per tkm. The reasons for this were explained under the overall infrastructure cost coverage ratio, including missing revenue data for France. On the other side, Romania and Germany have significantly higher than average revenues of €ct 0.35 per tkm and €ct 0.32 per tkm, respectively. The reasons for this are discussed under the overall total cost coverage ratio.

Figure 82 - IWT Variable infrastructure cost coverage for sample of 16 EEA countries (magnified subset)



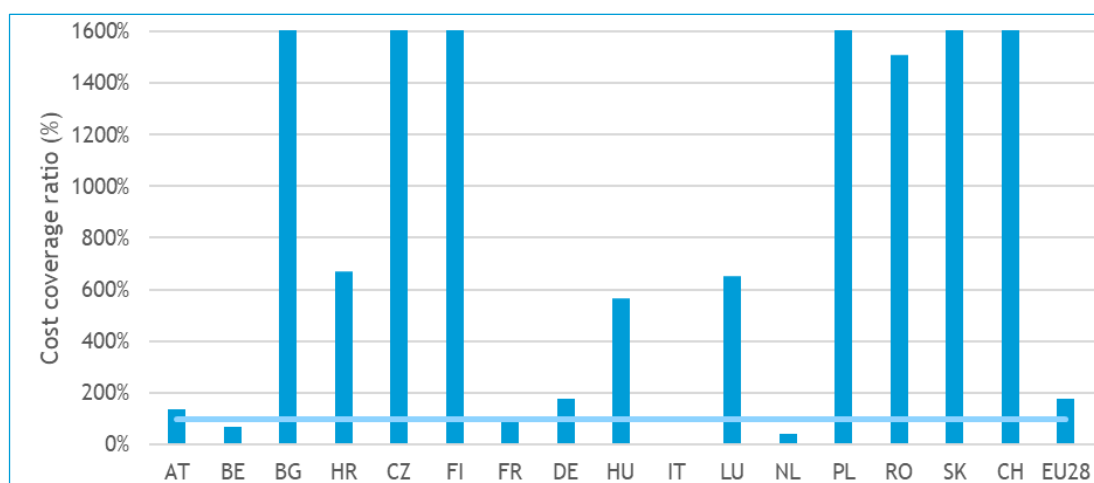
As shown by Figure 83, the majority of countries internalise their variable infrastructure costs. The figure cuts off at 1,600% cost coverage, but countries falling above this range are Bulgaria (6,816%), Croatia (673%), the Czech Republic (27,271%), Finland (109,297%), Poland (1,104,430%), Slovakia (4,214%), and Switzerland (99,919%). These are all countries with low utilisation of the inland waterway network. Additionally, some of these countries with high-cost coverage have variable costs that constitute a small proportion of their total infrastructure cost. Croatia, Finland, the Czech Republic and Poland have a very low proportion of variable infrastructure costs (1.7%, 0.03%, 0.1% and 0.05% respectively) (CE Delft, 2019a).

Some of the outlier results discussed above can be attributed to poor data or difficulties applying the average cost and revenue calculations to inland waterway transport. The data from Poland and Finland is of poor quality.

Across the sample, the average variable infrastructure cost coverage is 176%. This is much higher than any of the other IWT cost coverage ratios considered in this report because variable infrastructure costs typically account for less than 15% of the total overall infrastructure cost (CE Delft & VU, 2014), yet most revenues collected are categorised as variable infrastructure charges (CE Delft, 2019b). Hence, the majority of countries have ratios over 100%.

Countries with high use of their inland waterway networks that recover less than 100% of costs are the Netherlands (42%) and Belgium (70%). Both Belgium and the Netherlands have relatively large inland waterway networks to maintain (CE Delft, 2019a). In addition, Belgium's infrastructure costs per km are the highest reported in Europe (CE Delft, 2019a), and the proportion of these that are variable is also larger than other EU countries.

Figure 83 - IWT variable infrastructure cost coverage for sample of 16 EEA EU countries



6.3 Marginal social cost-based internalisation

The marginal cost coverage ratios for IWT compare marginal external and infrastructure costs with marginal tax and charge revenues for three scenarios: a high external cost scenario, a representative scenario, and a low external cost scenario. As before, these are defined for the countries with IWT infrastructure only.

As previously presented in Section 2.4.2, there are a number of key attributes of marginal cost coverage scenarios to consider when analysing the results.

Considerations with respect to marginal cost scenarios

When interpreting the results of the marginal cost coverage analyses, the following issues with respect to the marginal cost scenarios should be considered:

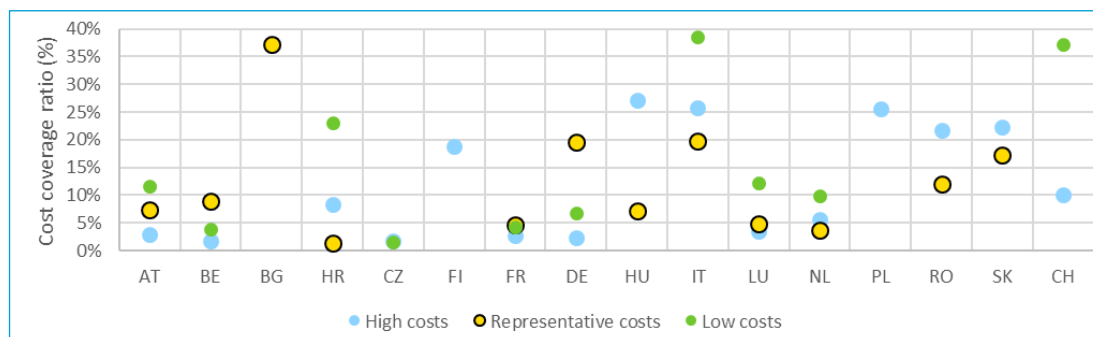
- The high and low-cost scenarios considered are sometimes a bit extreme, in order to reflect cases with high or low marginal external cost values. As a consequence, these scenarios are not necessarily reflecting cases that are fully representative of real-world situations.
- The scenarios are defined based on the level of external costs. The marginal cost coverage ratios, however, are also driven by marginal infrastructure costs and taxes/charges. Therefore, low marginal cost coverage ratios may be found for low external cost scenarios, if marginal infrastructure costs are relatively high or tax/charge levels relatively low.

6.3.1 Freight vessel

The representative scenario looks at an average journey of an inland water freight vessel. The high external cost scenario considers costs, charges and taxes for vessels in the CEMT II (bulk) size division and a CCR-1 engine. The low external cost scenario is based on a vessel within the larger CEMT Va (bulk) division with a CCR-2 engine.

Figure 84 shows a magnified subset of the marginal cost coverage for these scenarios of IWT freight vessels. Due to the large range of variation in the scenarios, some countries' representative cost ratios are not displayed. This applies to the Czech Republic (611%), Poland (2,275%) and Switzerland (971%).

Figure 84 - Freight vessel marginal cost coverage ratios for sample of 17 EEA countries and Switzerland (magnified subset)



The smallest variation is seen in the **high external cost scenario**, which has an average cost coverage of 15% with a minimum of 2% (Belgium, the Czech Republic, Germany) and a maximum of 62% (Bulgaria). Bulgaria's high-cost coverage is linked to relatively low marginal external costs (such as air pollution), as well as high marginal charge revenues. Of the five countries with relatively high usage of their inland waterway networks (Belgium, France, Germany, the Netherlands, and Romania), Romania has the highest cost coverage ratio (22%) in this scenario due to a combination of lower than average costs and higher than average revenues. Lower costs for Romania are attributed mainly to external costs, with lower than average accident, air pollution and well-to-tank emissions compared to other EU Member States. The remaining four countries have cost coverage ratios that do not exceed 6%. Belgium (2% cost coverage), France (3%), Germany (2%) and the Netherlands (6%) all have low marginal revenues compared to high marginal costs (chiefly external costs of air pollution).

There is a large increase in cost coverage for the **representative scenario**. The five countries with high network usage have cost coverage ratios ranging from 4% (the Netherlands) to 20% (Germany) in this scenario. For two of these countries, Romania and the Netherlands, cost coverage decreases in this scenario compared to the high external cost scenario. Also, cost coverage in France only rises to 5% from 3% in the high external cost scenario. Notably, Germany's cost coverage is much higher in this scenario due to a significant decrease in the marginal costs of air pollution (the main external cost for IWT) and a corresponding small increase in marginal revenues. Belgium's cost coverage ratio increases to 9% in this scenario from 2% under the high external cost scenario for the same reason as Germany.

Within the **low external cost scenario**, there is an overall reduction in average cost coverage and the sample average is 37%. However, this is largely due to a reduction in the maximum ratios in the sample; the sample ranges from 2% (Czech Republic) to 124% (Bulgaria). Romania has a much higher cost coverage in this scenario of 57% (compared to 12% in the representative scenario) due to a decrease in marginal costs (chiefly external) and a corresponding increase in marginal revenues. In addition, the cost coverage for the Netherlands rises to 10% compared to 4% in the representative scenario due to a doubling of marginal revenues and a significant decrease in marginal external costs of air pollution. For France, Belgium, and Germany, other countries with high network utilisation, cost coverage falls in this scenario compared to the representative scenario.

6.4 Broader context of internalisation of the external costs of IWT transport

In the previous sections the role of taxes and charges in the internalisation of the external and infrastructure costs of IWT is discussed. As discussed in Section 2.5, other instruments (i.e. command-and-control measures, subsidies) can be used to meet the objectives of internalisation. In this section, we discuss the role of these policy instruments in the reduction of the main external costs (i.e. climate change, air pollution and accidents) of IWT.

6.4.1 Climate change

Apart from the taxes and charges that are implemented on IWT by countries, there are several other policies that support the mitigation of CO₂ emissions from IWT in the EU. The most relevant instruments at the EU level are the **Fuel Quality Directive**, **Renewable Energy Directive** (both targeting the GHG intensity and type of transport fuels) and the **Directive on the deployment of alternative fuels infrastructure for Europe** (requiring Member States to provide minimum infrastructure for alternative fuels for IWT). These three instruments have been discussed in detail in Section 4.5.1.

All three instruments do complement national IWT taxes and charges. The FQD and RED target the supply of renewable energy (including setting sustainability criteria for this energy). The directive on the deployment of alternative fuels infrastructure for Europe can be considered a supply side measure, complementing the more demand side character of IWT taxes/charges.

6.4.2 Air pollution

The general framework for air quality in Europe is established in the **Air Quality Directive** (introducing ambient air quality standards for the protection of human health) and the **National Emission Ceilings Directive** (see Section 4.5.2 for a discussion on these two Directives). As part of meeting the targets set by these two Directives the EU has implemented emission standards for inland navigation vessels. In addition, there are some subsidy schemes at the national and local level to support cleaner inland vessels and in some inland port the use of onshore power supply is mandatory. The latter three types of instruments are discussed in more detail below.

European emission standards

Emission standards for inland navigation standards in Europe were introduced in 2004, when the European Parliament adopted Directive 2004/26/EC setting emission standards for IWT vessels. Two stages (Stage IIIA and IIIB) of emission limit values were set for these vessels, covering NO_x, particulate matter, carbon monoxide and hydrocarbons. The non-road Mobile Machinery Regulation (Regulation 2016/1628), adopted by the European Parliament in 2016, introduced updated emission standards becoming effective from 2019/2020 for IWT vessels.

As the emission standards for IWT were implemented by the same Directives/Regulations as the emission standards for locomotives and railcars, we refer to Section 5.5.2 for a more detailed discussion on this instrument (the same interactions with tax/charge schemes as for rail transport are relevant).

National subsidy schemes to stimulate cleaner IWT

At the national level, subsidy schemes have been implemented to stimulate cleaner IWT. For instance, the Netherlands provided subsidies in the range of € 25,000 to € 250,000 for innovative projects directed at reducing NO_x and particulate matter emissions from IWT vessels (Rijksoverheid, 2018). Similar schemes also exist at the regional level. For instance, the province of South-Holland had a subsidy scheme in place in 2014 to facilitate the installation of SCR-catalytic converters in inland vessels (DRV, 2018). SCR-catalytic converters significantly reduce a vessel's NO_x emissions. Such subsidy schemes have even been put in place at the port level, e.g. by the Port of Rotterdam Authority, where practical projects leading to reduced fuel consumption, CO₂ emissions and/or air polluting emissions are eligible for financial aid (EICB, 2019). These subsidy schemes complement national and local tax/charge schemes for IWT, as they provide very specific incentives to invest in cleaner IWT. As the tax/charge levels in IWT are in general relatively low, these instruments are less appropriate to incentivise relatively high investments in cleaner technologies.

Use of onshore power supply

Some port authorities have implemented regulations aimed at reducing the emissions of harmful air pollutants. For instance, in the ports of Rotterdam and Amsterdam using onshore power supply is now mandatory (De Binnenvaartkrant, 2010). Onshore power supply makes the use of diesel generators to generate electricity used on board redundant. This reduces the emissions of air pollutants in the port (Drechtsteden, 2012).

6.4.3 Accidents

The EU aims to enhance safety in inland waterway transport. This is currently exclusively done through non-pricing instruments such as regulations and directives. These are discussed below.

None of the taxes and charges that are levied on IWT are currently directly linked to the safety of the transport mode⁹⁰. This is in contrast to other externalities, e.g. climate change, where the fuel tax is a direct way of taxing CO₂ emissions. Therefore, there is no interaction between any of the directives and the pricing instruments.

EU safety regulations for IWT

The EU has regulated several safety aspects of IWT by using command-and-control measures:

- *Technical requirements to the vehicle*: Directive (2016/1629) establishes the technical requirements that vessels navigating inland waterways have to fulfil. Certificates are issued to guarantee these vessels comply with the requirements. Setting minimum safety standards therefore enhances safety to a level above the minimum but does not necessarily continue to stimulate further innovation beyond the minimum level in the field of safety.
- *Requirements for IWT personnel*: Directive (2017/2397) states conditions and procedures for the certification and qualifications of persons involved in the operation of a craft navigating on inland waterways in the EU. The conditions and procedures for the recognition of qualifications for navigation is also part of the directive. Additionally, Directive (2014/112) implements certain minimum requirements regarding the organisation of working times in inland waterway transport. Individual Member States are at liberty to introduce provisions more favourable than detailed in the directive.
- *River information Systems (RIS)*: Directive (2005/44) establishes a framework for the deployment and use of harmonised river information systems. Its goal is to enhance safety, efficiency and environmental friendliness and facilitates interfaces with other transport modes.

Each of the directives listed above aims to regulate certain aspects of inland waterway transport, such that the vessel itself becomes safer, but also that those working on vessels are adequately educated and have a sufficient balance between working time and time off work. These aspects are all important drivers of accidents, thus regulating them is a way to reduce the externality.

CCNR regulations

In addition to the EU safety regulations for IWT, also the Police Regulations and Regulations for Rhine navigation personnel of the Central Commission for Navigation of the Rhine (CCNR) are relevant. The Police Regulations for the Navigation of the Rhine contains rules for navigating and the behaviour of vessels on the Rhine (CCR, 2018). Each of the countries in the CCNR each have their own police regulations, which are nearly identical and presented in the official languages. The rules inform shippers of the expected code of conduct with the aim to enhance safety.

⁹⁰ There may be an indirect link, as IWT taxes/charges may affect the demand for IWT and hence the size (and composition of the) traffic flow on inland waterways. The latter may affect the total accident costs of IWT (e.g. an increase of the number of vessels will result in more accidents, assuming a constant accident risk).

The regulations for Rhine Navigation Personnel demands particular qualifications of staff on IWT vessels on the Rhine and states rules regarding navigation and resting time, minimum crew on board, etc.

7 Maritime transport

7.1 Introduction

This chapter discusses the resulting marginal cost coverage ratios for maritime freight via the sample of ports selected for this study (Section 7.3). All financial figures are adjusted for differences in purchase power between countries (by using Purchasing Power Standards, PPS), in order to allow for direct comparisons between countries. In addition, Section 7.2 outlines data constraints hindering the analysis of average cost coverage for maritime transport. Section 7.4 provides a discussion on the broader context of the non-pricing measures introduced across Europe that impact maritime externalities.

Marginal cost coverage ratios for maritime freight are estimated for three scenarios - high cost, low cost and very low cost. These are defined in Table 24. The reference vehicles used in these are described in the related report, 'Transport Taxes and Charges in Europe' (CE Delft, 2019b). The data underpinning the marginal cost coverage ratios for maritime comes from a selection of sources, described in detail in that report as well.

Table 24 - Definition of maritime marginal cost scenarios

	High external cost scenario	Representative scenario	Low external cost scenario	Very low external cost scenario
Freight vessels	Small Vessel (container) Tier 1 500 km	N/A	Large Vessel (container) Tier 2 15,000 km	Large Vessel (bulk) Tier 2 15,000 km

7.2 Average cost-based internalisation

While Chapter 3 discussed total cost coverage in maritime, it was not possible to calculate average cost coverage ratios for maritime transport per tkm for each maritime port considered in this project due to missing data on transport performance data (i.e. ship-kilometres, tonne-kilometres) per port.

Despite this issue, it has been possible to estimate the total costs and revenues for the selection of all maritime ports considered. The total external and infrastructure costs for the 34 maritime ports considered sums up to € 45 billion. The most significant costs consist of air pollution costs and costs of GHG emissions. Taxes and charges total € 1.83 billion, resulting in a cost coverage of 4%.

7.3 Marginal social cost-based internalisation

The marginal cost coverage ratios for maritime vessels compares marginal external and infrastructure costs with marginal tax and charge revenues for three scenarios: a high external cost scenario, a low-cost scenario, and a very low external cost scenario. The taxes and charges used in analysis are determined for the set of ports in our sample.

A representative scenario could not be calculated for maritime due to the absence of cost and revenue data per tkm for this study.

As previously presented in Section 2.4.2, there are a number of key attributes of marginal cost coverage scenarios to consider when analysing the results.

Considerations with respect to marginal cost scenarios

When interpreting the results of the marginal cost coverage analyses, the following issues with respect to the marginal cost scenarios should be considered:

- The high and low-cost scenarios considered are sometimes a bit extreme, in order to reflect cases with high or low marginal external cost values. As a consequence, these scenarios are not necessarily reflecting cases that are fully representative of real-world situations.
- The scenarios are defined based on the level of external costs. The marginal cost coverage ratios, however, are also driven by marginal infrastructure costs and taxes/charges. Therefore, low marginal cost coverage ratios may be found for low external cost scenarios, if marginal infrastructure costs are relatively high or tax/charge levels relatively low.

7.3.1 Freight Vessel

For maritime, only freight vessels are analysed. For the high-cost scenario, a small container vessel with a Tier 1 engine travelling 500 km is considered. The low external cost scenario is based on a large container vessel, with a Tier 2 engine, travelling 15,000 km and the very low-cost scenario is based on a large bulk vessel, with a Tier 2 engine, travelling 15,000 km. There is no representative scenario available for maritime, due to the above-mentioned lack in tonne-kilometre data per port. The different engine standards (Tier 1 versus Tier 2) relate to NO_x emission standards. Tier 1 emission limits apply for marine engines installed from 2000, while Tier 2 emission limits apply for engines installed between 2011 and the present⁹¹.

The high, low cost and very low external cost scenarios are shown below in Figure 85. There is no data on taxes and charges in all the scenarios for the following ports: Limassol (CY), Travemünde (DE), Helsingør (DK), Calais (FR), Piraeus (EL), and Marsaxlokk (MT). These are not included in the figure.

In the **high external cost scenario**, the ports coverage ranges from 12% (Marseille, France) to 139% Tallinn (Estonia). Tallinn is the only port to reach full cost coverage. Marginal tax and charge revenues are high in Tallinn due to relatively high port charges against low marginal infrastructure costs. Additionally, Estonia applies fairway dues for maritime transport. Many other ports, however, have moderate cost coverage in this scenario. Ports with especially low-cost coverage in this scenario include Antwerp (18%), Hamburg (16%), Bremerhaven (13%), and Marseille (12%). These ports, like most ports in the sample, do not charge fairway dues.

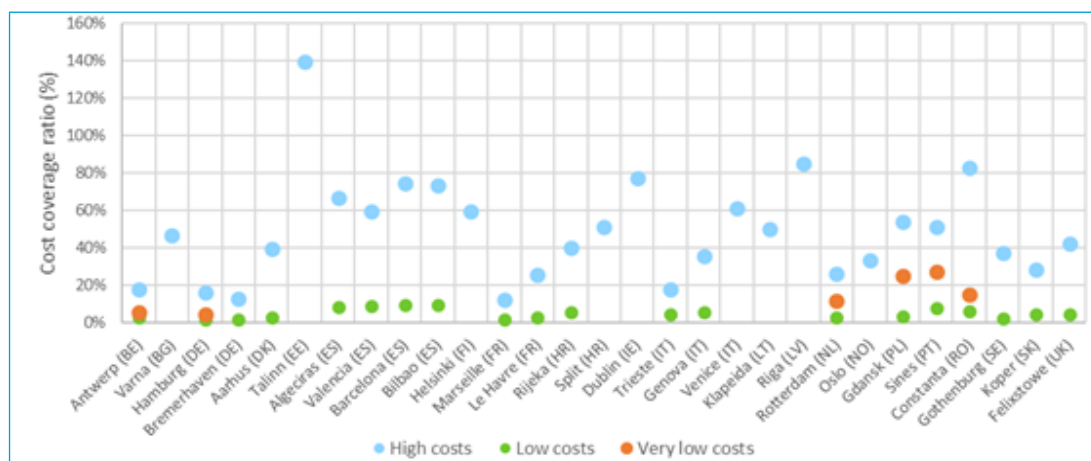
In the **low external cost scenario**, the sample average cost coverage falls significantly. The range of ratios for ports covered in this scenario is from 2% (Gothenburg, Marseille, Bremerhaven, and Hamburg) to 10% (Barcelona and Bilbao). There are decreases in both external costs (chiefly air pollution and climate costs) and revenues in this scenario. However, revenues decrease more sharply.

There was only limited data availability for port dues for the **very low external cost scenario** as this type of ship is not accepted in all harbours. As a result, revenue figures were collected in only 6 of the ports in the study. As shown in Figure 85, the cost coverage

⁹¹ Or until 2016 for Emission Control Areas, which are not currently in force in Europe.

ratios are low for each of these ports: Antwerp (BE) 6%, Hamburg (DE) 4%, Rotterdam (NL) 12%, Gdansk (PL) 25%, Sines (PT) 27%, Constanta (RO) 15%. For these ports, cost coverage under the very low external cost scenario is higher than under the low external cost scenario. This is due to higher infrastructure costs for large bulk as opposed to large container vessels for these ports. On the other hand, Rotterdam, Gdansk, and Sines have far higher port charges for large bulk than large container vessels, and this is why the cost coverage ratios for these ports are slightly higher in this scenario.

Figure 85 - Maritime marginal cost coverage ratios for sample of 29 EEA Ports



7.4 Broader context of internalisation of the external costs of maritime transport

In the previous sections the role of taxes and charges in the internalisation of the external and infrastructure costs of maritime transport is discussed. As discussed in Section 2.5, other instruments (i.e. command-and-control measures, subsidies) can be used to meet the objectives of internalisation. In this section, we discuss the role of these policy instruments in the reduction of the main external costs (i.e. climate change, air pollution and accidents) of maritime transport.

7.4.1 Climate change

In addition to maritime charges implemented by countries and ports, there are several other policies that support the mitigation of CO₂ emissions from maritime transport in the EU. Many of the regulations that apply in Europe are actually determined in the IMO's International Convention for the Prevention of Pollution from Ships (MARPOL 73/78), although some are instigated at the EU level (e.g. Regulation on the monitoring and reporting of emissions). The most relevant policy instruments are discussed below.

Technical and operational energy efficiency measures: Energy Efficiency Design Index (EEDI) and Ship Energy Efficiency Management Plan (SEEMP)

Regulation 21 of MARPOL Annex VI that entered into force in January 2013, requires the attained Energy Efficiency Design Index (EEDI) of certain categories of ships not to exceed the required EEDI. The required EEDI is thereby determined according to a ship's size and type by using a reference line value, which represents an average EEDI value of ships

delivered in the preceding 10 years (from 1 January 1999 to 1 January 2009). The measure incentivizes the improvement of the technical efficiency of new ships. The Ship Energy Efficiency Management Plan (SEEMP) is an operational measure that establishes a mechanism to improve the energy efficiency of a ship in a cost-effective manner.

The global market that characterises maritime transport implies that a global approach, as illustrated by Marpol's EEDI and SEEMP, avoids distortions to the single market. Alternatively, national (tax) policies may cause such distortions. Similarly, these standards provide a clear market signal of long-term certainty. This may be particularly relevant in an industry where the lifetime of ships is roughly 25-30 years. The use of the EEDI may also address the issue of split incentives between ship owners and operators⁹², which is seen as one of the main barriers to invest in fuel efficiency measures in maritime transport (CE Delft ; Marena Ltd, 2012). National (tax/charge) measures may be used to support the implementation of the EEDI, as they can be used to stimulate the demand for ships meeting the EEDI (e.g. by differentiating port charges to the EEDI). However, this approach is currently not used by ports/countries.

Monitoring and reporting emissions

In 2015 the European Parliament and the Council of the European Union adopted a regulation on the monitoring, reporting and verification of CO₂ emissions from ships arriving at, within or departing from ports under the jurisdiction of a Member State. The aim of the regulation is to reduce CO₂ emissions in a cost efficient manner by providing insight into robust and verified emissions data and to stimulate the uptake of energy efficiency solutions and inform future policy making decisions (European Commission, 2019a). The first emission reports are due in April 2019. There is currently a proposal (2019/0017) to amend the previous regulation, so that it can be harmonised with the global Data Collection System (DCS) for fuel oil consumption of ships established by the IMO (COM (2019) 38). The monitoring obligation of the IMO's DCS starts in 2019, with reporting in 2020.

Monitoring and reporting of CO₂ emissions aims to reduce emissions by providing insights in fuel consumption. By providing this kind of information, this instrument complements price measures applied for maritime transport.

Climate change strategy of the IMO

In April 2018 the IMO's Marine Environment Protection Committee (MEPC) adopted an initial strategy on the reduction of GHG emissions from international shipping (50% reduction by 2050 relative to 2008) and to phase them out, as soon as possible in this century (IMO, 2018a). Different policy instruments are considered to realise the CO₂ reduction objective.

7.4.2 Air pollution

As discussed in detail in Section 4.5.2, the general framework for air quality in Europe is established in the **Air Quality Directive** and the **National Emission Ceilings Directive**. Specifically to maritime transport, several policy instruments are implemented to address air pollutant emissions. These include taxes/charges, but also some non-pricing policies. From the latter, the most important ones are discussed below.

⁹² There is a split incentive to invest in fuel efficient technologies because a ship owner has to invest in the fuel efficiency of a ship while the charterer pays for the fuel.

Emission standards

Annex VI of the MARPOL Convention (IMO, 2013) regulates the sulphur content in marine fuels to 0.1% in Emission Control Areas (the Baltic Sea, the North Sea and the English Channel in Europe). In 2016, the Marine Environment Protection Committee established that a fuel oil standard of 0.5% sulphur limit will become effective on 1 January 2020 for the rest of the world (as opposed to the current 3.5%). The EU directive regulating the sulphur content of marine fuels (Directive 2016/802) is consistent with these international commitments, but with further restrictions for passenger ships and ships in territorial waters (European Parliament, 2016). In addition, there are progressive NO_x emission limits for marine diesel engines installed on ships based on the year of manufacturing (IMO, 2019).

The global dimension of shipping emissions requires that these emissions are preferably addressed at the global level. Therefore, global emission standards are a suitable instrument to reduce the emissions of (new) ships. The harmonised approach of global emission standards may also (compared to national tax/charge instruments) contribute to less barriers to the internal market, resulting in a lower administrative/financial burden for the maritime sector and a better long-term investment climate for emission reducing technologies.

Emission control areas

Emission Control Areas (ECAs) are sea areas in which stricter emission standards for maritime vessels (regulated by the MARPOL Convention of the IMO) are established. In Europe, Sulphur Emission Control Areas (SECAs) have been implemented in the Baltic Sea, the North Sea and the English Channel). In these areas a sulphur limit of 0.5% holds (as opposed to the general limit of 3.5%). The Baltic Sea and North Sea are also designated by the IMO as NO_x Emission Control Areas, starting from 1 January 2021. In these areas the most stringent NO_x emission standards (Tier III) of the IMO applies to all vessels constructed after 1 January 2021. National tax/charge instruments (e.g. differentiated port dues, fairway dues) may have an additional effect to ECAs, as these instruments do also affect the vessels that are not required to meet the limits set for the ECAs (e.g. the non-Tier III ships with respect to NECAs) (IVL and CE Delft, 2016). In this respect, both types of instruments can be considered complementary.

7.4.3 Accidents

Maritime safety in the EU is exclusively addressed by command-and-control measures, mainly by setting (minimum) standards or requirements. The main command-and-control measures are discussed below.

Market-based measures applied in the maritime sector (i.e. port charges, fairway dues) are not directly linked to external accident costs. Therefore, there is no interaction between any of the measures discussed below and the pricing instruments covered in the previous sections.

Technical and operational safety requirements

Directive 2014/90/EU aims to enhance safety at sea and to prevent maritime pollution. This is done through the uniform application of relevant international instruments relating to marine equipment being placed on board on EU ships. This Directive is complemented by the international convention for the Safety of Life at Sea (SOLAS). The SOLAS Convention's

main objective is to specify minimum standards for the construction, equipment and operation of ships, compatible with their safety. Flag states are responsible for ensuring that ships under their flag satisfy the requirements, with certificates acting as proof.

Technical inspection requirements

The safety of maritime ships can be improved by regularly inspecting whether ships meet the technical requirements set by the IMO and the EU. The requirements for such technical inspections are regulated by two Directives:

- Directive 2009/21/EC aims to enhance safety and prevent pollution from ships by ensuring that Member States effectively and consistently discharge their obligations as flag states, including technical inspections of the ships.
- Directive 2009/16/EC on port state control (i.e. inspection of foreign ships in port in States other than the State of registry) is targeted at reducing substandard shipping in EU waters. Its main goals are to increase compliance, establish common criteria for the control of ships, inspection and detention. Inspection issues that are regulated by this Directive include the competency of the crew, the condition of a ship and its equipment, and the fact that the vessel is manned and operated in compliance with applicable international law.

Vessel Traffic Monitoring/Maritime surveillance

The European seas and coastal waters combine dense traffic routes with areas of serious danger to shipping. For this reason, the EU has initiated the establishment of a vessel traffic monitoring and information system (Directive 2002/59). Its purpose is to enhance the safety and efficiency of maritime traffic, to improve the response of authorities to incidents, accidents or potentially dangerous situations at sea and to contribute to better prevention and detection of pollution by ships.

Requirements to training of seafarers

Directive 2008/106/EC requires Member States to ensure that seafarers are trained in accordance with the requirements of the IMO's International Convention on Standards of Training, Certification and Watchkeeping for Seafarers. The ultimate goal is to enhance maritime safety through education, training and certification of seafarers (European Commission, 2017a).

Passenger safety regulations

Directive 2009/45/EC sets safety rules and standards for passenger ships, such that safety of life and property on new and existing passenger ships on domestic and international voyages is harmonised.

8 Aviation

8.1 Introduction

This chapter discusses the resulting average and marginal cost coverage ratios for passenger aviation via the sample of airports selected for this study. All financial figures are adjusted for differences in purchase power between countries (by using Purchasing Power Standards, PPS), in order to allow for direct comparisons between countries. Average cost coverage ratio results are discussed in the following order:

- overall total cost coverage ratio;
- overall total cost coverage ratio with variable infrastructure costs;
- overall variable cost coverage ratio;
- overall infrastructure cost coverage ratio;
- variable infrastructure cost coverage ratio.

In addition, Section 8.4 will provide a discussion on the broader context of the non-pricing measures introduced across Europe that impact aviation externalities. Table 25 shows the categories of revenues, taxes/charges, and external costs considered for each ratio.

Table 25 - Costs and revenues used for different passenger aviation cost coverage ratios

Type of comparison	Infrastructure costs	External costs	Taxes and charges
Overall average	All infrastructure costs (excluding non-aviation costs).	All external costs.	All taxes and charges.
Fixed	All investments and traffic independent part of O&M and renewal costs.	Habitat	None
Variable	Traffic dependent part of O&M and renewal costs (estimated as one third of all infrastructure costs for aviation activities).	Accidents, air pollution, climate, noise, WTT.	Fuel taxes, aviation taxes, charges (LTO, passenger, security, PRM, noise/emissions, airbridge, aircraft parking, ground handling services, fuelling, infrastructure.

For aviation specifically, some charges data could not be collected or allocated at airport level as part of the data exercise conducted for the related study on transport taxes and charges (CE Delft, 2019b). These include EU ETS allowances, en route air traffic management charges, and terminal navigation charges. Revenues for these charges were not available at the airport level. In addition, aviation tax revenues have only been included for selected airports (mainly airports in AT, DE, UK, NO) where aviation taxes are levied. For these reasons, the cost coverage ratios presented are expected to be an underestimate for aviation.

The following text box explains EU ETS allowances (not included in the data presented) in further detail.

Charges levied via the European Emission Trade System (EU ETS)

Since 2012 aviation has been covered by the European Emission Trade System (EU ETS): The ETS is designed as compensation scheme - every emitted tonne of carbon dioxide must be offset through an emission right. Emissions are however 'capped'; the emission cap for the period 2013-2020 equals to 95% of the historical emissions. Airlines receive 82% of their emission rights without paying for them, for free, and 15% need to be acquired on the market (the remaining 3% constitute a special reserve). The geographic scope of the EU ETS is limited to intra-EEA flights. Under the ETS fourth phase, both the cap and the share of free allowances will be significantly reduced. A further element to be taken into account is the introduction of the so-called Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) as of 2021. EU ETS allowances are not included in this report because it is not possible to allocate to specific airports the ETS revenues calculated in the related report, "Transport Taxes and Charges in Europe" (CE Delft, 2019b).

It is also important to note that the aviation sector is a net buyer of ETS allowances, which results in CO₂ emissions savings in other sectors covered by the ETS. These emissions savings have not been taken into account in calculating the external costs of aviation used in this study. This is coherent with the approach as regards revenues from other taxes and charges - those can also be used to cover the cost of e.g. GHG emissions or other externalities and this is actually also done. As regards aviation, these emissions savings would reduce the average CO₂ related costs of intra-EEA flights by around 40%.

Table 26, summarising data from the related study on transport taxes and charges, shows the roughly estimated cost for a European Emission Allowance (EEA) per pkm based on the average price of an EEA in 2016 (5.20 euro/tCO₂) (CE Delft, 2019b). However, recently the EEA allowance prices experienced an increase up to 20 euro/tCO₂ meaning that these costs per pkm would be currently higher. In addition, the calculations of the climate change costs in this study have been based on a medium-term avoidance cost, estimated at 100 euro/tCO₂, based on literature review. This medium-term avoidance costs are in line with the Paris Agreement ambition. It is clear that the EU ETS allowance price of 2016 is very different from it.

Table 26 - Cost for a European Emission Allowance per passenger-kilometre (€)

Aircraft type	Bombardier CRJ900	Embraer 170	Airbus A320	Boeing 737
Distance (km)	500	500	1,500	1,500
CO ₂ emissions (g/vkm)	11,224	15,247	11,313	12,676
Cost per pkm (€ct/pkm)	0.07	0.09	0.04	0.06

Marginal cost coverage ratios for passenger aviation are estimated for three scenarios - high external cost scenario, representative scenario, and low external cost scenario. For aviation, these are defined in Table 27. The reference vehicles used in these scenarios come from those in the related report, "Transport Taxes and Charges in Europe" (CE Delft, 2019b). For the representative scenario, the costs and revenues presented are equal to the average variable costs and revenues, representing the weighted averages of the actual real-world conditions/situations. This means that the average in the representative scenario may not lie in the middle of the high-cost and low external cost scenario (e.g. climate change costs for aviation).

Table 27 - Definition of aviation marginal cost scenarios

	High external cost scenario	Representative scenario	Low external cost scenario
Passenger aircraft	Embraer 170 Short-haul (500 km) High emission level High noise class Night	Average airplane Average day/night	Airbus A34-300 Long-haul (15,000 km) Low emission level Low noise class Daytime

8.2 Average cost-based internalisation

Overall cost coverage ratio

Figure 86 shows the spread of the overall total cost coverage for our sample of airports, comparing revenues from all internalisation measures with all external and infrastructure costs (labels were removed for legibility). The line in the figure represents full cost coverage. The graph shows the data spread, a version of the graph with airport data labels can be found the excel file in Annex H.

Revenues from taxes and charges are lower than total external and infrastructure costs for all but one airport in the sample (Sofia). Another pattern shown in the figure is that average total costs vary greatly between the airports sampled, with the weighted average for the EU28 airports⁹³ at €ct 4.83 per pkm. On the other hand, the (weighted) average total revenue only amounts to €ct 1.52 per pkm.

Luxembourg and Ljubljana airports stand out as they have the highest total average costs, at €ct 10.01 per pkm and €ct 9.88 per pkm. The main reason for this is the comparably high average external costs per pkm of these two airports, resulting mainly from a high share of (very) short distance flights that have the highest external costs per pkm (mainly climate change and noise costs). In addition, both airports have high average infrastructure costs due to their small size and hence limited economies of scale. Luxembourg has an infrastructure cost of €ct 2.5 per pkm and Ljubljana of €ct 3.5 per pkm - compared to the EU28 average airport infrastructure costs (for our sample of airports) of €ct 1.6 per pkm. Other airports in the sample with high average costs are Bratislava (€ct 8.7 ct per pkm) and Tallinn (€ct 8.0 per pkm), both Eastern European airports. These two airports experience high average costs for the same reasons. There are no notable outliers with low average costs.

There is one airport with exceptionally high average revenues, Sofia airport. This is discussed below in greater detail.

⁹³ All financial figures are adjusted for differences in purchase power between countries (by using Purchasing Power Standards, PPS), in order to allow for direct comparisons between countries.

Figure 86 - Overall spread of total cost coverage for sample of 38⁹⁴ EU, US, and Canada airports

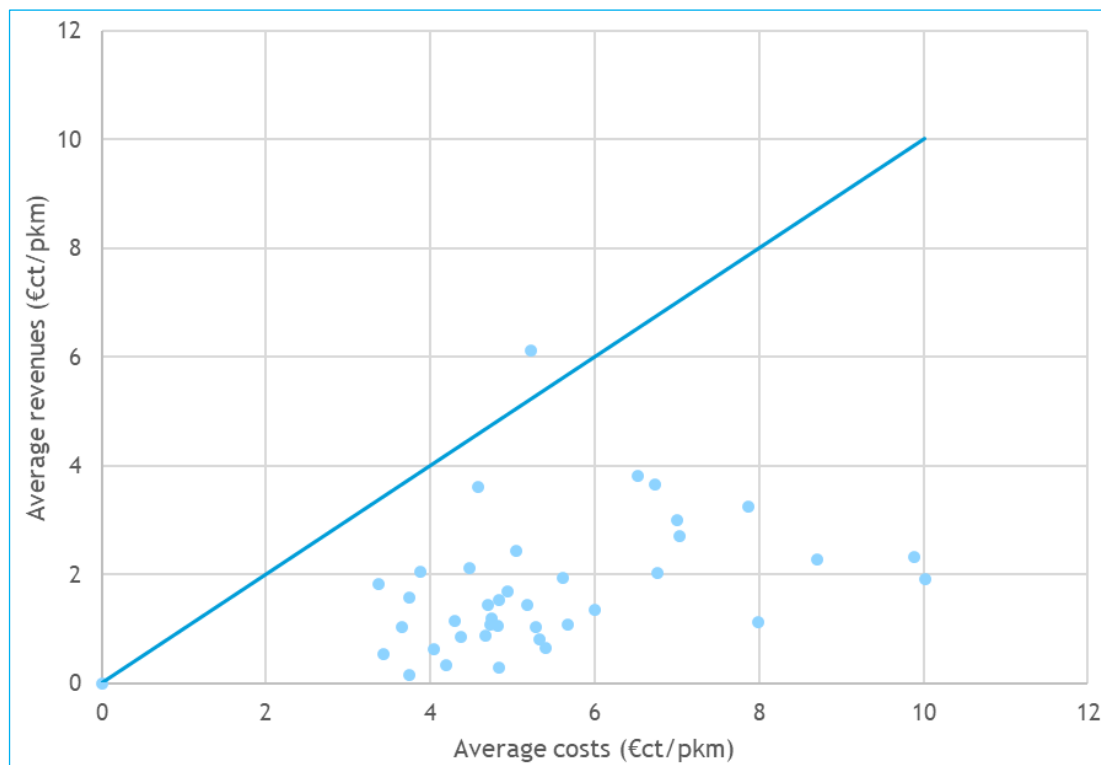
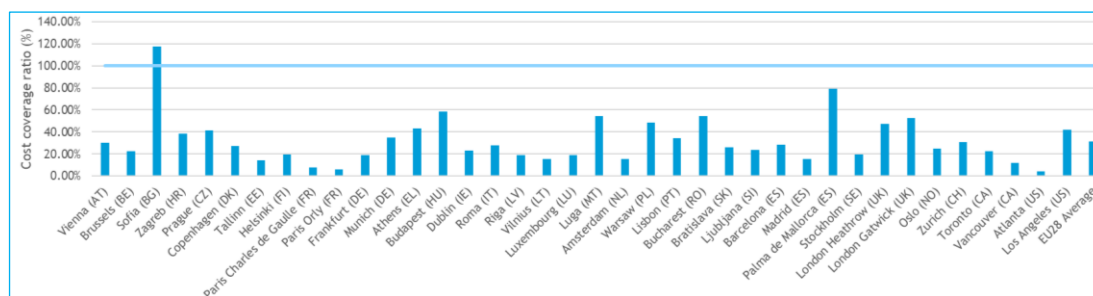


Figure 87 shows the total cost coverage ratio attained by each airport in the sample, with missing ratios for Larnaka and Tokyo Haneda airport due to unavailable data. On average, EU28 airports attained a 32% total cost coverage ratio. Only one airport passes 100% cost coverage - Sofia airport. Palma de Mallorca is second-highest with 79% cost coverage. Sofia airport achieves greater than 100% cost coverage via exceptionally high average revenues of €ct 6.1 per pkm due to high LTO and security charges in Sofia. For Palma, the main reasons are the high level of average taxes and charges, combined with relatively moderate average costs.

EU28 airports achieving notably low overall total cost coverage ratios are Paris CDG (7.8%) and Paris Orly (6.2%), due to low average revenues. For example, neither airports have airbridge, fuelling, groundhandling, security, noise or emission charges. In addition, data on aviation tax revenues for French airports could not be collected for this study.

⁹⁴ The data for this ratio could not be collected from Larnaka and Tokyo Haneda Airport.

Figure 87 - Overall total cost coverage ratio for sample of 38 EU, US, and Canada airports

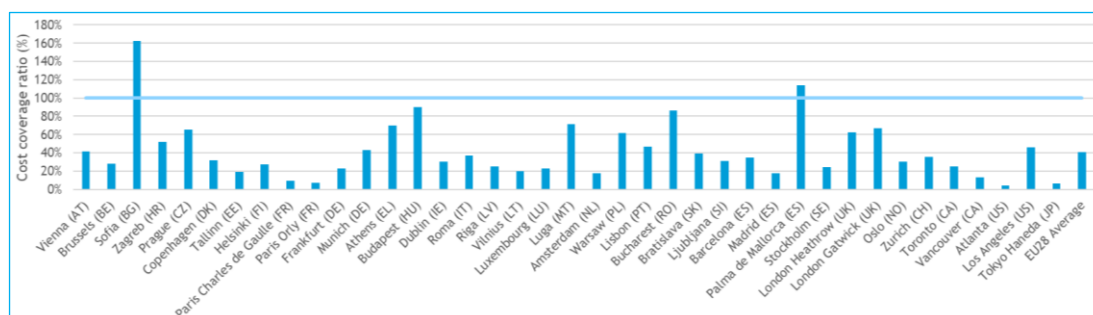


Overall cost coverage ratio excluding fixed infrastructure costs

Airport variable infrastructure costs were estimated as one third of all costs (CE Delft, 2019a) for all airports, so the spread of total cost coverage with variable infrastructure costs for our sample of airports (measuring revenues from all internalisation measures with all external and variable infrastructure costs) shows the same patterns as the figure on total costs and revenues in the section above. For this reason, the graph has not been repeated.

Figure 88 shows the cost coverage ratios for the airports in our sample, with an EU28 average of 41%, slightly higher than the EU28 average overall total cost coverage ratio discussed above due to the exclusion of fixed infrastructure costs. Patterns here are the same as under the overall total cost coverage analysed.

Figure 88 - Overall total cost coverage ratio with variable infrastructure costs for sample of 39 EU, US, Canada, and Japan airports



Variable external and infrastructure cost coverage ratio

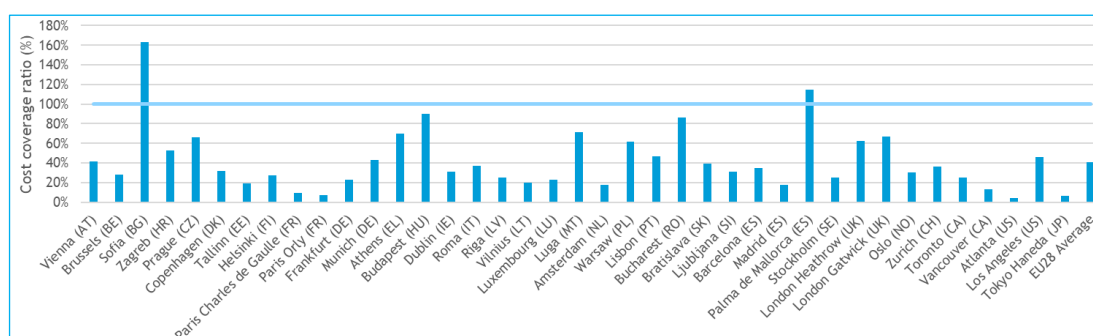
Total variable cost coverage for airports in our sample compares revenues from variable taxes and charges with variable external and infrastructure costs. Variable taxes and charges cover infrastructure charges and fuel/energy taxes. Variable external costs are all those excluding habitat costs, while variable infrastructure costs, as previously discussed, are defined as one third of all infrastructure costs for all airports.

As none of the aviation taxes and charges are fixed charges, and all but one external cost is considered to be a variable cost, the overall picture is the same as the one presented under the overall total cost coverage with variable infrastructure costs subsection above. For this reason, the figure showing the spread of variable costs and revenues is not repeated in this section.

Average variable costs in the EU28 airports come out to €ct 3.73 per pkm, while average revenues sit at €ct 1.52 per pkm.

Figure 89 shows the overall total variable cost coverage ratio attained for each airport in our sample. The overall level of cost coverage attained under this indicator is slightly higher than under the overall total cost coverage (average of 41% for the EU28) and the trends are the same as those presented in that section.

Figure 89 - Aviation overall total variable cost coverage ratio for sample of 39 EU, US, Canada, and Japan airports



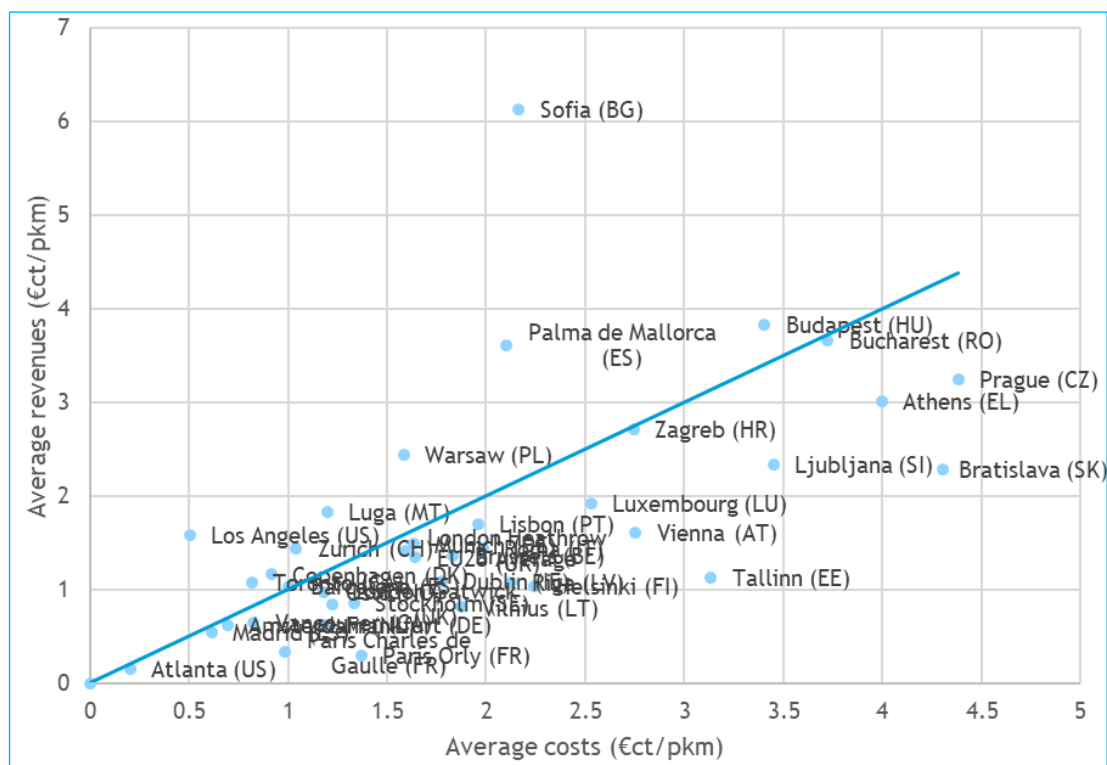
Overall infrastructure cost coverage ratio

Figure 90 shows the spread of overall infrastructure cost coverage for passenger aircraft, comparing revenues from infrastructure charges with all infrastructure costs in the airports sampled for this study. This analysis covers all airports sampled in the study except Larnaka (Cyprus) and Tokyo Haneda airports.

Infrastructure revenues in the figure cover revenues from LTO, passenger, security, persons with reduced mobility (PRM), noise/emission, airbridge, aircraft parking, ground handling, fuelling, other infrastructure charges (e.g. IT) but exclude taxes⁹⁵.

⁹⁵ For terminal navigation and en-route charges, no data were available for most of the airports. Thus this definition differs from the term 'infrastructure charges' used for aviation charges in (CE Delft, 2019b) in order to match the coverage of infrastructure costs.

Figure 90 - Overall spread of infrastructure cost coverage for sample of 38⁹⁶ EU, US, and Canada airports



The average cost for the EU28 airports sampled is €ct 1.64 per pkm, although many Eastern European airports have higher average infrastructure costs, such as Prague, Athens, Bratislava, Bucharest, Budapest, Zagreb, Ljubljana, and Tallinn. Airport costs are most affected by the share of intercontinental flights and airports with low shares of these flights have much higher average costs per passenger-kilometre. Another reason is that these airports tend to be smaller and as a result, costs per passenger for these airports are also higher than average.

The average revenue for the EU28 airports sampled is €ct 1.34 per pkm. Sofia Airport is an outlier, with average revenue of €ct 6.1 per pkm, which is the highest level for average infrastructure revenues of all airports (from charges). Other airports with higher revenues are Budapest (€ct 3.8 per pkm), Bucharest (€ct 3.7 per pkm), Palma de Mallorca (€ct 3.6 per pkm), Prague (€ct 3.2 per pkm), and Athens (€ct 3.0 per pkm) - as a result of airport charges. In particular, Budapest has high revenue from passenger charges, Prague from high LTO charges, and Athens from passenger charges and their airport development fund. There is no data on the breakdown of airport charges for Bucharest and Palma de Mallorca.

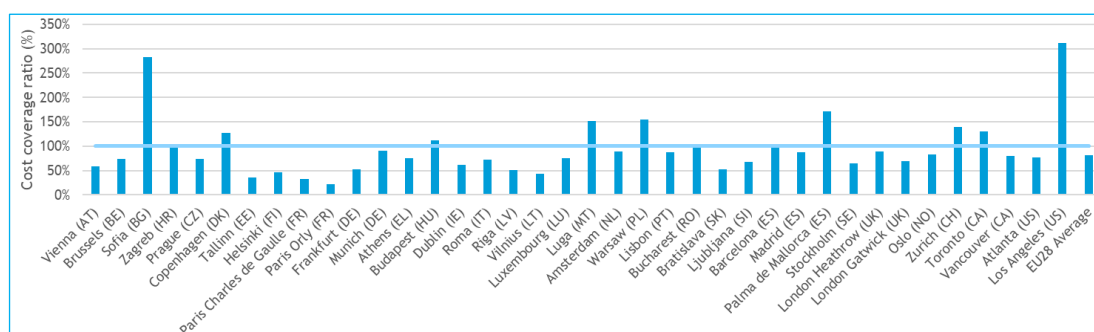
Figure 91 shows the infrastructure cost coverage ratios for the airports studied. For the EU28 airports sampled, the average infrastructure cost coverage ratio is 82%. The EU airports with the highest cost coverage ratios are Sofia (283%) and Palma de Mallorca (172%). The case of Sofia and Palma was discussed previously under the overall total cost coverage ratio.

⁹⁶ The data for this ratio could not be collected from Larnaka and Tokyo Haneda Airport.

Other EU airports with more than 100% overall infrastructure cost coverage are Warsaw (154%), Luga (152%), Copenhagen (127%), Budapest (112%), and Barcelona (103%). These airports have high-cost coverage ratios through higher than average revenues, except for Copenhagen and Barcelona, which have low costs compared to the EU28 average (and lower revenues compared to the average but enough to more than recover costs).

Tallinn Airport (36%) has a relatively low infrastructure cost coverage due to the high level of costs discussed under the overall total cost coverage ratio. In addition, Paris Charles de Gaulle (33%) and Paris Orly (22%) have low-cost coverage ratios due to low revenues (this was also discussed under the overall total cost coverage ratio).

Figure 91 - Overall infrastructure cost coverage ratio for sample of 38 EU, US, and Canada airports



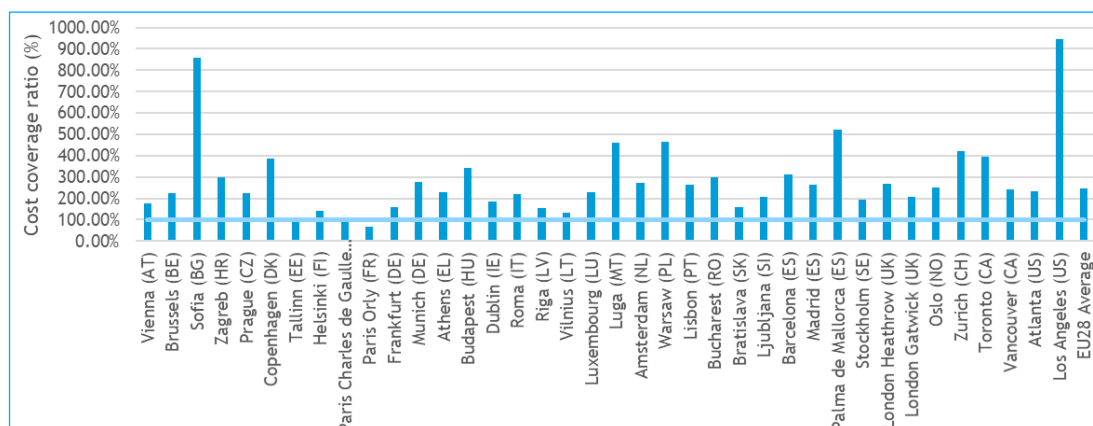
Variable infrastructure cost coverage ratio

Figure 92 displays the spread of variable infrastructure cost coverage, comparing revenues from variable infrastructure charges with variable infrastructure costs. Variable costs were estimated as one third of all costs for all airports (CE Delft, 2019a) while all revenues collected were defined as variable (CE Delft, 2019b).

As the revenues covered do not change from the overall infrastructure revenues considered above, and costs have only been divided by a constant number, the patterns are the same as those already discussed. For this reason, the scatter plot is not repeated. Only the magnitude of the costs changes in this figure due to the subset taken for this ratio, with average costs for the EU28 airports at €ct 0.54 per pkm. As a result, all but one airport in the sample (Paris Orly) cover at least 100% of costs.

Figure 92 shows the corresponding variable infrastructure cost coverage ratios. They are far higher now that all revenues remain in the numerator, but only a third of costs are now in the denominator. Again, the overall patterns are the same as those in the overall infrastructure cost coverage ratio and the average cost coverage ratio for the EU28 airports is 247% here.

Figure 92 - Variable infrastructure cost coverage ratio for sample of 38 EU, US, and Canada airports



8.3 Marginal social cost-based internalisation

The marginal cost coverage ratios for passenger aircraft compare marginal external and infrastructure costs with marginal tax and charge revenues for three scenarios: a high external cost scenario, a representative scenario, and a low-cost scenario. As with all previous cost coverage ratios, these are defined for the set of airports in our sample.

The variable average infrastructure costs are used as a proxy for the marginal infrastructure costs, but for the specific vehicle types and scenarios defined.

As previously presented in Section 2.4.2, there are a number of key attributes of marginal cost coverage scenarios to consider when analysing the results.

Considerations with respect to marginal cost scenarios

When interpreting the results of the marginal cost coverage analyses, the following issues with respect to the marginal cost scenarios should be considered:

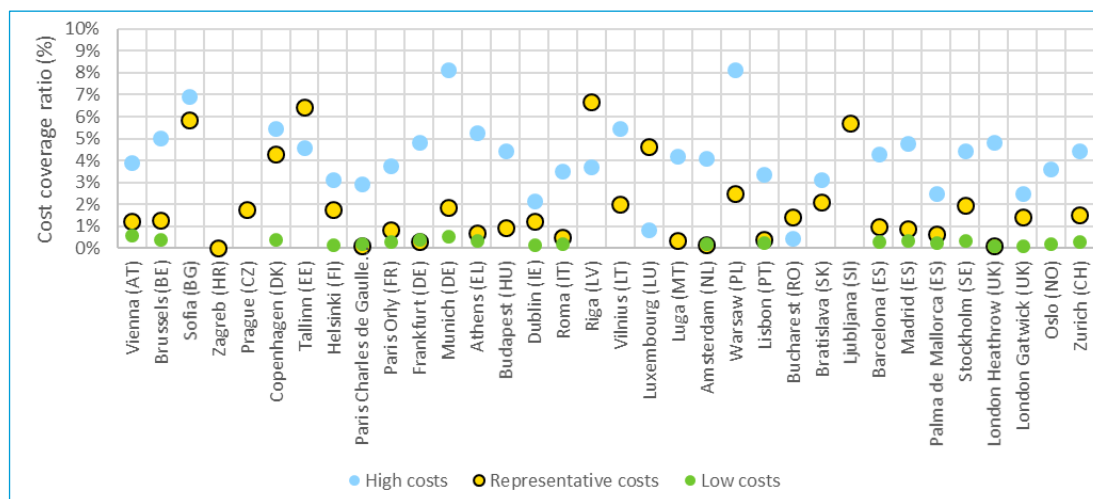
- The high and low-cost scenarios considered are sometimes a bit extreme, in order to reflect cases with high or low marginal external cost values. As a consequence, these scenarios are not necessarily reflecting cases that are fully representative of real-world situations.
- The scenarios are defined based on the level of external costs. The marginal cost coverage ratios, however, are also driven by marginal infrastructure costs and taxes/charges. Therefore, low marginal cost coverage ratios may be found for low external cost scenarios, if marginal infrastructure costs are relatively high or tax/charge levels relatively low.

8.3.1 Passenger aircraft

The representative scenario looks at an average airplane for an average day or night flight. Meanwhile, the high external cost scenario considers costs, charges and taxes associated with an Embraer 170 passenger airplane flying short-haul (500km), with high emissions and a high noise class, flying at night. The low external cost scenario analyses costs, charges and taxes for an Airbus A34-300 passenger plane, flying long-haul (15,000km), with low emissions and a low noise class. This scenario considers daytime flights.

Figure 93 shows the spread of cost coverage ratios for each scenario by airport (excluding Larnaka airport due to missing infrastructure data), focused on the range where most ratios lie.

Figure 93 - Aviation marginal cost coverage ratios for sample of 34 EEA airports (magnified subset)



Under the **high external cost scenario**, the average cost coverage ratio is 5% and it ranges from 0.5% (Bucharest) to 26% (Prague). Airports with higher cost coverage under the high external cost scenario are Prague (26%), Zagreb (14%), and Ljubljana (12%) – all Eastern European airports⁹⁷. This is a similar pattern to that seen under the overall infrastructure cost coverage ratio for average cost-based internalisation. Mainly Prague, Zagreb, and Ljubljana all have a high level of taxes and charges for the reference flight in the high external cost scenario, and all comparably moderate external and infrastructure costs.

Airports with low-cost coverage ratios under the high external cost scenario are Bucharest (0.5%), Luxembourg (1%), London Gatwick (2%), and Dublin (2%). This is due to low revenues compared to costs under this scenario. Bucharest and Luxembourg have a very low level of taxes and charges and quite high infrastructure costs at the same time. For London Gatwick and Dublin, also the taxes and charges for the high external cost scenario are comparably low.

In the **representative scenario**, the average airport has a cost coverage ratio of 2%, though they range between 0% and 20%. Airports achieving higher cost coverage in this scenario include Luxembourg (5%), Sofia (6%), Tallinn (6%), Ljubljana (6%), Riga (7%), and Oslo (20%). Aside from Luxembourg and Oslo, higher cost coverage is achieved in Eastern European airports. The two non-Eastern European airports, Luxembourg and Oslo airports, are small airports, which may help explain higher cost coverage⁹⁸.

The sample of airports with a cost coverage ratio under the **low external cost scenario** is limited to airports with long-haul flights, by definition, for 21 airports in our sample. Cost coverage is very low across all airports, with an average of 0.3%. This is mainly because the

⁹⁷ These airports (Prague, Zagreb, and Ljubljana) all sit outside of the magnified subset displayed in Figure 92.

⁹⁸ Though Oslo airport doubled its terminal space in 2017, this is not reflected in the 2016 data collected for this study.

average revenues from taxes and charges per pkm are very low for long-haul flights: the total level of taxes and charges is not dependent on the flight distance in most cases (i.e. constant). On the other hand, the external costs for long-haul flights are getting larger for longer flights due to increasing climate change costs. As a consequence, the average external costs per pkm are only slightly lower for long-haul flights than for short-haul flights, whereas the average revenues from taxes and charges are by a factor lower than for short-haul flights. This all leads to significantly lower cost coverage ratios for long distance flights.

8.4 Broader context of internalisation of the external costs of air transport

In the previous sections the role of taxes and charges in the internalisation of the external and infrastructure costs of aviation is discussed. As discussed in Section 2.5, other instruments (i.e. command-and-control measures, subsidies) can be used to meet the objectives of internalisation. In this section, we discuss the role of these policy instruments in the reduction of the main external costs (i.e. climate change, air pollution, noise, and accidents) of aviation.

8.4.1 Climate change

As discussed in CE Delft et al (2019b)), the main EU policy instruments to reduce the GHG emissions of aviation is the inclusion of intra-EEA aviation in EU ETS. In addition, to this market-based instrument, the EU also applies some non-pricing instruments. The main ones are the CO₂ standards for new aircrafts (based on the ICAO standards) and the Single European Sky initiative. Both instruments are discussed in more detail below. In addition, we also briefly discuss the on-going work of ICAO on CORSIA.

CO₂ standards for new aircraft

In 2017, the International Civil Aviation Organisation (ICAO) adopted CO₂ emission standards for new aircrafts (ICAO, 2017a). Contained in a new Volume III to Annex 16 of the Chicago Convention, this standard sets limits to the CO₂ emissions from aircrafts in relation to their size and weight. The standard will apply to new aircraft type designs from 2020 and to aircraft type designs already in production as of 2023. Aircraft designs in-production that do not meet the standard by 2028 are not allowed to be produced any longer unless they are sufficiently modified.

The global scale of the CO₂ emission standards recognises the largely transnational nature of aviation, with almost 90% of GHG emissions from aviation in the EU coming from international flights (European Commission, 2016a). The global approach also avoids possible distortions to the single market for aviation, which could be the case by implementing national (tax) policy incentives (Worldbank, 2012). This harmonised approach reduces the administrative burden for industry (EASA, 2017) and it also provide more (regulatory) certainty to the industry, supporting investments in fuel-efficient technologies and providing options to realise economies of scale. The standards also provide more long-term certainty (compared to national tax/charge schemes, which are often more volatile), which is required given the long lead-times in and high costs of developing fuel efficiency measures for aircrafts (Lee & Mo, 2011). Another way in which the CO₂ standards complement the European ETS is by reducing the number of allowances needed for aviation in the EU ETS, reducing the costs of the EU ETS and strengthen the likelihood that targets are met (CE Delft, 2010). The other way around, market-based instruments like the

European ETS also complements CO₂ standards, as they address reduction options (e.g. operational efficiency measures) that are not incentivised by the CO₂ standards.

Single European Sky initiative

The Single European Sky (SES) initiative was adopted by the European Commission in 2004 (and amended in 2009) in order to modernise and harmonise air traffic management systems through the definition and deployment of innovative technological and operational solutions. The core idea of the SES is to shift the design of air traffic management from national level to the EU level to benefit from efficiencies of scale and overcoming administrative and technical barriers created by the legacy of national approaches. For this purpose, national air traffic control organisations are required to work together in regional airspace blocks (Functional Airspace Blocks - FAB), binding key performance targets were introduced for safety, capacity cost efficiency and environmental performance (that must be met nationally or at FAB level), and a network manager (Eurocontrol) is established that performs certain tasks that are most efficiently carried out centrally (e.g. route design). To support these actions, the technical programme SESAR (Single European Sky Air traffic management Research) was launched in 2007, aimed to modernise the current equipment and procedures. After a report on the first SES package in 2007, the European Commission came up with a SES II legislative package in 2013, addressing in particular the inefficiency of air navigation services and the fragmented air traffic management system.

One of the main objectives of the SES initiative is to reduce the environmental impact per flight with 10%. This should be mainly done by simplify flight paths in the EU, which are often longer than necessary (ATAG, 2015). In this respect, this policy instrument is complementary to aviation taxes and charges, as these instruments do not affect air traffic management decisions. The CO₂ reduction realised by implementing the SES initiative may also complement the EU ETS in the same way as CO₂ standards do.

Ongoing work in ICAO on CORSIA

In 2016, the ICAO agreed to address international aviation emissions by establishing a global market-based measure in the form of the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA). This scheme aims to stabilise CO₂ emissions at 2020 levels by requiring airlines to offset the growth of their emissions after 2020 (by purchasing eligible emission units generated by projects that reduce emissions in other sectors). Participation will be voluntary during the pilot and first phase (2021-2026) and will become mandatory for all states in the second phase, as of 2027. Work is ongoing at ICAO to develop the necessary implementation rules and tools to make the scheme operation. If this ongoing work would result in a cap-and-trade scheme, CORSIA should be considered a price-based measure (like ETS).

The EU ETS for aviation will be subject to a new review in the light of the international developments related to the operationalisation of CORSIA. The next review should consider how to implement the global measure in Union law through a revision of the EU ETS legislation. (European Parliament, 2018c).

8.4.2 Air pollution

As mentioned in Section 4.5.2, the general framework for air quality in Europe is established in the **Air Quality Directive** (introducing ambient air quality standards for the protection of human health) and the **National Emission Ceilings Directive** (see Section 4.5.2 for a discussion on these two Directives). As part of meeting the targets set by these two Directives the EU has implemented aircraft emission standards, which are in line with the **engine certification standards** adopted by the Council of ICAO (ICAO, 2017b). As these standards were originally designed to improve air quality in the vicinity of airport, they are developed for a reference landing and take-off (LTO) cycle below 915 metres of altitude. The standards cover NO_x, carbon monoxide, unburned hydrocarbons and non-volatile particular matter emissions. Furthermore, there are provisions regarding smoke and vented fuel.

Like the CO₂ standards for aircrafts, the global scale of the aircraft engine emissions standards avoids the distortion of the internal market, resulting in a lower administrative burden for industry and a harmonised long-term target that provides certainty to invest in emission reduction technologies (EASA, 2017). In these ways, the engine emissions standards complement airport charges differentiated to aircraft's emission levels as applied at some European airports CE Delft et al. (2019b), as these charges provide a more fragmented incentive to reduce the emission levels of new aircrafts.

8.4.3 Noise

The EU aims to reduce the nuisances of aviation noise on citizens through general rules on environmental noise management as well as by specific regulations on aviation noise. The general framework on environmental noise management is set by the Environmental Noise Directive (Directive 2002/49/EC), which requires Member States to regular map noise (including around large airports), provide information to the public and provide action plans to prevent or reduce exposure to environmental noise. A more detailed discussion on the Environmental Noise Directive can be found in Section 4.5.3.

In addition to the general framework on environmental noise management, specific air-traffic noise management policies are implemented at the EU level, including the application of noise standards developed within the ICAO and the use of noise measures to implement the 'balance approach principle at European airports. Next to these EU-wide policy measures, individual Member States and airport also apply different kinds of noise abatement measures (e.g. insulation programmes). These various EU and national aviation noise policy instruments are discussed in more detail below.

Noise certification standards

Over the past 40 years, ICAO has regulated aircraft noise at source with implementing noise standards (ICAO, 2017c). These noise standards have been tightened over the years for newly certificated aircrafts and for aircrafts that recertification is requested. The ICAO noise certification standards have been implemented in EU legislation by Directive 2006/93/EC. The same standards are also applied in Regulation 748/2012, which provides rules for the airworthiness and environmental certification of aircrafts in the EU.

Like the CO₂ and engine emission standards for aircrafts, the global scope of the noise standards avoids the distortion of the global market, resulting in lower administrative burden for industry as the same standards will likely be applicable in world regions other than Europe as well (EASA, 2017). Furthermore, globally harmonised standards would

provide a consistent target that provides certainty to invest in noise-reducing technologies. Due to this harmonised approach, the noise standards can be considered complementary to the more fragmented pattern of noise differentiated airport charges. The latter may, however, complement the noise standards as they address other noise reducing options (e.g. operational measures) as well.

Operating restrictions at Community airports

The EU have implemented a regulation on the procedures concerning the introduction of noise-related operating restrictions (Regulation 598/2014). Leaving the actual implementation of noise abatement measures under the remit of Member States, a common approach is set by this Regulation in line with the internationally principles on noise management, the so-called ‘Balanced approach’, agreed and recommended by the ICAO. This approach consists of identifying the noise problem at a specific airport and analysing various measures available to reduce noise based on objective and measurable criteria (including cost-effectiveness). The noise abatement measures that should be considered are:

- making aircrafts quieter by setting noise standards;
- managing the land around airports in a sustainable way;
- adapting operational procedures to reduce the noise impact on the ground;
- introducing operating restrictions (including phasing out marginally compliant aircrafts, i.e. when international standards would only be met by a margin on less than 10 dB).

Noise-related operating restrictions should be introduced only when other Balanced Approach measures are not sufficient to attain the specific noise abatement objectives

An important objective of this regulation is to reduce the inconsistencies as to how operating restrictions are applied at European airports. Operation noise restrictions may have an impact on the capacity of an airport, which can in turn have a knock-on effect at other airports (European Parliament, 2014a). Therefore, harmonisation of operating restrictions may remove some barriers to the internal market. It may also result in lower administrative and financial costs for industry and may provide more certainty with respect to investments in noise reduction technologies (CEP, 2012). The prescribed approach to decide on noise abatement measures also requires to take other (environmental) impacts into account, which may result in co-benefits in other fields (e.g. climate change, air pollution) as well (European Commission, 2011b).

By applying a harmonised approach to implement noise abatement measures, this regulation complements noise differentiated airport charges and aviation taxes. As the latter differ between Member States, they will not provide a common incentive to airport/airlines throughout Europe, resulting in sub-optimal outcomes. Furthermore, the holistic approach presented in the Regulation to choose noise abatement measures (including other impacts of the measures as well) complements the more targeted objectives of noise differentiated taxes/charges.

National/local programmes for the acquisition or insulation of dwellings

Many airports are applying noise abatement schemes in order to reduce the negative impacts of aircraft noise for residents whose dwellings are located in the surroundings of the airport. These abatement schemes often include insulation programmes for houses and public buildings like schools and hospitals, financing the implementation of insulation measures. For example, the Passive Noise Abatement program of Frankfurt airport provides financial support to noise protection measures, differentiated to four noise protection zones (defined based on measured noise levels). At some airport, voluntary dwelling purchase

schemes are applied in addition to the insulation programmes. For example, at Dublin airport an offer of purchase for all houses that are exposed to noise levels above 69 dB LAeq should be made prior to the commencement of operation of a new runway (Fingal County Council, 2018). As these national/local abatement schemes address specific dwellings, they can address the situations with most serious noise problems. In this way, these measures complement the noise charges (and other airport charges and aviation taxes) that have a more general scope.

8.4.4 Accidents

As there are no taxes or charges for aviation that address the accident externality, this is done exclusively through technical requirements and regulation. Many of the Directives set (minimum) standards or requirements in order to enhance safety during the flight and on the ground.

The market failure addressed by each of the directives is the negative externality in the form of external accident costs. As airport charges and aviation taxes are not directly linked to aviation safety, there is no interaction with price instruments.

Regulations

Air safety regulations exist at two main levels, at the level of the ICAO and at the European Union.

At the level of the International Civil Aviation Organization (ICAO) a number of Standards and Recommended Practices have been developed to enhance aviation safety. They provide the foundation of all safety regulatory regimes at a global scale. To ensure uniform application of the ICAO standards the Universal Safety Oversight Audit Programme was established in 1999. There are also a number of articles in the Convention on International Civil Aviation that detail rules regarding aerodromes (article 15) and navigation services (article 28). For air traffic management there are a number of manuals.

At the level of the EU there is a vast array of regulations aimed to enhance aviation safety. There are regulations for aircraft technical requirements, technical inspection requirements, aerodromes, air traffic management, air navigation, air operations and air crew. Some regulations (e.g. 216/2008) cover multiple areas. A short description of the relevant regulations is provided below:

- *Regulation 2018/1139* (and its predecessor *regulation 216/2008*) was adopted to establish and maintain a high and uniform level of civil aviation safety in the EU by implementing technical standards, taking measures to improve safety standards and establishing an independent European Union Aviation Safety Agency.
- *Regulation 736/2006* and its amendment *Regulation 90/2012* establish the working methods of the European Aviation Safety Agency such that it can conduct standardised inspections. The European Aviation Safety Authority is able to carry out inspections of the national aviation authorities of individual Member States and will report on this. This was done to ensure that aviation authorities in the EU increasingly harmonise their technical inspections.
- *Regulation 7/2013* (amending *regulation 748/2012*) details rules for the airworthiness and environmental certification of aircraft and related products, parts and appliances. It also contains rules for the certification for design and production organisations.
- *Regulation 965/2012* specifies technical requirements and administrative procedures related to air operations. The rules for issuing, maintaining, amending, limiting,

suspending or revoking of certificates of aircraft operators are also detailed in this regulation.

- *Regulation 1899/2006* contains guidelines for the harmonisation of technical requirements, administrative procedures and air operations, including flight times, in the field of civil aviation.
- *Regulation 290/2012* contains cabin crew authority requirements and organisation requirements related to aircrew, such as licenses and training.

The EU regulation and ICAO technological standards all act to ensure a minimum safety standard is reached. As there are currently no taxes or charges targeted for safety, there is no interaction effect between these regulations and the price instruments.

Single European Sky

In addition to the EU's regulations, the European Commission also introduced the Single European Sky (SES) initiative. Its aim is to reform the previously fragmented European air traffic management system, such that the future needs of the European airspace is met in terms of capacity, safety, efficiency and environmental impact. The initiative was launched in 2000, a legislative package was drafted at the end of 2001 and the package was adopted by the European Parliament and Council in 2004. The package aims to:

- enhance safety and efficiency of air transport in Europe;
- reduce delays by improving the use of scarce airspace and airport resources;
- improve services and reduce cost to air transport passengers by reducing the fragmentation of the air traffic management in Europe;
- improve the integration of military systems into the European air traffic management system.

After a report on the first SES package in 2007, the European Commission came up with a SES II legislative package where one of the main aims is to create a single safety framework to enable the harmonised development of safety regulations and their effective implementation. In 2013 a SES II+ package was proposed in 2013, an interim update of the second SES package addressing in particular the inefficiency of air navigation services and the fragmented air traffic management system.

9 Conclusions & recommendations

9.1 Introduction

In this section, we summarise the scope and key findings from the study. Section 9.2 provides an overview of the scope of the study, highlighting the key caveats which are outlined in detail in the introduction. Section 9.3 provides a summary of the key findings from each cost coverage ratio assessed in the mode chapters, to highlight the relevance of fixed charges/costs and variable charges/costs in different cost coverage ratios. Following this, Section 9.4 provides a focused analysis of the overall average cost coverage for each mode, offering greater detail on the cost coverage ratio which provides a complete analysis of all costs, charges and taxes contributing towards transport internalisation. Section 9.5 offers the key conclusions and caveats linked to marginal cost coverage analysis. Finally, Section 9.6 provides EU-wide policy applications for increasing and differentiating tax/charge levels and 9.7 offers recommendations for further research on the state of play of internalisation in the European transport sector.

9.2 Summary of scope

Prior to discussing the key conclusions from the comparison of total and average cost coverage ratios in the EU28, the primary caveats are summarised below:

- **Geographical scope:** There is disparity in the geographical scope between modes. Road, rail and IWT are assessed at the country level whilst aviation and maritime through a sample of (air)ports.
- **External cost data:** There are specific robustness concerns for the data collected in each external cost category, described in detail in Section 0 and in the updated Handbook on the external costs of transport.
- **Infrastructure cost data:** There is no coherent framework for accounting transport infrastructure expenditures with differences may existing in the various countries. Furthermore, there are significant data gaps on infrastructure expenditures and some uncertainties with respect to the methodology and supporting data used, described further in Section 1.3.4.
- **Tax/charge revenue data:** For some taxes/charges (or countries), the total revenues in 2016 have been estimated using data for earlier years or a bottom-up approach. The allocation of total tax/charge revenues to various vehicle categories has often been estimated, resulting in a certain extent of uncertainty in the final results. This is discussed further in Section 1.3.5.
- **Subsidies are excluded:** In this study we do not consider transport subsidies and public service obligations (PSO), with the exception of tax/charge breaks or exemptions. This is discussed further in Section 1.3.6.
- **Transport performance data:** Road transport performance data is taken from Eurostat, following the nationality principle. The impact of this is discussed further in Sections 1.3.7 and 4.1.

In addition to these key caveats, it is also important to note that taxes have other purposes (e.g. health, education) and it is not necessarily the case that transport taxes and charges should only respond to transport costs. On the other hand, transport is often considered a public service that may be co-financed by governments in order to provide socially relevant transport services to citizens (e.g. improving accessibility of rural areas for all citizens). This may be an argument for not aiming for a full cost coverage (e.g. of the fixed

infrastructure costs), which is particularly important for regional trains and public bus services. Finally, increasing taxes in the transport sector may create the opportunity to reduce taxes in other sectors, restructuring the tax system rather than placing additional costs on businesses and consumers.

9.3 Comparison of cost coverage across modes in EU28

The primary conclusions from the five cost coverage ratios explored at the EU28 level for all transport modes are outlined below.

Overall cost coverage

The overall cost coverage ratio provides an insight into total cost recovery, determining whether external and infrastructure costs are internalised by the tax and charge revenues. The highest average cost coverage ratio is found for passenger cars. The cost coverage ratios for buses and coaches are significantly lower, due to typically lower taxes. For rail, the cost coverage is relatively low, and differs between train types, due to differences in infrastructure utilisation, load factor and energy taxation (diesel vs. electricity taxes). The cost coverage for aviation is slightly higher than rail, offering an indication for the average airplane (short and long-haul flights).

As for the passenger vehicle types, the costs exceed the revenues for all freight vehicle types. For HGVs, the cost coverage is approximately 26%. The cost coverage ratios for diesel freight trains are higher than for electric freight trains, primarily due to the relatively high diesel tax levels compared to electricity tax levels. The cost coverage ratio for inland navigation in the EU28 is only 6%, reflecting the fact that in most countries only a few taxes/charges are levied on this mode.

Overall cost coverage excluding fixed infrastructure costs

The overall cost coverage excluding fixed infrastructure costs illustrates the extent to which all external costs and variable infrastructure costs are internalised by all taxes and charges⁹⁹. For the road passenger vehicles, the highest cost coverage ratio is again found for passenger cars (63%), followed by coaches, buses and motorcycles, with lower cost coverages explained by relatively lower tax/charge levels for buses and coaches and by high average external costs for motorcycles. Rail transport cost coverages are higher for this ratio: High speed rail trains exceed full cost coverage (179%), while passenger conventional electric and diesel trains do not. Such difference is due to disparities in tax/charge levels. For aviation, the cost coverage ratio is 9 percentage points higher than under the overall cost coverage. For freight transport, for all vehicle types, the cost coverage ratios are higher than the ratios for overall cost coverage (as fixed infrastructure costs are excluded). The highest cost coverage ratio is found for diesel trains (56%), followed by HGVs (36%), electric trains (32%) and IWT vessels (12%)¹⁰⁰. The largest differences, compared to the

⁹⁹ This indicator is in line with the ambitions of the Commission to realise full internalisation of external costs, including wear and tear costs. It recognises that fixed infrastructure costs are sunk costs and that paying for these costs may result in (further) underutilisation of existing infrastructure (e.g. rail).

¹⁰⁰ For maritime transport, no data was available for tonne kilometres, therefore no comparable average cost and revenue figures could be calculated for this transport mode. As previously mentioned, presenting the average infrastructure costs in €/ct/tkm would result in very high and meaningless values for LCVs. However, the cost coverage for LCVs could be estimated (based on total cost and revenue values), as 53%.

overall cost coverage including fixed costs, are found for rail transport, because for this mode fixed infrastructure cost has the largest share in total external and infrastructure costs

Variable infrastructure and external cost coverage

This ratio compares revenues from variable taxes/charges with variable external and infrastructure costs. For all passenger vehicle categories, the variable costs exceed the variable tax/charge revenues. For the road vehicles, the cost coverage ratio for passenger cars (48%) and motorcycles (15%) is lower than the previous two indicators, due to a reduction in total tax/charges levels associated with the lack of fixed vehicle taxes (i.e. purchase and ownership taxes). Cost coverage is greater than total cost coverage for passenger rail transport, due to rail transports' high fixed costs being excluded from this ratio. Aviation's cost coverage is comparable to the previous cost coverage, as all aviation taxes/charges are considered variable and fixed costs are not significant. For freight transport, the highest variable cost coverage share is found for diesel trains (62%), which is significantly higher than for electric trains (37%), due to the fuel taxes on the respective fuels. The HGV cost coverage of 33% is achieved through revenues from road tolls and fuel taxes, while about 13% of the variable costs of IWT are covered by variable taxes/charges¹⁰¹.

Overall infrastructure cost coverage

The overall infrastructure cost coverage ratio provides an insight into whether revenues from infrastructure charges internalise all infrastructure costs. The cost coverage for buses and coaches is particularly low, at 3%. This is due to significant wear and tear costs caused by these vehicles, as well as by exemptions on road charges in several Member States. Cost coverage is higher for cars and motorcycles. For rail transport, the highest average infrastructure cost coverage are found for high speed rail (34%), followed by electric passenger trains (23%) and diesel passenger trains (18%). Finally, the infrastructure cost coverage ratio for passenger aircraft is 81%, indicating that the aviation-related infrastructure costs are largely paid for by the air passengers.

The HGV cost coverage is 13%, with revenues linked to road charges. The relatively low-cost coverage ratio is explained by the fact that infrastructure charges for HGVs are (mainly) applied on motorways, while a significant part of the infrastructure costs are associated with non-motorways. The cost coverage for diesel freight trains (25%) is higher than for electric freight trains (17%). The higher revenues on diesel freight trains mainly originate from higher average rail access charges in countries where all rail freight transport is performed by diesel trains. The overall infrastructure cost coverage for IWT vessels is equal to 12%, due to low average taxes and charges compared to average costs.

Variable infrastructure cost coverage

This cost coverage compares revenues from infrastructure charges with variable infrastructure costs. For most vehicle types the infrastructure charges far exceed the variable infrastructure costs: passenger car (347%), Motorcycle (473%), high-speed rail (477%), electric passenger train (190%), Diesel passenger train (137%) and aircraft (247%). The exceptions are buses and coaches, whose cost coverage is 5% and 6% respectively, as a

¹⁰¹ For maritime transport, no data was available for tonne kilometres. LCV cost coverage was estimated, at 48%

result of high wear and tear costs. HGV taxes and charges do not cover costs, with a cost coverage of 43%. For rail freight, no full cost coverage is found for electric freight trains (90%) while for diesel freight trains (140%) it is. As mentioned in the previous section, this can be explained by the higher EU28 average access charge levels for diesel trains. The revenues from infrastructure charges for IWT exceed the variable infrastructure costs for this mode with a cost coverage ratio of 176%.

To conclude, the very high coverage ratios for variable infrastructure have to be seen also in context of the low overall cost coverage ratios, as infrastructure charges also serve as internalisation measures of both external and infrastructure costs.

Earmarking of revenues

According to economic theory earmarking of revenues leads, in general, to a loss of efficiency. This is because there is no guarantee that transport or environmental mitigation projects are the most efficient projects available to be financed with the revenues and it may even lead to over-investments in those sectors (CE Delft et al., 2008; OECD, 2001; Parry et al., 2012). On the other hand, earmarking of revenues is often considered as a way to gain public support for the implementation of the internalisation measures (CE Delft et al., 2008; OECD, 2001; REVENUE, 2006). For example, the revenues of noise charges on airports can be used to finance a noise isolation programme. There is a distinction between taxes and charges in relation to earmarking. Although a proportion of tax revenues are often earmarked for infrastructure projects, infrastructure charges directly provide income for the infrastructure in question and therefore, can be viewed as earmarked to infrastructure and its related services.

At the EU28 level, about 10% of the road transport tax and charge revenues are earmarked for expenditures on transport infrastructure, enabling revenues to be directed towards enhancing public infrastructure or encouraging the uptake of active modes. For rail transport, the revenues of rail access charges (about 85% of the total tax and charge revenues from rail transport) are earmarked to cover part of the rail infrastructure costs. No evidence was available for earmarked revenues from other rail transport taxes and charges. For IWT, maritime transport and aviation, only fragmented data on earmarking of taxes and charges in the EU28 is available. It seems that (at least part of) the (air)port charges are earmarked to cover infrastructure expenditures, but no quantitative evidence is available.

9.4 Average cost coverage per country and tax/charge levels

The average cost coverage ratios provide an insight into total cost recovery, determining whether all external and infrastructure costs are internalised by tax and charge revenues. It does not consider other motives for taxation, such as revenue generation or the incentive to establish a level playing field between modes in the context of such revenue generation.

9.4.1 Road transport

Road passenger transport

Under the overall cost coverage ratio, none of the EU Member States achieve complete cost internalisation. The EU28 overall average cost coverage for road passenger transport is 47%; however, there is significant variation in cost coverage, from 17% in Luxembourg to 99% in

Denmark. The high-cost coverage in Denmark is linked to a combination of high vehicle purchase taxes (PPS corrected), low average infrastructure costs and relatively low average accident and air pollution costs. The majority of EU28 countries generate most of their average revenues from fuel taxes, whilst Denmark is the only Member State to generate the majority of its average revenues from purchase tax for passenger cars, buses and coaches.

Revenue generation varies greatly between EU Member States; however, high vehicle ownership and purchase taxes, as well as fuel taxes, are important factors for countries with higher cost coverage. Finland, Greece, Ireland and the Netherlands also achieve relatively high-cost coverages of 81%, 74%, 74% and 76% respectively. The highest average revenues in the EU28 are generated by the Netherlands, primarily derived from fuel excise duty and ownership tax. The average fuel tax revenues are relatively high, due to the high tax levels and the high average fuel consumption (CE Delft, 2019b). The Netherlands and Denmark generate similar levels of average revenue, through different channels. In, Finland, Greece and Ireland, relatively high average revenues are generated primarily from fuel taxes. Ownership and purchase taxes also contribute towards average revenues in these countries for passenger cars, but to a lesser extent. The low-cost coverage in Luxembourg is primarily linked to the relatively limited number of taxes and charges applied to road transport, as well as relatively low fuel taxes for general and business use. Luxembourg also generates particularly high average congestion and accident costs, which may be linked to the previously discussed data robustness issue, due to disparities in transport performance and cost data (territorial vs. national definition).

From the point of view of internalisation, high variable taxes (e.g. fuel taxes) are better placed than fixed taxes (e.g. vehicle taxes), to influence the behaviour of users. For example, Croatia and Portugal generate high average revenues across road passenger vehicle types primarily due to variable taxes (i.e. road tolls and fuel taxes), relative to other Member States.

Although none of the countries achieve complete cost internalisation, non-pricing policies also contribute towards the reduction of costs, as discussed in Section 2.5.

When excluding fixed infrastructure costs, similar results are achieved. As with overall cost coverage, Denmark has the highest cost coverage ratio of 121%, followed closely by Finland, Portugal and Norway. Denmark's high cost coverage is due to relatively high vehicle purchase tax revenues, alongside relatively low average external accident and air pollution costs. The high cost coverage in Finland is linked to the relatively low average accident, air pollution and noise costs associated with road passenger transport. In Finland, variable expenditure levels per kilometre of road network are relatively low as well, as the majority of the variable expenditures are spent on a small proportion of the road network (CE Delft, 2019a). The low costs in Finland are combined with relatively high average revenues from a variety of sources, primarily generated by fuel taxes. Luxembourg also displays a low cost coverage under this ratio, followed by Romania, Hungary and Germany. The explanations for the low cost coverage in Luxembourg and Romania reflect the justifications provided for the overall cost coverage ratio. The low cost coverages in Germany and Hungary are attributed to a combination of relatively high average costs and relatively low average revenues.

Road freight transport

As with road passenger transport, none of the EU Member States achieve complete cost internalisation for road freight HGVs¹⁰². The EU28 overall average cost coverage is significantly lower than road passenger transport, at 26%. Malta achieves the highest cost coverage of 59%, linked to the moderate tax on vehicle ownership for HGVs, relatively high diesel fuel taxes and vehicle insurance tax (11% of the insurance premium). Furthermore, relatively low average external air pollution and noise costs, as well as low average infrastructure costs, result in Malta bearing the second-lowest average costs in the sample, leaving relatively minimal costs to cover. Bulgaria also achieves relatively high-cost coverage (46%), due to high fuel taxes (PPS corrected). As with passenger transport, for the majority of EU Member States, fuel excise duty, make up a large portion of average revenues for HGVs. Revenues from tolls and vignettes comprise the next largest component across the board, whilst high ownership taxes in Greece contribute towards relatively high-cost coverage in that Member State (53%).

The Netherlands and Austria achieve relatively low-cost coverage, of 17% and 16% respectively. This is linked to a combination of high average costs and relatively low average revenues. For both of these countries, high average infrastructure costs contribute considerably to high average costs, whilst high average external accident costs also result in higher average costs in Austria. However, this could be linked to the previously mentioned disparity in the scope of transport performance data and cost data.

Croatia and the Czech Republic generate the highest average revenues in the EU28, due to a combination of road infrastructure charging and fuel tax revenues. In Croatia, this is primarily linked to the relatively high distance-based road charge on motorways for all vehicles, as well as the bridge tolls at KRK and RUPA. It is also linked to high average revenues derived from fuel, as Croatia enforces one of the highest diesel fuel taxes in the EU28 (PPS corrected). In the Czech Republic, high average revenues are primarily linked to high average revenues from the relatively high fuel taxes, as well as the distance-based road toll for vehicles exceeding 3.5 tonnes. In addition, a proportion of average revenues are linked to the relatively high ownership taxes levied on truck trailers.

Luxembourg generates the lowest average revenues in the EU28, which, similar to road passenger transport, is linked to relatively low fuel tax revenues. Spain, Estonia, Poland and Ireland also generate some of the lowest average revenues. In Ireland and Spain, this is linked to relatively low diesel fuel taxes (PPS corrected), as well as relatively low ownership taxes. Increasing fuel taxes in these countries could translate to higher average revenues, and therefore, greater cost coverage. Estonia could generate revenues by introducing a road toll for HGVs, as other Member States that have introduced road charges generate a significant proportion of average revenues from tolls and vignettes. However, across most Member States, fuel taxes comprise the highest proportion of average revenues.

Generally, average accident and air pollution costs, as well as infrastructure costs, contribute most substantially to overall average costs.

Under the overall cost coverage ratio excluding fixed infrastructure costs, none of the countries reach 100% cost coverage. Some EU28 Member States, such as Greece, Malta and Slovenia, come close to achieving cost internalisation, reflecting the overall cost coverage. This is linked to the combination of relatively low average costs, alongside relatively high

¹⁰² Only HGV data is presented, as most LCVs are used for services, rather than for goods delivery. Therefore, LCV costs and revenues which are measured in €ct per tkm are not representative of the way LCVs are used, and therefore, would distort the freight data.

average revenues. In Malta, Slovenia and Greece, relatively high average revenues are all linked to fuel taxes. In Slovenia, high distance-based charges for HGVs also contribute to high average revenues and in Greece, ownership tax revenues are also significant. Luxembourg and Austria experience the lowest cost coverages in the EU. For both of these countries, this could be linked to the data robustness issue linked to the disparity in the scope of transport performance and external cost data.

9.4.2 Rail transport

The results of the average cost-based internalisation of rail transport highly depend on the extent to which fixed and variable infrastructure cost components are considered. In this respect, it is worth noting that the fixed part of infrastructure costs, which mainly consist of expenditures for construction of new infrastructure, or expansion and renewal of the existing infrastructure, are generally a large share of the overall (external plus infrastructure) costs.

The average costs of all infrastructure cost components is markedly higher than the average revenues from infrastructure access charges and therefore not sufficient to achieve full cost coverage. The average costs of the external cost components¹⁰³ generated by rail transport is small compared to infrastructure costs and the average revenues from related internalisation measures (i.e., fuel and electricity consumption and the EU ETS) are low, or very low, relative to the average revenues from infrastructure access charges.

This implies that the overall cost coverage ratio, which compares revenues from all internalisation measures with all external and infrastructure costs is found low across all the Member States. Notably, the overall cost coverage ratios found at EU28 level are equal to 21% and 17% for passenger and freight modes, respectively. There are, however, notable differences between countries. For example, for passenger rail transport, the highest cost coverage ratios are found for France, Latvia, Germany, and Lithuania (i.e. 61%, 36%, 35%, 30%). For France and Germany, these higher costs coverage ratios can mainly be explained by the significant share of high speed trains in total rail transport, as the average charge levels for these trains are - on average - higher as for conventional passenger trains. For Latvia and Lithuania, the result depends on the high infrastructure access charges and revenues from fuel taxes. On the other hand, Finland, Greece, Luxembourg and Slovenia present the lowest ratios (i.e. 3%, 4%, 2%, and 4, respectively), reflecting the relatively low access charge levels in these countries.

The cost coverage ratio markedly increase once fixed infrastructure costs are excluded. They become four times higher for passenger transport (i.e., 80%) and more than twice the initial value for freight transport (i.e., 39%), respectively. In some countries, even full cost coverage is achieved with this indicator. For passenger rail transport, this is the case for Belgium, France, Latvia, Lithuania and the UK, while for freight rail transport full cost coverage is achieved in Estonia and Lithuania.

It is worth noting that, as pointed out at the beginning of Chapter 5 on rail transport, the treatment of subsidies has been excluded from the analysis, although this is an aspect that could, to some extent, influence the results discussed and may explain some of the differences found between train types and countries. Subsidies are generally granted at different levels to rail undertakings and users to encourage a modal shift from less environmentally sustainable modes. Nevertheless, data availability on subsidies is rather

¹⁰³ Accidents, air pollution, climate change, noise, WTT and habitat. Figures on congestion costs (or scarcity costs) are not available for this mode.

poor and a large number of subsidy and PSO schemes exist, both at national and regional/local level. This implies that the average revenues found could be gross of subsidies and not a net value. This is an aspect, which may deserve further research in the future to improve the quality of the analysis of the external costs of rail transport.

9.4.3 Inland waterway transport

For inland waterway transport, the overall average cost coverage ratio was calculated for Switzerland and fifteen EU countries with inland waterway networks, however there are only five EU countries with high use of the inland navigation networks and the analysis focuses on these countries - Belgium, France, Germany, the Netherlands and Romania - rather than the outliers with limited inland waterways.

The overall average cost coverage ratio for the 16 countries in the sample is low, 6% on average. The five countries with the highest utilisation of inland waterways have cost coverage ratios ranging between 1% (France) and 22% (Romania). Within this range, the Netherlands has a cost coverage ratio of 2%, Belgium 4%, and Germany 8%.

Average external and infrastructure costs for the 16 countries is €ct 3.9 per tkm. On the cost side, half of the costs for this mode are external costs, and nearly all external costs are air pollution costs. For infrastructure costs (the other half of the costs), the vast majority are fixed costs for this mode of transport. The five countries with the highest utilisation rates have overall average costs within range of the sample average, however Romania has far lower costs (due to lower infrastructure costs) while Belgium has the highest average costs in the sample, followed by France. High average costs for Belgium and France are due to high infrastructure costs. In Belgium, high infrastructure costs can be attributed to a low share of maritime vessels on the network compared to the Netherlands, and a higher share of canals in Belgium compared to Germany. Whereas for Romania, the lower average infrastructure costs are as a result of having highest shares of maritime vessels on the network of the five countries.

For the sixteen countries, average revenues fall at €ct 0.25 per tkm. France and the Netherlands have average revenues far below the sample average, but the other three countries with high utilisation of inland waterways have revenues near or above the sample average. Higher average revenues for Belgium, Romania and Germany can be explained by Belgium's dues for locks and bridges, and for Romania and Germany, high port revenues complemented by fairway dues. On the other hand, the Netherlands does not charge fairway dues, which partly explains the country's lower average revenues. While France does charge fairway dues, revenue data was not available for this charge, so the average revenue for France is higher than reported here.

When excluding fixed infrastructure costs, most countries do not cover costs and 12 countries display cost coverage ratios under 15%. The cost coverage ratios for the countries with the highest utilisation of the inland waterway network range from 3% (France and the Netherlands) to 27% (Romania), within range of the overall sample average of 12%. This reflects the situation under the overall cost coverage ratio, with France and the Netherlands bearing the lowest cost coverages and Romania experiencing the highest cost coverage. Romania's high cost coverage is linked to low average infrastructure costs and relatively low average external costs, alongside previously mentioned relatively high port revenues. The low cost coverage in France is due to high infrastructure costs; however, it is also important to account for the lack of available data on fairway dues, mentioned previously. The low cost coverage in the Netherlands is also explained by the same reasons presented for the overall cost coverage ratio.

9.4.4 Maritime transport

As discussed in Section 7.2, average cost coverage ratios could not be calculated for maritime transport, due the unavailability of transport performance data in the required unit (tkms).

The total costs and revenues for maritime transport was estimated for a selection of maritime ports (as explained in section 3.24.1, no EU28 figures were available). The resulting overall cost coverage ratio is low, at around 4%. This is due to high total external and infrastructure costs of ports (totalling about € 45 billion) which are targeted by a limited number of tax/charge schemes.

Additionally, marginal cost coverage ratios have been calculated and these are discussed in Section 9.5.

9.4.5 Aviation

For air transport, total average cost coverage was calculated for a sample of 38 EEA, US, Canadian, and Japanese airports, however the analysis of results focused on the EU airports.

On average, EU28 airports sampled for this study had a 32% total cost coverage ratio. The average total costs vary widely between airports sampled, with the average for the EU28 airports at €ct 4.83 per pkm. The average total revenue for these airports only amounts to €ct 1.52 per pkm. There is also variation in the total taxes and charges figures. In particular, UK airports have significantly higher taxes and charges, compared to other airports: Heathrow (UK) airport's charges are over 7 times the (unweighted) average of other airports included and Gatwick's are over twice the (unweighted) average. Excluding these airports from the calculation, reduces the EU28 overall cost coverage to 29%.

Two-thirds of average costs for the EU airports are external costs, with climate change and well-to-tank costs being the most significant contributors. The average costs vary between flight types: Short-haul flights incur the highest external costs, followed by medium and long-haul flights. Average infrastructure costs per pkm are driven by the share of long-haul flights, and airports with low shares of this segment of flights have higher costs. For example, Luxembourg and Ljubljana airports had the highest total average costs in the sample, and this was driven by a high share of short-haul flights for these airports compared to others in the sample.

Only one airport in the sample exceeded 100% cost coverage, i.e. Sofia airport. In addition, Palma de Mallorca had the second-highest cost coverage (79%). Sofia airport had high LTO and security charges, while Palma airport had high overall levels of charges combined with moderate costs. Two EU28 airports had especially low overall total cost coverage ratios: Paris CDG and Paris Orly. This is due to low average revenues at both airports who do not have airbridge, fuelling, groundhandling, security, noise or emission charges. They may also be low partly due to the fact that data on aviation tax revenues for French airports could not be collected for this study.

When excluding fixed infrastructure costs, the EU28 average cost coverage ratio is 41%. This is slightly higher than the EU28 average overall total cost coverage ratio discussed above, due to the removal of fixed infrastructure costs. Patterns under this cost coverage reflect the scenario presented under the overall total cost coverage ratio. Two airports achieve complete cost internalisation: Sofia airport (162%) and Palma de Mallorca airport (114%). The explanation for these high cost coverages reflect the same reasons presented for the

overall cost coverage ratio. The two airports in Paris achieve the lowest overall cost coverage excluding infrastructure costs in the EU28, echoing the overall cost coverage ratio. Paris CDG achieves a cost coverage of 9.3% and Paris Orly achieves a cost coverage of 7.6%. For both airports, this is linked to aforementioned low average revenues, due to the limited number of charges implemented.

9.5 Marginal cost coverage ratio and differentiation of taxes/charges by vehicle type

To assess the extent of internalisation from the perspective of Marginal Social Cost Pricing (MSCP), we utilise the marginal cost coverage ratio. This compares marginal infrastructure and external costs to marginal taxes and charges collected, showing the degree of cost internalisation for each additional vehicle. These ratios are calculated by vehicle type.

A key limitation of the analysis is that the marginal cost coverage ratios have only been estimated for a few scenarios. Therefore, we are not able to assess marginal cost coverage ratios in a broad range of situations, limiting the number of final conclusions that can be drawn from this analysis for specific vehicles or road types. Furthermore, the scenarios presented are not necessarily representative of the real world. For example, the very low external cost scenario presents electric cars operating on motorways, rather than in urban areas over shorter distances.

The analyses carried out do, however, show that for many transport modes the marginal cost coverage ratios differ widely between the various scenarios. This indicates that the current taxes and charges are often not able to capture the large variance in the size of marginal external and infrastructure costs across different situations. This highlights that in practice, there is great difficulty in charging in accordance with the MSCP principle. This would require that highly differentiated taxes and charges are applied. An exception is rail transport (particularly electric and diesel passenger trains), where the rail access charges and diesel taxes reflect the variable nature of most of the external costs and part of the infrastructure costs. However, improvements could be made to further differentiate the access charges, e.g. to noise.

9.6 EU-wide policy applications for increasing/differentiating tax/charge levels

In this section we briefly discuss some policy implications of the results found in this study. We describe per transport mode some potential options to further internalise the external and infrastructure costs, focusing on the main gaps identified in the previous assessments. Possible interaction effects between modes (e.g. increasing the charge levels for rail transport may lead to a shift of freight transport to road, which may have negative environmental impacts) are not considered in this section. The analysis applied has just a scoping character.

9.6.1 Road transport

As discussed in Section 9.4.1, the taxes and charges levied in the EU Member States are - in general - insufficient to fully internalise the external and infrastructure costs of road transport, or even to internalise all external costs and variable infrastructure costs. There are, however, large differences between the various vehicle categories, with significantly higher cost coverage ratios found for passenger cars than for the other road vehicle categories. The large variance in the marginal cost coverage ratios found for the

various scenarios also provides some indication that the current taxes and charges applied in the EU Member States are not able to reflect the varying nature of the marginal external and infrastructure costs. There are also doubts that such differentiation would be technically feasible in the foreseeable future.

For all road vehicle categories, the introduction or extension of distance-based road charging schemes may be an option to further internalise their external and infrastructure costs. By differentiating these charges to vehicle characteristics, location and time, the (marginal) external air pollution, noise, climate change and congestion costs can (theoretically) be better internalised (although pragmatic choices could be made in order to keep the scheme understandable for road users). Such a road charging scheme may complement other policy instruments addressing the external costs of road transport, like the various types of vehicle standards (e.g. CO₂ standards, Euro standards, noise standards).

Differences in the current internalisation levels between motorways, urban roads and other roads should be carefully considered in further internalising the external and infrastructure costs of road transport. Particularly in urban areas additional efforts may be required, as external costs (e.g. air pollution, noise) are higher, while average tax/charge levels are often lower than on motorways. A location-differentiated, network-wide implementation of road charging schemes may be a possible solution for this issue. However, also the implementation of local measures (e.g. urban road charging schemes) may be an option.

Applying differentiated road charges to further internalise the external accident costs may not be straightforward, as the level of these costs depend on a complex set of cost drivers. Insurance taxes are applied in many countries though the taxation levels are usually small compared to accident external costs. An alternative approach suggested by (CE Delft; INFRAS; ISI; IWW; University of Gdansk, 2008) is to charge the insurance company involved a lump sum at the level of the estimated average external costs for each accident. As insurance companies have detailed information on cost drivers and differences in the risk rates between drivers, they are in a good position to pass on these costs in an efficient way¹⁰⁴ to their clients through higher and differentiated insurance rates (e.g. using pay-as-you-drive schemes). In this way drivers receive further incentives to reduce their risks.

9.6.2 Rail transport

The overall cost coverage ratio for rail transport showed that only part of the external and infrastructure costs in the EU28 Member States are covered (see Section 9.4.2). In general, the variable infrastructure costs are covered by the rail access charges (although there are large differences between countries), but coverage of fixed infrastructure costs is not found for any of the EU countries. Introducing a mark-up on the current access charges may be an option to internalise a larger part of these fixed costs. However, rail transport is often considered a public service that may be co-financed by governments in order to provide socially relevant transport services to citizens (e.g. improving accessibility of rural areas for all citizens). This may be an argument for not aiming for a full cost coverage of the fixed rail infrastructure costs (particularly for regional trains). Furthermore, social marginal cost pricing does not require the internalisation of fixed infrastructure costs and rail transport shows the highest coverage across modes in overall cost coverage excluding fixed infrastructure costs.

¹⁰⁴ For example, they may pass on higher costs to drivers in regions with more dangerous roads or to drivers with higher risk profiles. In this way, marginal accident costs are better reflected in the taxes/charges levied.

An option to further internalise the external costs of rail transport is to introduce noise differentiations in the rail access charges. This instrument is applied in some EU countries already. The main added value of this instrument is that it may speed up the implementation of noise abatement measures at the existing fleet (e.g. replacing cast iron blocks with composite one at freight trains), effectively complementing the impact of the noise limits that are set for new wagons. Furthermore, reducing the number of exemptions on diesel and electric taxes (or increasing their levels up to a minimum EU-wide level) may contribute to a further internalisation of the climate change (incl. WTT emissions) and air pollution costs of rail transport.

9.6.3 Inland Waterway Transport

As indicated in Section 9.4.3, the taxes and charges levied in the EU Member States are insufficient to fully internalise the external and infrastructure costs of IWT. This is mainly caused by the fact that only a limited number of relevant taxes/charges are levied on IWT in the EU28. In the main IWT countries, only port charges are applied, in some countries supplemented by fairway dues on a limited part of the network. A higher level of internalisation may be achieved by introducing other pricing instruments as well.

An option to increase the level of internationalisation is to levy e.g. fuel taxes on IWT, which is currently only done by a few minor IWT countries (e.g. Bulgaria, Hungary, Italy, and Slovakia). A second option is applying fairway dues on a larger part of the EU inland waterways. By differentiating these dues by air pollutant emissions, this instrument may contribute to reducing the air pollutant costs of IWT (by far the most important externality of IWT). Such an instrument may also effectively complement the European emission standards applied for inland navigation vessels. The latter only affects new inland vessels, while differentiated fairway dues may also provide an incentive to install emission reduction technologies on the existing fleet. As the replacement ratio of vessels is generally low which limits the effectiveness of the emission standards at the fleet level, this effect may have significant added value. Differentiated fairway dues may also contribute to further internalise the CO₂ emissions of IWT, e.g. by applying lower charge levels for fuel-efficient or alternatively fuelled vessels.

An important barrier for the implementation of pricing instruments like fuel taxes and fairway dues is the fact that at present Belgium, Germany, France, the Netherlands and Switzerland, which are Member States of the Central Commission for Navigation on the Rhine, have agreed in a supplementary protocol of the Mannheim Convention not to levy charges on the gasoil used by ships on the Rhine and its tributaries. The Rhine is the most important river for the freight IWT in Europe.

Implementing environmentally differentiated port charges is another option to address the air pollutant emissions of IWT. This instrument is currently applied in a few European inland ports and it may be extended to other ports as well.

9.6.4 Maritime transport

As was mentioned in Section 9.4.4, the extent by which the external and infrastructure costs of maritime transport are internalised in the EU is rather low. As for IWT, this is mainly caused by the limited number of taxes/charges levied on maritime transport. For most ports/countries, port charges are the only pricing instrument currently used. Although these charges seem to cover the port infrastructure costs, they do not cover for the main external costs of maritime transport, i.e. air pollution and climate change.

An option to improve the internalisation of the air pollution costs of maritime transport is to apply environmentally differentiated port charges. Some European ports already apply such a differentiation (discount based on the environmental ship index), but this instrument can be further elaborated and/or applied on a wider scale. Another option is to apply a specific environmental levy (e.g. a NOx charge) on specific trips or specific areas (e.g. a differentiated fairway due). Both instruments will complement the current IMO emission standards for new vessels, particularly as they also incentivize to apply emission reduction technologies on the existing fleet. Applying stricter or more emission control areas may also be an option to reduce the air pollution costs of maritime transport in Europe.

Given the intrinsically global character of the shipping sector, the EU works with global partners to encourage further efforts and build on the progress that has been recently achieved in the International Maritime Organisation (IMO). More stringent limits for the Energy Efficiency Design Index is an example of option to further reduce the climate change costs of maritime transport.

9.6.5 Aviation

The aviation taxes and charges applied in the EU28 do cover for most of the infrastructure costs, but not the external costs of aviation (see Section 9.4.5). The main external cost of aviation is climate change, which is - at the EU level - mainly addressed by the EU ETS.

Given the intrinsically global character of the aviation sector, the EU works with global partners to encourage further efforts to reduce the GHG emissions of aviation and build on the progress that has been recently achieved in the International Civil Aviation Organization (ICAO).

To address local externalities of aviation (i.e. air pollution, noise), the use of environmentally differentiated airport charges may be recommended. Currently, these kinds of differentiations are only fragmentally applied throughout Europe. Introducing (environmentally differentiated) aviation taxes may be another instrument to address these externalities (in support of the emission and noise standards set by the ICAO for new aircrafts).

9.7 Recommendations for further research and assessment

This study provides a detailed overview of the extent of internalisation of the external and infrastructure costs of transport, based on state-of-the-art data on external costs, infrastructure costs and transport taxes and charges. However, there are some options to further improve and elaborate the analyses done in this report. For that purpose, further research on various topics is recommended. The main ones are:

- *Further improve the estimates on external costs, infrastructure costs and transport taxes and charges.* For this study we have used of state-of-the-art data on the external and infrastructure costs of transport as well as on transport taxes and charges applied in the various countries considered. However, as discussed in Sections 1.3 and 2.2 there are several uncertainties with respect to the input data and methodologies used to estimate these data. Therefore, further research on the quantification of these three concepts is required. Specific issues for further research are listed in the previous deliverables of this project (i.e. CE Delft et al., (2019a); (2019b); (2019c)).
- *Assess the size and structure of transport subsidies in Europe.* The extent of internalisation is affected by the amount of subsidies provided in the various countries to the different vehicle categories. However, due to a lack of data on these data it was not possible to include subsidies in our assessments for this report. It is therefore

recommended to further investigate the size and structure of transport subsidies applied in EU Member States for the various transport modes.

- *Provide cross-modal comparisons for different market segments and/or corridors.* The cross-modal comparisons of cost coverage ratios made in Chapter 3, do not take into account that various transport modes are not always competing on the same market. For example, an average airplane does not compete with an average coach. In order to provide even more useful comparisons, it is recommended to comply these analyses for specific sub-markets (e.g. short-haul trips) or corridors (e.g. Paris - Amsterdam) as well. Such analyses provide a fair comparison of the various modes as the specific characteristics of these sub-markets/corridors can be taken into account.
- *Provide more detailed assessments for specific parts of the network.* The external and infrastructure costs as well as the tax/charge levels differ widely between different parts of the network. Particularly for road transport, it would be interesting to study the cost coverage ratios for urban roads and other roads (in addition to the cost coverage ratios for motorways and the entire road network).
- *Assess a broader range of marginal cost scenarios.* In the current study, the marginal cost coverage ratios were assessed for only three/four scenarios. As these scenarios differ in many aspects it is difficult to identify which factors significantly affect the marginal cost coverage ratios. Therefore, assessing a broader range of marginal cost scenarios (differing on just one or two aspects) would be recommended.
- *Study the extent of internalisation from the Baumol perspective.* As discussed in Section 2.3.2, the Baumol perspective is often applied in transport policy in Europe. For that reason, it would be very interesting to assess to what extent the taxes and charges, together with command-and-control measures, applied in the various countries effectively contribute to achieving the objectives set for the reduction of the various externalities.

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