Sustainable Transport Infrastructure Charging and Internalisation of Transport Externalities: Main Findings

May 2019

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Abstract

This report presents the main findings of the project 'Sustainable Transport Infrastructure Charging and Internalisation of Transport Externalities'. The overall aim of this project was to assess to what extent EU Member States and selected other countries (i.e. Norway, Switzerland, United States, Canada and Japan) have implemented the 'user-pays' and the 'polluter-pays' principles. It provides an overview of the progress EU Member States have made towards the goal of full internalisation of external and infrastructure costs of transport and to identify approaches for further internalisation. As input for this analysis, the infrastructure and external costs of all main transport modes (i.e. road, rail, inland navigation, maritime transport and aviation) were estimated and a comprehensive overview of transport taxes and charges applied in the various countries was made.

The results of the project show that the external and infrastructure costs of transport in the EU28 are only partly internalised. For most transport modes, only 15 to 25% of these costs are covered by revenues from current transport taxes and charges. There is also little evidence that marginal social cost pricing principles are applied on a large scale in transport pricing in the EU28. Finally, for most transport modes (except maritime transport and aviation) the infrastructure costs are not covered by infrastructure charges, reflecting that the 'users-pays' principle is often not met.

Executive summary

The project 'Sustainable Transport Infrastructure Charging and Internalisation of Transport Externalities' aims to assess the extent to which existing policies internalise the external and infrastructure costs of transport and to discuss ways by which further internalisation could be achieved. As input for this assessment, the infrastructure and external costs of the various transport modes are estimated and a comprehensive overview of transport taxes and charges applied in the various countries is provided. The results of these assessments are presented in four separate deliverables[1]. This report summarises the main findings from these deliverables.

The project considers all main transport modes, i.e. road transport, rail transport, inland waterway transport (IWT), maritime transport and aviation in the EU28 Member States, Norway, Switzerland, Japan, and some US states and Canadian provinces. For maritime transport and aviation, assessments were performed at the level of (air)ports instead of countries. In this report, we only present aggregate results for the EU28 (and the selection of EU28 (air)ports considered). For country-specific (or (air)port-specific) results we refer to the other deliverables of this study. All results in this study are presented for the year 2016.

Infrastructure cost

For this study, infrastructure costs are defined as the direct expenses plus the financing costs. Annual infrastructure costs in 2016 are thus equal to the sum of the annual depreciation and financing costs. The transport infrastructure costs include investments in new infrastructure, renewal costs of existing infrastructure, expenditures on the maintenance of infrastructure, and operational expenditures enabling the use of transport infrastructure.

Total infrastructure costs

For road, rail and inland waterway transport (IWT), the total infrastructure costs in the EU28 amount to € 267 billion for 2016 (€ 184 billion for road, € 81 billion for rail, and € 3 billion for IWT). The main part of these costs can be attributed to passenger cars and heavy goods vehicles (HGVs), as is shown in Table 1. The total infrastructure costs for the 33 selected EU28 airport and 34 selected EU28 maritime ports are equal to € 14 billion and € 1.4 billion, respectively.

[1] CE Delft et al. (2019a) – Overview of transport infrastructure expenditures and costs.
CE Delft et al. (2019b) – Transport taxes and charges in Europe – An overview study of economic internalisation measures applied in Europe.
CE Delft et al. (2019c) – Handbook on the external costs of transport.
CE Delft et al. (2019d) – The state-of-play of internalisation in the European transport sector.

Average infrastructure costs

For passenger transport, the average infrastructure costs (in €-cent/pkm) are higher for rail transport than for road transport (see Table 1). This is mainly explained by the higher fixed[2] costs (e.g. construction costs) for rail transport than for road transport. The average costs are highest for diesel passenger trains, which is due to the lower occupancy rate of diesel trains (compared to electric trains). An additional explanation is the lower utilisation rate of diesel rail infrastructure compared to electric rail infrastructure.

Table 1 – Infrastructure costs in the EU28 in 2016 (all figures are PPS adjusted)

Vehicle category	Total infrastructure costs	Average infrastructure costs	Marginal infrastructure costs
Passenger transport modes	**Billion €**	**€-cent/pkm**	**€-cent/pkm**
Passenger car	98	2.1	0.1
Bus	8	4.0	1.9
Coach	13	3.7	1.8
Motorcycle	3	1.8	0.1
High speed train (HST)	12	10.6	0.8
Electric passenger train (incl. HST)	51	13.4	1.6
Diesel passenger train	18	27.0	3.5
Aircraft[a]	14	1.6	0.5
Light commercial vehicles	**Billion €**	**€-cent/vkm**	**€-cent/vkm**
Light Commercial vehicle	20	4.1	0.3
Freight transport modes	**Billion €**	**€-cent/tkm**	**€-cent/tkm**
Heavy Goods Vehicle	42	2.3	0.7
Electric freight train	9	3.0	0.6
Diesel freight train	3	3.2	0.6
IWT vessel	3	1.9	0.1
Maritime vessel[ab]	1	n/a	n/a

[a] The figures for aviation and maritime transport refer to the 33/34 selected EU28 (air)ports.

[b] Due to a lack of data, no average and marginal costs (in €-cent/tkm) for maritime transport could be calculated.

For road transport, the average infrastructure costs for buses/coaches are significantly higher than for passenger cars, which can be explained by the relatively high weight-dependent infrastructure costs caused by these vehicles. Finally, the average infrastructure costs for aviation are relatively low (in the same order of magnitude as those for passenger cars). However, the result for aviation is an average, covering short-, medium- and also long-haul flights to and from European airports. As aviation only competes with other modes on short distances, this figure cannot directly be compared to the results for the other vehicle categories[3].

Table 1 also shows the average infrastructure costs for road, rail and inland navigation freight transport. The highest costs for passenger transport are for rail transport, followed by road transport and IWT.

[2] Fixed costs are costs that do not vary with transport volumes (on the short term). Construction costs of new infrastructure are an example of fixed infrastructure costs. Variable costs, on the other hand, do vary with transport volumes. Maintenance of potholes is an example of variable infrastructure costs.

[3] The average infrastructure costs will be higher for short-haul flights than for medium- or long-haul flights (as the fixed infrastructure costs are allocated to a lower number of passenger kilometres). However, due to a lack of data, the average infrastructure costs for aviation could not be differentiated to flight distances.

Marginal infrastructure costs

Marginal infrastructure costs refer to additional costs to the transport infrastructure manager caused by an additional vehicle kilometre (or LTO or call) on the network.
As shown in Table 1, the highest marginal infrastructure costs for passenger transport are again found for diesel trains. However, the difference between the marginal infrastructure costs experienced by road and rail vehicles is significantly lower than the difference in the average infrastructure costs borne by these modes, which can be explained by the fact that marginal infrastructure costs are not affected by the relatively high fixed costs of rail infrastructure (in contrast to average costs).

For freight transport, the highest marginal infrastructure costs are found for heavy goods vehicles (HGVs), reflecting the relatively large variable element of road infrastructure costs. Marginal infrastructure costs for IWT are relatively low, as only a limited share of infrastructure costs directly depends on the actual use of the inland waterways.

External costs

Based on state-of-the-art methodologies and cost factors, the total, average and marginal external costs for transport in the EU28 have been estimated. For this purpose, the following externalities were taken into account: accidents, air pollution, climate change, noise, congestion, well-to-tank emissions, and habitat damage.

Total external costs

The total external costs of transport in the EU28 are estimated at € 987 billion. This figure only includes congestion costs for road transport, as it was not possible to estimate congestion costs for other modes. In general, the most important cost category is accident costs equating to 29% of the total costs, followed by congestion costs (27%). Overall, environmental costs (climate change, air pollution, noise, well-to-tank and habitat damage) make up the remaining 44% of the total costs. However, large differences exist between transport modes.

As shown in Table 2, road transport (and particularly passenger cars) is the largest contributor to external costs (83% of the total costs, € 820 billion), which is partly explained by the large share of road transport in the total EU28 transport performance[4]. The total external costs for rail transport and IWT amount to € 18 billion and € 3 billion, respectively. Finally, for aviation and maritime transport the external costs in the EU28 are roughly estimated to be € 48 and € 98 billion.

Average external costs

As shown in Table 2, motorcycles cause the highest average external costs, which is due to relatively high noise and accident costs. The average external costs of buses/coaches are significantly lower than for passenger cars, which can be explained by the higher occupancy rates of these vehicles. For rail transport, the average external costs for diesel trains are significantly higher than for electric trains. This is mainly explained by the significantly higher air pollution costs of diesel trains as well as their lower occupancy rates.

[4] Excluding congestion, road transport would still make up for 77% of the total costs.

For freight transport, HGVs have the highest external costs, followed by IWT, rail transport and maritime transport. The relatively high external costs for HGVs are mainly explained by relatively low load factors relative to rail. Furthermore, for road transport congestion costs are taken into account, but are not included for the other modes. The average external costs for IWT are currently slightly higher than for rail transport, which is mainly explained by the relatively high air pollution costs of IWT[5]. The low average external costs for maritime shipping cannot be directly compared to the other modes, as this figure is an average for both short sea shipping and long-distance shipping (and only the former directly competes with the other modes).

Table 2 - External costs in the EU28 in 2016 (all figures are PPS adjusted)

Vehicle category	Total external costs	Average external costs
Passenger transport modes	**Billion €**	**€-cent/pkm**
Passenger car	565	12.0
Bus/coach	19	3.6
Motorcycle	41	24.5
High speed train	1	1.3
Electric passenger train	11	2.6
Diesel passenger train		3.9
Aircraft	48[a]	3.4
Light commercial vehicles	**Billion €**	**€-cent/vkm**
Light Commercial vehicle	118	24.7
Freight transport modes	**Billion €**	**€-cent/tkm**
Heavy Goods Vehicle	78	4.2
Electric freight train	5	1.1
Diesel freight train		1.8
IWT vessel	3	1.9
Maritime vessel	98[a]	0.7

[a] Rough estimations. For more details, see CE Delft et al. (2019c).

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[6]. For road transport, all EU28 Member States apply fuel taxes and vehicle taxes (e.g. purchase and registration taxes), while in most countries road charges (tolls and/or vignettes) are also applied. For rail transport, rail access charges are applied in all EU28 Member States. Diesel taxes (and to a lesser extent) electricity taxes are also applied. For IWT and maritime transport, most countries/ports only apply port charges. Finally, for aviation, airport charges (for local externalities) and the EU ETS[7] (for all CO_2 emissions from intra-EU flights, although non-CO_2 climate impacts are not covered) are applied in the EU28. They are supplemented with aviation taxes in some countries.

5 Engines of IWT vessels have rather long economic lifetimes (e.g. compared to HGVs) and hence the penetration of new, less polluting engines in the fleet is relatively slow. As a consequence, the average air pollutant emissions per IWT vessel decrease at a slower pace than the average emission levels of HGVs.

6 This definition excludes general taxes like profit taxes and wage taxes, as they are only indirectly related to transport activities. VAT levied on transport related taxes and charges are nevertheless included.

7 Although the EU ETS is neither a tax nor charge (but rather a market-based carbon pricing measure), it is nevertheless considered in this study as a tax.

Externalities are, to a limited extent, used as differentiation parameters for transport taxes and charges. These differentiations are more frequently applied to road transport, e.g. CO_2 differentiated vehicle taxes and road toll for HGVs differentiated to air pollutant emissions standards. Airport charges are frequently differentiated to noise levels of the aircraft (about 50% of the considered airports apply such a differentiation). Rail access charges, on the other hand, are hardly differentiated to externalities in the EU28, while port charges (for IWT and maritime transport) are differentiated to environmental standards in only a limited number of ports.

Total tax/charge revenues

The total tax/charge revenues from road, rail and inland waterway transport in the EU28 amount to € 370 billion for 2016 (€ 350 billion from road, € 20 billion from rail and € 0.4 billion from IWT). As is shown in Table 3, the majority of these revenues (81%) is from passenger cars, which reflects the large share this vehicle category has in total transport performance and the relatively high tax/charge burden on these vehicles. The total tax/charge revenues for the 33/34 EU28 (air)ports are approximately equal to € 14 billion and € 1.8 billion, respectively.

Average tax/charge revenues

For passenger transport, the highest average tax/charge revenues are identified for diesel trains (see Table 3). These revenues are significantly higher than for electric passenger trains, which can be explained by the lower occupancy rate of diesel trains and, even more important, the higher energy taxes (diesel taxes for rail transport are — on average — higher than electricity taxes for this mode). The higher average tax/charge revenues for passenger cars and motorcycles compared to buses/coaches is explained by higher vehicle tax levels and lower occupancy rates. Finally, the relatively low average tax/charge revenues for aviation should be considered carefully, as this figure is an average (including both short-, medium- and long-haul flights) and hence cannot be compared directly to the other modes.

For freight transport, the highest average revenues are found for HGVs, followed by diesel trains, electric trains and IWT vessels. The higher revenues for diesel trains compared to electric trains are mainly explained by the higher energy tax levels for diesel trains.

Table 3 – Tax/charge revenues in the EU28 in 2016 (all figures are PPS adjusted)

Vehicle category	Total tax/charge revenues	Average tax/charge revenues
Passenger transport modes	**Billion €**	**€-cent/pkm**
Passenger car	267	5.4
Bus/Coach	7	1.2
Motorcycle	9	5.0
High speed train	4	3.0
Electric passenger train	8	2.6
Diesel passenger train	5	6.8
Aircraft[a]	14	1.5
Light commercial vehicles	**Billion €**	**€-cent/vkm**
Light Commercial vehicle	35	7.3
Freight transport modes	**Billion €**	**€-cent/tkm**
Heavy Goods Vehicle	33	1.5
Electric freight train	2	0.5
Diesel freight train	1	1.3

Vehicle category	Total tax/charge revenues	Average tax/charge revenues
IWT vessel	0.4	0.3
Maritime vessel[ab]	2	n/a

[a] The figures for aviation and maritime transport refer to the 33/34 selected EU28 (air)ports.

[b] Due to a lack of data, no average tax/charge revenues (in €-cent/tkm) for maritime transport could be calculated.

State-of-play of internalisation

The extent to which external costs and infrastructure costs are internalised by current taxes and charges in the EU28 is assessed from two perspectives:

1. *Average cost pricing*: charges/taxes are set at the level of average infrastructure and external costs.
2. *Marginal social cost pricing (MSCP)*: variable charges/taxes are set at the level of marginal infrastructure and external costs.

Five indicators have been used to assess the extent of internalisation from the perspective of average cost pricing (see Table 4). To assess the extent of internalisation from the MSCP perspective, we made use of the marginal cost coverage ratio. This ratio compares the marginal external and infrastructure costs with the marginal tax/charge revenues for three/four specific situations.

Table 4 - Overview of the indicators for average cost pricing

Cost coverage ratio	Explanation
Overall cost coverage ratio	Comparison of revenues from all taxes/charges with all external and infrastructure costs.
Overall cost coverage ratio excluding fixed infrastructure costs	Comparison of revenues from all taxes/charges with all external and variable infrastructure costs (i.e. excluding fixed infrastructure costs)[a].
Variable external and infrastructure cost coverage ratio	Comparison of revenues from variable taxes/charges with variable external and infrastructure costs.
Overall infrastructure cost coverage ratio	Comparison of revenues from infrastructure charges with all infrastructure costs.
Variable infrastructure cost coverage ratio	Comparison of revenues from infrastructure charges with variable infrastructure costs.

[a] 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).

The results for the assessment of the extent of internalisation from the average cost pricing perspective are given in Table 5. Based on these results, the following conclusions can be drawn:

— *External and infrastructure costs of transport in the EU28 are only partly internalised by current taxes and charges*. As shown by the results in the second column of Table 5, the overall costs are not covered by revenues from transport taxes/charges for any of the vehicle categories. For most vehicle categories, only 15 to 25% of the external and infrastructure costs are covered. For IWT and maritime transport, much lower cost coverage ratios were found (6 and 4%, respectively), reflecting the limited tax/charge burden levied on these transport modes. Even if we exclude fixed infrastructure costs from the analyses (see third column of Table 5), current taxes and charges do not cover the external and infrastructure costs for most vehicle categories (except for high speed trains).

- *Little evidence for application of marginal social cost pricing*. The results of the analyses of marginal social cost coverage ratios show that for many transport modes, the marginal cost coverage ratios differ widely between the various scenarios. This indicates that 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. Therefore, the analyses provide a first indication that there is a lack of charging in accordance with the MSCP principle in the EU28. Therefore, some form of averaging seems inevitable. However, even in a more simplified way, MSCP is not achieved at the EU28 level, as is shown by the fourth column of Table 5. Variable infrastructure and external costs are generally not covered by variable taxes/charges. An exception is rail transport (particularly high speed trains and diesel passenger trains), where the rail access charges and diesel taxes reflect the variable nature of the external costs and the variable part of the infrastructure costs.
- *Limited use of the 'users-pays' principle in the EU28*. As shown by the results for the total infrastructure cost coverage, for most vehicle categories only 15 to 30% of the infrastructure costs are covered by infrastructure charges[8]. Exceptions are aviation and maritime transport. The revenues from (air)port charges do cover for (most of) the infrastructure costs of (air)ports. On the other hand, the variable infrastructure costs (i.e. wear and tear costs) are covered by the revenues from infrastructure charges for most vehicle categories (see the last column of Table 5). The main exceptions are heavy road vehicles (HGV, bus, coach), which can be mainly explained by the high weigh-dependent infrastructure costs caused by these vehicles. The very high coverage ratios for variable infrastructure have to be considered in the context of the low overall cost coverage ratios, as infrastructure charges also serve as internalisation measures of both external and infrastructure costs.

Table 5 – Overview cost coverage ratios for the average cost perspective

	Overall cost coverage	Overall cost coverage excluding fixed infra costs	Variable infrastructure and external cost coverage	Total infrastructure cost coverage	Variable infrastructure cost coverage
Passenger transport					
Passenger car	51%	63%	48%	27%	417%
Bus	17%	24%	21%	3%	6%
Coach	18%	26%	23%	3%	6%
Motorcycle	19%	20%	15%	35%	576%
High speed train	26%	145%	208%	28%	394%
Electric pax train	16%	61%	70%	19%	160%
Diesel pax train	22%	91%	101%	16%	122%
Aircraft	34%	45%	46%	82%	247%
Freight transport					
LCV	43%	53%	48%	11%	153%
HGV	26%	37%	33%	14%	44%
Elec. freight train	12%	30%	35%	16%	86%
Diesel freight train	26%	55%	61%	25%	138%
IWT vessel	6%	12%	13%	12%	176%
Maritime vessel	4%	4%	4%	127%	4,571%[a]

[a] This very high cost coverage ratio can be explained by the fact that the variable share of port infrastructure costs is assumed to be low. Combined with the fact that port charges are often set to cover (most of the) total infrastructure costs, this results in very high variable infrastructure cost coverage ratios.

[8] Although users do pay taxes other than infrastructure charges that can be used to fund infrastructure projects.

Broader context of internalisation

In addition to transport taxes and charges, other policy instruments (e.g. command and control measures and subsidies) may also contribute to achieving the objectives of internalisation, in particular the reduction of the external costs of transport. Non-pricing measures are applied instead of, or in addition to, taxes and charges for several reasons. For example, some of the externalities have transboundary impacts (e.g. climate change, air pollution) and addressing them at the EU level has added value. As transport taxes/charges are under Member States competence, they cannot be easily harmonised at the EU level and hence using alternative EU-wide instruments may be preferred. The fact that non-pricing instruments can be applied in a harmonised way at the EU level also reduces the risks on distortions of the internal market and provides better conditions to invest in technologies reducing external costs[9]. The lack of social and political support for implementing or raising taxes and charges is another example where non-pricing measures may be more appropriate. Finally, some externalities (particularly accident costs) are not targeted by taxes and charges, mainly because it is not straightforward to do so. In these cases, other policy instruments (e.g. command-and-control measures) are more appropriate to reduce the external costs.

Options for further internalisation

The assessment of the state-of-play of internalisation shows that there is room for improvement with respect to the internalisation of external and infrastructure costs of transport in the EU28. For that reason, a scoping analysis of potential further internalisation options has been carried out. The main results of this analysis are:

- Wider use of distance-based road charges differentiated to vehicle characteristics, location and/or time may improve the extent of internalisation for road transport. For urban areas, the use of specific urban road charging schemes may be considered to address the relatively high external costs of urban transport.
- Wider application of noise differentiations in rail access charges may be an option to further internalise the noise costs of rail transport. Mark-ups on these access charges may be used in case a larger share of the fixed infrastructure costs should be covered.
- Introducing fairway dues or higher port charges may be options to internalise a larger share of the external and infrastructure costs of IWT. Applying differentiations to air pollutant emissions in these instruments may help to address the relatively high air pollutant costs of this transport mode. Current legislation does, however, prohibit the introduction of fairway dues on the Rhine and its tributaries (the most important inland waterway(s) of the EU).
- Environmentally differentiated port charges or fairway dues may be options to further internalise the air pollution cost of maritime transport. With respect to GHG emissions of maritime transport, the EU already works with global partners in the International Maritime Organisation (IMO) on further policy instruments.
- Further policies in the field of GHG emissions from aviation are being developed in cooperation with global partners in the International Civil Aviation Organisation (ICAO). Furthermore, environmentally differentiated airport charges or aviation taxes may be options to further internalise externalities of aviation.

[9] 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.

Résumé

Le projet Tarification de l'infrastructure de transports durables et internalisation des externalités dans le secteur des transports » vise à évaluer dans quelle mesure les politiques existantes internalisent les coûts externes et infrastructurels des transports et à examiner différentes manières de parvenir à un niveau d'internalisation supérieur. Cette évaluation s'appuie sur une estimation des coûts externes et infrastructurels des divers modes de transport et sur un bilan complet des taxes et droits relatifs aux transports appliqués dans les différents pays. Les résultats de ces évaluations sont présentés sous la forme de quatre éléments livrables[10] distincts. Ce rapport fait la synthèse des conclusions principales tirées de ces éléments livrables.

Le projet prend en considération tous les modes de transport principaux, à savoir le transport routier, le transport ferroviaire, le transport fluvial, le transport maritime et le transport aérien dans les 28 États membres de l'UE, la Norvège, la Suisse, le Japon et quelques États des États-Unis d'Amérique et provinces canadiennes. Dans les cas du transport maritime et du transport aérien, les évaluations ont été effectuées au niveau des (aéro)ports plutôt que des pays. Ce rapport ne présente que des résultats globaux pour les 28 États membres de l'UE (et les (aéro)ports des 28 États membres de l'UE pris en considération). Pour les résultats propres à chaque pays (ou (aéro)port), le lecteur est renvoyé aux autres éléments livrables de cette étude. Tous les résultats présentés dans cette étude se rapportent à l'année 2016.

Coût infrastructurel

Dans le cadre de cette étude, les coûts infrastructurels sont définis comme le total des dépenses directes et des coûts de financement. Les coûts infrastructurels annuels en 2016 sont donc équivalents à la somme des coûts liés à la dépréciation et des coûts de financement annuels. Les coûts infrastructurels du transport comprennent les investissements d'expansion infrastructurelle, les coûts de renouvellement de l'infrastructure existante, les dépenses liées à l'entretien de l'infrastructure, et les dépenses de fonctionnement permettant l'utilisation de l'infrastructure de transport.

Coûts infrastructurels totaux

Pour le transport routier, ferroviaire et fluvial, les coûts infrastructurels totaux dans les 28 États membres de l'UE s'élèvent à 267 milliards d'euros pour 2016 (184 milliards d'euros pour le transport routier, 81 milliards d'euros pour le transport ferroviaire et 3 milliards d'euros pour le transport fluvial). L'essentiel de ces coûts peut être attribué aux voitures

[10] CE Delft et al. (2019a) – Overview of transport infrastructure expenditures and costs. (Vue d'ensemble des dépenses et coûts associés à l'infrastructure de transport.)
CE Delft et al. (2019b) – Transport taxes and charges in Europe – An overview study of economic internalisation measures applied in Europe. (Taxes et droits de transport en Europe - Une étude synoptique des mesures d'internalisation économiques appliquées en Europe.)
CE Delft et al. (2019c) – Handbook on the external costs of transport. (Livre de référence sur les coûts externes du transport.)
CE Delft et al. (2019d) – The state-of-play of internalisation in the European transport sector. (État des lieux de l'internalisation dans le secteur du transport européen.)

particulières et aux poids lourds, comme indiqué dans le Tableau 6. Les coûts infrastructurels totaux pour l'échantillon choisi de 33 aéroports et 34 ports maritimes des 28 États membres de l'UE s'élèvent respectivement à 14 milliards d'euros et 1,4 milliard d'euros.

Coûts infrastructurels moyens

Pour le transport de voyageurs, les coûts infrastructurels moyens (en centimes d'euro/voy-km) sont plus élevés pour le transport ferroviaire que pour le transport routier (voir le Tableau 6). Ceci s'explique principalement par les coûts fixes[11] (par ex. les coûts de construction) supérieurs pour le transport ferroviaire par comparaison avec le transport routier. Les coûts moyens sont les plus élevés pour les trains de voyageurs diesel, en raison du taux d'occupation moindre des trains diesel (par rapport aux trains électriques). Une explication supplémentaire réside dans le taux d'utilisation inférieur de l'infrastructure ferroviaire diesel comparativement à l'infrastructure ferroviaire électrique.

Tableau 6 – Coûts infrastructurels dans les 28 États membres de l'UE en 2016 (tous les chiffres sont ajustés selon les SPA)

Catégorie de véhicule	Coûts infrastructurels totaux	Coûts infrastructurels moyens	Coûts infrastructurels marginaux
Modes de transport de voyageurs	**Milliards d'euros**	**Centimes d'euro/voy-km**	**Centimes d'euro/voy-km**
Voiture particulière	98	2,1	0,1
Bus	8	4,0	1,9
Car	13	3,7	1,8
Moto	3	1,8	0,1
Train à grande vitesse (TGV)	12	10,6	0,8
Train de voyageurs électrique (dont TGV)	51	13,4	1,6
Train de voyageurs diesel	18	27,0	3,5
Avion[a]	14	1,6	0,5
Véhicules utilitaires légers	**Milliards d'euros**	**Centimes d'euro/véh-km**	**Centimes d'euro/véh-km**
Véhicule utilitaire léger	20	4,1	0,3
Modes de transport de marchandises	**Milliards d'euros**	**Centimes d'euro/t-km**	**Centimes d'euro/t-km**
Poids lourd	42	2,3	0,7
Train de marchandises électrique	9	3,0	0,6
Train de marchandises diesel	3	3,2	0,6
Navire fluvial	3	1,9	0,1
Navire maritime[ab]	1	s.o.	s.o.

[a] Les chiffres pour le transport aérien et le transport maritime concernent l'échantillon choisi de 33/34 (aéro)ports des 28 États membres de l'UE.

[b] En raison d'une insuffisance de données, il n'a pas été possible de calculer les coûts moyens et marginaux (en centimes d'euro/t-km) pour le transport maritime.

[11] Les coûts fixes sont des coûts qui ne varient pas en fonction des volumes de transport (à court terme). Les coûts de construction d'expansion infrastructurelle sont un exemple de coûts infrastructurels fixes. Les coûts variables, en revanche, varient en fonction des volumes de transport. La réparation des nids de poule est un exemple de coûts infrastructurels variables.

Pour le transport routier, les coûts infrastructurels moyens pour les bus/cars sont considérablement plus élevés que pour les voitures particulières, ce qui peut s'expliquer par les coûts infrastructurels en fonction du poids relativement élevés générés par ces véhicules. Pour finir, les coûts infrastructurels moyens pour le transport aérien sont relativement faibles (du même ordre de grandeur que ceux des voitures particulières). Le résultat pour le transport aérien est toutefois une moyenne, incluant les vols court, moyen ainsi que long-courriers, à destination et en provenance d'aéroports européens. Le transport aérien n'entrant en concurrence avec les autres modes que pour les courtes distances, ce chiffre ne peut être comparé directement aux résultats pour les autres catégories de véhicule[12].

Le Tableau 6 indique également les coûts infrastructurels moyens pour le transport routier, ferroviaire et fluvial de marchandises. Les coûts les plus élevés pour le transport de voyageurs sont associés au transport ferroviaire, suivi du transport routier et du transport fluvial.

Coûts infrastructurels marginaux

Les coûts infrastructurels marginaux correspondent à des coûts additionnels pour le gestionnaire de l'infrastructure de transport résultant d'un véhicule-kilomètre (ou un décollage/atterrissage ou une escale) additionnel sur le réseau. Comme indiqué dans le Tableau 6, les coûts infrastructurels marginaux les plus élevés pour le transport de voyageurs sont à nouveau associés aux trains diesel. Cependant, la différence entre les coûts infrastructurels marginaux correspondant aux véhicules routiers et ferroviaires est considérablement inférieure à la différence entre les coûts infrastructurels moyens associés à ces modes, ce qui peut s'expliquer par le fait que les coûts infrastructurels marginaux (à la différence des coûts moyens) ne sont pas influencés par les coûts fixes relativement élevés de l'infrastructure ferroviaire.

Pour le transport de marchandises, les coûts infrastructurels marginaux les plus élevés correspondent aux poids lourds, ce qui reflète la composante variable relativement grande des coûts infrastructurels routiers. Les coûts infrastructurels marginaux pour le transport fluvial sont relativement faibles, étant donné que seule une part limitée des coûts infrastructurels dépend directement de l'utilisation effective des voies fluviales.

Coûts externes

Les coûts externes totaux, moyens et marginaux pour le transport dans les 28 États membres de l'UE ont été estimés en s'appuyant sur des facteurs de coût et des méthodologies à la pointe des connaissances actuelles. Pour ce faire, les externalités suivantes ont été prises en compte : accidents, pollution de l'air, changement climatique, bruit, congestion, émissions du puits au réservoir, et dégradation des habitats.

Coûts externes totaux

Les coûts externes totaux du transport dans les 28 États membres de l'UE sont estimés à 987 milliards d'euros. Ce chiffre n'inclut les coûts liés à la congestion que pour le transport routier car il n'était pas possible d'estimer les coûts liés à la congestion pour les autres

[12] Les coûts infrastructurels moyens seront plus élevés pour les vols court-courriers que pour les vols moyen ou long-courriers (étant donné que les coûts infrastructurels fixes sont rapportés à un nombre inférieur de voyageurs-kilomètres). Cependant, en raison d'une insuffisance de données, les coûts infrastructurels moyens pour le transport aérien n'ont pu être différenciés en fonction des distances de vol.

modes. De manière générale, les coûts liés aux accidents, constituant 29% des coûts totaux, représentent la catégorie de coûts la plus importante, suivis des coûts liés à la congestion (27%). Dans l'ensemble, les coûts environnementaux (changement climatique, pollution de l'air, bruit, bilan du puits au réservoir et dégradation des habitats) constituent les 44% restants des coûts totaux. D'importantes différences existent toutefois entre les modes de transport.

Comme indiqué dans le Tableau 7, le transport routier (et notamment les voitures particulières) est le plus gros contributeur aux coûts externes (83% des coûts totaux, 820 milliards d'euros), ce qui s'explique en partie par la part importante du transport routier dans la performance totale des 28 États membres de l'UE sur le plan du transport[13]. Les coûts externes totaux pour le transport ferroviaire et le transport fluvial s'élèvent respectivement à 18 milliards d'euros et 3 milliards d'euros. Enfin, pour le transport aérien et le transport maritime, les coûts externes dans les 28 États membres de l'UE sont approximativement estimés à 48 et 98 milliards d'euros.

Coûts externes moyens

Comme indiqué dans le Tableau 7, les motos génèrent les coûts externes moyens les plus élevés du fait de coûts liés au bruit et aux accidents relativement élevés. Les coûts externes moyens des bus/cars sont considérablement inférieurs à ceux des voitures particulières, ce qui peut s'expliquer par les taux d'occupation plus élevés de ces véhicules. En ce qui concerne le transport ferroviaire, les coûts externes moyens pour les trains diesel sont considérablement supérieurs par comparaison avec les trains électriques. Ceci s'explique principalement par les coûts liés à la pollution de l'air qui sont considérablement plus élevés pour les trains diesel, ainsi que par leurs taux d'occupation inférieurs.

En ce qui concerne le transport de marchandises, les coûts externes les plus élevés sont associés aux poids lourds, suivis du transport fluvial, du transport ferroviaire et du transport maritime. Les coûts externes relativement élevés des poids lourds s'expliquent principalement par des coefficients de charge relativement faibles par rapport au transport ferroviaire. En outre, pour le transport routier, les coûts liés à la congestion sont pris en compte, tandis qu'ils ne sont pas inclus pour les autres modes. Les coûts externes moyens pour le transport fluvial sont actuellement légèrement plus élevés que pour le transport ferroviaire, ce qui s'explique principalement par les coûts liés à la pollution de l'air qui sont relativement élevés dans le cas du transport fluvial[14]. Les coûts externes moyens faibles associés au transport maritime ne peuvent pas être comparés directement avec les autres modes, étant donné que ce chiffre est une moyenne pour le transport maritime à courte distance et le transport maritime à longue distance (et que seul le premier entre en concurrence directe avec les autres modes).

[13] Sans compter la congestion, le transport routier représenterait tout de même 77% des coûts totaux.

[14] Les moteurs des navires fluviaux possèdent des durées de vie économiques plutôt longues (par ex. en comparaison des poids lourds) et la pénétration de nouveaux moteurs moins polluants dans la flotte est, de ce fait, relativement lente. En conséquence, les émissions moyennes d'agents de pollution de l'air par navire fluvial diminuent à un rythme plus lent que les niveaux d'émissions moyens des poids lourds.

Tableau 7 - Coûts externes dans les 28 États membres de l'UE en 2016 (tous les chiffres sont ajustés selon les SPA)

Catégorie de véhicule	Coûts externes totaux	Coûts externes moyens
Modes de transport de voyageurs	**Milliards d'euros**	**Centimes d'euro/voy-km**
Voiture particulière	565	12,0
Bus/car	19	3,6
Moto	41	24,5
Train à grande vitesse	1	1,3
Train de voyageurs électrique	11	2,6
Train de voyageurs diesel		3,9
Avion	48[a]	3,4
Véhicules utilitaires légers	**Milliards d'euros**	**Centimes d'euro/véh-km**
Véhicule utilitaire léger	118	24,7
Modes de transport de marchandises	**Milliards d'euros**	**Centimes d'euro/t-km**
Poids lourd	78	4,2
Train de marchandises électrique	5	1,1
Train de marchandises diesel		1,8
Navire fluvial	3	1,9
Navire maritime	98[a]	0,7

[a] Estimations approximatives. Pour plus de détails, voir CE Delft et al. (2019c).

Taxes et droits de transport

Les taxes et droits de transport sont définis, dans le cadre de cette étude, comme l'ensemble des taxes/droits directement liés à la possession et à l'utilisation de véhicules de transport, y compris les taxes/droits associés à l'utilisation de l'infrastructure[15]. En ce qui concerne le transport routier, les 28 États membres de l'UE appliquent tous des taxes sur le carburant et des taxes sur les véhicules (par ex. taxes d'achat et d'immatriculation), la plupart des pays prélevant également des droits d'usage de la route (péages et/ou vignettes). Dans le cas du transport ferroviaire, des droits d'accès au réseau ferroviaire sont perçus dans l'ensemble des 28 États membres de l'UE. Des taxes sur le diesel et (dans une moindre mesure) des taxes sur l'électricité sont également appliquées. En ce qui concerne le transport fluvial et le transport maritime, la plupart des pays/ports appliquent uniquement des droits d'usage des ports. Enfin, pour le transport aérien, des droits d'usage des aéroports (pour les externalités locales) et le système d'échange de quotas d'émission de l'Union européenne[16] (pour toutes les émissions de CO_2 résultant de vols au sein de l'Union, bien que les impacts climatiques non liés au CO_2 ne soient pas couverts) sont appliqués dans les 28 États membres de l'UE. Des taxes de transport aérien s'y ajoutent dans certains pays.

Les externalités sont, dans une certaine mesure, utilisées comme paramètres de différenciation pour les taxes et droits de transport. Ces différenciations sont plus fréquemment appliquées au transport routier, par ex. les taxes sur les véhicules

[15] Cette définition exclut les taxes générales telles que les impôts sur les bénéfices et les impôts sur les salaires, celles-ci n'étant qu'indirectement liées aux activités de transport. La TVA prélevée sur les taxes et droits liés au transport est cependant incluse.

[16] Bien que le système d'échange de quotas d'émission de l'Union européenne ne soit ni une taxe, ni un droit (mais plutôt une mesure de tarification du carbone reposant sur les mécanismes du marché), il est toutefois considéré comme une taxe dans le cadre de cette étude.

différenciées en fonction des émissions de CO_2 et les péages pour les poids lourds différenciés en fonction de normes d'émissions d'agents de pollution de l'air. Les droits d'usage des aéroports sont fréquemment différenciés en fonction des niveaux de bruit de l'avion (environ 50% des aéroports pris en considération appliquent une telle différenciation). Les droits d'accès au réseau ferroviaire, en revanche, ne sont pratiquement pas différenciés en fonction des externalités dans les 28 États membres de l'UE, tandis que les droits d'usage des ports (pour le transport fluvial et le transport maritime) sont différenciés en fonction de normes environnementales uniquement dans un nombre limité de ports.

Recettes totales issues des taxes/droits

Les recettes totales issues des taxes/droits pour le transport routier, ferroviaire et fluvial dans les 28 États membres de l'UE s'élèvent à 370 milliards d'euros pour l'année 2016 (350 milliards d'euros pour le transport routier, 20 milliards d'euros pour le transport ferroviaire et 0,4 milliard d'euros pour le transport fluvial). Comme indiqué dans le Tableau 8, la plus grande partie de ces recettes (81%) provient des voitures particulières, ce qui reflète la part importante de cette catégorie de véhicule dans la performance totale sur le plan du transport et la charge de taxes/droits relativement élevée pesant sur ces véhicules. Les recettes totales issues des taxes/droits pour les 33/34 (aéro)ports des 28 États membres de l'UE représentent respectivement un montant approximatif de 14 milliards d'euros et de 1,8 milliard d'euros.

Recettes moyennes issues des taxes/droits

En ce qui concerne le transport de voyageurs, les recettes moyennes issues des taxes/droits les plus élevées sont associées aux trains diesel (voir le Tableau 8). Ces recettes sont considérablement plus élevées que dans le cas des trains de voyageurs électriques, ce qui peut s'expliquer par le taux d'occupation inférieur des trains diesel et, de façon plus importante encore, par les taxes énergétiques supérieures (les taxes sur le diesel pour le transport ferroviaire sont — en moyenne — supérieures aux taxes sur l'électricité pour ce mode). Les recettes moyennes issues des taxes/droits supérieures pour les voitures particulières et les motos par comparaison avec les bus/cars s'expliquent par des niveaux de taxation des véhicules supérieurs et des taux d'occupation inférieurs. Enfin, les recettes moyennes issues des taxes/droits relativement faibles dans le cas du transport aérien doivent être interprétées avec circonspection, ce chiffre étant une moyenne (incluant les vols court, moyen et long-courriers) et ne pouvant donc pas faire l'objet d'une comparaison directe avec les autres modes.

Pour ce qui est du transport de marchandises, les recettes moyennes les plus élevées proviennent des poids lourds, suivis des trains diesel, des trains électriques et des navires fluviaux. Les recettes supérieures associées aux trains diesel par comparaison aux trains électriques s'expliquent principalement par les niveaux de taxation énergétique supérieurs pour les trains diesel.

Tableau 8 - Recettes issues des taxes/droits dans les 28 États membres de l'UE en 2016 (tous les chiffres sont ajustés selon les SPA)

Catégorie de véhicule	Recettes totales issues des taxes/droits	Recettes moyennes issues des taxes/droits
Modes de transport de voyageurs	**Milliards d'euros**	**Centimes d'euro/voy-km**
Voiture particulière	267	5,4
Bus/car	7	1,2
Moto	9	5,0
Train à grande vitesse	4	3,0
Train de voyageurs électrique	8	2,6
Train de voyageurs diesel	5	6,8
Avion[a]	14	1,5
Véhicules utilitaires légers	**Milliards d'euros**	**Centimes d'euro/véh-km**
Véhicule utilitaire léger	35	7,3
Modes de transport de marchandises	**Milliards d'euros**	**Centimes d'euro/t-km**
Poids lourd	33	1,5
Train de marchandises électrique	2	0,5
Train de marchandises diesel	1	1,3
Navire fluvial	0,4	0,3
Navire maritime[ab]	2	s.o.

[a] Les chiffres pour le transport aérien et le transport maritime concernent l'échantillon choisi de 33/34 (aéro)ports des 28 États membres de l'UE.

[b] En raison d'une insuffisance de données, il n'a pas été possible de calculer les recettes moyennes issues des taxes/droits (en centimes d'euro/t-km) pour le transport maritime.

État des lieux de l'internalisation

La mesure dans laquelle les coûts externes et les coûts infrastructurels sont internalisés par les taxes et droits actuels dans les 28 États membres de l'UE est évaluée sous deux angles :

1. *Tarification en fonction du coût moyen* : les droits/taxes sont établis au niveau des coûts infrastructurels et externes moyens.
2. *Tarification en fonction du coût social marginal* : les droits/taxes variables sont établis au niveau des coûts infrastructurels et externes marginaux.

Cinq indicateurs ont été utilisés pour évaluer la mesure de l'internalisation sous l'angle de la tarification en fonction du coût moyen (voir le Tableau 9). Pour évaluer la mesure de l'internalisation sous l'angle de la tarification en fonction du coût social marginal, le taux de couverture des coûts marginaux a été utilisé. Il s'agit du rapport entre les coûts externes et infrastructurels marginaux et les recettes issues des taxes/droits marginales pour trois/quatre situations spécifiques.

Tableau 9 - Vue d'ensemble des indicateurs pour la tarification en fonction du coût moyen

Taux de couverture des coûts	Explication
Taux de couverture globale des coûts	Comparaison entre les recettes issues des taxes/droits et la totalité des coûts externes et infrastructurels.
Taux de couverture globale des coûts excluant les coûts infrastructurels fixes	Comparaison entre les recettes issues des taxes/droits et la totalité des coûts externes et des coûts infrastructurels variables (c'est-à-dire excluant les coûts infrastructurels fixes)[a].
Taux de couverture des coûts externes et infrastructurels variables	Comparaison entre les recettes issues des taxes/droits variables et les coûts externes et infrastructurels variables.
Taux de couverture globale des coûts infrastructurels	Comparaison entre les recettes issues des droits d'usage de l'infrastructure et la totalité des coûts infrastructurels.
Taux de couverture des coûts infrastructurels variables	Comparaison entre les recettes issues des droits d'usage de l'infrastructure et les coûts infrastructurels variables.

[a] Cet indicateur est en conformité avec les ambitions de la Commission visant une internalisation complète des coûts externes, y compris les coûts d'usure. Il intègre le fait que les coûts infrastructurels fixes sont des coûts irrécupérables et que le fait de payer pour ces coûts peut se traduire par une sous-utilisation (accrue) de l'infrastructure existante (par ex. du réseau ferroviaire).

Les résultats de l'évaluation de la mesure de l'internalisation sous l'angle de la tarification en fonction du coût moyen sont indiqués dans le Tableau 10. On peut formuler, à partir de ces résultats, les conclusions suivantes :

- *Les coûts externes et infrastructurels pour le transport dans les 28 États membres de l'UE ne sont que partiellement internalisés par les taxes et droits actuels*. Comme le montre les résultats dans la deuxième colonne du Tableau 10, les coûts totaux ne sont couverts par les recettes issues des taxes/droits relatifs au transport pour aucune des catégories de véhicule. Pour la plupart des catégories de véhicule, 15 à 25% seulement des coûts externes et infrastructurels sont couverts. En ce qui concerne le transport fluvial et le transport maritime, on a constaté des taux de couverture des coûts bien inférieurs (respectivement 6 et 4%), ce qui reflète la charge de taxes/droits limitée imposée à ces modes de transport. Même si l'on exclut les coûts infrastructurels fixes des analyses (voir la troisième colonne du Tableau 10), pour la plupart des catégories de véhicule (à l'exception des trains à grande vitesse), les taxes et droits actuels ne couvrent pas les coûts externes et infrastructurels.
- *Peu de données à l'appui de l'application d'une tarification en fonction du coût social marginal*. Les résultats des analyses des taux de couverture des coûts sociaux marginaux montrent que, pour bon nombre des modes de transport, les taux de couverture des coûts marginaux diffèrent grandement entre les divers scénarios. Ceci indique que les taxes et droits actuels ne sont souvent pas en mesure de prendre en compte l'important écart de grandeur des coûts externes et infrastructurels marginaux dans différentes situations. Par conséquent, les analyses ne fournissent qu'une première indication du fait que l'imposition est insuffisante conformément au principe de la tarification en fonction du coût social marginal dans les 28 États membres de l'UE. Le recours à une certaine moyenne semble donc inévitable. Cependant, même en simplifiant davantage, la tarification en fonction du coût social marginal n'est pas effective au niveau des 28 États membres de l'UE, comme le montre la quatrième colonne du Tableau 10. Les coûts externes et infrastructurels variables ne sont généralement pas couverts par les taxes/droits variables. Le transport ferroviaire (en particulier les trains à grande vitesse et les trains de voyageurs diesel) constitue une exception, les droits d'accès au réseau ferroviaire et les taxes sur le diesel reflétant la nature variable des coûts externes et la part variable des coûts infrastructurels.

— *Utilisation limitée du principe de l'« utilisateur-payeur » dans les 28 États membres de l'UE*. Comme le montre les résultats de couverture des coûts infrastructurels totaux, pour la plupart des catégories de véhicule, 15 à 30% seulement des coûts infrastructurels sont couverts par les droits d'usage de l'infrastructure[17]. Le transport aérien et le transport maritime font exception. Les recettes provenant des droits d'usage des (aéro)ports assurent la couverture (de la plus grande partie) des coûts infrastructurels des (aéro)ports. En revanche, les coûts infrastructurels variables (c'est-à-dire les coûts d'usure) sont couverts par les recettes provenant des droits d'usage de l'infrastructure pour la plupart des catégories de véhicule (voir la dernière colonne du Tableau 10). Les principales exceptions sont les véhicules lourds de transport routier (poids lourd, bus, car), ce qui peut s'expliquer principalement par les coûts infrastructurels en fonction du poids élevés générés par ces véhicules. Les taux de couverture très élevés pour les coûts infrastructurels variables doivent être appréciés dans le contexte des faibles taux de couverture globale des coûts, les droits d'usage de l'infrastructure servant également de mesures d'internalisation à la fois des coûts externes et des coûts infrastructurels.

Tableau 10 – Vue d'ensemble des taux de couverture des coûts sous l'angle de la tarification en fonction du coût moyen

	Couverture globale des coûts	Couverture globale des coûts excluant les coûts infrastructurels fixes	Couverture des coûts infrastructurels et externes variables	Couverture des coûts infrastructurels totaux	Couverture des coûts infrastructurels variables
Transport de voyageurs					
Voiture particulière	51%	63%	48%	27%	417%
Bus	17%	24%	21%	3%	6%
Car	18%	26%	23%	3%	6%
Moto	19%	20%	15%	35%	576%
Train à grande vitesse	26%	145%	208%	28%	394%
Train de voyageurs électrique	16%	61%	70%	19%	160%
Train de voyageurs diesel	22%	91%	101%	16%	122%
Avion	34%	45%	46%	82%	247%
Transport de marchandises					
Véhicule utilitaire léger	43%	53%	48%	11%	153%
Poids lourd	26%	37%	33%	14%	44%
Train de marchandises électrique	12%	30%	35%	16%	86%
Train de marchandises diesel	26%	55%	61%	25%	138%
Navire fluvial	6%	12%	13%	12%	176%

[17] Les utilisateurs payant toutefois des taxes autres que les droits d'usage de l'infrastructure qui peuvent être employées pour financer les projets infrastructurels.

	Couverture globale des coûts	Couverture globale des coûts excluant les coûts infrastructurels fixes	Couverture des coûts infrastructurels et externes variables	Couverture des coûts infrastructurels totaux	Couverture des coûts infrastructurels variables
Navire maritime	4%	4%	4%	127%	4.571%[a]

[a] Ce taux de couverture des coûts très élevé peut s'expliquer par le fait que la part variable des coûts infrastructurels portuaires est présumée faible. En ajoutant à cela le fait que les droits d'usage des ports sont souvent établis de façon à assurer la couverture (de la plus grande partie) des coûts infrastructurels totaux, il en résulte des taux de couverture des coûts infrastructurels variables très élevés.

Contexte élargi de l'internalisation

Outre les taxes et droits appliqués au transport, d'autres instruments de politique (par ex. des mesures de réglementation stricte et des subventions) peuvent également contribuer à l'atteinte des objectifs d'internalisation, en particulier la réduction des coûts externes associés au transport. Des mesures non tarifaires sont appliquées au lieu, ou en plus, de taxes et de droits pour diverses raisons. Par exemple, certaines des externalités ont des impacts transfrontières (tels que changement climatique et pollution de l'air) et une approche communautaire offre une valeur ajoutée. Les taxes/droits relatifs au transport relevant de la compétence des États membres, il est difficile de les harmoniser au niveau communautaire et il est donc possible que l'utilisation d'autres instruments à l'échelle communautaire soit préférée. Le fait que des instruments non tarifaires puissent être appliqués de manière harmonisée à l'échelle communautaire réduit également les risques d'altérations du marché intérieur et offre de meilleures conditions pour l'investissement dans les technologies réduisant les coûts externes[18]. Le manque de soutien social et politique pour la mise en place de taxes et de droits ou leur augmentation est une autre raison faisant que des mesures non tarifaires pourraient être plus appropriées. Enfin, certaines externalités (en particulier les coûts associés aux accidents) n'entrent pas dans le champ d'application des taxes et droits, principalement parce qu'il est difficile de les inclure. Dans ces cas, d'autres instruments de politique (par ex. des mesures de réglementation stricte) sont plus appropriés pour réduire les coûts externes.

Options pour une internalisation accrue

L'évaluation de l'état des lieux de l'internalisation indique qu'il y a matière à amélioration sur le plan de l'internalisation des coûts externes et infrastructurels relatifs au transport dans les 28 États membres de l'UE. C'est pourquoi une étude des options potentielles pour une internalisation accrue a été menée. Les principaux résultats de cette étude sont :

— Une plus grande utilisation de droits d'usage des routes basés sur la distance différenciés en fonction des caractéristiques du véhicule, du lieu et/ou de l'heure peut accroître l'internalisation sur le plan du transport routier. Dans le cas des zones urbaines, l'utilisation de systèmes spécifiques de prélèvement de droits d'usage des routes urbaines peut être envisagée afin d'apporter une réponse aux coûts externes relativement élevés associés au transport urbain.

[18] Des politiques harmonisées au niveau communautaire pourraient assurer des conditions équitables étendues, dans le cadre desquelles les fabricants de véhicules (et les autres industries) auraient à répondre aux mêmes exigences par des technologies/actions réduisant les externalités dans l'ensemble de l'UE. Il en découle un climat d'investissement plus favorable pour ces types de technologies/d'actions.

- Une plus grande utilisation de différenciations fondées sur le bruit au niveau des droits d’accès au réseau ferroviaire peut être une option pour accroître l’internalisation des coûts associés au bruit dans le cas du transport ferroviaire. Des hausses de ces droits d’accès peuvent être employées si la couverture d’une part plus importante des coûts infrastructurels fixes est requise.
- L’introduction de cotisations d’usage des voies navigables ou de droits d’usage des ports plus élevés peuvent constituer des options pour internaliser une part plus importante des coûts externes et infrastructurels associés au transport fluvial. L’application de différenciations en fonction des émissions d’agents de pollution de l’air au sein de ces instruments peut contribuer à apporter une réponse aux coûts relativement élevés associés aux agents de pollution de l’air dans le cas de ce mode de transport. Toutefois, la législation actuelle interdit l’introduction de cotisations d’usage des voies navigables sur le Rhin et ses affluents (qui représentent les voies fluviales les plus importantes de l’UE).
- Une différenciation environnementale des droits d’usage des ports ou l’application de cotisations d’usage des voies navigables peuvent être des options permettant une internalisation accrue du coût associé à la pollution de l’air généré par le transport maritime. En ce qui concerne les émissions de gaz à effet de serre du transport maritime, l’UE travaille déjà sur d’autres instruments de politique avec des partenaires mondiaux au sein de l’Organisation maritime internationale (OMI).
- D’autres politiques portant sur les émissions de gaz à effet de serre produites par le transport aérien sont en cours de développement dans le cadre d’une coopération avec des partenaires mondiaux au sein de l’Organisation de l'aviation civile internationale (OACI). En outre, une différenciation environnementale des droits d’usage des aéroports ou l’application de taxes de transport aérien peuvent être des options permettant une internalisation accrue des externalités du transport aérien.

Glossary

Term	Explanation
Average cost pricing	Internalisation approach where charges/taxes are set at the level of average infrastructure and external costs.
Average costs/revenues	Costs/revenues per transport performance unit (e.g. Euro per pkm, Euro per tkm).
Avoidance cost approach	Approach to valuate external costs. This approach determines external cost valuation factors (i.e. shadow prices) by determining the cost to achieve a particular policy target (e.g. EU CO_2 reduction targets).
Baumol pricing	Internalisation approach where charges/taxes are set at the level that is expected to be sufficient to achieve a given (environmental) objective.
Bus	Passenger road motor vehicle designed to carry more than 24 persons (including the driver), and with the provision to carry seated as well as standing passengers.
Charge	Compulsory requited payment, where requited means that the payer does receive anything directly in return.
Coach	Passenger road motor vehicles designed to seat 24 or more persons (including the driver) and constructed exclusively for the carriage of seated passengers.
Cost driver	Factor that expresses the responsibility or the causation of a vehicle for the level of total costs.
Damage cost approach	Approach to valuate external costs. It values all damage experienced by individuals as a result of the existence of an externality (e.g. health impacts due to traffic noise).
Deadweight costs	Measure to define road congestion costs as the value of utility loss due to congestion levels above the economically optimal levels.
Delay costs	Measure to define road congestion costs as the value of the total travel time lost relative to a free-flow situation.
Enhancement costs	Costs of new infrastructure or expansion of existing infrastructure with respect to its functionality and/or lifetime.
Equivalency factor method	Approach used to allocate the total infrastructure costs to various vehicle categories, based on selected cost drivers (proportionality factors).
External cost	Unintended cost imposed on third parties for which no compensation is received. Important types of external costs are: air pollution, climate change, noise, accidents and congestion.
Fixed costs	Costs that do not vary with transport volumes.
Gross Domestic Product (GDP)	Aggregate measure of production equal to the sum of the gross value added of all residents, institutional units engaged in production.
Heavy Goods Vehicle (HGV)	Goods road vehicle with a gross vehicle weight above 3,500 kg, designed, exclusively or primarily, to carry goods.
High speed line (HSL)	Rail lines dedicated to high speed trains (see: High speed train).
High speed train (HST)	Trains designed to operate at a speed of at least 250 km/h on dedicated high speed lines (see: High speed line).
Infrastructure costs	The direct expenses on 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.
Inland Waterway Transport (IWT)	Any movement of goods and/or passengers using inland waterway vessels which is undertaken wholly or partly on navigable inland waterways.
Landing and Take-Off (LTO)	Cycle of landing and take-off of an aircraft.
Light Commercial Vehicle (LCV)	Four-wheeled goods road motor vehicle with a gross vehicle weight of not more than 3,500 kg. Also known as van.

Term	Explanation
Maintenance costs	Costs referring to the costs of ‘ordinary’ maintenance. These are relatively minor repairs with an economic lifetime of less than 1 to 2 years.
Marginal costs	Additional costs caused by an additional vehicle kilometre (or LTO or call) on the transport network.
Marginal Social Cost Pricing (MSCP)	Internalisation approach where charges/taxes are set at the level of marginal infrastructure and external costs.
Motorcycle (MC)	Two-, three- or four-wheeled road motor vehicle not exceeding 400 kg of unladen weight. All such vehicles with a capacity of 50 cc or over are included.
Operational costs	These costs refer to the costs of the organisation of efficient use of the infrastructure.
Passenger car	Road motor vehicle, other than a moped or a motorcycle, intended for the carriage of passengers and designed to seat no more than nine persons (including the driver).
Passenger kilometre (pkm)	Unit of measurement representing the transport of one passenger over one kilometre.
Perpetual Inventory Method (PIM)	Method to estimate infrastructure costs based on time series data on infrastructure expenditures. To estimate enhancement and renewal costs, the annual depreciation costs are calculated by distributing the initial investments over the lifetime of the infrastructure. In addition, financing costs are calculated by using an appropriate interest rate. The sum of depreciation and financing costs equals enhancement and/or renewal costs. Operational and maintenance costs are based on running expenditures.
Price index figure	Indicator measuring the weighted average of prices in a predetermined basked of goods (and/or services). Changes in this indicator are used to correct monetarised data for inflation.
Purchase Power Standard (PPS)	Indicator reflecting the purchasing power of countries. This indicator is used to correct monetarised figures for differences in purchasing power of an euro across countries.
Ramsey pricing	Internalisation approach where charges/taxes are set at the level that maximises revenues.
Renewal costs	All costs associated with the renewal of (parts of) the infrastructure. The renewed (parts of) the infrastructure will at least have a lifetime of more than 1-2 years. Renewal costs do include extraordinary maintenance with a lifespan of more than 1-2 years.
Ship-kilometre	Unit of measurement representing the movement of a ship over one kilometre.
Subsidy	Fiscal support with direct relevance to public budgets and with no direct service in return.
Tax	Compulsory unrequited payment, where unrequited means that the payer does not receive anything directly in return.
Tonne-kilometre (tkm)	Unit of measurement of goods transport which represents the transport of one tonne over one kilometre.
Total costs	Total costs within a certain geographic boundary (e.g. EU28 or a country) associated to the relevant transport infrastructure (e.g. road network).
Train kilometre	Unit of measurement representing the movement of a train over one kilometre.
Transport infrastructure	The physical and organisational network which allows movements between different locations.
Value of a Statistical Life (VSL)	Measure for how much people are willing to pay to reduce their risk on death.
Value Of Life Year lost (VOLY)	The amount of money that people are willing to pay for one year of additional life expectancy.
Variable costs	Costs that vary with transport volumes.
Vehicle kilometres (vkm)	Unit of measurement representing the movement of a vehicle over one kilometre.

1 Introduction

1.1 Background of the Study

Transport is a precondition for the functioning of modern society and for the wellbeing of people and the economy. However, transport comes with various external effects, such as air pollution and accidents. In addition, constructing and managing transport infrastructure gives rise to significant costs. The external and infrastructure costs of transport tend not to be borne by transport users (without policy intervention), and hence users tend not to consider them when making transport decisions. By internalising the external and infrastructure costs (by using transport taxes and charges), 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, average cost pricing may be considered to be fair, as it is more in line with the ‘user pays’ and ‘polluter pays’ principles. Other alternative internalisation approaches are Baumol pricing[19] and Ramsey pricing[20].

The aim of the project, ‘Sustainable Transport Infrastructure charging and internalisation of Transport Externalities’, commissioned by the European Commission DG MOVE to a consortium led by CE Delft, is to better understand the extent to which existing policies internalise the costs of transport (both from the perspectives of average and marginal cost pricing) and to discuss ways that further internalisation could be achieved. The focus of the project is on the EU28 Member States, but also assessments for Norway and Switzerland and some non-European countries are carried out as well.

In order to assess the current state of play of internalisation, detailed assessments of transport infrastructure costs and external costs have been carried out. Furthermore, a thorough analysis of the transport taxes and charges applied in the countries considered has been performed. Based on these data, the state of play of internalisation in the EU28 Member States (and the other relevant countries) has been assessed, both from the average cost pricing and marginal cost pricing perspective. Finally, options for further internalisation have been formulated.

The methodologies used for these different types of assessments and their results are presented in four separate deliverables (see the following text box). This report provides a summary of the main findings from these four deliverables.

[19] Taxes/charges are set at a level at which a certain objective (e.g. congestion level) is met.

[20] Taxes/charges are set at a level which maximises total revenues.

Textbox 1 - Sustainable Transport Infrastructure Charging and Internalisation of Transport Externalities project deliverables

- Overview of transport infrastructure expenditures and costs.
  - This deliverable provides an overview of the infrastructure costs of all transport modes and countries.
- Handbook on external costs – version 2019.
  - This deliverable 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 deliverable presents the total, average and marginal external costs for all transport modes and countries.
- Transport taxes and charges in Europe - An overview study of economic internalisation measures applied in Europe.
  - This deliverable provides an overview of the structure and level of transport taxes and charges applied for the various transport modes. Furthermore, this study presents the total revenues from transport taxes and charges for the various transport modes and countries.
- The state of play of internalisation in the European transport sector.
  - This deliverable 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.

1.2 Objective

This report summarises the key findings from the deliverables produced as part of the project. These findings include:
- an overview of the infrastructure costs, external costs and taxes/charges of all transport modes in the EU28;
- an assessment of the state of play of internalisation in the EU28;
- options for further internalisation of the external and infrastructure costs of transport.

1.3 Scope

1.3.1 Transport modes

This report considers road transport, rail transport, inland waterway transport (IWT), maritime transport and aviation. The vehicle types per mode that are considered are presented in Table 11.

Table 11 - Transport modes and vehicle types covered

Road transport	Rail transport	IWT	Maritime transport	Aviation
– Passenger car – Motorcycle – Bus – Coach – Van – Heavy Goods Vehicle (HGV)	– High speed passenger train (HSL) – Passenger train electric[a] – Passenger train diesel – Freight train electric – Freight train diesel	– Inland vessel	– Freight vessel	– Passenger aircraft

[a] Passenger train electric consists of both high speed and conventional electric trains.

1.3.2 Geographical coverage

For road, rail and inland navigation transport, this report presents results for the EU28. For aviation and maritime transport, this report presents aggregate results for 33 selected EU28 airports[21] and 34 selected EU28 ports[22]. Country-specific (or (air)port-specific) results and results for the non-EU28 countries can be found in the other deliverables of the project.

1.3.3 Total, average and marginal costs/revenues

In the study, different types of costs and tax/charge revenues are considered:

- *Total costs/revenues* refer to all costs/revenues within a geographical boundary (e.g. EU28) related to (a specific mode of) transport. Total costs/revenues are usually presented in billions or millions Euros.
- *Average costs/revenues* are closely related to total costs/revenues, as they express the costs/revenues per transport performance unit (e.g. €-cent/pkm, €-cent/tkm or €-cent per vkm).
- *Marginal costs/revenues* are the additional costs/revenues occurring due to an additional transport activity. In this study we consider short run marginal costs/revenues, i.e. costs/revenues linked to constant infrastructure capacity. Generally, marginal costs/revenues are presented in the same units as average costs/revenues.

1.3.4 Transport subsidies

In this study, we do not consider transport subsidies and public service obligations (PSO), with the exception of tax/charge breaks or exemptions. The latter are implicitly addressed when assessing taxes and charges. In addition, subsidies for infrastructure (e.g. CEF funding), are fully accounted for in calculating the transport infrastructure costs. Other subsidies (e.g. subsidies to purchase low-emission vehicles) are not considered, as data availability on these types of subsidies is rather poor. Only a few, incomplete and mostly older studies are available on this subject at the European level (e.g. CE Delft et al., 2017; Ecologic, CE Delft and TU Dresden, 2006; Ecologic, 2005). Collecting data on all transport subsidies applied in Europe is therefore 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).

1.3.5 Transport performance data

Several types of transport performance data (e.g. vehicle-kilometres, tonne-kilometres, passenger-kilometres) have been used in the wide range of assessments carried out in this project. For the purpose of this project, a consistent set of transport performance data have been composed, mainly based on EU aggregated sources (like Eurostat and COPERT).

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[21] This selection includes: Wien-Schwechat, Brussels, Sofia, Zagreb Pleso, Larnaka, Prague Ruzyne, Copenhagen-Kastrup, Tallinn, Helsinki-Vantaa, Paris Charles de Gaulle, Paris Orly, Frankfurt, Munich, Athens Eleftheriios Venizelos, Budapest Liszt Ferenc, Dublin, Roma Flumicino, Riga, Vilnius, Luxembourg, Luga, Amsterdam Schiphol, Warsaw Chopina, Lisboa, Bucharest Henri Coandă, Bratislava M.R. Stefanik, Ljubljana Brink, Barcelona El Prat, Adolfo Suarez Madrid – Barajas, Palma de Mallorca, Stockholm Arlanda, London Heatrow, and London Gatwick.

[22] This selection includes, i.e. Antwerp, Varna, Rijeka, Split, Limassol, Arhus, Helsingør, Tallinn, Helsinki, Calais, Le Havre, Marseille, Hamburg, Bremerhaven, Travermünde, Piraeus, Dublin, Genova, Trieste, Venice, Riga, Klapeida, Marsaxlokk, Rotterdam, Gdansk, Sines, Constanta, Koper, Algericas, Barcelona, Bilbao, Valencia, Goteburg, and Felixstowe.

Road transport performance data has been 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. The territoriality principle would have been more consistent with the scope of the infrastructure and external costs as well as some of the taxes/charges (e.g. fuel taxes, road charges). However, as a detailed EU-wide data set on road transport performance, based on the territoriality principle, is not available, the official Eurostat dataset, based on the nationality principle, has been used for this study[23]. This choice affects the results of the study and should be taken into account when considering the results of this study. Results at country level are much more affected than EU28 results.

1.3.6 Base year

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

1.3.7 Price level

All financial figures are expressed in Euro price levels of 2016. Data from sources where price levels from other years were used have been 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 report is structured as follows:
- Chapter 2 presents the main findings of the assessment of infrastructure costs, including a discussion on the methodology applied and the main results for the EU28.
- Chapter 3 provides a brief description of state-of-the-art methodologies to estimate the external cost of transport and an overview of the external costs for the EU28.
- Chapter 4 presents an overview of the transport taxes and charges applied in the EU28 as well as a discussion on the tax/charge revenues raised for the various transport modes.
- Chapter 5 provides an overview of the state of play of internalisation in the European transport sector as well a discussion on the broader context of internalisation.
- Chapter 6 presents the main conclusions of the study and an overview of some relevant policy applications. Furthermore, the main recommendations for further research are presented in this chapter.

[23] To estimate the infrastructure costs of road vehicles, data on vehicle weight and axle load is required as well. Territorialised activity is presented by Eurostat only at aggregate level, i.e. no data on weight and axle load is available. See CE Delft (2019a) for more details.

2 Infrastructure costs

2.1 Introduction

A good understanding of the total, average and marginal infrastructure costs of transport is essential to assess the current state of internalisation of transport in Europe. Therefore, a detailed assessment based on country and mode specific data on transport infrastructure expenditures has been carried out in order to provide state-of-the-art estimates of infrastructure costs for all transport modes. In this chapter, we briefly discuss the methodology applied (Section 2.2), the main results for the EU28 (Section 2.3) and the robustness of the results found (Section 2.4). For more detailed results and a broader discussion on the methodology applied, we refer to CE Delft et al. (2019a).

2.2 Methodology applied

2.2.1 Defining infrastructure costs

Infrastructure costs can be defined as the direct expenses on transport infrastructure[24] 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). These costs consist of various types of costs:

- *Enhancement costs*: costs of new infrastructure or expansion of existing infrastructure (e.g. construction of a new rail line or adding an additional lane to a motorway).
- *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).

Infrastructure costs can be further classified as fixed or variable costs. The enhancement and operational costs are fully fixed, while also part of the maintenance and renewal costs are considered fixed as well (e.g. maintenance of traffic signs, traffic lights and road sides). The remaining part of the maintenance and renewal costs are assumed to be variable, i.e. they vary with transport volumes and hence are directly linked to the usage of the infrastructure.

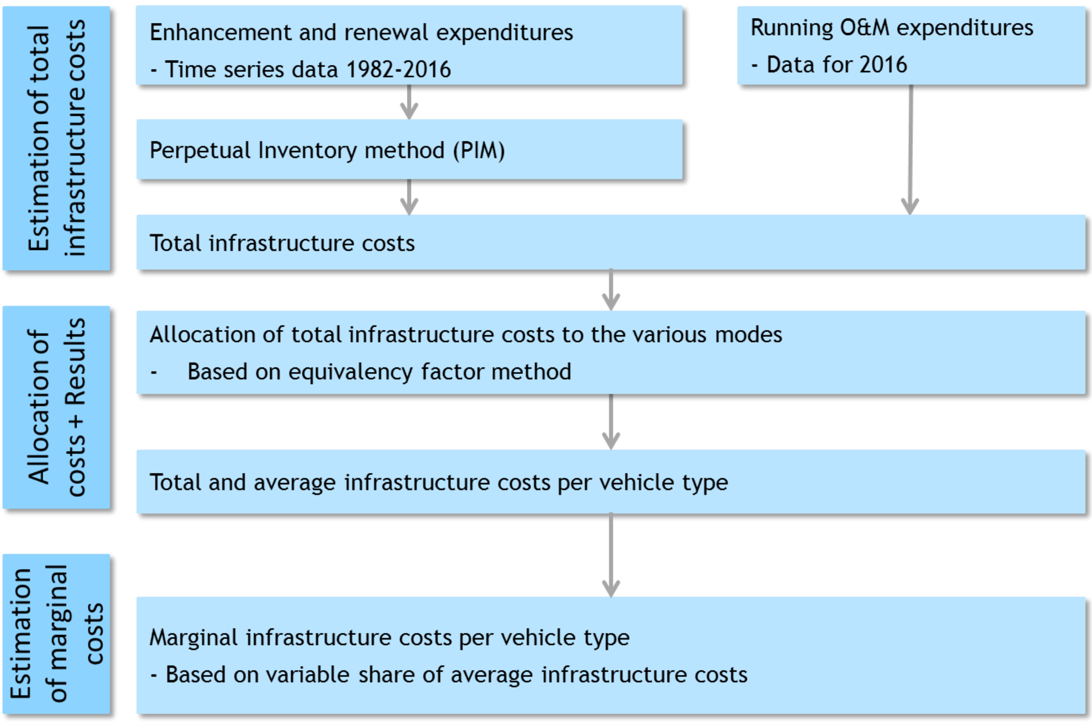
[24] Transport infrastructure is defined as the physical and organisational network which allows movements between different locations (HLG, 1999). By applying this definition, organisational aspects (e.g. transport policy, traffic management) are considered as part of the infrastructure as well.

2.2.2 Methodology

A top-down approach has been applied to estimate infrastructure costs for the various transport modes (see Figure 1), consisting of three steps:

1. *Estimation of total infrastructure costs per transport mode*. Total infrastructure costs were estimated based on the widely applied Perpetual Inventory Method (PIM)[25]. As for the enhancement and renewal costs, the approach calculates the annual depreciation costs by distributing the initial investments (for a period of 35 years) over the lifetime of the infrastructure. Additionally, interest/financing costs are estimated by using an appropriate interest rate. The sum of depreciation and financing costs equals the total enhancement and renewal costs. Regarding the maintenance and operational costs, the PIM assumes that they are equal to the running costs (expenditures in 2016) and hence no capitalisation (as done for the enhancement and renewal costs) is required for these cost elements.
2. *Allocation of the total infrastructure costs to the various vehicle categories*. The total infrastructure costs per transport mode (road, rail, IWT, maritime and aviation) are further allocated to the various vehicle categories by using the equivalency factor method. This method allocates the various cost categories based on relevant cost drivers (e.g. number of vehicle kilometres, number of axle-load weighted kilometres).
3. *Estimation of marginal infrastructure costs*. This is achieved by assuming that the marginal costs are equal to the variable share of the average infrastructure costs.

Figure 1 – Approach to estimate infrastructure costs



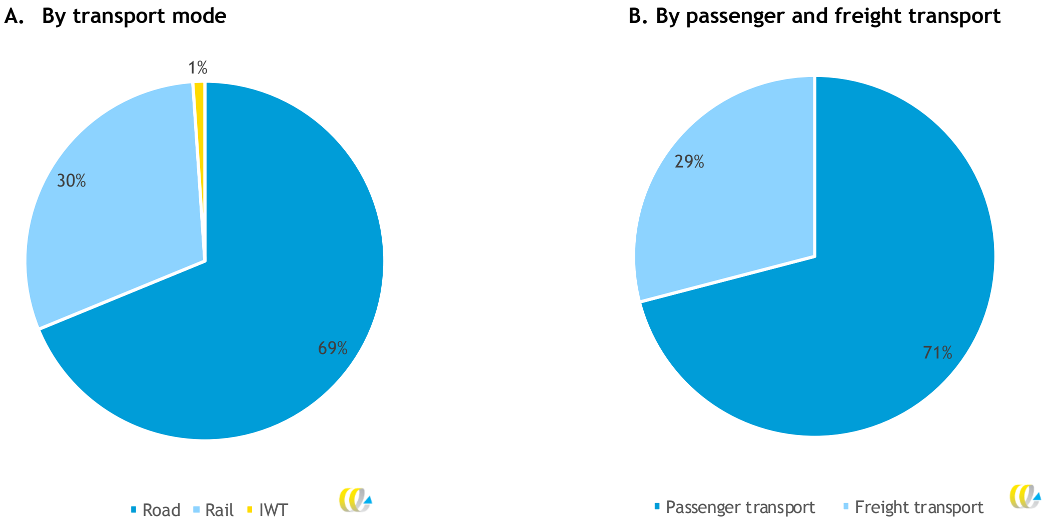
25 For maritime transport and aviation data availability was insufficient to apply the PIM for enhancement and renewal costs. For aviation, the depreciation costs were not calculated but taken directly from the annual reports of the respective airports. For maritime transport, depreciation costs were assumed to be equal to the investments in 2016.

2.3 Infrastructure costs of transport in the EU28

2.3.1 Total infrastructure costs

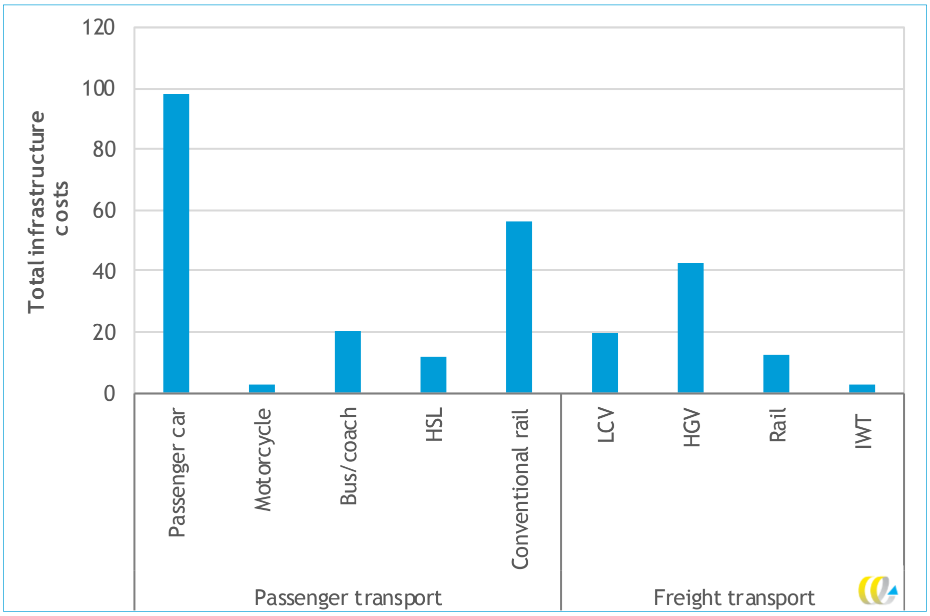
The total infrastructure costs for road, rail and inland waterway transport in the EU28 amount to € 267 billion for 2016. As shown in Figure 2, the majority of these costs (69%) is caused by road transport (€ 184 billion). Rail transport is responsible for 30% of these costs (€ 81 billion), while IWT contributes 1% to the total costs (€ 3 billion). Figure 2 presents the total infrastructure costs by passenger and freight transport: 71% of the total infrastructure costs of road, rail and inland waterway transport are allocated to passenger transport, while 29% to freight transport.

Figure 2 – Composition of total infrastructure costs in 2016 for road, rail and inland waterway transport in the EU28



The total infrastructure costs for the various road, rail and IWT vehicle categories are presented in Figure 3. The highest total costs can be attributed to passenger cars, which can be explained by the large share this vehicle category has in the total number of vehicle kilometres (vkm). Also conventional rail and HGVs significantly contribute to the total infrastructure costs in the EU28.

Figure 3 – Total infrastructure costs in 2016 for road, rail and inland waterway transport in the EU28 (billion €, PPS adjusted)



Finally, the infrastructure costs for maritime transport and aviation have been estimated for a set of selected ports and airports (see Section 1.3 for more details). For the selected 34 EU ports the infrastructure costs are estimated at € 1.4 billion, while the costs for the 33 EU airports amount € 14 billion. It was not possible to determine what the share of these costs in the total infrastructure costs of maritime transport and aviation in the EU28 is.

2.3.2 Average infrastructure costs

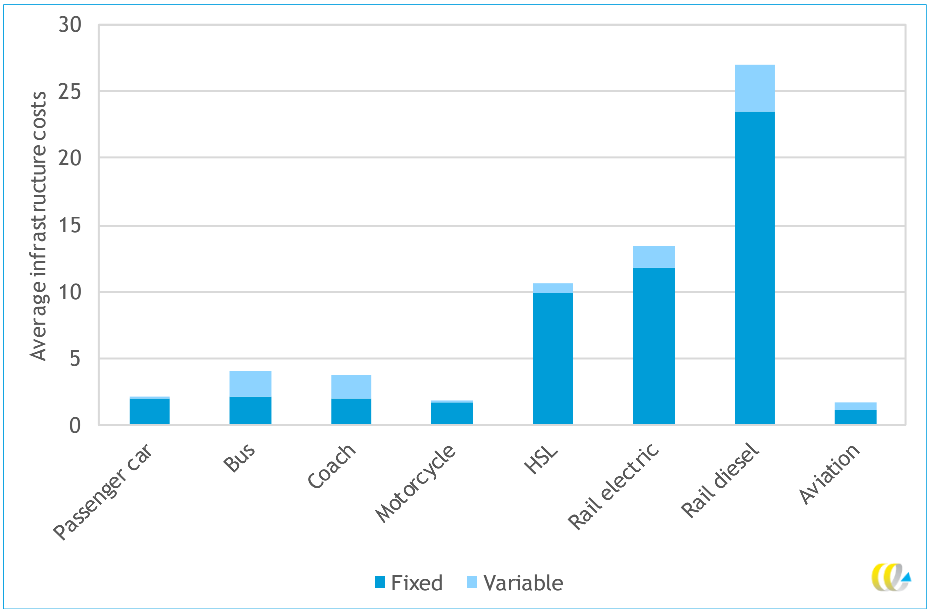
The average infrastructure costs of passenger transport in the EU28 are presented in Figure 4. These costs are significantly higher for rail transport than for road transport. This is partly explained by the higher fixed costs (e.g. construction costs) of rail infrastructure: the infrastructure costs per kilometre of road in the EU are about € 30,000, while the cost per track-kilometre rail amount to slightly more than € 200,000. Another explanation is the — on average — lower utilisation rate of rail infrastructure compared to road infrastructure, such that the fixed costs are allocated to fewer passenger kilometres (pkm). The average infrastructure costs for aviation are approximately equal to those for passenger cars and hence significantly lower than for rail transport. It should, however, be noted that we consider the average infrastructure costs for an average airplane[26], which competes on a completely different market than an average passenger car or passenger train. Therefore, the results for the various modes cannot be directly compared.

The highest average infrastructure costs are found for a diesel passenger train, which is partly due to the low occupancy rate of these trains (compared to electric trains). Furthermore, the utilisation rate of rail infrastructure by diesel trains is lower than by electric trains, leading to higher average cost figures. The average infrastructure costs for high speed trains are lower than for other passenger trains, particularly due to higher utilisation rates of the HSL network and higher occupancy rates.

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

For road transport, the highest average infrastructure costs are found for buses and coaches, which can be explained by the relatively large share of variable (weight dependent) infrastructure costs caused by these vehicles.

Figure 4 – Average infrastructure costs in 2016 for passenger modes in the EU28[a] (€-cent/pkm, PPS adjusted)

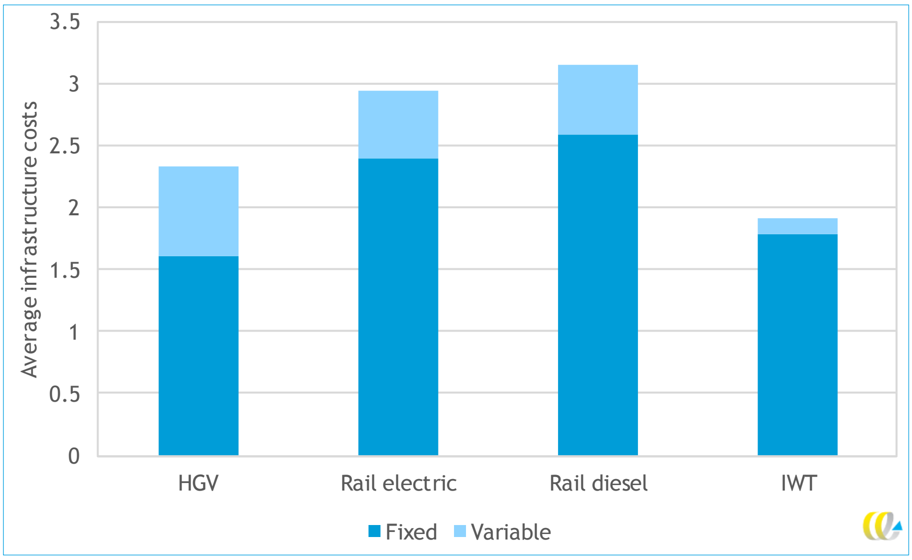


[a] For aviation, the average infrastructure costs are estimated based on data for the 33 selected EU airports.

The average infrastructure costs for freight transport in the EU28 are shown in Figure 5. Regarding freight transport, the main elements of the infrastructure costs is fixed (particularly for IWT). The highest average cost figures are found for rail transport[27], followed by HGVs and IWT. For maritime transport, no average infrastructure costs (in €-cent/tkm) were estimated due to lack of relevant transport performance data.

27 The average cost figures for diesel trains are slightly higher than for electric freight trains. This can be explained by — on average — slightly lower load factors for diesel trains compared to electric trains.

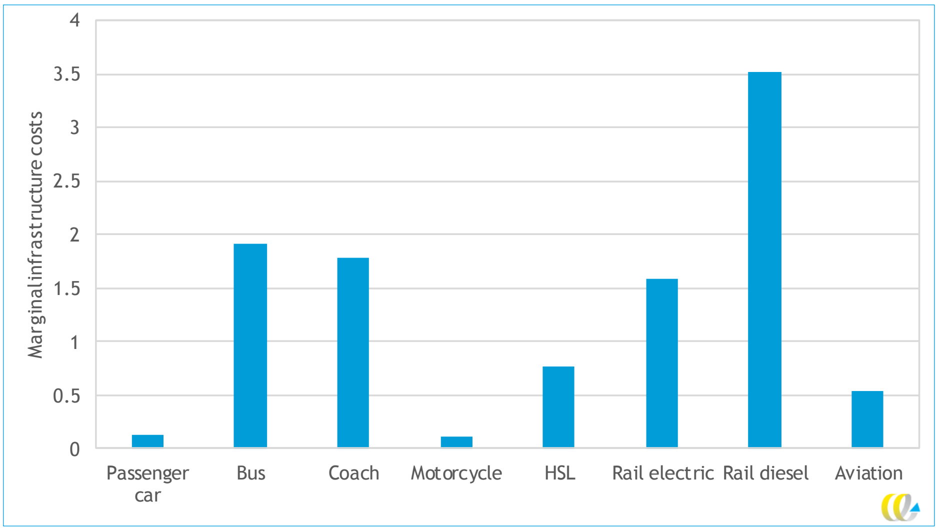
Figure 5 - Average infrastructure costs in 2016 for freight modes in the EU28 (€-cent/pkm, PPS adjusted)



2.3.3 Marginal infrastructure costs

The marginal infrastructure costs for passenger transport modes in the EU28 are presented in Figure 6. The highest cost figures are found for diesel passenger trains. The fact that these figures are significantly higher than those for electric passenger trains is again explained by lower occupancy rates and utilisation rates of rail infrastructure. Compared to the average cost figures, the differences in marginal cost figures of road and rail transport are less significant. This can be explained by the fact that the relatively high fixed costs of rail infrastructure costs (an important explanation of the high average infrastructure costs for rail) are not part of the marginal costs. Finally, with respect to aviation it should again be mentioned that an average airplane competes on another market than road and rail transport and hence the marginal cost figures are not directly comparable.

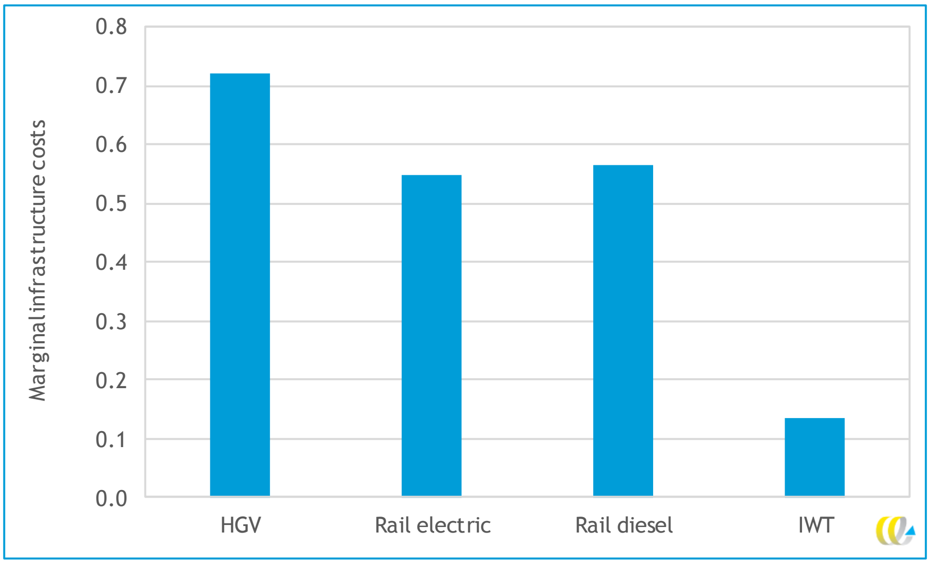
Figure 6 – Marginal infrastructure costs in 2016 for passenger transport modes in the EU28[a] (€-cent/pkm, PPS adjusted)



[a] For aviation, the average infrastructure costs are estimated based on data for the 33 selected EU airports.

The marginal infrastructure cost figures for freight transport (excl. maritime transport) are shown in Figure 7. The highest costs are found for HGVs, reflecting the significant wear and tear costs caused by this vehicle category. Marginal infrastructure costs for IWT are relatively low, as only a limited share of the infrastructure costs directly depend on the use of inland waterways.

Figure 7 - Marginal infrastructure costs in 2016 for freight transport modes in the EU28 (€-cent/tkm, PPS adjusted)



2.4 Robustness of infrastructure cost estimates

The infrastructure cost figures presented in the previous section are calculated based on state-of-the-art methodologies and the best available data. However, there are some uncertainties with respect to the methodology and data that should be kept in mind when interpreting the results of the assessment.

In general, direct comparisons between transport modes should be made carefully, since data availability and quality vary significantly between modes. Particularly the infrastructure cost calculations for maritime transport and aviation are hampered by a lack of (robust) data, resulting in higher levels of uncertainty. Furthermore, total cost figures are considered more reliable than figures per vehicle category, as the allocation of total figures to vehicle categories results in some additional uncertainty. Finally, total cost figures are more robust than average and marginal cost figures, as the latter have to deal with relatively large uncertainties in traffic performance data (particularly for road transport, see Section 1.3).

3 External costs of transport

3.1 Introduction

As part of the project an updated and extended version of the Handbook on External Costs of Transport has been produced (CE Delft; INFRAS; TRT, 2019c). This Handbook provides state of the art methodologies, input values and output values for total, average and marginal external costs of transport, both at the EU28 level and at the level of individual countries. This is done for all transport modes and all (main) external cost categories.

Textbox 2 - Previous versions of the Handbook on External Costs of Transport

The current Handbook on External Costs of Transport is the successor of two previous versions:

- In 2008 the European Commission commissioned the first Handbook on External Costs of Transport, as part of the IMPACT study (INFRAS; CE Delft; ISI; University of Gdansk, 2008). This Handbook presented best practices on the methodology and input values (e.g. value of time or the value of a statistical life) that can be used to produce estimations of external costs by users of the Handbook themselves. In addition, the Handbook presented external cost figures which could be used directly by the users. The 2008 Handbook focus was on marginal external costs, covering all main external cost categories.
- In 2014, the Handbook was updated with new developments in research and policy (Ricardo-AEA; TRT; DIW-Econ; CAU, 2014). In line with the 2008 version, the focus of the 2014 Handbook was on marginal external costs of transport.

In the remainder of this chapter, we briefly discuss the methodologies recommended/ applied to estimate the external costs of transport (Section 3.2). The main results for external costs at the EU28 level are presented in Section 3.3. Finally, the robustness of the results is discussed in Section 3.4.

3.2 Recommended methodology to estimate external costs

3.2.1 The concept of external costs

External costs, also known as externalities, 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 of transport 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.

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). As the market does not provide an incentive to transport users to take external costs into account, they only take part of the social costs into account when taking a transport decision, resulting in sub-optimal outcomes. By internalising these costs, externalities are made part of the decision making process of transport users.

Using market-based instruments to internalise external costs is generally regarded as an efficient way to limit the negative side effects of transport and/or to generate income for the government. Applying these instruments in an efficient way requires detailed and reliable estimates of external costs. External cost figures are also useful parameters for other applications (e.g. use in Cost Benefit Analyses)

3.2.2 External costs of transport

This study covers all main externalities of transport, as is illustrated in Table 12. Although congestion (or scarcity costs) can be relevant for the non-road modes as well, these are not addressed in detail in the study due to a lack of data.

Table 12 - Externalities covered in this study

Externality	Road	Rail	IWT	Maritime	Aviation
Accidents	✓	✓	✓	✓	✓
Air pollution	✓	✓	✓	✓	✓
Climate change	✓	✓	✓	✓	✓
Noise	✓	✓			✓
Congestion	✓				
Well-to-tank emissions[a]	✓	✓	✓	✓	✓
Habitat damage	✓	✓	✓		✓

[a] Emissions of energy production.

In addition to the external costs mentioned in Table 12, other externalities caused by transport can be identified, including soil and water pollution, up- and downstream emissions (e.g. emissions from the production, maintenance and disposal of vehicles), separation impacts in urban areas, etc. These externalities are briefly discussed in the Handbook, but are not considered in this report.

3.2.3 Methodology to estimate total/average external costs

The methodology to estimate the total and average external costs differs between the various cost categories. Based on a thorough review of the latest evidence on estimating external costs of transport in research and policy, we have updated the Handbook on External Cost of Transport within this project. The Handbook provides a recommended methodology to quantify and monetarise these effects for each externality.
Table 13 provides an overview of these methodologies and also presents some of the most important input values.

Table 13 - Recommended/used methodologies to estimate total/average external costs

Cost category	Used/recommended methodology	Important input values (EU28 values)
Accidents	Damage cost approach Top-down approach, based on the following input values: – accidents: number of casualties (fatalities, injuries) per vehicle category – costs per casualty (human costs, production loss, medical costs, administrative costs, material costs)	Total external cost per casualty: – fatalities: € 3,274,000 – serious injuries: € 498,600 – slight injuries: € 38,500 Value of statistical life: € 3.6 million

Cost category	Used/recommended methodology	Important input values (EU28 values)
	– allocation to different transport modes (according to responsibility) and to vehicle types (according to damage potential/intrinsic risk)	
Air pollution	Damage cost approach, covering the following impacts: health effects, crop losses, material and building damage, biodiversity loss. Bottom-up approach, based on the following input values: – emission factors (per vkm) – transport performance – cost factors (health costs and non-health costs)	Some important cost factors for average air pollution damage costs: – NO_x transport city: 21.3 €/kg – NO_x transport rural: 12.6 €/kg – $PM_{2.5}$ trsp. Metrop.: 381 €/kg – $PM_{2.5}$ transport city: 123 €/kg – $PM_{2.5}$ transport rural: 70 €/kg – PM_{10} average: 22.3 €/kg – SO_2: 10.9 €/kg – NH_3: 17.5 €/kg – NMVOC: 1.2 €/kg Value Of Life Year lost (VOLY): € 70,000
Climate change	Avoidance cost approach: global avoidance costs, based on the targets from the Paris Agreement Paris Agreement, i.e. preventing temperature rises above 1.5-2 degrees Celsius (i.e. CO_2-concentration in the atmosphere below 450 ppm). Bottom-up approach, based on the following input values: – greenhouse gas emission factors per vehicle type – transport performance data – climate change costs per tonne of CO_2 equivalent – factor 2 increase for aviation due to non-CO_2 impacts; however it should be noted that there is currently still high uncertainty regarding the non-CO_2 impacts and thus the factor to be used.	Cost factor for CO_2 emissions (based on literature review): – Central value for the short-and-medium-run costs (up to 2030): • € 100/tCO_2-eq. [a] • main value used in handbook – Central value for the long run costs (up to 2060): • € 269/tCO_2-eq. [b]
Noise	Damage cost approach, covering health effects and annoyance due to noise exposure. Bottom-up approach, based on the following input values: – number of people exposed to noise for each transport mode – noise costs per person exposed (health costs and annoyance costs)	Noise costs per person exposed, differentiated by noise class: decibel-class Lden (dB(A)). Costs for road transport: – 50-54 dB: 17 €/dB/person/year – 55-59 dB: 31 €/dB/person/year – 60-64 dB: 34 €/dB/person/year – 65-69 dB: 63 €/dB/person/year – 70-74 dB: 67 €/dB/person/year – ≥ 75 dB: 72 €/dB/person/year
Congestion	Two approaches have been developed to estimate congestion costs at urban and inter-urban level: – delay costs – deadweight loss For both methodologies common input values are: – speed-flow functions – transport demand curves (based on literature cost elasticity) – value of time for car and coach passengers by purpose (i.e., commuting, business and leisure) and for road freight transport.	– Elasticity values: e.g. for cars: • urban demand, commuting-business -0.49 • urban demand, personal -0.58 • inter-urban demand, commuting-business -0.56 • inter-urban demand, personal -0.67 – value of time: e.g. the average for cars:

Cost category	Used/recommended methodology	Important input values (EU28 values)
	– average vehicle occupancy/load factors for cars, buses, coaches, LCVs and HGVs Additional inputs to estimate urban congestion: – data on the level of congestion and road network length by road type (i.e., trunk urban road, other urban road), average delay per day and total accumulated delay per year (related to peak period journeys) – car mode share in a set of European cities – population of European cities – typology of NUTS3 according to the degree of urbanisation urban/mixed/rural Additional inputs to estimate inter-urban congestion: – localisation of the congested spots on the European inter-urban road network – road network characteristics to determine speed-flow functions of the roads where the spots are located in order to estimate the amount of vehicles experiencing congestion in in peak time Daily traffic profiles	• short distance, commuting-business 13.3 • € per passenger per hour • long distance, commuting-business 16.3 € per passenger per hour • personal 6.1 € per passenger per hour – vehicle occupancy/load factors – level of congestion available from TomTom for a set of European cities – localisation of congested spots on the European inter-urban road network,provided by the EC, Joint Research Centre
Well-to-tank emissions	Damage cost approach for the air pollutioncosts and avoidance costs for the climate change costs caused by the well-to-tank emissions of energy production Bottom-up approach, based on the following input values: – e production and transport/transmission of fossil fuels and electricity (differentiated by country) – transport performance – cost factors: air pollution and climate change costs	See cost factors for air pollution and climate change costs.
Habitat damage	Restauration cost approach for the following costs: habitat loss (ecosystem loss) and habitat fragmentation. Bottom-up approach, based on the following input values: – infrastructure network length (or area) – average cost factors for habitat loss and habitat fragmentation	Total habitat damage costs per year: – road motorways: 93,500 €/km/y – road other roads: 4,100 €/km/y – rail high speed: 84,500 €/km/y – rail other rail: 14,100 €/km/y – aviation: 437,500 €/km^2/y – inland waterways: 6,600 €/km/y

[a] Short-and-medium-run costs: cost range from € 60/tCO_2-eq. (low estimate) to € 189/tCO_2-eq. (high estimate).
[b] Long run costs: cost range from € 156/tCO_2-eq. (low estimate) to € 489/tCO_2-eq. (high estimate).

3.2.4 Methodology to estimate marginal external costs

For some cost categories, the marginal external costs are equal to the average external costs. This is true for the air pollution costs, the climate change costs, and the well-to-tank emission costs. For habitat damage, it is assumed that the marginal costs are zero, since they primarily occur due to the construction of infrastructure. For the other externalities (i.e. noise costs, accidents costs, and congestion costs) the marginal costs differ from the average costs. The methodologies used to estimate these marginal costs are described hereafter.

Marginal accident cost

The marginal accident costs represent the extra costs that adding an extra vehicle to the traffic flow brings. The main input values for marginal accident costs are the accident risk per vehicle type and road type, the costs per casualty and the risk elasticity. The costs per casualty are the same as those used for the calculation of total and average costs. Combining the accident risk with assumptions on the degree of risk internalisation, the external costs per casualty and the risk elasticity allows us the calculate the marginal external accident costs per vehicle category.

Marginal accident costs are only calculated for road transport. For all other modes of transport, the marginal accident costs are considered to be equal to the average costs. This is because the other modes are scheduled services, which implies that the accident risk is less dependent on the amount of traffic for these modes.

Marginal noise costs

Marginal noise costs differ from average noise costs mainly because local factors influence the noise level and the damage and annoyance level. There are three main cost drivers for marginal noise costs: population density, existing noise levels (depending on traffic volume, traffic mix and speed), and time of the day.

For road and rail transport the marginal noise costs are estimated based on earlier calculations of marginal costs (INFRAS & IWW, 2004; CE Delft, INFRAS & Fraunhofer ISI, 2011). For deriving up-to-date marginal noise costs, the development of the average noise costs per transport mode and vehicle type over time, i.e. between the older studies and the average noise costs calculated in the present Handbook, has been taken into account.

Marginal congestion costs

The social marginal road congestion cost has been estimated starting from the outputs of the deadweight loss approach, because the estimation of the social marginal cost curve is required for this purpose. It is worth noting that the social marginal cost curve is an additional input needed with respect to the delay cost approach, which estimates the road congestion costs only relying on information of the private cost curve. Furthermore, because road congestion is highly dependent on the context, the estimation has been developed using representative types of circumstances, which have been reflected in (i) different road types (i.e., urban roads, urban trunk roads, inter-urban roads and motorways) and (ii) different levels of traffic intensity (i.e., near capacity, congested and over capacity).

Two different approaches have been considered: on the one hand, the estimation has been made assuming the perspective of a vehicle *incurring* in a situation of road congestion, which allowed to take into account differences in values of time (and elasticity of demand). On the other hand, marginal social costs *generated* by vehicle type has been carried out (where the costs generated by road vehicles other than passenger cars are derived from the valued estimated for passenger cars by using the Passenger Car Equivalent coefficient (PCEs) of each vehicle type). The latter approach allows the comparison with the marginal external costs computed for the other categories.

3.3 External costs of transport in the EU28

3.3.1 Total external costs

Figure 8 presents the total external costs of transport for EU28 by transport mode and cost category for 2016. The total external costs for road, rail, inland waterway transport, aviation and maritime (excluding congestion costs, because they are not calculated for all modes) amount to € 716 billion, which corresponds to 4.8% of the total GDP in EU28. The congestion costs amount to another € 271 billion for 2016 (delay costs generated by road transport modes[28]). The total external costs including congestion costs sum up to € 987 billon (6.6% of the GDP). More detailed figures on the total external cost per vehicle category can be found in Annex A.2.

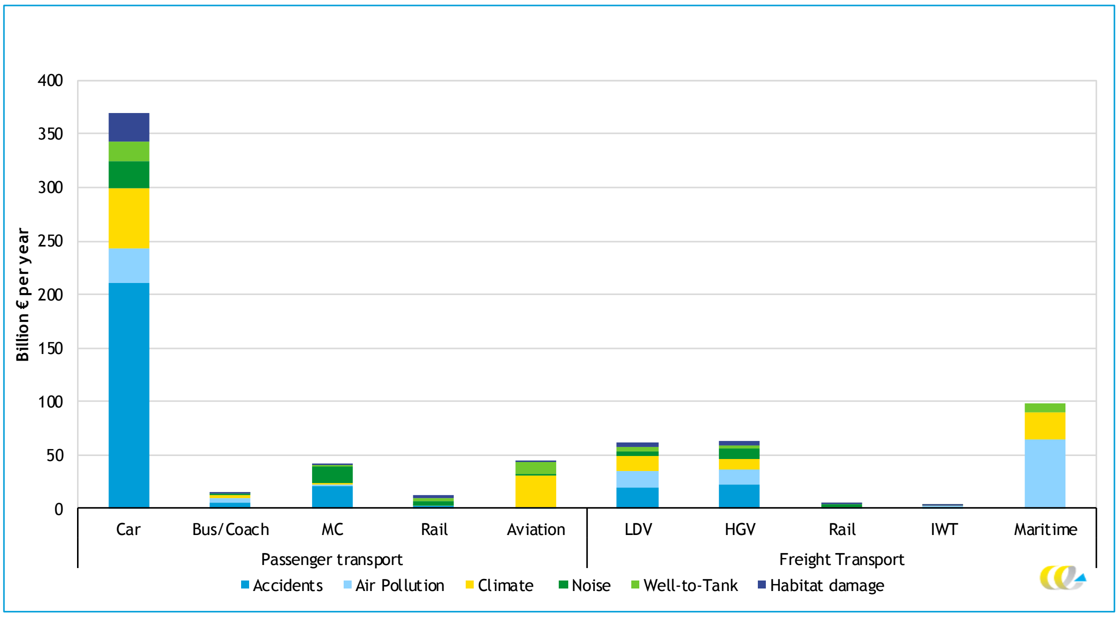
For aviation[29] and maritime transport, the detailed calculation of the external costs has only been undertaken for a set of selected airports and ports (see Section 1.3.2). For the 33 selected EU airports the external costs amount to € 33 billion, whereas the costs for the 34 selected EU ports amount to € 44 billion. The total external costs for EU28 for aviation and maritime have been roughly estimated[30] at about € 48 billion and € 98 billion per year. This is approximately 0.3 and 0.7% of the GDP, respectively. The total external costs of road transport for EU28 in 2016 amount to € 820 billion including congestion (€ 550 billion excluding congestion), the external costs of rail transport are € 18 billion and for inland waterways they amount to € 3 billion (those values are included in the total of € 987 billon mentioned above).

[28] Please note that out the € 271 billion — that are the total ‘delay costs’ — only a part is not internalised. The other costs are already internalised, i.e. borne by the transport users themselves.

[29] Climate change cost of non-CO_2 emissions are also considered.

[30] Based on extrapolation of the values for the selected (air)ports. It should be noted that these estimates are relatively rough, as they assume that the transport to/from the selected (air)ports (in terms of aircraft, ships and distances) are representative for the entire EU28. Furthermore, not for all external costs categories an estimation of the total EU28 costs for aviation and maritime transport can be calculated. For those (small) cost categories without specific EU28 estimation, the results for the selected airports and ports have been used.

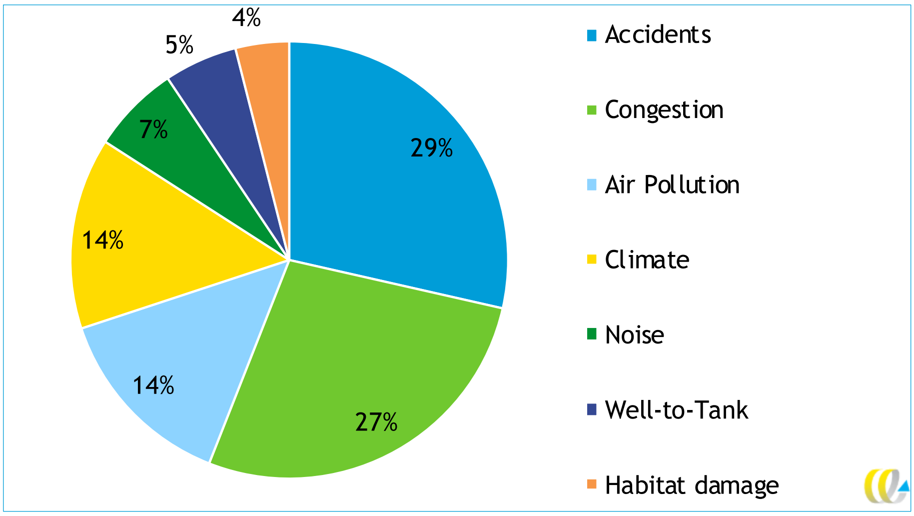
Figure 8 – Total external costs 2016 for EU28 (excluding congestion)



Note: Data for aviation and maritime transport is based on rough estimations for EU28.

In general, the most important cost category is accident costs equating to 29% of the total costs, followed by the congestion costs (27%) (see Figure 9). Overall, environmental costs (climate change, air pollution, noise, well-to-tank and habitat damage) make up for the remaining 44% of the total costs. Climate change and air pollution costs each contribute to 14% of the total costs, noise costs are 7% and habitat damage are 4% of the total costs. Well-to-tank emission costs due to energy production and distribution lead to 5% of the costs. However, large differences do exist between the various transport modes. For road transport, accident and congestion costs are indeed the main externalities, but for IWT and maritime transport, air pollution costs contribute most to the total external costs (about 65%). For aviation the majority of the external costs consists of climate change costs (about 70%). Finally, for rail transport noise costs contribute most to the total external costs (about 35%). For more details on the size of the various total external cost categories per vehicle category, see Annex A.2.

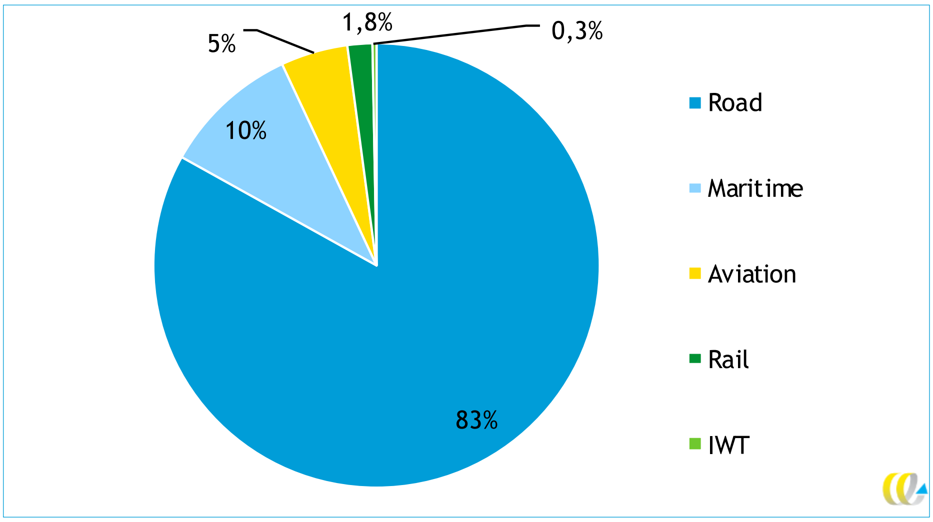
Figure 9 - Share of the different cost categories on total external costs 2016 for EU28



Note: Including data for aviation and maritime transport, which is based on rough estimations for EU28.

As is shown in Figure 10, road transport is the mode that causes by far the most external costs (83% of the total costs incl. aviation and maritime; 97.5% excl. aviation and maritime). This is partly explained by the fact that the main share of transport performance in the EU28 can be attributed to road vehicles[31]. 10% of external costs can be attributed to maritime transport causes, 5% to aviation, 1.8% to rail transport and 0.3% to inland waterways (see Figure 10). Furthermore, the results show that 69% of the total costs are due to passenger transport, while 31% of the costs are caused by freight transport (including LCVs).

Figure 10 - Share of the different transport modes on total external costs 2016 for EU28



Note: Data for aviation and maritime transport is based on rough estimations for EU28.

31 Excluding congestion, road transport would still make up for 77% of the total costs.

3.3.2 Average external costs

The average external costs of transport are expressed in Euro cent per passenger kilometre (pkm) and tonne kilometre (tkm). Please note that for aviation and maritime, the EU average costs are averages for the selected EU-(air)ports that may not be representative for all EU (air)ports. More detailed average external cost figures can be found in Annex A.3.

Considering passenger transport (see Figure 11), cars cause external costs of 7.8 €-cent per pkm without congestion and 12.0 €-cent/pkm including congestion. The highest average external costs per pkm are caused by motorcycles, which is a result of their high accident and noise costs (plus their low occupancy rate)[32]. For buses and coaches the average external costs are significantly lower than for passenger cars (3.6 €-cent/pkm), which is mainly explained by the higher occupancy rates of these vehicles.

The average costs of passenger rail transport amount to 2.8 €-cent/pkm, which is 2.8 times lower than the costs for the road sector (without congestion). Average costs for rail transport differ a lot between electric trains and diesel trains. Due to significantly higher air pollution costs, the average costs of diesel trains are 3.9 €-cent/pkm, whereas the costs of electric trains only amount to 2.6 €-cent/pkm (average of all electric trains). The cost of high speed rail is even lower, i.e. 1.3 €-cent/pkm. A second reason for this difference (apart from the higher emission factors) is the fact that passenger diesel trains have lower load factors (number of passengers per vehicle) than electric trains.

The average costs of air transport are around 3.4 €-cent/pkm, which is only about 20% higher than average rail costs. However, the result for air transport is an average, including data for short, medium and also long haul flights to and from European airports[33].
The average costs between these distance classes differ from 4.3 €-cent/pkm for short haul flights, to 2.8 €-cent/pkm for medium haul and 3.2 €-cent/pkm for long haul[34].
When comparing aviation and rail for the same distance classes, external costs of aviation (short haul flights: 4.3 €-cent/pkm) are 3 times higher than rail (high speed rail: 1.3 €-cent/pkm).

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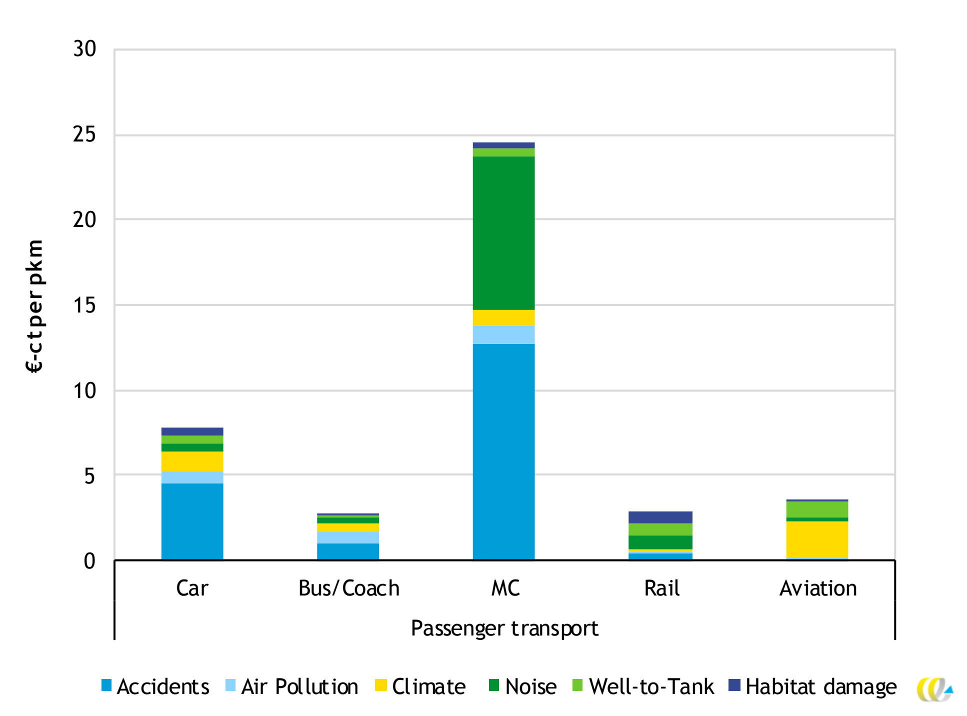
32 As discussed in CE Delft et al. (2019b), motorcycles are involved in a relatively high number of accidents, often resulting in victims in the opposing vehicle as well. As a consequence, motorcycles have relatively high average accident costs. As motorcycles produce relatively much noise (compared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

33 Main cost drivers for the external costs of aviation are the share of the LTO cycle of the total flight (which is higher for short haul flights), the size and fuel use of the aircrafts and the load factor. All these factors differ widely between short, medium and long-haul flights.

34 The average external costs per pkm for medium-haul flights are slightly lower than for long-haul flights. This is mainly a consequence of the slightly lower greenhouse gas emission factors per pkm for medium flights than for long-haul flights. This again is mainly influenced by the high average occupancy rate for medium-haul flights according to statistics. Another factor for the higher greenhouse gas emissions of long-haul flights is the higher share of the cruise at high altitude of the whole flight (with a higher global warming potential in high altitude).

Figure 11 - Average external costs 2016 for EU28: passenger transport (excluding congestion)



Note: The figures for aviation are averages for selected EU28 airports.

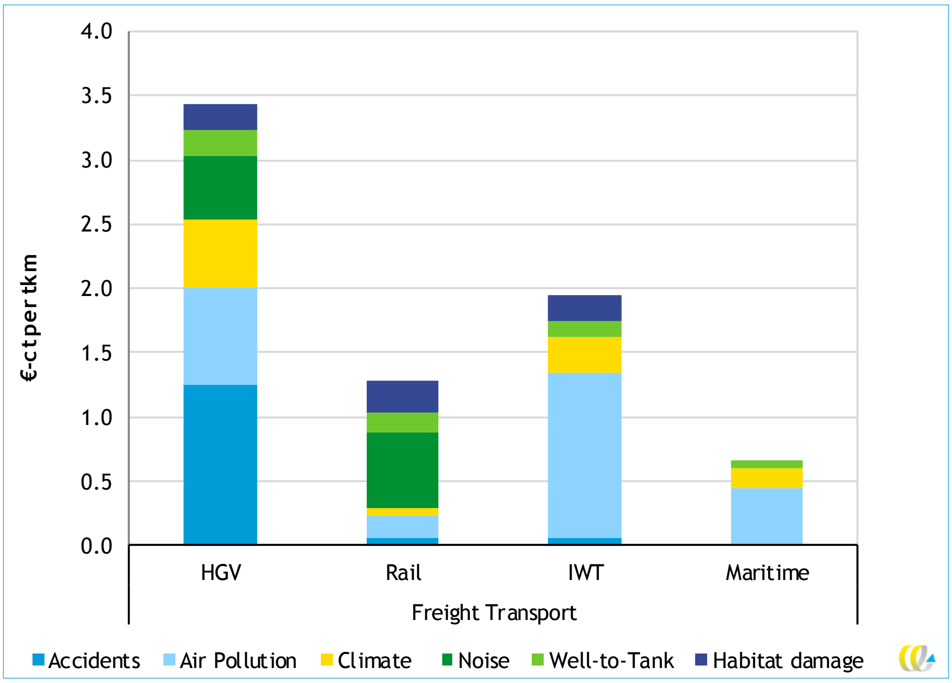
For freight transport (see Figure 12), the average costs for rail transport are 1.3 €-cent/tkm. The average costs for road freight transport (HGVs) are 3.4 €-cent/tkm (without congestion) which is 2.6 times higher than for rail. Including congestion, the average costs for road freight transport are 4.2 €-cent/tkm (3.2 times higher than for rail freight transport).
The higher average costs for HGVs compared to rail (and IWT) can be explained by the lower average load factors. Drawing on the data used from the noise maps, the noise costs for rail are higher per tkm than for a HGV. There are separate maps for road and rail transport, which reveal that fewer people experience noise nuisance per vkm on the road, compared to the number of people that experience noise nuisance per vkm on the railway tracks.

The costs for inland waterways are slightly higher (1.9 €-cent/tkm) than for rail. IWT mainly cause air pollution costs, which are significantly higher than for the other freight modes. Due to the relatively long economic life time of the engines of IWT vessels, the replacement of older engines with high air pollutant emissions is relatively slow. As a consequence, the share of older vessels in the European IWT fleet is relatively high, resulting in high average air pollution costs.

The lowest average external costs for freight transport are identified for maritime shipping, i.e. 0.7 €-cent/tkm. However, it should be noted that this is an average, including both short sea shipping and long-distance shipping. As the air pollution costs (the main externality of maritime shipping) are mainly related to the kilometres made in the continental waters, the external costs for short sea shipping are expected to be (significantly) higher than for long-distance shipping. However, in this project no distinction between different types of maritime transport has been made and hence no direct comparison between short sea shipping and the other freight transport modes[35] can be made.

Finally, for air cargo freight transport, no external costs have been calculated due to lack of data.

Figure 12 – Average external costs 2016 for EU28: freight transport (excluding congestion)



Note: The figures for maritime transport are averages for selected EU28 ports.

Light commercial vehicles (LCV) are used both for freight and passenger transport. Therefore, a comparison with other passenger or freight modes cannot be easily made. The derivation of average costs per tkm or pkm is not feasible as it is not known which part of the transport performance (vkm) is freight or passenger transport[36]. Therefore, the results for LCV are presented in €-cent per vkm. The average external costs are equal to about 25 €-cent per vkm. Congestion costs are the main part of these costs (47%), followed by accident costs (about 16%).

3.3.3 Marginal external costs

In this project a large range of marginal cost figures have been estimated, differentiated to vehicle characteristics, infrastructure types, traffic situations, locations, time of the day, etc. An overview of these marginal cost figures can be found in CE Delft et al. (2019c). It is important to state that these marginal external costs reflect very different conditions regarding the vehicle type, road/infrastructure type and many other characteristics like

[35] Such a comparison would be most relevant, as short sea shipping directly competes with the other transport modes.

[36] Furthermore, as LCVs are often used for services related transport (e.g. by plumbers), the average load of these vehicles is relatively low. Therefore, presenting average cost figures in €-cent/tkm would result in very high and meaningless values.

population density, time of the day, traffic situation, level of congestion etc. The marginal costs presented are not necessarily representative for the real world and can therefore differ significantly from the average costs.

3.4 Robustness of the external cost methodologies and estimates

The calculation of the external costs of transport in this study has been undertaken according to the most recent and high quality evidence and methods. Nonetheless, there are a few aspects that are sources of uncertainties, both in data and methodology:

- *Emission factors (air pollution, climate change, well-to-tank)*: The emission data have been taken from the most recent sources that provide data for all European countries and the vehicle categories covered. However, data has not been available for all differentiations that are required (e.g. detailed vehicle categories, size or emission classes).
- *Valuation of immaterial damage to humans*: An important factor for uncertainties is the valuation of immaterial damage (i.e. the value of value of life year lost VOLY). The value used is based on a meta-analysis. However, due to results from various studies varying significantly, some uncertainty in the value used is unavoidable.
- *Cost factor for greenhouse gas emissions*: The cost factor used to monetise the costs of climate change is based on an avoidance costs approach. The literature review confirmed that, at present, the use of avoidance costs is a superior method to the use of damage costs (see full discussion in Handbook). However, uncertainties will always remain[37]. To take away some of that uncertainty, the calculations in the Handbook also provide high and low case climate change costs, which can be used as a sensitivity analysis.
- *Congestion costs*: Due to the fact that road congestion costs are so highly dependent on the methodological approach and specific for local conditions, there is a huge variation in total, average and marginal congestion costs estimations. This large variation conceptually complicates what is meant by road congestion costs, as a unique approach does not exist. For this reason, total and average road congestion costs have been estimated for both delay and deadweight loss in the Handbook.
- *Transport data*: The results for total/average/marginal external costs are directly affected by the transport performance data used (vkms, tkms, pkms). As discussed in Section 1.3.5, for this study a consistent set of transport performance data has been composed. However, some uncertainties remain, e.g. due to different approaches of national transport statistics, mainly for the differentiated vehicle categories. The road transport data based on Eurostat follow the nationality principle, i.e. transport activity is allocated to countries where the vehicle is registered. This causes some inconsistencies with some of the other data used, e.g. the accident and noise data, which are in line with the territorial principle. The difference between these two approaches mainly has an impact in countries with a high share of transit traffic and is therefore likely to impact the results.
- *Other uncertainties*: There are also a number of other uncertainties for the different cost categories, e.g. the share of the accident costs that transport users internalise in their transport decision, the damage cost factors for different cost categories (mainly air pollution costs, noise costs) and the number of people exposed to noise (based on noise maps). For more detailed discussions of the uncertainties, please see the Handbook on external costs of transport.

[37] Another high uncertainty is related to the estimation of the non-CO_2 impacts of air transport.

4 Transport taxes and charges

4.1 Introduction

Transport taxes and charges are defined in this study as all taxes/charges[38] that are directly related to the ownership and use of transport vehicles, including the taxes/charges related to infrastructure use[39]. A brief overview of the main transport taxes and charges applied in the EU28 and their link to internalising external and infrastructure costs is provided in Section 4.2. The revenues of transport taxes/charges in the EU28 in 2016 are discussed in Section 4.3, while the robustness of these figures are discussed in Section 4.4. For a more detailed discussion on the transport taxes and charges applied in the EU28, we refer to CE Delft et al. (2019c).

4.2 Transport taxes and charges applied in the EU28

4.2.1 Road transport

The main pricing instruments applied for road transport are fuel taxes, vehicle taxes (purchase and ownership taxes) and road charges (tolls and vignettes)[40]. Fuel taxes are applied in all EU Member States, with levels set equal to or (often) above the minimum levels set in Directive 2003/96/EC. In some countries (i.e. Denmark, Finland, France, Ireland, Luxembourg, Portugal, Slovenia, Sweden) specific CO_2 taxes are incorporated into the fuel taxes for road transport.

Purchase or registration taxes are applied in most EU28 Member States for passenger cars and motorcycles and in a significant number of countries for LCVs. However, only a minority of countries apply these taxes for heavy vehicles (i.e. Denmark, France, Greece, Ireland, Italy, Poland, and Romania). For passenger cars, CO_2 emissions are used by about 55% of the purchase tax schemes as differentiation parameter. For motorcycles and LCVs only 10% of the schemes apply a differentiation to CO_2 emissions, while for heavy duty vehicles no differentiation to CO_2 emissions is applied[41]. Differentiations to emission class (e.g. Euro standards) are applied by about 10% of the schemes, while differentiations to fuel type is particularly applied for passenger cars (about 40% of the schemes).

Ownership taxes are widely levied on all road vehicles in the EU28. In all Member States this tax is applied for HGVs, while the other vehicle categories are only exempt from this tax in a few countries. As for purchase taxes, CO_2 emissions are widely used as differentiation parameter for passenger cars (about 50% of the schemes), while ownership taxes for motorcycles and LCVs are differentiated to CO_2 emissions for about 10% of the schemes. Differentiations to air pollutant emissions are applied by about 10% of the schemes, while

[38] Only charges that can be considered compulsory payments to governments and infrastructure operators are taken into account. Payments for transport services delivered by other semi-private agents are considered internal costs and are not taken into account.

[39] This definition excludes general taxes like profit taxes and wage taxes, as they are only indirectly related to transport activities.

[40] Other pricing instruments are insurance taxes, taxes for bridges/tunnels and the VAT on transport taxes.

[41] As no CO_2 labelling exist for HDVs, such that there is no good tax base that can be used to implement a CO_2 differentiation.

differentiations to fuel type is particularly applied for passenger cars (about 35% of the schemes).

Distance-based road tolls and/or vignettes are applied in almost all European countries. In 2016, only Cyprus, Estonia, Finland and Malta did not have such a system in place. Road charging schemes for passenger cars are applied in 17 EU Member States, of which nine apply a distance-based road charge, while the other eight have implemented vignette schemes. For HGVs, 15 EU Member States have implemented a distance-based road charging schemes, while nine other countries apply vignettes for these vehicles. About 40% of the road charging schemes in the EU are differentiated to emission standards (mainly for heavy vehicles), while differentiations to CO_2 emissions are not applied in any of the schemes currently implemented in the EU.

4.2.2 Rail transport

The taxes and charges applied for rail transport in the EU28 are fuel taxes (diesel), electricity taxes and rail infrastructure charges. Emissions Trading System (ETS) for the electricity used in rail is also considered. Fuel taxes on diesel consumed by rail transport are taxed in most countries (rail transport in Belgium, Hungary and Sweden is exempt from this tax), while 16 EU28 Member States also tax electricity consumption by rail transport. Electricity consumption is also indirectly charged as electric power supply falls under the EU ETS. All these different types of energy taxes/charges are directly linked to the CO_2 emissions of rail transport. Furthermore, diesel taxation is linked to air pollutant emissions as well.

In addition to the various types of energy taxation, all countries are also obliged to apply rail infrastructure charges, which provides infrastructure managers a mechanism to recover the infrastructure costs borne. These charges currently hardly consider external costs: in Austria, Germany and the Netherlands access charges are differentiated to noise, while Sweden is the only country that applies a differentiation to air pollutant emissions.

4.2.3 IWT

The main charge applied for IWT are port charges, which is applied in all relevant IWT countries. These charges are used to cover part of the infrastructure costs of IWT. There are large differences in the charge levels and structures applied by the various IWT ports in the EU28. Differentiation parameters that are applied include tonnage, type of cargo, number of calls, etc. In some ports a differentiation to environmental standards is applied as well.

In addition to port charges, fairway dues are applied on (parts of) the IWT network in six EU countries, and are usually calculated as charges per ton-kilometre for different types of goods. In Belgium and Poland, specific dues for the use of bridges and locks are also applied. These types of infrastructure charges are not applied on the Rhine or any of its tributaries, as this is not allowed according to the Mannheim Convention[42].

Because of the same Mannheim Convention, fuel taxes are only applied in some of the non-Rhine states. Finally, water pollution charges (expressed in € per litre fuel) are used in some EU countries to cover for the costs of collection, deposit and reception of waste produced during navigation on the Rhine and its tributaries.

[42] The Mannheim Convention is an agreement between the Rhine-States that Member States must refrain from imposing any fee on the fact of navigation in the Rhine area.

4.2.4 Maritime transport

Port charges are the main pricing instrument applied for maritime transport. These charges are applied in all 34 selected EU28 ports, although there are large differences in the fees levied on maritime vessels calling these ports. A large range of differentiation parameters are applied as well (e.g. gross tonnage, net tonnage, amount of cargo handled, type of cargo, number of calls, etc.). In 11 ports a rebate on environmental grounds (based on the environmental ship index[43] (ESI) of the vessel) is provided. Furthermore, the structure and level of port charges heavily depend on the pricing policies of ports, including (unofficial) discounts provided. For this reason, the uncertainty on the revenues from port charges is relatively high.

In addition to port charges, three EU countries (Estonia, Finland and Sweden) also apply fairway dues. The levies do not consider external costs in any of these countries.
Finally, based on the Energy Taxation Directive, maritime transport is exempted from fuel taxes in the EU.

4.2.5 Aviation

Airport charges are used by all airports to cover the (operational) costs of providing airport infrastructure and related services. A large range of specific airport charges are applied by the various airports considered for this study. Specific noise charges are applied by 11 airports from the set of 33 EU28 airports considered, while another 7 airports apply noise differentiated LTO charges. Differentiation of airport charges to emission level of the aircraft is hardly applied at the considered airports. In a few countries (i.e. Austria, Germany, France, Croatia and UK) aviation taxes were applied in 2016 in addition to the airport charges. These taxes are mainly differentiated to destination of the passenger, while external costs are hardly considered.

The CO_2 emissions of aviation are partly covered by the EU Emission Trading Scheme (ETS) since 2012, as all CO_2 emissions of intra-EEA flights emission allowances have to be submitted. On the other hand, fuel taxes on commercial aviation are not applied by any of the EU28 Member States.

4.3 Revenues from transport taxes and charges

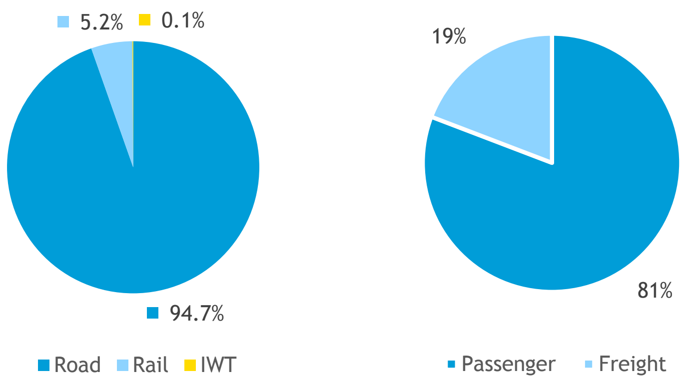
4.3.1 Total revenues

The total tax/charge revenues from road, rail and inland waterway transport in the EU28 amount to € 370 billion for 2016. This is about 2.5% of the EU28 GDP. As shown in Figure 13, the majority of the revenues (about 95%) come from road transport (about € 350 billion). Rail transport contributes about 5% (about € 20 billion), while IWT is responsible for 0.1% of the revenues (about € 0.4 billion) It is also shown that passenger transport is responsible for 81% of the tax/charge revenues, while the remaining part is from taxes/charges levied on freight transport.

[43] The ESI covers NO_x, SO_x and GHG emissions.

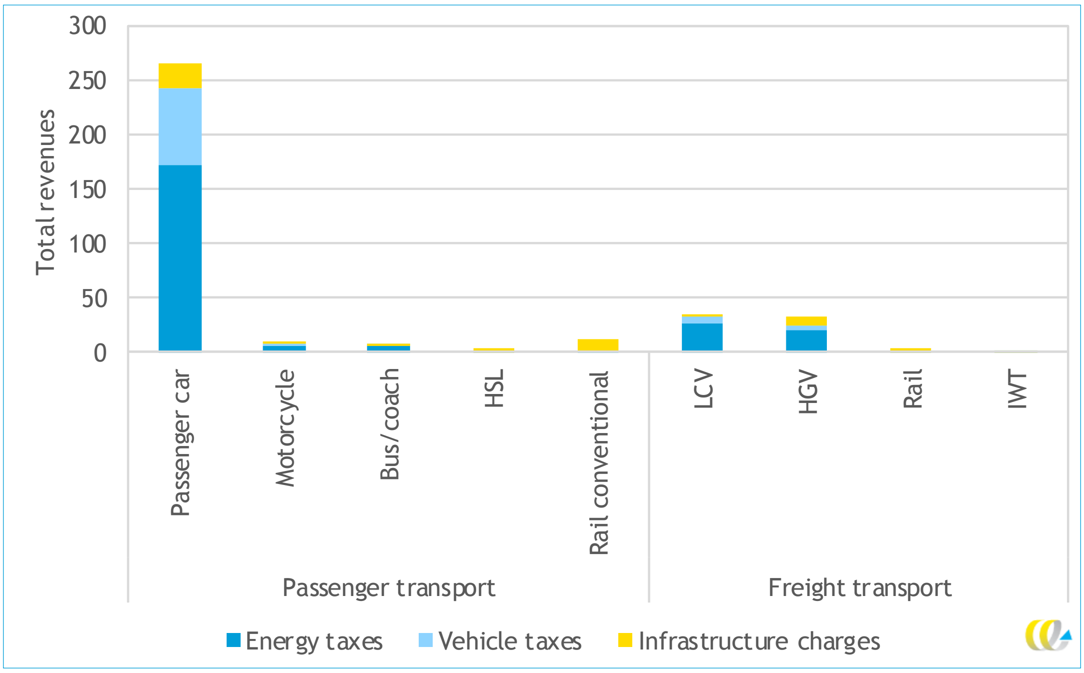
Figure 13 - Composition of total tax/charge revenues in 2016 for road, rail and inland waterways transport in the EU28

A. By transport mode **B. By passenger and freight transport**



As is shown in Figure 3, the main share of the total revenues are from taxes/charges levied on passenger cars, which can be explained by both the large share this vehicle category has in total transport performance and the relatively high tax/charge burden on these vehicles. Next to passenger cars, also light commercial vehicles and HGVs contribute significantly to the total tax/charge revenues. For all road vehicles, energy taxes (mainly fuel taxes) contribute most to the total revenues. Vehicle taxes are particularly relevant for passenger cars and motorcycles, and to a lesser extent LCVs. Infrastructure charges contribute most to the tax/charge revenues from HGVs. For the non-road modes, the infrastructure charges are responsible for the majority (more than 80%) of the total tax/charge revenues.

Figure 14 - Total tax/charge revenues for road, rail and inland waterway transport in the EU28 (billion €, PPS adjusted)



Finally, the revenues for the 33 selected EU airports are estimated at about € 13.5 billion, while the revenues for the 34 selected EU ports are (roughly) estimated at €1.8 billion[44]. For both aviation and maritime transport, these revenues consist mainly of revenues from infrastructure charges (i.e. airport charges and port charges, respectively).

4.3.2 Average revenues

Figure 15 presents the average revenues of taxes and charges for the various passenger transport modes in the EU28. These revenues are highest for diesel passenger trains, followed by passenger cars and motorcycles. The relatively high tax/charge revenues for diesel trains (compared to electric trains) can partly be explained by the lower occupancy rate of these trains. Another important explanation is the fact that diesel taxes in the EU28 are — on average — higher than the electricity taxes for rail transport[45]. The higher average tax/charge revenues for high speed trains compared to conventional trains is mainly explained by the — on average — higher access charge levels levied on these types of trains[46].

The higher average tax/charge revenues for passenger cars and motorcycles compared to buses/coaches are explained by higher vehicle tax levels (e.g. only in a few countries purchase taxes are levied on buses/coaches, while they are levied on passenger cars in most EU countries) and lower occupancy rates.

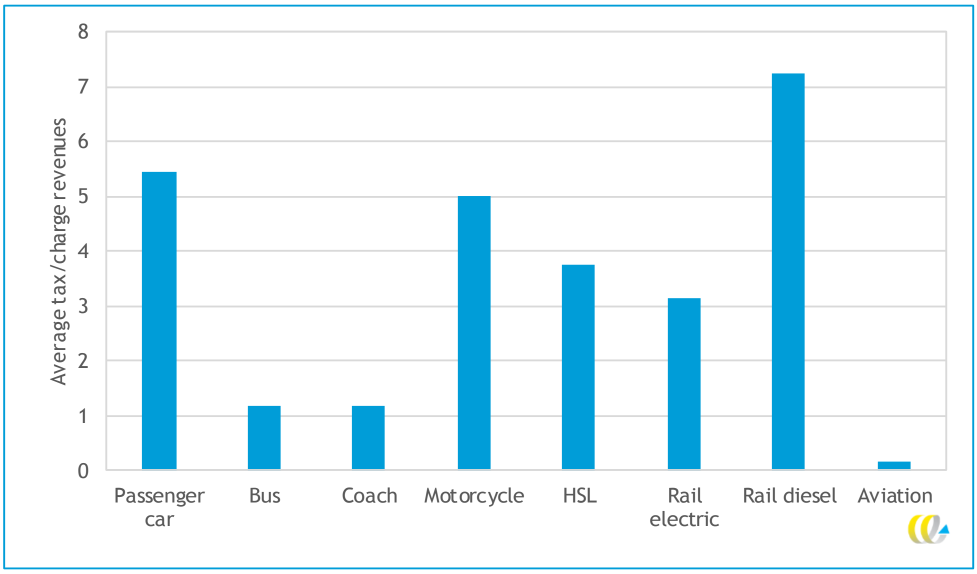
Finally, for aviation the average tax/charge revenues are relatively low compared to the other passenger transport modes. However, it should be taken into account that the tax/charge burden for an average aircraft is considered (weighted average of aircrafts used on short-, medium- and long-haul flights) and hence a direct comparison with road and rail transport is difficult (as aviation do not compete with these modes on medium- and long-haul flights).

[44] These are the revenues collected in 30 EU ports, as for 4 ports no data on tax/charge revenues was available.

[45] In 12 EU Member States, rail transport is exempted from electricity taxes or no electricity tax is levied at all.

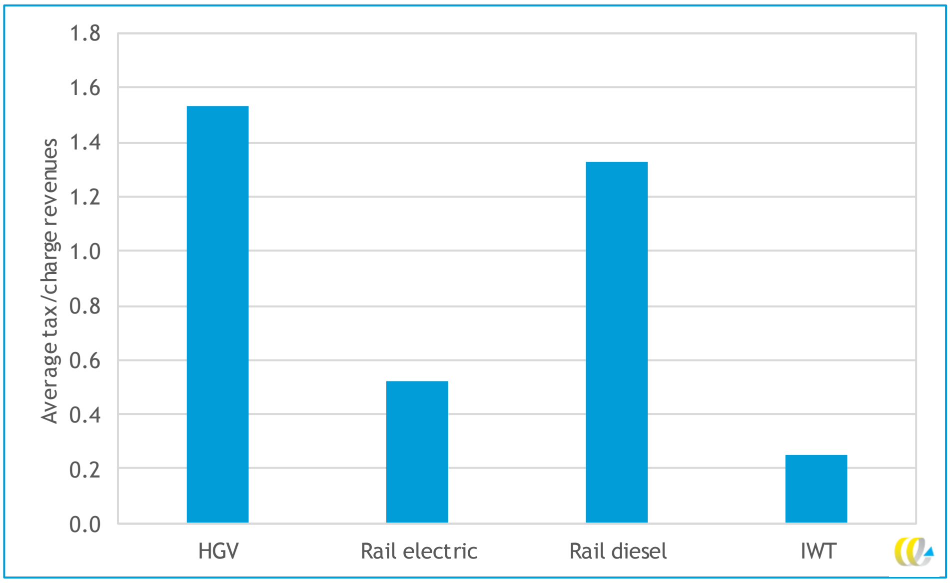
[46] These higher access charge levels may reflect the fact that in some countries the access charges for conventional (regional) trains may be kept low by subsidising rail operators. As these subsidies are not assessed in this project, we are not able to quantify this aspect.

Figure 15 - Average tax/charge revenues in 2016 passenger transport in the EU28 (€-cent/pkm, PPS adjusted)



The average tax/charge revenues for freight transport vehicles are presented in Figure 16. The highest average revenues are found for HGVs, followed by diesel trains, electric trains and IWT vessels. The higher revenues for diesel trains compared to electric trains are explained by the higher energy tax for diesel trains (the average diesel tax for rail transport significantly exceed the average electricity tax) and the (slightly) lower load factors for diesel trains.

Figure 16 - Average tax/charge revenues in 2016 freight transport in the EU28 (€-cent/tkm, PPS adjusted)



4.3.3 Marginal revenues

In this project, we have also assessed in detail the marginal tax/charge revenues (or levels) for the various vehicle categories and taxes/charges. An overview of these marginal tax/charge levels in specific situations is provided in the Excel database accompanying CE Delft et al. (2019c). We refer to this database for more information on this issue.

4.3.4 Earmarking of revenues

Part of the revenues from transport taxes and charges are earmarked for expenditures on transport infrastructure. Earmarking of revenues is often considered as a way to gain public support for the implementation of new tax/charge schemes or for increasing existing tax/charge levels. However, according to economic theory earmarking of revenues leads, in general, to a loss of efficiency. This is because there is no guarantee that transport infrastructure projects are the most efficient projects available to be financed with the revenues. Second, earmarking creates inflexibility, 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.

Our study shows that at the EU28 level about 10% of the road transport tax/charge revenues are earmarked for expenditure on transport infrastructure. For rail transport, the revenue of rail access charges (about 85% of the total tax/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/charges. For IWT, maritime transport and aviation, only fragmented data on earmarking of taxes/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.

4.4 Robustness of estimates on tax/charge revenues

The main uncertainties with respect to the tax/charge revenues are:
- For some taxes/charges, the total revenues in 2016 were not available (for all countries). In these cases, the revenues have been estimated by using data for earlier years or using bottom-up approaches[47].
- The allocation of total tax/charge revenues to various vehicle categories have been estimated based on specific allocation approaches, resulting in a certain extent of uncertainty.
- To estimate average revenues, transport performance data have been used. However, as the scope of these data is inconsistent with the scope of some of the taxes[48], alternative second-best approaches have been applied to estimate the average revenues for some of the road transport taxes/charges.

[47] Total revenues are estimated based on data on tax/charge levels and specific transport performance data.
[48] Transport performance data applied in this study is defined on the basis of the nationality principle (transport performance is allocated to the country in which the vehicle is registered), while the scope of some of the taxes and charges (e.g. fuel taxes, road tolls, vignettes) is more in line with the territoriality principle. See Section 1.3 for more details.

5 State of play of internalisation in the European transport sector

5.1 Introduction

This chapter assesses the extent to which external and infrastructure costs are internalised by current taxes and charges for all countries and modes in the European transport sector. We discuss the methodological framework, providing an overview of the internalisation approaches considered and offering justification for the use of average and marginal cost coverage ratios (Section 5.2). A brief comparison of the total external and infrastructure costs and tax/charge revenues for the five transport modes (road, rail, IWT, maritime transport and aviation) is given in Section 5.3. The conclusions for the average and marginal cost coverage ratios for all vehicle categories are presented afterwards (Section 5.4 and Section 5.5). Finally, a summary of the broader context of internalisation is offered, to discuss the contribution non-pricing measures introduced may have in meeting the objectives of internalisation strategies (Section 5.6).

5.2 Methodology applied

5.2.1 Brief overview of internalisation approaches

A summary of various internalisation approaches, their main objective(s) and their relevance is given in Table 14.

Table 14 – Overview of main internalisation strategies

Internalisation approach	Brief description	Main objective(s)	Relevance
Marginal social cost pricing (MSCP)	Variable charges/taxes are set at the level of marginal infrastructure and 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 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

Internalisation approach	Brief description	Main objective(s)	Relevance
			relevant over the last decade(s) – Not in line with internalisation philosophy of the Commission

Marginal Social Cost Pricing (MSCP) and average cost pricing were selected 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 (EC, 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 into the extent to which total external and infrastructure costs are covered by taxes and charges.

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 CO_2 differentiation to existing taxes/charges). However, assessing the state-of-play of internalisation from this perspective requires a detailed assessment of 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.

5.2.2 Indicators applied to study the state of internalisation

As mentioned above, the state-of-play of internalisation is assessed from both the average cost pricing and MSCP perspective. 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 15, including a brief explanation and justification of those indicators.

Table 15 – Overview of the indicators for average cost pricing

Cost coverage ratio	Explanation	Justification
Overall cost coverage ratio	Comparison of revenues from all taxes/charges with all external and infrastructure costs.	Good indication of the extent to which transport user pays for the average external and infrastructure costs caused.
Overall cost coverage ratio excluding fixed infrastructure costs	Comparison of revenues from all taxes/charges with all external and variable infrastructure costs (i.e. excluding fixed infrastructure costs).	This indicator is in line with the policy 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).

Cost coverage ratio	Explanation	Justification
Variable external and infrastructure cost coverage ratio	Comparison of revenues from variable taxes/charges with variable external and infrastructure costs.	This indicator is measuring MSCP, in a simplified way (as proposed by the Communication of the Strategy for the internalisation of external costs). However, fixed taxes (and costs) are not considered at all, while they have an important role in many countries.
Overall infrastructure cost coverage ratio	Comparison of revenues from infrastructure charges with all infrastructure costs.	This indicator may provide an indicator of the extent by which the user pays principle is met. However, it should be noted that infrastructure charges are also used to cover external costs and that other taxes and charges can be used to fund infrastructures.
Variable infrastructure cost coverage ratio	Comparison of revenues from infrastructure charges with variable infrastructure costs.	As discussed above, there may be reasons to consider the level of internalisation without fixed infrastructure costs.

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 revenues 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.

The following four marginal cost scenarios are considered:
- *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. The weighting of both the costs and tax/charge levels has been based on transport performance data for the various countries. This implies that this scenario presents the actual 'average' marginal cost coverage ratios.
- *High external cost 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.
- *Low external cost scenario*: this scenario is based on a selection of cost drivers that results in relatively low marginal external costs.
- *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 car, motorcycle, bus, LCV).

For each vehicle type, these three/four scenarios are clearly defined. An example of the detailed definition of these scenarios is presented in Table 16, for passenger car.

Table 16 – Example of marginal cost scenarios (passenger car)

Representative scenario	High external cost scenario	Low external cost scenario	Very low external cost scenario
Average vehicle Average daytime/night Average congestion level Average road	Large car Diesel EURO 3 CO_2 emissions: 176 g/km Daytime Congested traffic Urban road in metropolitan area	Small car Petrol EURO 6 CO_2 emissions: 99 g/km Daytime Thin traffic Motorway in rural area	Battery Electric Vehicle Daytime Thin traffic Motorway in rural area

5.3 Cross-modal comparison of total costs and revenues

In this section we present a comparison of the total external and infrastructure costs and total tax/charge revenues for the five main transport modes: road, rail, IWT, maritime and aviation. Two types of comparisons are made: one including all costs and revenues and one including all cost except fixed infrastructure costs and all revenues.

When comparing the results for the various modes, care should be taken, as they do not often compete within the same market. For example, the average airplane operates in a completely different market than the average train. Furthermore, for maritime transport and aviation no EU28 figures were available. Instead, costs and revenues estimated for a selection of maritime ports and airports were considered.

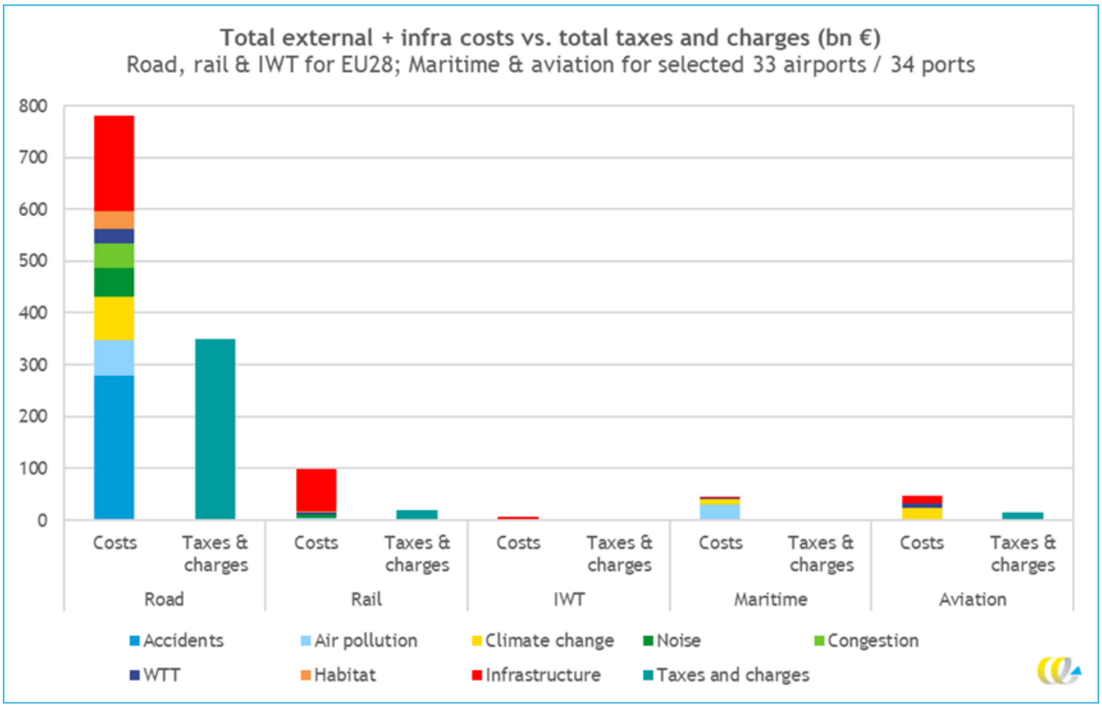
Figure 17 presents the total external and infrastructure costs and the total tax and charge revenues for the various transport modes in the EU28. The highest costs are found for road transport (about € 780 billon), with accident costs (€ 279 billion) and infrastructure costs (€ 184 billion) as the main cost categories[49]. 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[50]. 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%).

[49] Please notice that for road congestion costs the deadweight loss costs are presented in this chapter. 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.

[50] For the cross-modal comparison, LCVs are included within the road cost coverage, as this section looks at total figures, rather than average figures, where disparities in the services provided by HGVs and LCVs result in difficulties aggregating the figures for freight transport in a meaningful way.

As explained before, 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 billion[51]. 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 levied[52]), 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.

Figure 17 - Total external and infrastructure costs vs. total taxes and charges (bn €). Rail, road, IWT for EU28; Maritime and aviation for selected 33 airports and 34 ports



In Figure 18, 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.

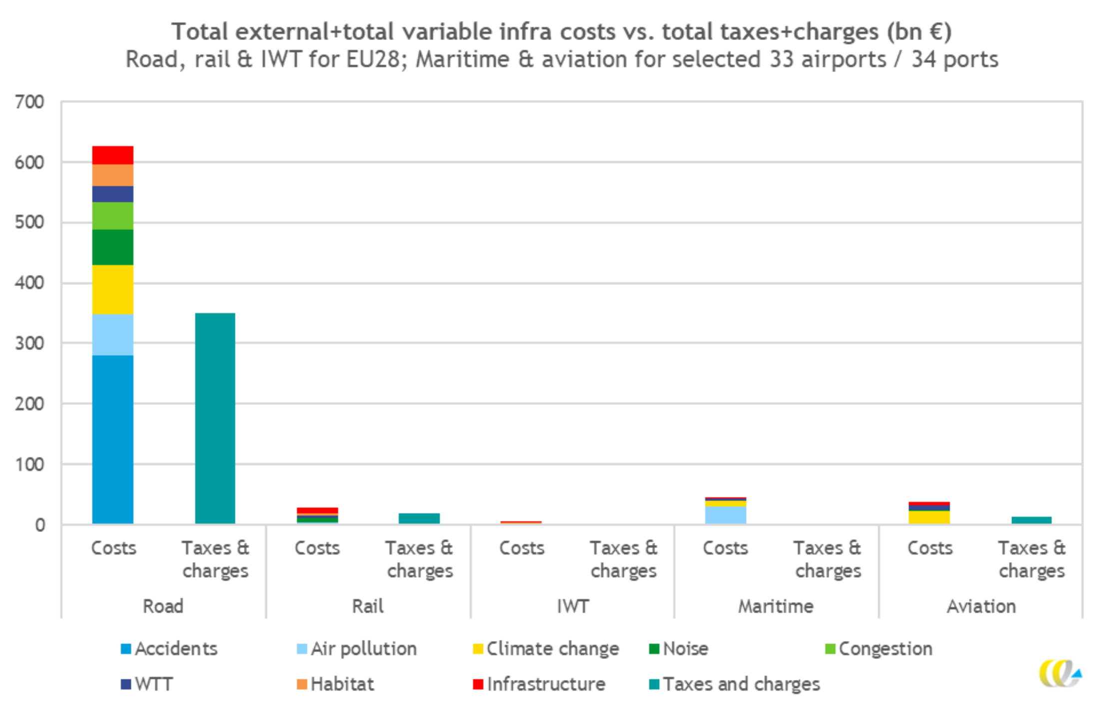
The highest coverage ratios for this indicator are found for rail transport (69%), followed by road transport (56%), aviation (37%), IWT (12%) and maritime transport (4%). Particularly for rail transport, this cost coverage ratio is significantly higher than the overall cost coverage ratio for this mode, 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

51 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.

52 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.

(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%).

Figure 18 - Total external and total variable infra costs vs. total taxes and charges (bn €). Road, rail and IWT for EU28; Maritime and aviation for selected 33 airports/34 ports



5.4 Total/average cost coverage

In this section we discuss the various cost coverage ratios for the various vehicle categories at the EU28 level. It should be noted that there are differences between EU Member States with respect to some of 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)). However, the analysis presented in this section is mainly focused on the comparison of EU28 and network-wide average external and infrastructure costs, and tax and charge revenues/levels for passenger and freight vehicles.

As mentioned above, the various vehicle types do not often compete within the same market and hence their cost coverage ratios cannot directly be compared. This should be considered when interpreting the results presented in this section.

For road transport, LCVs are not included in the graphs. As LCVs are often used for service-related transport (e.g. by plumbers), the average load of vans is relatively low. Therefore, presenting the average costs and revenues in €-cent/tkm would result in very high and meaningless values. It is however possible to calculate ratios based on the total costs and revenues collected (in million €). These ratios are presented in each subsection in a footnote.

Finally, for maritime transport no data was available for tonne-kilometres. Therefore, average cost and revenue figures could not be calculated for this transport mode. For this reason, maritime transport is not included in the graphs presented in this section. However, the cost coverage ratios for maritime transport could be calculated, based on total cost and revenue data (as was done in the previous section as well). These ratios are also presented as a footnote in each subsection.

5.4.1 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. Figure 19 shows a comparison of the average external and infrastructure costs and the average tax/charge revenues for all passenger vehicle types.

The highest average cost coverage ratio is found for passenger cars; the average tax/charge level of 5.5 €-cent/pkm covers 51% of the average external and infrastructure costs of about 11 €-cent/pkm. Despite similar levels of taxes and charges being collected for motorcycles (5.0 €-cent/pkm), the vehicle has a cost coverage of 19%. This is due to extremely high external costs, 26 €-cent/pkm, as a result of significant accident and noise costs. The cost coverage ratios for buses and coaches are also low, about 17 and 18% of the average external and infrastructure costs are covered, respectively. Typically, significantly lower taxes are applied to these vehicles compared to passenger cars; the average taxes and charges are found to total about 1.2 €-cent/pkm, for both buses and coaches.

For rail transport, the cost coverage ratios for the different types of passenger trains are in the same range. For high speed trains the ratio is equal to 31%, while for overall electric (including high speed) and diesel passenger trains these ratios are 20 and 23%. Differences in infrastructure utilisation, load factor and 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 (about 4.8 €-cent/pkm) are covered by taxes and charges[53]. However, it should be noticed that this is the cost coverage ratio for an average airplane (covering both short- and long-haul flights) and hence cannot directly be compared to the cost coverage ratios of the other modes.

53 Note that this figure does not include the EU ETS, as it is not possible to attribute such charges to individual airports, or the different flight types (long, medium and short-haul).

Figure 19 – Average external and infrastructure costs vs. average taxes/charges for passenger transport

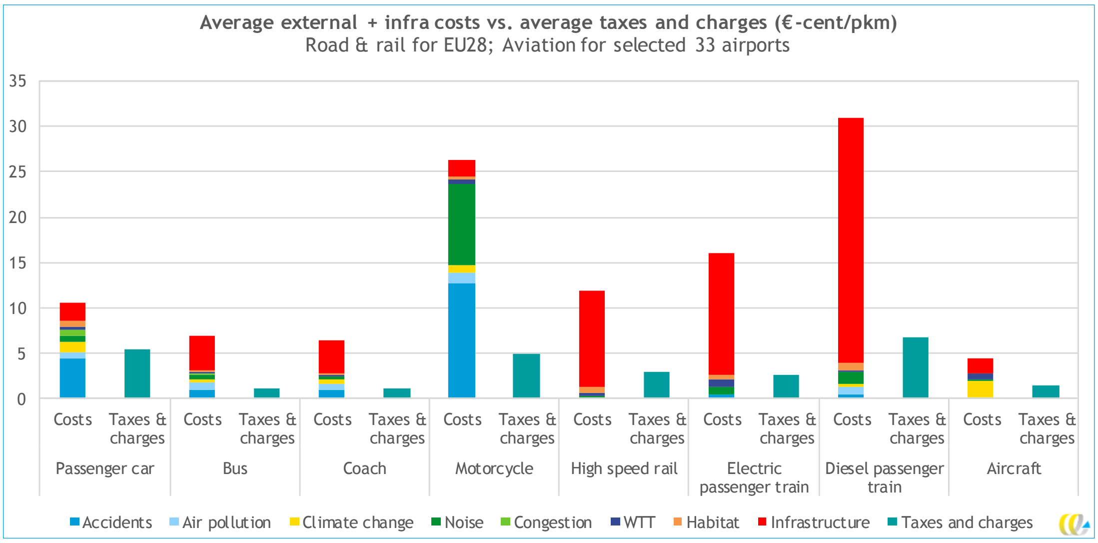


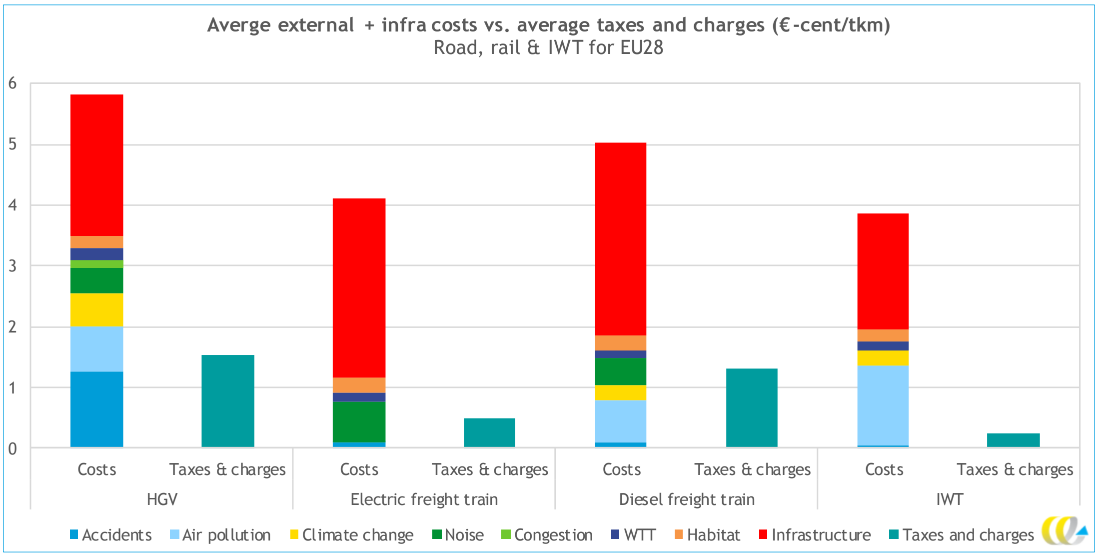
Figure 20 presents the comparison of average external and infrastructure costs and average tax/charge revenues for the various freight vehicle types[54,55]. As for the passenger vehicle types, the costs exceed the revenues for all freight vehicle types.

For HGVs about 26% of the average external and infrastructure costs are covered by tax/charge revenues, which averages at 1.5 €-cent/tkm. For rail transport, the cost coverage ratios for diesel freight trains are higher than for electric freight trains, at 27% and 13% respectively. This higher ratio is mainly explained by the relatively high diesel tax levels compared to electricity tax levels (see Section 4.3.2). As discussed in Section 5.3, the cost coverage ratio for inland navigation in the EU28 is 6%.

54 As explained above, for maritime transport no average cost and revenue figures could be calculated. For that reason, maritime transport is not included in the graphs in this Section. The overall cost coverage ratio, however, could be calculated based on data on the total external and infrastructure costs and tax/charge revenues for the selected EU28 ports. As discussed in Section 5.3, this ratio is equal to 4%. This low ratio is explained by the limited number of tax/charge schemes that are in place for maritime transport in the EU28 (often only port charges are levied).

55 As explained above, the cost coverage ratio for LCVs has been calculated based on total revenues and external costs and is equal to 43%.

Figure 20 – Average external and infrastructure costs vs. average taxes/charges for freight transport



5.4.2 Overall cost coverage 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. Figure 21 shows the EU28 average external and average variable infrastructure costs of the various passenger vehicle types, compared to the average taxes/charges.

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 5.4.1, the lower cost coverage ratios for buses and coaches compared to passenger cars is mainly explained by the relatively low tax/charge levels (about at 1.2 €-cent/pkm) 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 ratios.

Rail transport cost coverages are higher for this ratio: High speed rail trains exceed full cost coverage (181%), this is followed by diesel passenger trains (97%) and electric passenger trains (75%). The differences in cost coverage ratios between the various types of trains are mainly explained by differences in tax/charge levels. For high speed rail, these average 3.7 €-cent/pkm, for diesel passenger trains about 7.3 €-cent/pkm and for electric passenger trains about 3.2 €-cent/pkm. The differences are caused by different levels in energy taxation for different fuels and differences in access charges applied to high speed and conventional trains (as explained in more detail in Section 4.3.2).

Finally, for aviation, the cost coverage ratio including all flights of the 33 selected airports (including short-, medium- and long-haul flights) is shown in Figure 3. The ratio is equal to 41%, which is roughly 9% higher than the overall cost coverage ratio.

Figure 21 - Average external and average variable infrastructure costs vs. average taxes/charges for passenger transport

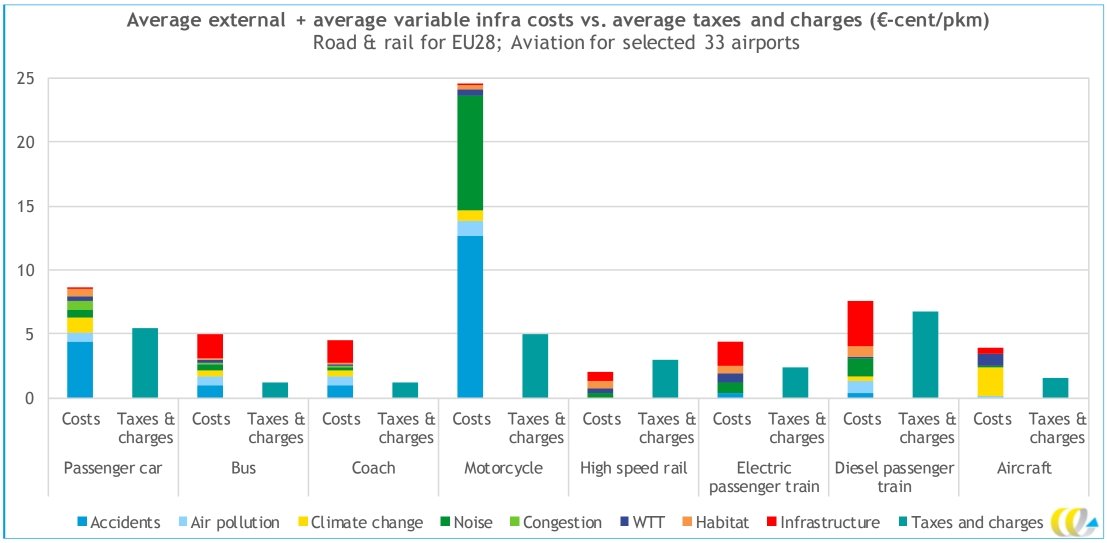
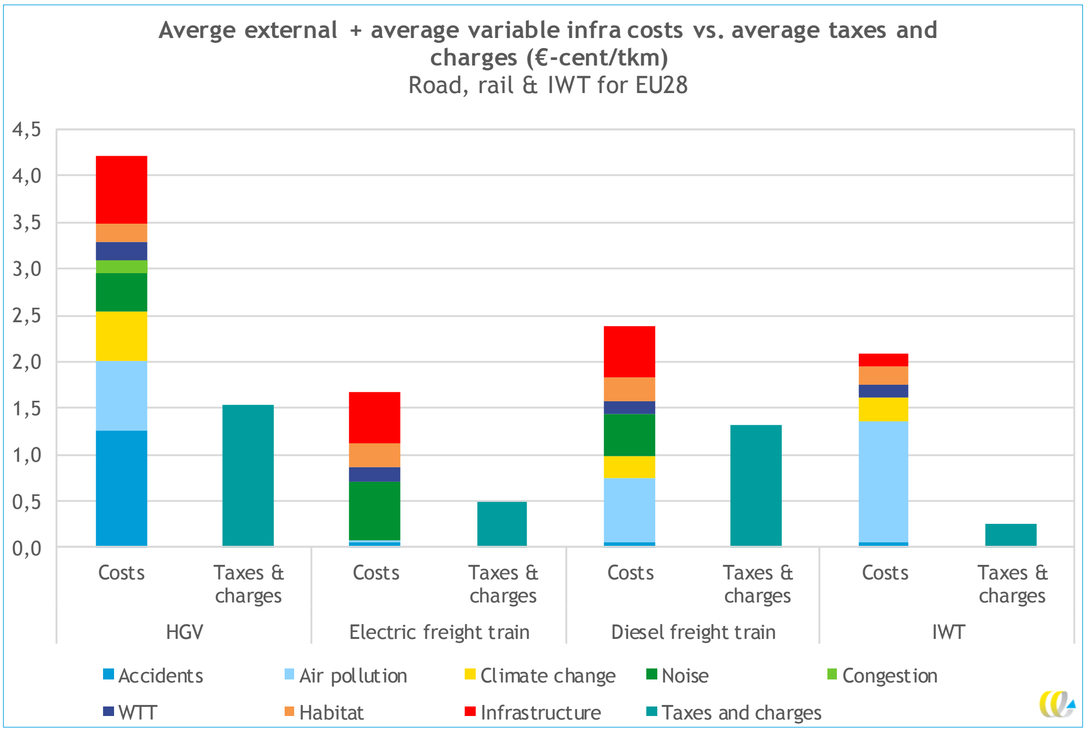


Figure 22 shows the average external costs and variable infrastructure costs against the average tax/charge revenues for freight vehicle types[56]. For all vehicle types, the cost coverage ratios are higher than the ratios for overall cost coverage (as fixed infrastructure costs are excluded). The largest 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 has been identified 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).

[56] The cost coverage ratio of maritime transport is equal to 4%, while for LCVs it is equal to 53%.

Figure 22 - Average external and average variable infrastructure costs vs. average taxes/charges for freight transport



5.4.3 Variable infrastructure and external cost coverage

This ratio compares revenues from variable taxes/charges with variable external and infrastructure costs. The cost coverage ratios for passenger transport are shown in Figure 23. 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. These are reduced due to a reduction in total tax/charges levels, as fixed vehicle taxes (i.e. registration, ownership and insurance taxes) are not included in this ratio. This results in EU28 average revenues of 3.9 €-cent/pkm for cars and 3.6 €-cent/pkm for motorcycles. However, buses and coaches cost coverage increases to 21 and 23% respectively, as result of the fixed external costs (habitat damage) being excluded.

Cost coverage is greater than total cost coverage for passenger rail transport. The ratios for high-speed rail, diesel passenger trains and electric passenger trains are 258%, 110% and 86%, respectively. These are a result of rail transports' high fixed costs being excluded from this ratio, while at the same time all rail taxes/charges being included, as they are considered variable.

Aviation's cost coverage of 41% is comparable to the total cost coverage ratio excluding fixed infrastructure costs. This is because all aviation taxes/charges are considered variable and fixed costs other than fixed infrastructure costs (excluded here) are not significant.

Figure 23 - Average variable external and infrastructure costs vs. average variable taxes/charges for passenger transport

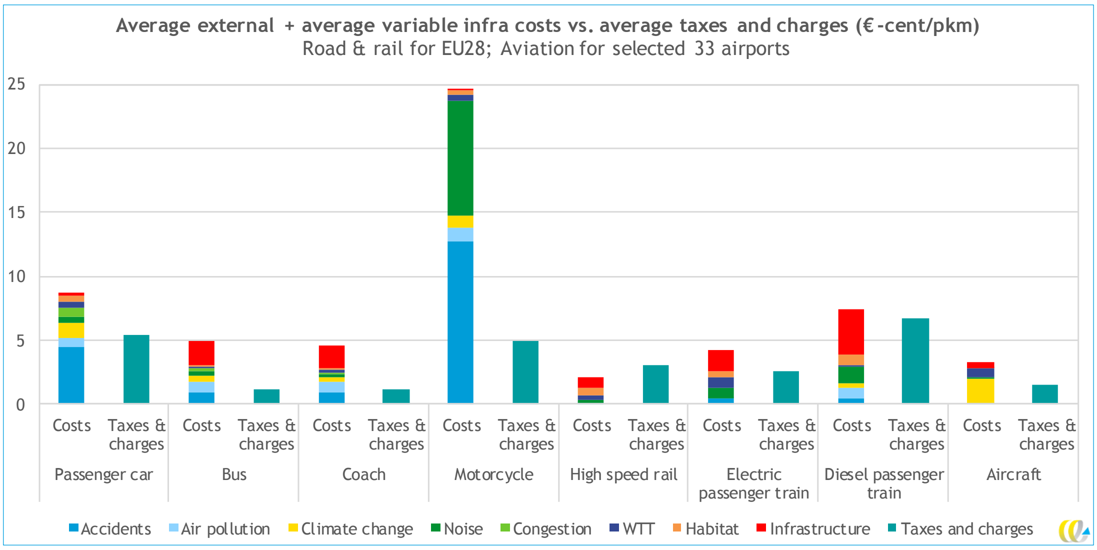
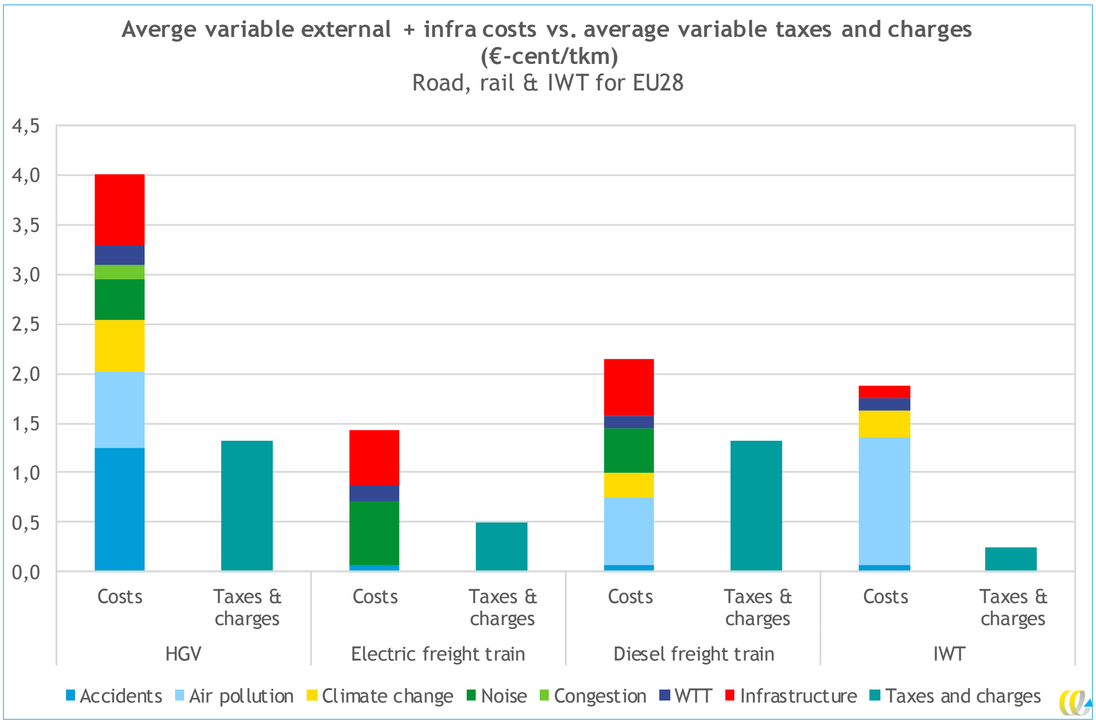


Figure 24 shows that the variable external and infrastructure costs of the various freight vehicle types exceed the revenues from variable taxes/charges levied on these vehicles[57]. The highest variable cost coverage share is found for diesel trains (62%), which is significantly higher than for electric trains (37%). Although the overall external costs for diesel freight trains are higher than for electric freight trains[58], this is more than compensated for by higher diesel tax levels (compared to electricity tax levels). HGV's cost coverage of 33% is achieved through from revenues from variable taxes and charges, road tolls and fuel taxes, amounting to 1.3 €-cent/tkm on average in the EU28. For IWT, the cost coverage ratio is equal to 13%.

[57] For maritime transport, the cost coverage ratio is equal to 4%, while for LCVs this ratio equals 48%.

[58] While in general, the noise costs per tonne kilometre for a diesel and electric freight train are highly comparable, Figure 22 shows that electric freight trains noise costs are 0.2 €-cent/tkm higher than for diesel. This is because some countries with low noise costs, due to low population densities, happen to only use diesel freight trains. This has effectively lowered the EU28 average noise costs per tonne kilometre for diesel trains.

Figure 24 - Average variable external and infrastructure costs vs. average variable taxes/charges for freight transport



5.4.4 Overall infrastructure cost coverage

The overall infrastructure cost coverage ratio provides insight into whether revenues from infrastructure charges internalise all infrastructure costs. As Figure 25 shows, total infrastructure costs exceed the total infrastructure charges for all passenger vehicle types.

Buses and coaches' coverage 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 the remaining road vehicles, i.e. passenger cars and motorcycles. Motorcycles have revenues of 0.5 €-cent/pkm and cars generate 0.6 €-cent/pkm, which results in an overall infrastructure cost coverage of 22% for passenger cars and 28% for 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%). The differences in average costs shown in Figure 25 are mainly explained by the differences in infrastructure costs and infrastructure charge levels discussed before.

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

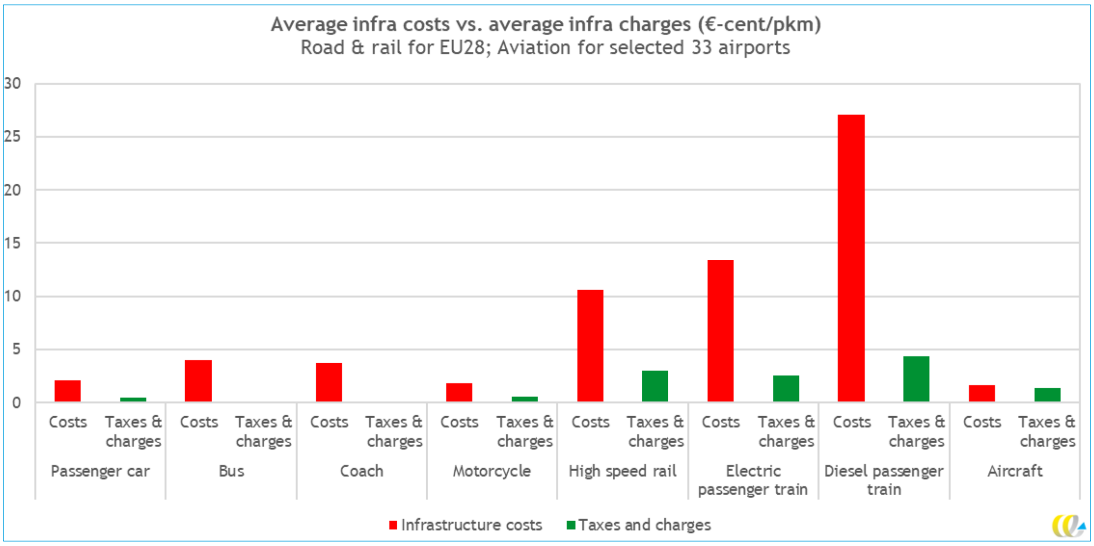


Figure 26 shows that, as with passenger vehicles, the total infrastructure costs caused by the freight vehicle types exceed the infrastructure charges levied on these vehicles[59,60]. HGV's cost coverage is 13%, with revenues (about 0.3 €-cent/tkm on average) coming from distance-based or time-based 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 to non-motorways.

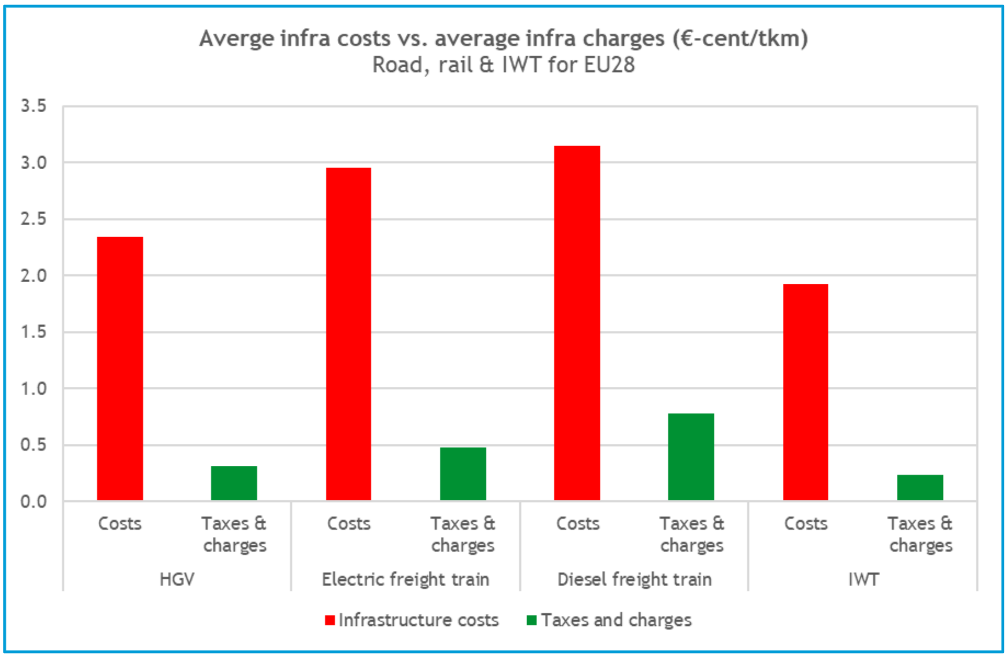
For rail transport, the cost coverage for diesel freight trains (25%) is higher than for electric freight trains (17%). The higher revenues on diesel freight trains mainly originate from higher average rail access charges in countries where all rail freight transport is performed by diesel trains, resulting in higher average access charge levels for diesel trains in the EU28.

The overall infrastructure cost coverage for IWT vessels is equal to 12%, because of low average taxes and charges (0.24 €-cent/tkm) compared to average costs (1.92 €-cent/tkm).

[59] An exception is maritime transport. For this mode, the total revenues from port charges are in line with the total infrastructure costs (cost coverage ratio of 127%). However, as discussed in previous chapters, due to limited maritime data availability, the uncertainty of both the total infrastructure costs and total port charge revenues for maritime transport is high.

[60] For LCVs, the overall infrastructure cost coverage ratio is 11%.

Figure 26 - Average infrastructure costs vs. average infrastructure taxes/charges for freight transport



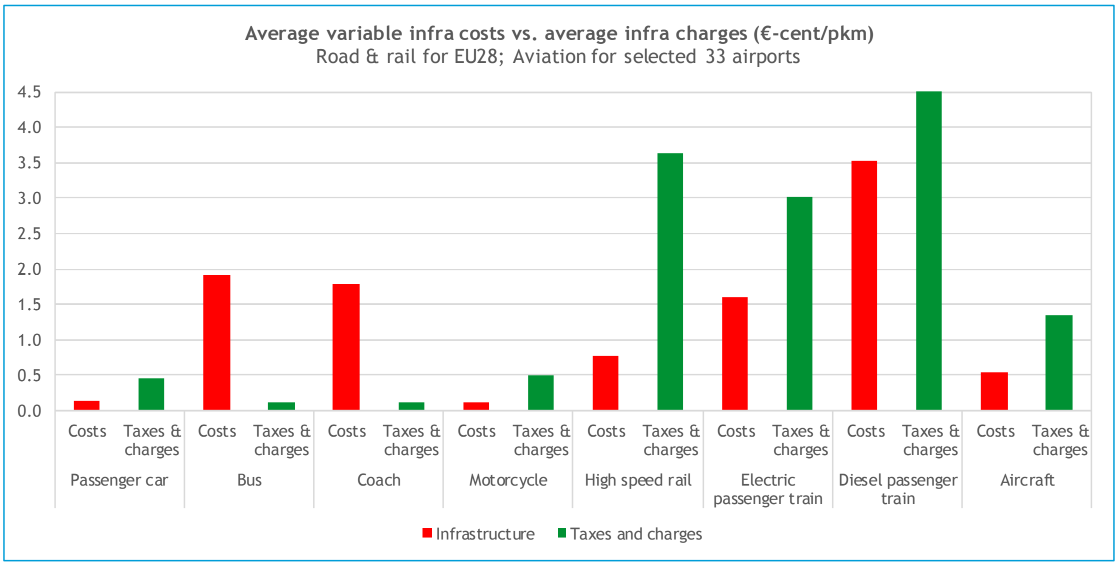
5.4.5 Variable infrastructure cost coverage

Figure 27 compares the average variable infrastructure costs with the total revenues from infrastructure charges for the various passenger vehicle types. 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 coverages are 5 and 6% respectively, as a result of high wear and tear costs (of about 1.9 €-cent/pkm and 1.8 €-cent/pkm, respectively) and the — on average — limited scope of road charges for these vehicles.
The variation seen for passenger trains, largely relates to the taxes and charges levied, in particular on the variations in access charges between vehicles types.

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

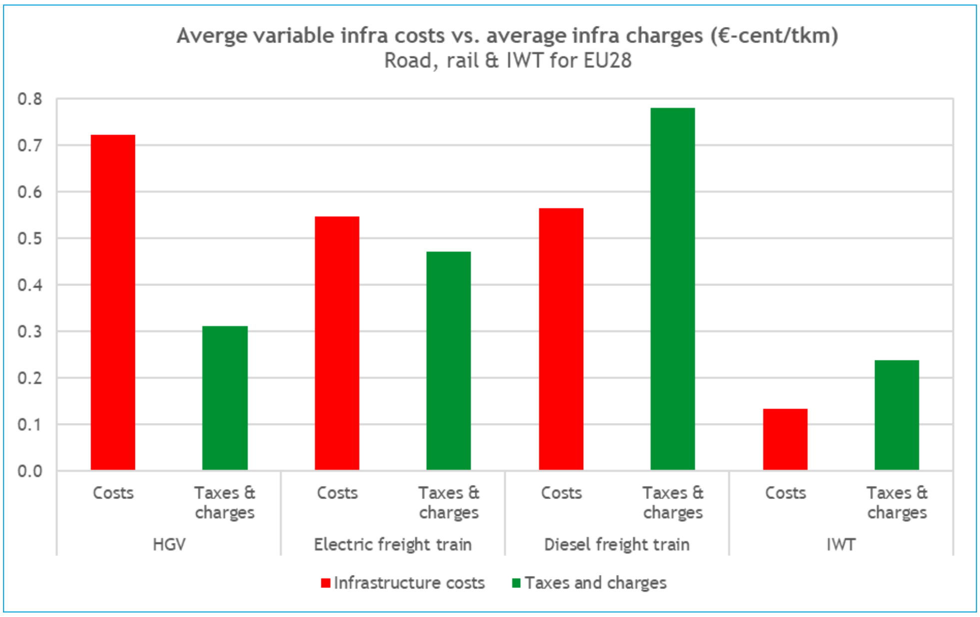


Finally, the average variable infrastructure costs and revenues from infrastructure charges for the freight vehicle types are presented in Figure 28[61,62]. HGV taxes and charges do not cover costs, with a cost coverage of 43%. For rail freight, no full cost coverage is found for electric freight trains (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. Finally, the revenues from infrastructure charges for IWT exceed the variable infrastructure costs for this mode with a cost coverage ratio of 176%.

61 For maritime transport, the revenues from port charges 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.

62 For LCVs, the variable infrastructure cost coverage is 153%.

Figure 28 - Average variable infrastructure costs vs. average infrastructure taxes/charges for freight transport



5.5 Marginal cost coverage

To assess the extent of internalisation from the perspective of Marginal Social Cost Pricing (MSCP), we utilise the marginal cost coverage ratio, as discussed in Section 5.2.2. 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. For example, for electric cars we only consider the marginal cost coverage ratio on motorways in rural areas. This scenario is not necessarily representative of real-world situations, as it is expected that electric vehicles will primarily operate in urban areas, over shorter distances.

The analyses carried out do, however, show that for many transport modes (except rail transport) 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. For example, to completely internalise marginal external congestion costs, a road charge differentiated by road segment and by time (minute by minute) should be implemented. Even if the marginal cost levels could be charged at this level of detail, it is unlikely that transport users would account for continuously fluctuating marginal external congestion cost levels. In addition, the technological solutions available for charging rapidly-varying levies are not straightforward. For these reasons, a certain degree of simplification (i.e. averaging of marginal cost figures) is inevitable when implementing MSCP.

The results of the marginal cost coverage analyses also show that the marginal cost coverage ratios for rail transport (except for high speed trains) are rather constant over the scenarios, indicating that the rail taxes and charges show some relevant aspects of marginal social cost pricing. This can be explained by the fact that rail access charges are (often) calculated with respect to marginal infrastructure costs. However, it is important to note that these are first, indicative statements and further assessment is required.

5.6 The broader context of internalisation

In addition to transport taxes and charges, other policy instruments (e.g. command and control measures and subsidies) may also contribute to achieving the objectives of internalisation. The analysis carried out focused on the contribution of these policy instruments towards reducing the external costs of transport. This review presents the key EU-level non-pricing measures, discussing their capacity to address market failures and their interaction with pricing measures. Table 17 provides a comprehensive list of the EU-level non-pricing instruments implemented in response to externalities in the transport sector, some of which are discussed below.

Non-pricing policies are applied instead of, or in addition to, taxes and charges for several reasons. Firstly, some external costs, such as air pollution, are **international in nature** and engender transboundary effects. Therefore, responding to these costs at an international (EU) level, brings added value. For example, the European emission standards, which define the acceptable limits for exhaust emissions of diesel locomotives and railcars, address the cross-border effects of air pollution associated with these rail vehicles. 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 effectiveness by which the air pollution issue is tackled.

Therefore, a harmonised approach at the European level, by applying emission standards to complement national taxes, may be preferred. In addition to rail, emissions standards also tackle the cross-border nature of air pollution for road, IWT, maritime and aviation, adding value to national instruments.

As transport taxes and charges lie under the authority of Member States, it is difficult to harmonise these at the EU level. Therefore, there is significant variation in taxes and charges between Member States, which may **distort the internal market**, as Member States implement varying specifications and place differing demands on industry. For this reason, EU-level harmonised measures may be preferable to national pricing measures.
For example, noise regulation for road vehicles creates a level playing field for vehicle OEMs, as all vehicles must satisfy the same standards. The clear framework, including the timeframe provided by the regulation, promotes research towards reducing noise. Therefore, this regulation not only ensures that administrative burden is consistent across all Member States, but also **supports investment** in noise-reducing technologies, establishing a level playing field for investment and enabling the development of economies of scale. Similar noise regulations apply to rail and aviation transport, enabling Member States to tackle noise through innovation.

Furthermore, as non-pricing measures are deemed less volatile than taxes and charges, they are likely to offer longer-term certainty to investors. For example, CO_2 performance standards for road vehicles are required to accelerate the market uptake of low-emission vehicles (LEVs). This complements preferential taxes and charges, through requiring a minimum standard and hence, reducing coordination and first-mover issues. In another example, the standards in place for professional drivers ensure that companies invest in training their employees and provide adequate working conditions, encouraging a high level of professionalism in the sector and enhancing road safety.

Non-pricing measures can also help to address the **energy paradox**, which refers to cases where vehicle owners are not incentivised to invest in fuel-reducing technologies, despite resultant reductions in fuel costs offsetting any investment costs. This can occur due to consumer myopia, barriers to financing options, imperfect information or split incentives. Although purchase and registration taxes differentiated by CO_2 emissions can partially solve the paradox, instruments such as fuel efficiency and CO_2 performance standards, are better equipped to solve it, as they provide consumers with greater certainty to invest in technologies and benefit from economies of scale. Concurrently, CO_2 differentiated taxes can support the demand for fuel-efficient vehicles, increasing the likelihood of meeting CO_2 performance standards in a cost-efficient way.

The **provision of information to consumers**, through instruments, such as labelling, has the potential to engender behavioural change and reduce the likelihood of the energy paradox. The EU implements car and tyre labelling schemes, to address the asymmetries of information between manufacturers and vehicle owners, with respect to fuel efficiency and the rolling-noise levels of tyres respectively. 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). Therefore, greater provision of information to consumers can help to address externalities, through encouraging consumers to act upon newfound awareness of the external costs caused by the transport sector.

A **lack of social and political support** for implementing or increasing taxes and charges may also provide the justification for implementing non-pricing measures. In some cases, non-pricing measures can even incentivise the implementation of pricing measures. For example, local authorities and national governments can draw upon the Ambient Air Quality Directive (AAQD), which requires Member States to adopt and implement air quality plans, to justify the implementation of taxes and charges. Pricing instruments may increase the pace of change, enabling countries and cities to meet the air pollutant concentration limits set by the AAQD over shorter timeframes. Therefore, in situations where charging vehicle owners or companies is unpopular, combining these measures with (or solely relying on) infrastructure investments, target-setting directives and softer measures, is more likely to effectively tackle the external cost at hand.

Non-pricing measures are also key to **addressing externalities which are not targeted by taxes and charges**. For example, accident costs are not directly addressed by current transport taxes and charges, largely due to the difficulty of internalising accident costs through pricing measures (CE Delft et al., 2008). Other policy instruments (mainly command and control measures) are used to improve transport safety. For example, road safety is regulated at the EU level by command-and-control measures, primarily through setting (minimum) safety standards or requirements. These EU-level measures, combined with national-level requirements (e.g. speed limits), provide a comprehensive response to external accident costs.

Table 17 - Overview of key EU-level non-pricing measures responding to external costs

Non-pricing Measure	Relevant Modes	Description
Climate change		
CO_2 standards	Road, Aviation	Sets mandatory targets for the average CO_2 emissions of vehicles/aircraft.
Car Labelling Directive	Road	Informs consumers on the fuel efficiency and CO_2 emissions of new cars.
Clean Vehicle Directive	Road	Requires that energy and environmental impacts linked to the lifetime of vehicles are taken into account in public procurement.
Alternative Fuels Infrastructure Directive	Road, IWT	Requires Member States to provide minimum infrastructure for alternative fuels.
Fuel Quality Directive	Road, Rail, IWT	Requires a reduction of the greenhouse gas intensity of transport fuels by 2020, to be achieved by using less CO_2 intensive fuels.
Renewable Energy Directive	Road, Rail, IWT	Sets targets for the share of renewable energy used in transport.
TEN-T Programme Funding	Rail	Funds electrification of rail infrastructure networks for the core TEN-T network.
Regulation on the monitoring and reporting of emissions	Maritime	Provides insight into robust and verified emissions data and stimulates the uptake of energy efficiency solutions.
Single European Sky Initiative	Aviation	Harmonise air traffic management systems through the deployment of innovative technological and operational solutions.
Air pollution		
Ambient Air Quality Directive	Road, Rail, IWT, Maritime, Aviation	Defines ambient air quality standards which require Member States to adopt and implement air quality plans.
National Emission Ceilings Directive	Road, Rail, IWT, Maritime, Aviation	Sets national total emission reduction targets and requires Member States to develop National Air Pollution Control Programmes.
Emissions Standards	Road, Rail, IWT, Maritime, Aviation	Defines acceptable emission limit values covering NO_x, carbon monoxide, unburned hydrocarbons and non-volatile particular matter emissions.
Noise		
Environmental Noise Directive	Road, Rail, Aviation	Monitors noise by requiring Member States to draw up 'strategic noise maps', provide information to the public and provide action plans to prevent or reduce exposure to noise.
Vehicle Noise Regulation	Road	Establishes requirements for the type-approval of all new motorised vehicles in relation to their sound level and silencing systems.
Noise regulation with respect to tyres	Road	Sets tyre-rolling noise requirements to ensure parameters relating to safety and environment are accounted for.
Tyre Labelling	Road	Introduces labelling requirements including information on the fuel efficiency, wet grip and external rolling noise of tyres.
Railway Interoperability Directive	Rail	Requirements for newly built wagons to meet certain noise emission limits.
Noise Certification Standards	Aviation	Regulates aircraft noise at source through noise standards.
Operating restrictions at Community airports	Aviation	Regulates procedures concerning the introduction of noise-related operating restrictions.

Non-pricing Measure	Relevant Modes	Description
Accidents		
Technical vehicle/vessel/aircraft regulations	Road, IWT, Maritime, Aviation	Regulation on type-approval requirements sets out safety and environmental requirements.
Vehicle/Vessel Inspection	Road, Maritime	Periodic technical inspection of vehicles/vessels and minimum standards for testing facilities.
Driving Licenses	Road	Provides harmonised EU-wide rules on driving licences.
Professional Driving Regulations	Road, Rail, IWT, Maritime, Aviation	Several measures are in place, such as required training and qualifications, minimum standards for working conditions and requirements for the use of speed limitation devices.
Road Infrastructure Safety	Road	Obliges Member States to conduct safety impact assessments and audits at the design, planning and operation stage of important European roads.
Railway Safety Directive	Rail	Creates a common European regulatory framework for safety and defines the tasks and responsibilities related to a safety management system (SMS).
Shift2Rail Joint Undertaking	Rail	A public private partnership, which pursues research activities in support of the achievement of the Single European Railway Area and aims to improve the competitiveness and safety of the European rail system.
River Information Systems	IWT	Establishes a framework for the deployment and use of harmonised river information systems.
Vessel Traffic Monitoring	Maritime	Establishes a vessel traffic monitoring and information system.
Passenger Safety Regulations	Maritime	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.
European Aviation Safety Agency	Aviation	Establishes the working methods of the European Aviation Safety Agency such that it can conduct standardised inspections.

6 Conclusions

6.1 Main conclusions

External and infrastructure costs are only partly internalised

The analyses carried out in this study show that the transport taxes and charges levied in the EU Member States are — in general — insufficient to fully internalise the external and infrastructure costs of transport. For most vehicle categories, only 15 to 25% of the external and infrastructure costs are covered by tax/charge revenues. The cost coverage ratio for passenger cars is higher (about 50%), which is mainly because of the relatively high fuel and vehicle tax levels applied in (some of) the EU Member States for these vehicles. For IWT and maritime transport, much lower cost coverage ratios were found (6 and 4%, respectively), reflecting the limited tax/charge burden levied on these modes in the EU.

Even if we exclude fixed infrastructure costs from the analyses[63], the current taxes and charges do not cover the external and variable infrastructure costs for most vehicle categories. High speed trains are an exception, as for these trains the current taxes and charges do cover all external and variable infrastructure costs.

Little evidence of using marginal social cost pricing

Variable external and infrastructure costs are generally not covered by variable taxes/ charges at the EU28 level, indicating that marginal social cost pricing in a simplified way is not achieved. This finding is supported/supplemented by the results of the analyses of marginal social cost coverage ratios. Despite the limitations of this analyses, it provides a first indication that there is a lack of charging in accordance with the MSCP principle in the EU28. Current transport tax/charge schemes are often not able to capture the large variance in the size of marginal external and infrastructure costs across different situations. In road passenger transport in particular, taxes and charges are very far from providing an approximate reflection of actual costs.

An exception is rail transport (particularly high-speed trains 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 can be made, even for rail, e.g. by further differentiating the access charges to noise.

Limited application of the user pays' principle

The 'user pays' principle is only applied to a limited extent in the EU28, as for most vehicle categories only 15 to 30% of the infrastructure costs are covered by infrastructure charges. For buses and coaches, even lower cost coverage ratios are found (3%), which reflects the relatively high (weight dependent) infrastructure costs caused by these vehicles as well as

[63] 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).

the fact that these vehicles are exempted from infrastructure charges in many EU Member States. In contrast to the land-based modes, aviation and maritime transport do meet the 'user pays' principle. The revenues from (air)port charges do cover for (most of) the infrastructure costs of (air)ports.

Although the total infrastructure costs are only partly covered by infrastructure charges, the variable infrastructure costs are internalised by these charges for most vehicle categories. The main exceptions are the heavy road vehicles (HGV, bus, coach), which can be mainly explained by the high weigh dependent infrastructure costs caused by these vehicles. Also for electric freight trains, full coverage of variable infrastructure costs is not achieved at the EU28 level.

Varying results with respect to earmarking of revenues

The revenues from transport taxes and charges in the EU28 are partly earmarked for expenditure for transport infrastructure. However, significant differences do exist between modes. For road transport, about 10% of the taxes/charges are earmarked, while for rail transport this is about 85%. For the other modes, only fragmented data on earmarking was identified, showing that (at least part of) the (air)port charges are earmarked to cover infrastructure expenditures.

Earmarking of revenues may be used to gain public support for future initiatives to increase the extent of internalisation of external and infrastructure costs of transport. However, it should be noted that applying earmarking results in a loss of efficiency, because revenues are not necessarily used to finance the most efficient projects (i.e. there may be economically more profitable projects to finance than transport infrastructure projects). Furthermore, 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.

6.2 Policy applications

Based on the results discussed above, a scoping analysis of potential policy options to further internalise the external and infrastructure costs of transport has been carried out. Some main options for further internalisation are:

- For *road transport*, the introduction of distance-based road charges differentiated to vehicle characteristics, location and/or time. This instrument may increase the overall internalisation rate, while at the same time it improves the internalisation of the (marginal) external air pollution, noise, climate change and congestion costs. 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. CO_2 standards, Euro standards, noise standards). For urban areas, specific urban road charging schemes may be considered in order to address the relatively high external costs of urban transport.
- For *rail transport*, mark-ups on rail access charges to cover the fixed infrastructure costs (although there may be arguments for not internalising these costs, as discussed above). Furthermore, the introduction of noise differentiations in the rail access charges may speed up the implementation of noise abatement measures at the existing fleet, effectively complementing the impact of the noise limits that are set for new wagons.
- For *IWT*, the appliance of fairway dues on a larger share 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). It complements the existing emission standards for new vessels, as this instrument also incentivise investments in emission reduction technologies for the existing fleet. Current legislations do, however, prohibit the introduction of fairway dues on the Rhine and its tributaries (the most important inland waterway(s) of the EU). Another option to further internalise the external costs of IWT is by extending the use of environmentally differentiated port charges.

- For *maritime transport*, environmentally differentiated port charges or differentiated fairway dues may be options to further internalise the air pollution costs. These measures would complement the IMO emission standards set for new vessels. With respect to GHG emissions, the EU works with global partners on further policy instruments.
- For *aviation*, further policies in the field of GHG emissions should preferably be done in cooperation with global partners in the International Civil Aviation Organisation (ICAO). Furthermore, environmentally differentiated airport charges or aviation taxes may be options to further internalise the local externalities of aviation (i.e. air pollution, noise).

Although taxes and charges are efficient policy instruments to reduce the external costs of transport, other types of policy instruments (e.g. command-and-control measures, subsidies) are applied as well to achieve this objective. Applying (differentiated) tax/charge measures to further internalise these costs may not be straightforward, particularly for (external) accident costs, as the level of these costs depend on a complex set of cost drivers. In this case, command-and-control measures are often more appropriate. Policies aimed to increase the utilisation rate of transport infrastructure (e.g. rail tracks) may result in lower average infrastructure costs and hence higher cost coverage ratios. But also for other externalities, non-pricing policies may effectively complement tax/charge schemes, e.g. by providing EU-wide harmonised incentives to invest in certain reduction technologies or because they are politically/socially more acceptable.

6.3 Recommendations for further research

This project provides state-of-the-art estimates of infrastructure and external costs of transport as well as a comprehensive overview of the transport taxes and charges applied in the EU28. Furthermore, a detailed overview of the extent of internalisation of the external and infrastructure costs of transport is given. However, there are some options to further improve and elaborate the analyses done in this project. For that purpose, further research on various topics is recommended. The main recommendations are to(see the other deliverables of this project for a more detailed description of the issues for further research):

- *Improve the accuracy and consistency of transport performance data sets at the EU level*. There are considerable differences between various sources on transport performance data in Europe. Improving and harmonising these data would be recommended. The composition of a consistent dataset based on the territoriality principle would significantly improve the assessments, particularly for road transport.
- *Construct more detailed and harmonised datasets on transport infrastructure expenditures*. More complete, detailed and harmonised datasets on transport infrastructure expenditures would result in more accurate estimates of infrastructure costs. For road, rail and IWT, data on transport infrastructure expenditure is available, but these data is often incomplete and not harmonised between countries, negatively affecting the robustness of the infrastructure cost estimates. For aviation and maritime transport, these data are currently not publicly available.

- *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.
- *More detailed comparisons of total/average costs and revenues*. As the various vehicle categories do not always compete on the same markets (e.g. average airplane vs. coach), it is recommended to carry out the analysis of average cost based pricing for specific sub-markets (e.g. short-haul trips) or corridors (e.g. Paris-Amsterdam) as well. Furthermore, detailed assessments for specific parts of the network (e.g. urban roads) may be interesting, as both external/infrastructure costs and tax/charge levels differ widely between different parts of the network.

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A Detailed external cost figures

A.1 Introduction

In this Annex, some more detailed external costs figures (at the EU28 level) are presented. In Annex A.2, we present detailed total external cost figures, while Annex A.3 shows the detailed average external cost figures.

A.2 Total external cost figures

The total external cost figures (at the EU28 level) for passenger transport and freight transport are presented in Table 18 and Table 19.

Table 18 - Total external costs 2016 for EU28 passenger transport by cost category and transport mode

	Road transport				Rail transport		
Cost category	Passenger car	Bus	Coach	Motorcycle	HST	Conventional electric train	Diesel train
Accidents	210.2	5.3		21.0	0.06	2.0	
Air pollution	33.4	1.4	2.7	1.8	0.002	0.03	0.52
Climate	55.6	0.8	1.6	1.5	0.00	0.00	0.22
Noise	26.2	0.8	0.9	14.8	0.4	2.6	0.9
Congestion[a]	196.1	4.5		n/a			
Well-to-Tank	18.1	0.3	0.5	0.8	0.3	2.7	0.1
Habitat damage	25.9	0.2	0.4	0.5	0.7	1.4	0.5
Total	**565.4**	**19.3**		**40.5**	**1.4**	**11.0**	
Total per mode	**625.2**				**12.5**		
Total as % of EU28 GDP	**4.2%**				**0.1%**		
Total passenger transport	**637.7**						

[a] Congestion in terms of delay cost.

Table 19 - Total external costs 2016 for EU28 freight transport by cost category and transport mode

	Road transport		Rail transport		IWT
Cost category	LCV	HGV	Electric train	Diesel train	Inland vessel
Accidents	19.8	23.0	0.3		0.1
Air pollution	15.5	13.9	0.01	0.7	1.9
Climate	13.2	9.6	0.00	0.2	0.4
Noise	5.4	9.1	2.1	0.4	
Congestion[a]	55.5	14.6			
Well-to-Tank	3.8	3.7	0.5	0.1	0.2
Habitat damage	4.4	3.6	0.8	0.2	0.3
Total	**117.6**	**77.5**	**5.4**		**2.9**
Total per mode	**195.1**		**5.4**		**2.9**
Total as % of EU28 GDP	**1.31%**		**0.04%**		**0.02%**
Total freight transport	**203.4**				

[a] Congestion in terms of delay cost.

Table 20 presents the total external costs for the selected EU28 (air)ports.

Table 20 - Total external costs for selected EU28 (air)ports

Cost category	Aviation							Maritime
	Passenger			Freight (belly freight)			Total	
	Short	Medium	Long	Short	Medium	Long		
Accidents	0.1						0.1	0.1
Air pollution	0.24	0.32	0.30	0.03	0.06	0.06	1.0	29.1
Climate	1.9	4.9	12.3	0.21	0.63	2.06	22.0	10.6
Noise	0.8						0.8	n/a
Congestion	n/a						n/a	n/a
Well-to-Tank	0.86	1.84	4.93	0.09	0.26	0.90	8.9	3.9
Habitat damage	0.050			0.006			0.056	n/a
Total selected (air)ports	**28.6[a]**			**4.3**			**32.9**	**43.6**
Total for selected (air)ports as % of EU28 GDP	**0.2%**			**0.03%**				**0.3%**

[a] Noise and accident costs have been allocated to passenger transport.

A.3 Average external cost figures

The average external cost figures (at the EU28 level) for passenger transport and freight transport are presented in Table 21 and Table 22.

Table 21 - Average external costs 2016 for EU28 passenger transport by cost category and transport mode

Cost category	Road transport				Rail transport		
	Passenger car	Bus	Coach	Motorcycle	HST	Conventional electric train	Diesel train
Accidents	4.5	1.0	1.0	12.7	0.1	0.5	0.5
Air Pollution	0.7	0.8	0.7	1.1	0.0	0.01	0.80
Climate	1.2	0.5	0.4	0.9	0.0	0.0	0.3
Noise	0.6	0.4	0.2	9.0	0.3	0.8	1.4
Congestion[a]	4.2	0.8	0.8				
Well-to-Tank	0.4	0.2	0.1	0.5	0.3	0.8	0.1
Habitat damage	0.5	0.1	0.1	0.3	0.6	0.6	0.8
Total	**12.1**	**3.8**	**3.3**	**24.5**	**1.3**	**2.71**	**3.9**
Environmental Costs[b]	**3.4**	**2**	**1.5**	**11.8**	**1.2**	**2.21**	**3.4**

[a] Congestion in terms of delay costs.

[b] Air pollution, climate, WTT, noise and habitat damage costs.

Table 22 - Average external costs 2016 for EU28 freight transport by cost category and transport mode

	Road transport		Rail transport		IWT
	LCV (diesel)	HGV	Electric freight	Diesel freight	Inland vessel
Cost category	€-cent/vkm	€-cent/tkm	€-cent/tkm	€-cent/tkm	€-cent/tkm
Accidents	4.1	1.3	0.1	0.1	0.1
Air Pollution	3.4	0.8	0.0	0.7	1.3
Climate	2.8	0.5	0.0	0.2	0.3
Noise	1.1	0.5	0.6	0.4	n/a
Congestion[a]	11.6	0.8			
Well-to-Tank	0.8	0.2	0.2	0.1	0.1
Habitat damage	0.9	0.2	0.2	0.2	0.2
Total	**24.7**	**4.3**	**1.1**	**1.7**	**2.0**
Environmental Costs[b]	**9**	**2.2**	**1**	**1.6**	**1.9**

[a] Congestion in terms of delay costs.

[b] Air pollution, climate, WTT, noise and habitat damage costs.

Finally, Table 23 presents the average external costs for selected EU28 (air)ports.

Table 23 - Average external costs for selected EU28 (air)ports

	Aviation passenger			Maritime
	Short haul	Medium haul	Long haul	Maritime ship
Cost category	€-cent/pkm	€-cent/pkm	€-cent/pkm	€-cent/tkm
Accidents	0.04	0.01	0.00	0.001
Air Pollution	0.30	0.13	0.06	0.44
Climate	2.39	1.85	2.24	0.16
Noise	0.46	0.11	0.01	n/a
Congestion	n/a	n/a	n/a	n/a
Well-to-Tank	1.06	0.70	0.91	0.06
Habitat damage	0.03	0.01	0.00	n/a
Total	**4.28**	**2.81**	**3.22**	**0.66**
Environmental Costs[a]	**4.24**	**2.8**	**3.22**	**0.66**

[a] Air pollution, climate, WTT, noise and habitat damage costs.

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