Infrastructure and external cost coverage of road freight transport on EU28 motorways

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Content

Summary

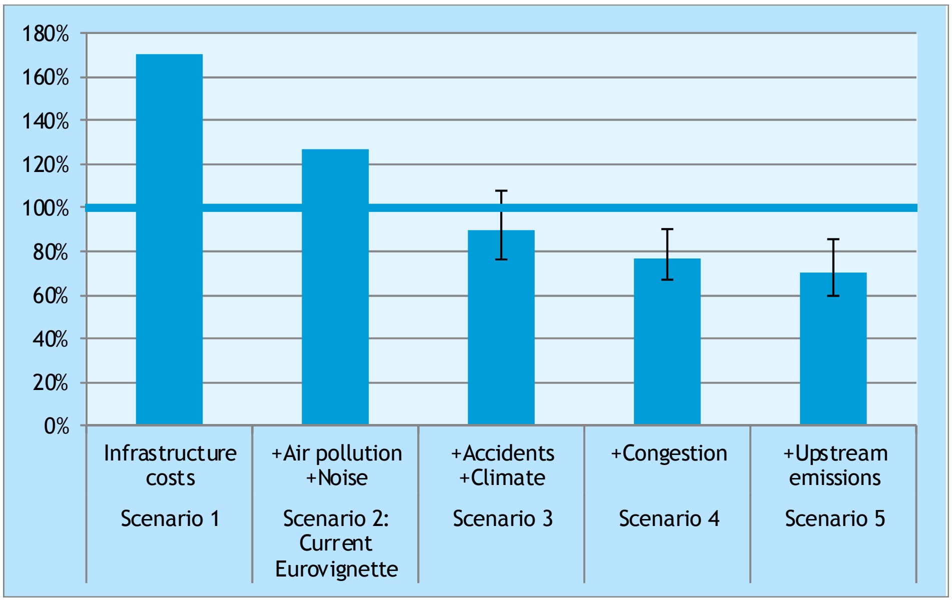
Internalising the infrastructure and external costs of transport is an important objective of the European Commission's transport policy. In road freight transport, the Eurovignette Directive is one of its main instruments to stimulate Member States to implement the 'polluter-pays' and 'user-pays' principles in their transport taxes and charges, in order to ensure that these national instruments better reflect the social costs of transport. Therefore, this Directive provides that the infrastructure costs and some external costs (air pollution, noise) can be leveraged through tolls and vignettes to heavy goods vehicles (HGVs).

In light of the planned revision of the Eurovignette Directive, IRU commissioned CE Delft to examine the infrastructure and external costs of road freight transport on EU28 motorways versus the revenue that is collected from taxes and charges paid by this sector.

A significant part of the infrastructure and external costs are already covered by taxes

The revenue from current taxes and charges related to the kilometres driven by vans and HGVs on EU28 motorways do cover the cost categories that are included in the current Eurovignette Directive (infrastructure costs, air pollution and noise) associated to these kilometres. The revenue exceeds these costs by 28% for HGVs (see Figure 1) and 42% for vans.

Figure 1 **Cost coverage ratios for all scenarios for HGVs on EU28 motorways in 2013**



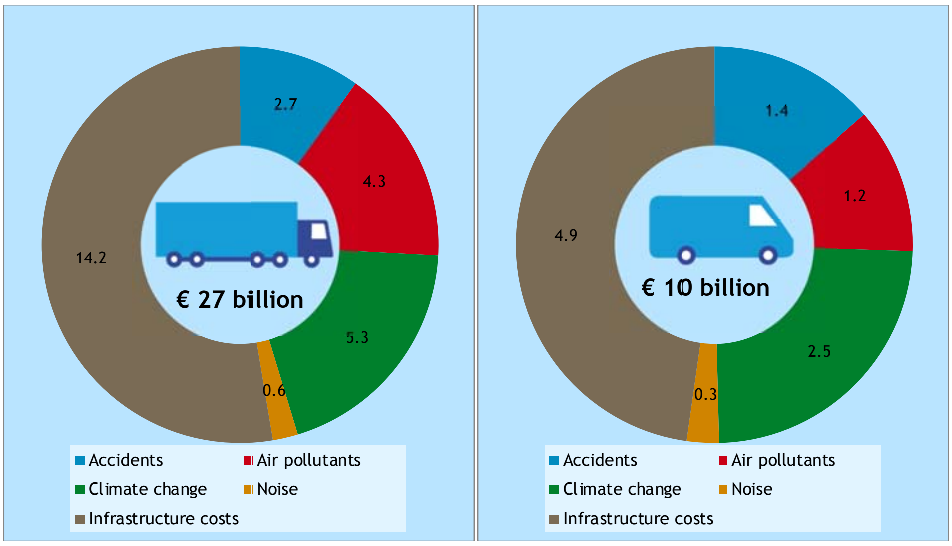
Note: A cost coverage ratio presents what share of the infrastructure and/or external costs are covered by tax revenues. E.g. a cost coverage ratio of 128% means that tax revenues are 28% higher than costs.

However, the revenue from current taxes and charges do not completely cover all infrastructure and external costs related to kilometres driven on EU28 motorways. As is shown in Figure 1, the costs exceed the revenue by 10% (-8% to 23%) for HGVs (and by -11% to 27% for vans)[1]. Including congestion costs and upstream emission costs as well would further increase the difference between cost and revenue.

Total infrastructure and external costs of road freight transport are € 37 billion

In this study the infrastructure costs of EU28 motorways that can be allocated to HGVs and vans are considered, as well as the external costs (accidents, air pollution, climate change, noise) that are related to the kilometres driven by these vehicles on these motorways. From the total infrastructure and external costs of € 37 billion, almost three quarters (73%) are caused by HGVs (€ 27 billion). Both for HGVs and vans, infrastructure costs contribute most to the total costs, followed by climate change and air pollution costs (see Figure 2).

Figure 2 **Total external and infrastructure costs (excluding congestion and upstream emissions) of HGVs and vans on motorways in the EU28 in 2013 (billion €$_{2013}$)**



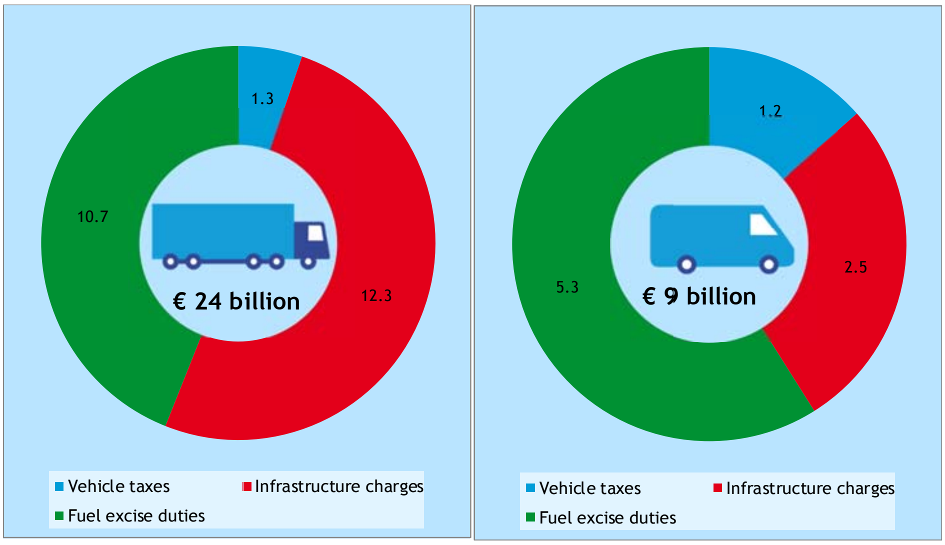
As congestion costs are (partly) borne by the same parties causing them, it is not completely clear to what extent they can be regarded external from a total cost perspective. For that reason these costs are presented separately in this study. The congestion costs of road freight transport on motorways are roughly estimated at € 7 billion in 2013 (HGVs: € 4 billion; vans: € 3 billion). The costs of upstream emissions are presented separately as well, as these effects are indirectly related to road transport. These costs are estimated at € 4.3 billion (€ 2.1 - € 6.4 billion).

[1] The range in these results is coming from the uncertainty in the costs of climate change and upstream emissions.

Revenue of road freight transport taxes estimated at € 33 billion

The revenue collected from specific transport taxes (registration tax, ownership tax, insurance tax, road infrastructure charges, fuel excise duties) for HGVs and vans in 2013 in the EU28 is estimated at € 33 billion. For all taxes/charges, only the share that can be related to the kilometres driven on motorways is taken into account. By breaking down the total revenue to vehicle type, it is seen that HGVs contribute about 73% of the total revenue (24 billion). Fuel excise duties (vans) and infrastructure charges (HGVs) contribute most, while the revenue from vehicle taxes is rather limited.

Figure 3 **Total tax/charge revenue from HGVs and vans associated to kilometres driven on motorways in the EU28 in 2013 (billion $€_{2013}$)**



Part of road freight transport tax revenue is earmarked

Based on a thorough analysis of national road freight transport taxation schemes, we find that part of the revenue of these taxes/charges are earmarked for investments in road infrastructure and/or mitigation measures for the external costs of road transport. For HGVs, 35% of the total tax/charge revenue related to kilometres driven on EU28 motorways has been earmarked, while for vans this share is about 20%. The majority of this earmarked revenue is coming from road infrastructure charges; in contrast to vehicle taxes and fuel excise duties, the revenue from this instrument is earmarked in most European countries.

Robustness of results

The results of this study contain some uncertainties, which has to be kept in mind when interpreting them. Particularly, the congestion cost estimates should be considered rough estimates, as they are based on model exercises (because EU wide consistent congestion indicators are not available). The costs of GHG emissions are uncertain as well, which is closely linked to the uncertainty on the social costs of climate change. To reflect this large uncertainty, a bandwidth of the cost of climate change is presented.
Finally, particularly the data on infrastructure expenditures in Eastern Europe is rather scarce, resulting in relatively significant uncertainties in the infrastructure cost estimates for EU28 motorways.
Despite these uncertainties, the order of magnitude of the results is reliable and hence the general conclusions presented in this study are considered to be robust.

1 Introduction

1.1 Background

Freight transport is fundamental to our economy. It facilitates the free flow of goods, contributes to productivity in all other economic sectors, and is a cornerstone in the growth of the EU economy. By accounting for about three quarters of the total inland freight transport (Eurostat, 2016) road transport is the most dominant freight transport mode. With an annual turnover of more than € 300 billion and almost 3 million jobs (1.3% of total EU employment) in 2012 (European Commission, 2015), road freight transport not only enables economic growth in the EU28, but is in itself a dominant economic sector in the EU28 as well.

On the other hand, road freight transport results in some societal cost. Governments spend a significant part of their budgets on the construction and maintenance of road infrastructure. Furthermore, road freight transport results in various types of external costs (e.g. air pollution, climate change, noise, accidents).

Internalising the external and infrastructure costs is an important objective of the transport policy of the European Commission. In its Transport White Paper, the Commission states that transport charges and taxes should better reflect the real costs to society by wider application of the 'polluter-pays' and 'user-pays' principle (European Commission, 2011). This aim is partly operationalised in the Eurovignette Directive[2], which provides a framework for internalising the infrastructure and external costs of heavy goods vehicles (HGVs) by use of distance-related tolls and time-based user charges (vignettes). The current Directive provides Member States the opportunity to charge HGVs for their infrastructure costs and part of their external costs (i.e. air pollution, noise) through tolls and vignettes.

In view of a future revision of the Eurovignette Directive, IRU has commissioned CE Delft to provide a state-of-the-art overview of the total infrastructure and external costs of road freight transport in the EU28, and to assess to what extent these costs are covered by the revenue from taxes and charges levied on this sector.

1.2 Objective

The objective of this study is to examine to what extent the infrastructure and external costs of road freight transport on EU28 motorways in 2013 are covered by the revenue from the taxes and charges related to the kilometres driven by these vehicles on these motorways. We investigate this for several scenarios, differentiating between the types of external cost to be covered and the type of vehicles considered.

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[2] Directive 1999/62/EC, modified by Directive 2006/38/EC and by Directive 2011/76/EU, (EC, 1999) (EC, 2006) (EC, 2011).

In order to achieve this objective, the following research questions are addressed in this study:

1. What are the infrastructure and external costs related to the kilometres driven by road freight transport on EU28 motorways in 2013?
   a How can infrastructure and external costs of road freight transport be defined?
   b Which methodologies should be applied to estimate the infrastructure and various external costs of road freight transport?
   c What is the total amount of infrastructure and external costs of HGVs and vans on EU28 motorways in 2013?
2. What is the amount of road tax/charge revenue related to the kilometres driven by road freight transport on EU28 motorways in 2013?
   a What are the relevant taxes/charges applied in the EU28?
   b What is the total revenue from these taxes/charges for HGVs and vans in the EU28 in 2013?
   c What share of the total revenue can be allocated to kilometres driven on the EU28 motorways in 2013?
   d What share of the revenue is earmarked for spending on road infrastructure or to mitigate the external costs of road transport?
3. How are the total infrastructure and external costs compared to the total tax/charge revenue, both related to the kilometres driven by road freight transport on EU28 motorways in 2013?
   a Which scenarios can be used to compare total costs and revenue?
   b What are the infrastructure and external cost coverage ratios for road freight transport on EU28 motorways in 2013?

1.3 Scope

In this study, the following basic principles are applied:

– This study considers the total infrastructure and external costs and the total tax/charge revenue, both related to the kilometres driven by HGVs and vans on motorways. The specific cost categories considered are discussed in Section 2.1, while the taxes and charges considered in this study are defined in Section 3.1. Transport subsidies are not covered by this study.
– The various infrastructure and external cost categories are defined in line with the concepts presented in the Eurovignette Directive. This implies, for example, that all cost elements mentioned in the Eurovignette Directive are included in this study. The Eurovignette Directive applies a hybrid perspective with respect to the cost perspective to be applied: the use of total/average infrastructure costs is prescribed, while for external costs a marginal cost perspective is recommended. However, for the purpose of this study (i.e. to examine to what extent tax/charge revenue cover the infrastructure and external costs of road freight transport) a marginal perspective is not appropriate. Therefore, we apply a total cost perspective. See the text box below for a more detailed discussion on this topic.
– Geographical scope: the study covers the EU28.
– All data is presented for the year 2013 and expressed in euro price level 2013. Data from sources where price levels from other years were used, were translated to price level 2013 by Consumer Price Indices (CPI). Furthermore, by using PPP corrections all figures are estimated at the EU28 average price level.

Total/average vs. marginal costs

In assessing infrastructure and external costs of transport, a clear distinction between total and average costs on the one hand and marginal costs on the other hand should be made:

- Total costs reflect the full costs in billion Euros. Average costs are closely related to total costs, as they are defined as the total costs divided by the total number of vehicle or tonne kilometres.
- Marginal costs are the costs caused by one vehicle entering an existing traffic flow.

Marginal costs may differ significantly from total/average cost figures. For example, the marginal noise costs heavily depend on traffic density: an additional vehicle on a road with a high traffic intensity results in relatively low marginal noise costs (i.e. the additional noise generated by the 'extra' vehicle is small), while an additional vehicle on a road with a low traffic intensity results in relatively high marginal noise costs (i.e. the additional vehicle produces a significant amount of extra noise). So, depending on the context, marginal noise costs may be higher or lower than the average noise costs. Also for external accident and congestion costs, large deviations between marginal and average cost figures may exist.

Total/average and marginal cost figures provide different information. These figures can, therefore, be used for different purposes:

- Total and average costs provide useful information on the user-pays and polluter-pays principle. By comparing these costs with the total/average revenue from taxes and charges, it is shown to what extent a certain vehicle category pays for the costs it imposes on society. As this is the main objective of this study, we have applied a total cost perspective for our assessments.
- Marginal costs provide a good basis to develop an efficient pricing scheme. By levying each individual vehicle the exact costs it imposes on society (i.e. marginal costs), transport users will take account of the additional external effects of their transport decision in just the same way as they do with private costs and hence the transport market can do its proper work in achieving social efficiency. Since the development of economic efficient charge levels is not the objective of this study, we haven't studied marginal cost values.

1.4 Outline of the report

The total infrastructure and external costs of kilometres driven by HGVs and vans on EU28 motorways in 2013 are estimated in Chapter 2, while the relevant tax and charge revenues are discussed in Chapter 3. In Chapter 4, several scenarios for comparing these costs and revenue are assessed. Finally, the main conclusions of this study are presented in Chapter 5.

2 Infrastructure and external costs

2.1 Introduction

Road freight transport on EU28 motorways results in different types of infrastructure and external costs. The main ones are:
- infrastructure costs;
- accident costs;
- air pollution costs;
- costs of climate change;
- noise costs;
- congestion costs;
- costs of upstream emissions.

All these cost categories will be assessed separately in this chapter, addressing the first research question of this study (see the text box below). Finally, in Section 2.8 an overview of the total infrastructure and external costs is presented for both HGVs and vans.

Research question **1**
What are the infrastructure and external costs related to the kilometres driven by road freight transport on EU28 motorways in 2013?

This question consists of three sub questions:
a *How can infrastructure and external costs of road freight transport be defined?*
b *Which methodologies should be applied to estimate the infrastructure and various external costs of road freight transport?*
c *What is the total amount of infrastructure and external costs of HGVs and vans on EU28 motorways in 2013?*

2.2 Infrastructure costs

2.2.1 Defining infrastructure costs

In line with the Eurovignette Directive, we define infrastructure costs as the direct expenses, 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). Financing or opportunity costs are expressed by the interest on capital, where the interest rates vary with the legal status of the investor. As financing of road infrastructure is an issue for public bodies (as well as for private investors), both direct expenditures and financing costs should be taken into account when considering infrastructure costs.

In this study, four types of infrastructure costs are considered:
- *Enhancement costs:* All costs of new infrastructure or expansion of existing infrastructure with respect to functionality and/or lifetime.
- *Renewal costs*: All costs associated to 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.

– *Maintenance costs:* These costs refer to the costs of 'ordinary' maintenance. These are relatively minor repairs with an economic lifetime of less than 1 to 2 years.
– *Operational costs:* These costs refer to the costs of the organisation of an efficient use of the infrastructure[3].

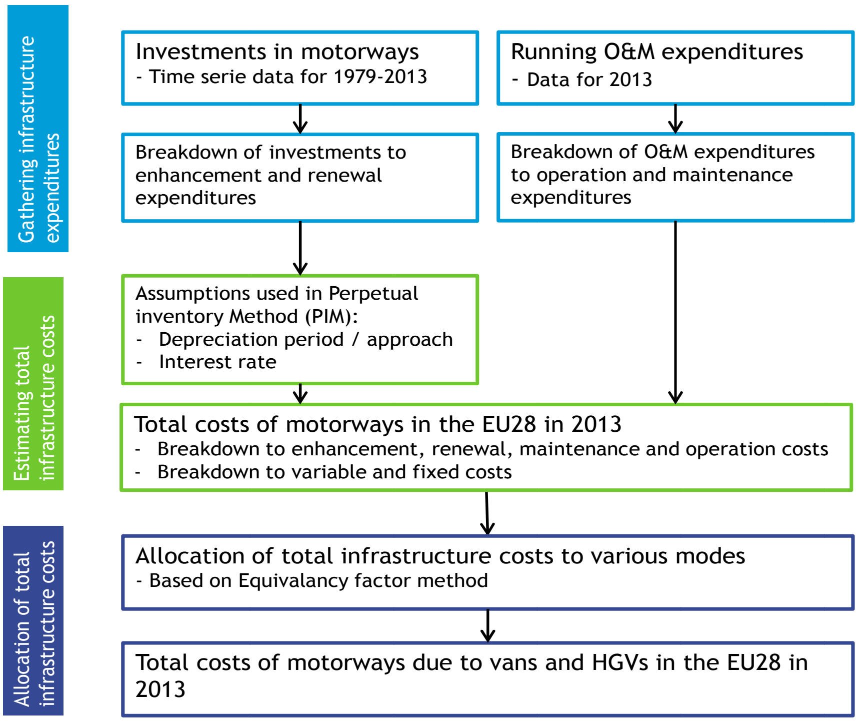
Infrastructure costs can be classified by the way they are influenced by the infrastructure usage, i.e. transport volumes. According to this classification, the following types of costs are defined (Ecorys ; CE Delft, 2006):
– *Variable costs*: Costs that vary with transport volumes while the functionality of the infrastructure remains unchanged. Part of the maintenance and renewal costs belongs to this cost category.
– *Fixed costs:* Costs that do not vary with transport volumes while the functionality of the infrastructure remains unchanged, or costs that enhance the functionality of the infrastructure. Construction costs and operational costs are examples of fixed infrastructure costs. Also some of the maintenance and renewal costs are (partly) fixed costs.

The distinction between variable and fixed infrastructure costs is used for the allocation of the costs to different vehicle types (see Section 2.2.2).

2.2.2 Methodology

Figure 4 shows the three step approach we have applied to estimate the costs of motorways for HGVs and vans:
– gathering data on infrastructure expenditures;
– estimating total infrastructure costs;
– allocation of total infrastructure costs to the various vehicle categories.

Figure 4 Methodology for estimating infrastructure costs



3 E.g. street lighting, traffic signs, etc.

Gathering data on infrastructure expenditures

The data on motorway infrastructure expenditures in the various EU Member States has been collected from national accounts and data from the International Transport Forum. If data was not available for a specific country, they have been estimated using average expenditure levels per kilometre motorway. More information on the approach applied to estimate the required data on total infrastructure expenditures can be found in Annex A.2.1.

For most countries, only a breakdown of infrastructure expenditures to investments and operational & maintenance expenditures was available. A further breakdown to the four types of infrastructure expenditures defined above has been made by the researchers. See Annex A.2 for more details.

Estimating total infrastructure costs

Based on the infrastructure expenditure data gathered in the first step, the total costs of motorways in the EU28 in 2013 are estimated. Therefore, different approaches have been used to estimate the enhancement and renewal cost on the one hand, and the maintenance and operation costs on the other hand.

Enhancement and renewal costs

The enhancement and renewal costs are estimated by applying the Perpetual Inventory Method (PIM). This method is closely related to the general philosophy of public accounting, and for that reason widely used in infrastructure cost studies (e.g. see ITS, 2000; UNITE, 2000; Fraunhofer ISI and CE Delft, 2008; CE Delft, on-going). The PIM calculates the annual depreciation costs by distributing the initial investments over the lifetime of the infrastructure. Additionally, the interest/financing costs are estimated by using an appropriate interest rate. The total enhancement/renewal costs are found by summing up the depreciation and interest costs. Details on the appliance of the PIM can be found in Annex A.2.2.

Once the enhancement and renewal costs are calculated by applying the PIM, a breakdown to fixed and variable costs is made. This is done based on detailed data for the Netherlands (see CE Delft and Free University Amsterdam, 2014). It is assumed that enhancement costs are fully fixed, while renewal costs are assumed 60% variable and 40% fixed.

Operation and maintenance costs

The operation and maintenance costs are directly based on the expenditures in 2013. As these expenditures generally have an economic lifetime below one or two years, capitalisation according to the PIM approach is not necessary.

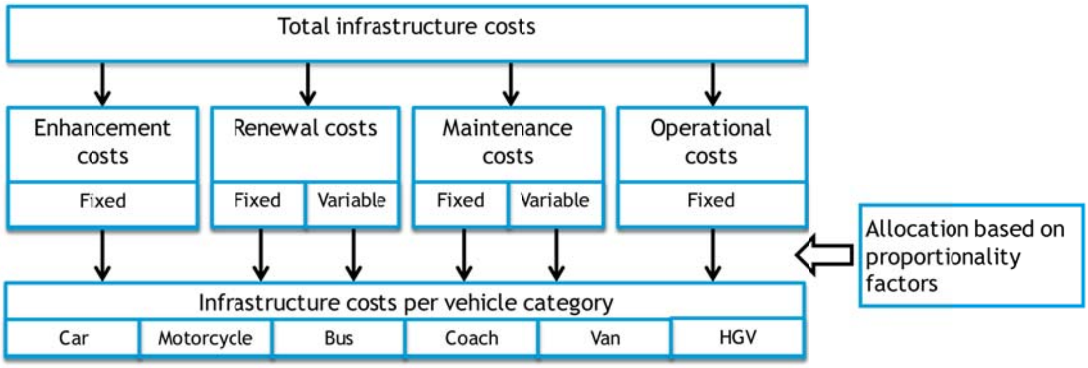
The breakdown to fixed and variable costs is again based on specific Dutch data (see CE Delft and Free University Amsterdam, 2014). Operation costs are assumed to be fully fixed, while maintenance costs are assumed 30% variable and 70% fixed.

Allocation of total infrastructure costs to various vehicle categories

In the final step, the total costs of motorways are allocated to the various vehicle categories. This has been done by applying the equivalency factor method, an approach widely applied in infrastructure cost studies (see for example: CE Delft and Free University Amsterdam, 2014; ProgTRans/IWW, 2007; ITS, 2000). This method defines certain proportionality factors (cost drivers) for each vehicle type and cost category which express the responsibility or the causation of the vehicles for the level of total costs

(Fraunhofer ISI and CE Delft, 2008). The approach is graphically illustrated in Figure 5.

Figure 5 Equivalency factor method



An overview of the specific proportionality factors applied in this study is given in Table 1. These proportionality factors are in line with the most recent infrastructure cost studies carried out in Europe (CE Delft and Free University Amsterdam, 2014; CE Delft, on-going). A more detailed discussion on the proportionality factors applied can be found in Annex A.2.3.

Table 1 Applied proportionality factors

Cost category	Proportionality factor
Enhancement costs	– PCE kilometres (90%) – 4th power axle load kilometres (10%)
Renewal costs	– PCE kilometres (40%) – 4th power axle load kilometres (60%)
Variable maintenance costs	– 4th power axle load kilometres (100%)
Fixed maintenance costs	– PCE kilometres (50%) – Vehicle kilometres (35%) – Allocated to HGVs (15%)
Operation costs	– Vehicle kilometres (30%) – PCE kilometres (70%)

2.2.3 Results

In Table 2, the total costs of motorway infrastructure allocated to HGVs and vans in the EU28 are presented. For vans, the total infrastructure costs are 95% fixed and 5% variable. The share of variable costs is higher for HGVs (about 18%); as variable costs are particularly weight dependent, they are mainly caused by vehicles with high axle loads (i.e. HGVs and buses).

Table 2 Total costs of motorway infrastructure allocated to vans and HGVs in the EU28 in 2013 (billion $€_{2013}$)

Vehicle category	Total costs	Fixed costs	Variable costs
HGV	14.2	11.5	2.7
Van	4.9	4.7	0.2

2.3 Accident costs

2.3.1 Defining accident costs

Traffic accidents result in several social costs, i.e. immaterial costs (lifetime shortening, suffering, pain, sorrow, etc.), medical costs, production losses, administrative costs (e.g. costs for police, justice, etc.), and material damages. A more detailed overview of these cost elements is given in Table 3.

Table 3 External accident costs elements

Cost element	Fatalities	Injuries
Immaterial costs	Loss of utility of the victim, suffering of friends and relatives	Pain and suffering of victims, friends and relatives
Medical costs	External costs for medical care before the victim deceased	External costs for medical care until the person completely recovers from his/her injury
Production losses	Net production losses due to reduced working time, replacement costs	
Administrative costs	Costs for police, for the administration of justice and insurance, which are not carried by the transport users	
Material damages	Damages to vehicles and/or road infrastructure	

From the various cost elements, only the external parts should be considered. The accident costs that are anticipated for by road users are internal and should therefore be excluded from the external cost estimation. In literature (e.g. GRACE, 2006; UNITE, 2000; CE Delft et al., 2011), it is usually assumed that road users do take their own accident risks into account, but not the risk they impose on other road users. We assume, therefore, that the costs experienced by the van/truck drivers themselves are internalised and should not be taken into account in the external cost estimation.

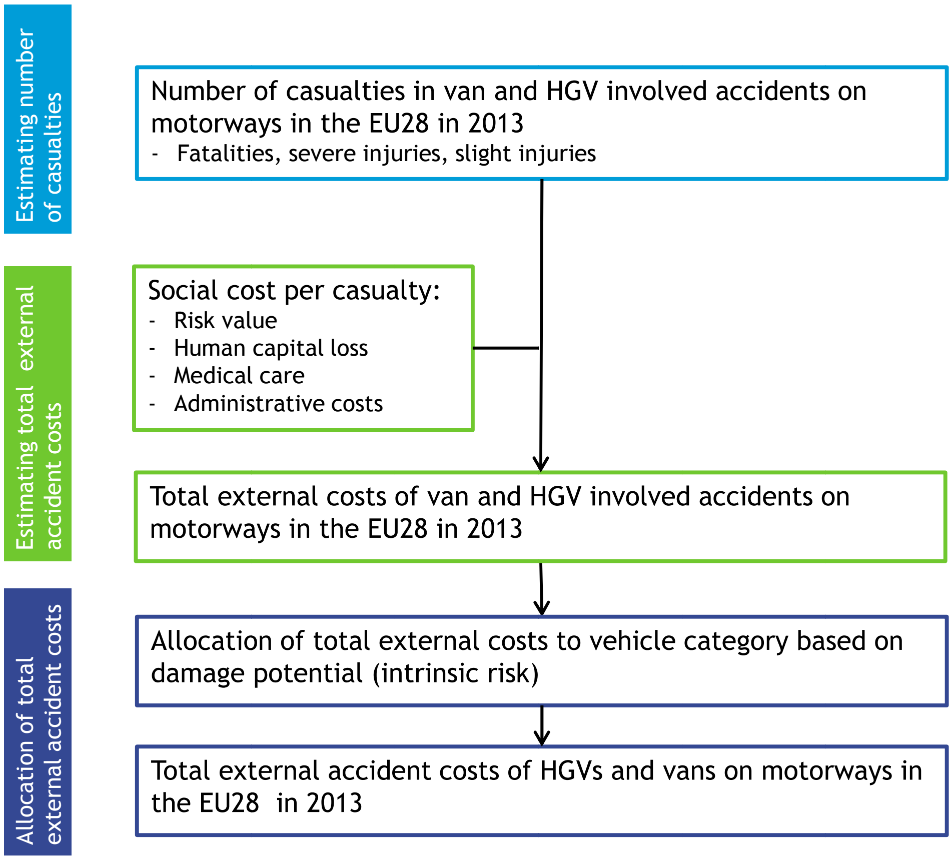
Furthermore, part of the accident costs are internalised by insurance premiums and are therefore excluded from the external cost estimation as well. We assume that all material damages are covered by insurances and hence are internalised. Additionally, we took into account that some part of the medical and administrative costs is covered by insurances as well.

2.3.2 Methodology

In Figure 6, the three step approach to estimate the external accident costs is explained:

- estimating the number of casualties;
- estimating the total external accident costs;
- allocation of total external accident costs.

Figure 6 Methodology to estimate external accident costs



Estimating the number of casualties

The total number of casualties in HGV and van involved accidents on EU28 motorways were available from the European Road Accident Database CARE. It provides data on the number of fatalities, severe injuries and slight injuries in these accidents, based on reported figures by the various Member States. Due to underreporting, these figures do probably not reflect the actual number of casualties. Particularly slight injuries are often not mentioned in policy reports and are therefore not reflected in the official statistics. CE Delft et al. (2008) present indicators that can be used to correct for such underreporting. However, these indicators are average figures for the total road network. As we expect that underreporting rates on motorways are significantly lower than on other road types, we decided not to correct for underreporting in this study. This may result in an underestimation of the total external accident costs, but we expect this underestimation to be limited.

Estimating the total external accident costs

To estimate the total external accident costs of HGV and van involved accidents on motorways, the number of casualties is multiplied with relevant cost indicators. An overview of these indicators is given in Table 4. The immaterial costs are monetarised by use of the Value of a Statistical Life (VSL). In this concept, individuals are asked how much they are willing to pay for a certain reduction of the accident risk. Based on these values, the VSL is calculated. In the literature a huge range of VSLs are presented. In this study we applied the VSL recommended by Ricardo-AEA (2014), which is about € 1.95 million (EU-average). The cost indicators for immaterial costs of severe and slight injuries are assumed to be 13% and 1% of the VSL, respectively (Ricardo-AEA, 2014; CE Delft et al., 2008). Additionally, other economic costs (net production losses, medical costs and administrative costs) are estimated at 10%, 2% and 0.1% of the VSL for fatalities, severe and slight injuries respectively (ibid).

Table 4 **EU28 average cost indicators external accident costs (x 1,000 $€_{2013}$)**

Cost element	Immaterial costs	Direct and indirect economic costs (production losses, medical and administrative costs)
Fatality	1,955	195
Severe injury	254	39
Slight injury	20	2

In estimating the total external accident costs, a distinction is made between single and multiple vehicle accidents. For multiple vehicle accidents all cost elements are considered, while for single vehicle accidents only the direct and indirect economic costs are considered (as we assume that the immaterial costs are internalised, because the road user has anticipated for his/her own accident risk; see Section 2.3.1).

Allocation of total external accident costs

As in CE Delft et al. (2011) and CE Delft and Free University Amsterdam (2014) we allocate the external accident costs to the various vehicle categories based on the damage potential (intrinsic risk) approach[4]. This approach allocates the total costs according to the damage potential of a certain vehicle. This means that all victims in a certain vehicle involved in a multiple party accident are attributed to the other vehicle involved. As this approach is based on the intrinsic risk the use of certain vehicles impose on other road users, it best reflects the specific nature of external costs (i.e. the costs that are imposed on third parties by deciding to travel).

2.3.3 Results

The total external costs of motorway accidents in the EU28 in 2013 are € 2.7 billion for HGVs and € 1.4 billion for vans. These costs are almost equally divided over fatalities and injuries. In previous studies (e.g. CE Delft et al., 2011; CE Delft, 2015) the costs of fatalities always exceeded the costs of injuries. Those studies did consider the whole network though, which implies that relatively higher risks on fatal accidents had to be taken into account.

Table 5 **Total external costs of motorway accidents of HGVs and vans in the EU28 in 2013 (billion $€_{2013}$)**

Vehicle category	Total costs	Costs of fatalities	Costs of injuries
HGV	2.7	1.4	1.3
Van	1.4	0.6	0.7

[4] Other approaches that can be used to allocate the external accident costs to the various vehicle categories are the monitoring perspective and the responsibility perspective (guilt). See Annex A.3 for more information.

2.4 Air pollution costs

2.4.1 Defining air pollution costs

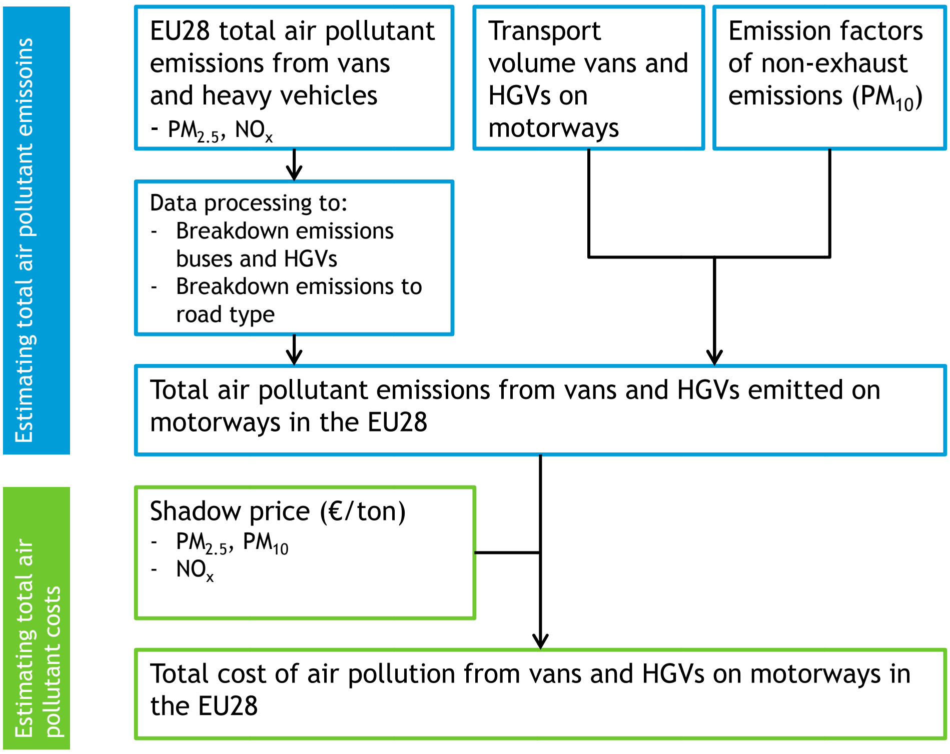
The most important road transport air pollutants are particulate matter (both exhaust ($PM_{2.5}$) and non-exhaust (PM_{10}) emissions) and nitrogen oxide (NO_x)[5]. These emissions result in various types of costs (CE Delft et al., 2011): health effects (increased risk of respiratory and cardiovascular diseases), building and material damages (i.e. soiling of building surfaces and degradation of facades and materials through corrosive processes), crop losses (due to increasing concentrations of NO_x emissions) and impacts on ecosystems and biodiversity (due to acidification and eutrophication of water and soil).

2.4.2 Methodology

A two-step approach is used to estimate the external costs of air pollutants emitted by HGVs and vans on motorways in the EU28 (see Figure 7):

– estimating total air pollutant emissions by HGVs and vans on motorways;
– estimating total external air pollutant costs.

Figure 7 Methodology for estimating air pollution costs



5 Recently, more and more evidence comes available on the significant health impacts of ultrafine particulate matter ($PM_{0.1}$), black carbon and NO_2. However, there are not yet reliable cost indicators to monetarise the health impacts of these emissions. For that reason, we have not taken these emissions into account in this study.

Estimating total air pollutant emissions by HGVs and vans on motorways

The Convention on Long-Range Transboundary Air Pollution (LRTAP) obliges all EU Member States to report on their total exhaust air pollutant emissions ($PM_{2.5}$ and NO_x) of road transport. This data is available from a public EEA database. It has been modified/detailed in two ways for this study:

- The LRTAP data present figures for HGVs and buses together. Based on a bottom-up approach using vehicle kilometres and emission factors, the shares of HGVs and buses in the total emissions are estimated.
- The LRTAP data only present data on a country level. Estimations on the share of air pollutants emitted on motorways have been made by the consultants (based on a bottom-up approach, using vehicle kilometre data and relevant emission factors).

The LRTAP data does not provide any figures on non-exhaust PM emissions. These emissions are therefore estimated by multiplying the total number of vehicle kilometres by relevant emission factors (from TREMOVE).

The total air pollutant emissions from HGVs and vans on motorways in the EU28 are presented in Table 6.

Table 6 **Total air pollutant emissions from HGVs and vans on motorways in the EU28 in 2013 (kton)**

Vehicle category	$PM_{2.5}$	PM_{10}	NO_x
HGVs	6.9	2.5	387
Vans	5.1	0.9	94

Estimating total air pollutant costs

The total air pollutant costs are estimated by multiplying the total emissions estimated above by relevant shadow prices. As recommended by Ricardo-AEA (2014) and CE Delft et al. (2011), NEEDS shadow prices are used for NO_x emissions. NEEDS also provides shadow prices for PM emissions, but these are not appropriate for transport. Therefore, in line with CE Delft et al. (2011), the shadow prices for $PM_{2.5}$ and PM_{10} are based on HEATCO (2006). More information on these shadow prices is given in Annex A.4.

2.4.3 Results

The estimated total costs of air pollutant emissions from HGVs and vans on motorways in the EU28 in 2013 are presented in Table 7. For HGVs, the costs are about € 4.3 billion, while for vans these costs are about 1.2 billion.

Table 7 **Total costs of air pollutant emissions from HGVs and vans on motorways in the EU28 in 2013 (billion €2013)**

Vehicle category	Total costs of air pollution
HGV	4.3
Van	1.2

2.5 Costs of climate change

2.5.1 Defining cost of climate change

The main greenhouse gas emissions with respect to road transport are carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4). Recent studies mention black carbon (root) as a potentially important GHG emission. But as the impact on global warming is still uncertain (IPPC, 2014), we do not take this effect into account in this study.

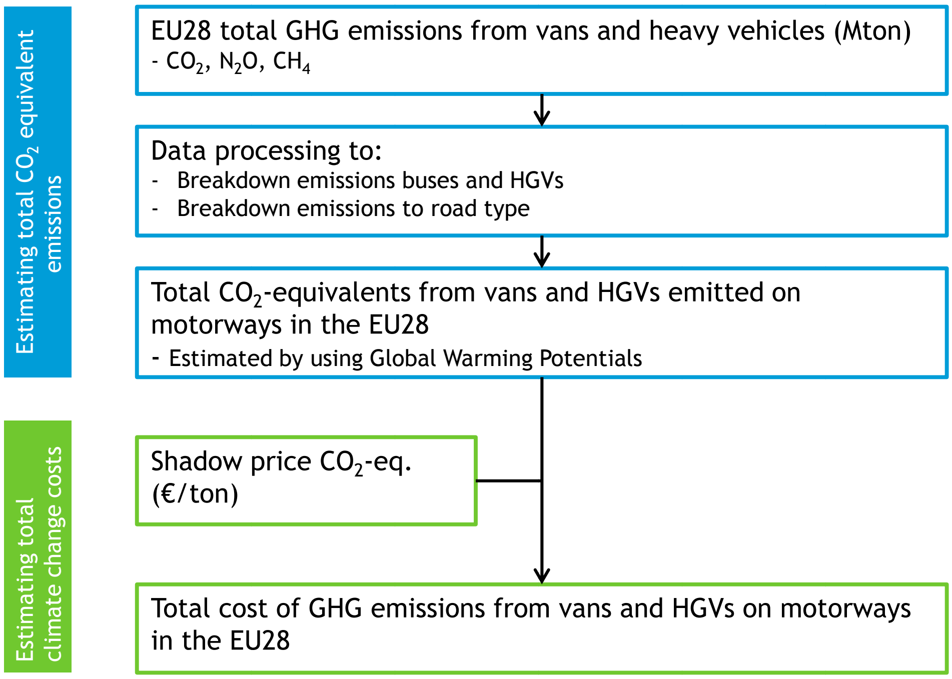
The various GHG emissions contribute to global warming, resulting in impacts such as sea level rise, agricultural impacts (due to changes in temperatures and rainfall), health impacts (e.g. increase in heat stress, expansion of areas amenable to parasitic and vector borne disease burdens), ecosystems and biodiversity impacts, increase in extreme weather effects, etc. The exact risk on and size of many of these impacts are uncertain, due to a lack of scientific knowledge.

2.5.2 Methodology

The external climate change costs are estimated by applying a two-step approach, comparable to the approach applied for air pollutant emissions (see Figure 8):

– estimating total CO_2 equivalent emissions by HGVs and vans on motorways;
– estimating total external climate change costs.

Figure 8 Methodology to estimate the external costs of GHG emissions



Estimating total CO_2 equivalent emissions

All EU Member States have to report their GHG emissions to the UNFCCC. These emissions are presented by the EEA GHG data viewer, distinguishing different emission sources, including light duty trucks (i.e. vans) and heavy duty vehicles (i.e. HGVs + buses). The same approach as for air pollutant emissions is applied to differentiate between HGV and bus emissions and to identify the share of GHG emissions emitted on motorways (see Section 2.4.2).

Furthermore, the various GHG emissions are translated to CO_2 equivalents by using Global Warming Potentials (IPPC, 2014), such that direct comparisons can be made between these different emissions[6].

The estimated total CO_2 equivalent emissions from HGVs and vans on motorways in the EU28 are presented in Table 8.

Table 8 Total GHG emissions from HGVs and vans on motorways in the EU28 in 2013 (Mton)

Vehicle category	Total CO_2 equivalent
HGVs	65.9
Vans	30.9

Estimating total climate change costs

Total climate change costs can be estimated by multiplying the total amount of CO_2-eq. emissions by the CO_2 price. As recommended by Ricardo-AEA et al. (2014) and CE Delft et al. (2011), a shadow price of € 80 per tonne CO_2 eq. is used. This CO_2 price is based on the cost for meeting the long term target for keeping CO_2-eq. level in the atmosphere below 450 ppm in order to keep global temperature rise below 2°Celsius (Kuik et al., 2009)[7]. Since the uncertainty in the CO_2 price is large (see CE Delft et al., 2011), also a low (€ 10) and high (€ 150) value for the CO_2 price is applied. The low CO_2 price is based on the costs to meet the 2020 CO_2 reduction target of the European Commission (20% reduction compared to 1990 level) (CE Delft, 2014), while the high level is based on the upper bound of the estimation of Kuik et al. (2009) to meet the 2°C target.

2.5.3 Results

Table 9 presents the estimated total costs of GHG emissions from HGVs and vans on motorways in the EU28 in 2013. These costs are € 5.3 and € 2.5 billion, respectively. The large range in the figures does, however, show the relatively large uncertainty in these estimations.

Table 9 Total costs of GHG emissions from HGVs and vans on motorways in the EU28 in 2013 (billion €2013)

Vehicle category	Total climate change costs
HGVs	5.3 (0.7-9.8)
Vans	2.5 (0.3-4.6)

[6] The following Global Warming Potentials are used: 265 for N_2O, and 28 for CH_4.

[7] This is the so-called avoidance cost approach, which estimates shadow prices by determining the cost to achieve a particular policy target. Another approach to estimate (CO_2) shadow prices is the damage cost approach. This approach valuates all damage experienced by individuals as a result of the existence of an externality (e.g. health impacts). In general, economists prefer the damage cost approach to estimate shadow prices, as this directly measures the willingness to pay of individuals to avoid externalities. However, as indicated by Van den Bergh and Botzen (2012), for estimating CO_2 prices, the avoidance cost approach is preferred. The main reason is that the cost of risks for the potentially high damages of climate change cannot be quantified well.

2.6 Noise costs

2.6.1 Defining noise costs

Noise can be defined as the unwanted sound or sounds of duration, intensity or other quality that causes physical or psychological harm to humans (CE Delft et al., 2008). In general, there are two adverse impacts of transport noise[8]:

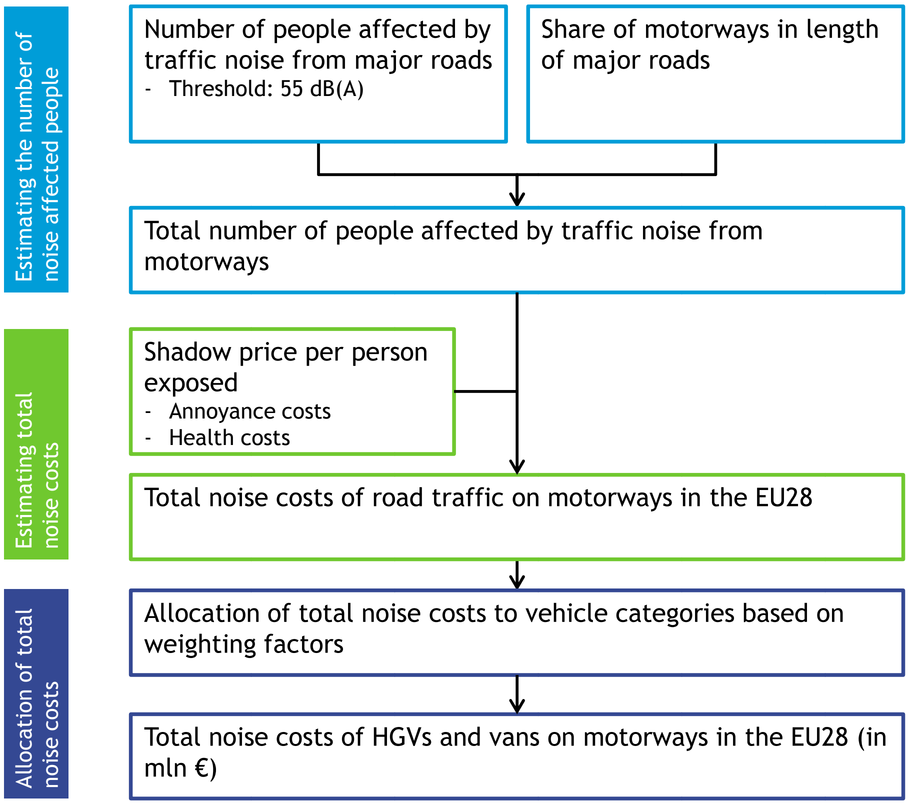
- *Annoyance costs*: transport noise imposes undesired social disturbances (e.g. restriction on desired leisure activities, discomfort or inconvenience), which lead to a decrease in human's well-being.
- *Health impacts*: regular exposure to transport noise may have significant health impacts, like increased risk of cardiovascular diseases (heart diseases, high blood pressure), cognitive impairment, and sleep disturbance (WHO, 2011). These adverse health impacts result in both mortality and morbidity costs.

2.6.2 Methodology

As is shown in Figure 9, a top-down approach is applied to estimate the external noise costs of HGVs and vans on motorways in the EU28.
This approach consists of three main steps:

- estimating the number of noise affected people;
- estimating the total noise costs;
- allocating the total noise costs to the various vehicle categories.

Figure 9 Methodology for estimating noise costs



[8] Transport noise may also result in productivity losses (i.e. the economic performance of employees deteriorates due to loss of concentration, tiredness due to noise-related sleep disturbance, etc.) and environmental impacts (e.g. harmful effects of noise on wildlife) (Defra, 2014). These impacts are only scarcely studied, and for that reason it is not possible to take them into account in this study.

Estimating the number of noise affected people

Based on the EU Directive on Environmental Noise (EC, 2002), all EU Member States are required to develop strategic noise maps. These maps provide information on the number of people affected by road, rail and aviation noise, both in agglomerations and from major traffic infrastructure networks (roads, rail network, airports). From the noise maps, data on the total number of people exposed to noise levels above 55 L_{den} dB(A)[9] due to major roads are used for this study (see Table 10). As motorways are only a part of the major roads for which the noise data is reported, the total number of people exposed is scaled down based on the share of motorways in the total length of the major roads. The resulting figures can be found in Table 10 as well.

Table 10 **Number of people exposed (in millions) to noise from major roads and motorways in the EU28**

Road type	55-59 dB(A)	60-64 dB(A)	65-69 dB(A)	70-74 dB(A)	≥75 dB(A)	Total
Major roads	10.8	6.7	4.2	2.0	0.5	24.2
Motorways	9.7	4.9	3.5	1.3	0.4	19.7

Estimating the total noise costs

By multiplying the total number of people exposed to noise from motorways and the noise cost per person affected, the total noise costs from road transport on motorways in the EU28 can be estimated. CE Delft et al. (2008) and Ricardo-AEA (2014) provide an extensive overview of studies on the noise cost per person affected. Both studies recommend to use the figures provided by HEATCO (2006). More information on these shadow prices is given in Annex A.5.1.

Allocating the total external noise costs to the various vehicle categories

In a final step, the total noise costs from motorways are allocated to the various vehicle categories (i.e. passenger cars, motorcycles, buses, vans and HGVs) based on the vehicle kilometres on motorways. As the vehicle types differ in noise characteristics, the vehicle kilometres should be weighted by a specific factor. In our analyses, we have made use of the weighting factors presented in Annex A.5.2.

2.6.3 Results

Table 11 shows that the total noise costs of HGVs and vans on motorways in the EU28 in 2013 is € 0.6 and € 0.3 billion, respectively.

Table 11 **Total noise costs of HGVs and vans on motorways in the EU28 in 2013 (billion €2013)**

Vehicle category	Total noise costs
HGVs	0.6
Vans	0.3

[9] No EU-wide data on people exposed to noise levels below 55 dB(A) is available, although at these noise levels people are still disturbed by traffic noise. Therefore, the annoyance costs of transport noise are underestimated in this study.

2.7 Congestion costs

2.7.1 Defining congestion costs

Congestion arises from the mutual impacts of road users competing for limited road capacity. It increases with traffic load, but is to some extent present at all levels of demand. Users may experience mutual disturbances resulting in lower speeds even before full capacity limits of roads are reached.

Costs related to congestion mainly consist of the costs of additional travel time. Additional cost elements are more unreliable travel times (not covered in this study) and extra vehicle operation and fuel costs.

Congestion differs from other external costs of transport as the people affected by it are largely identical to those causing it. In other words, the congestion costs are mainly borne by the transport sector itself. Therefore, it is often debated to what extent congestion costs are really external from a total cost perspective[10]. However, it should be considered that HGVs and vans are just a sub-segment of total road transport, and hence that only a part of the congestion costs are borne by themselves (the other part is borne by users of other vehicle categories, e.g. passenger cars). Furthermore, although congestion costs are (partly) borne by the sector itself, it still results in economically sub-optimal outcomes. As it is unclear to what extent congestion costs can be considered external from a total cost perspective and as EU-wide consistent congestion indicators are not available, these costs will be presented separately and not be added up in terms of total external costs of transport (in line with CE Delft et al., 2011).

2.7.2 Methodology

As shown in Figure 10, a three step approach is used to estimate the congestion costs of HGVs and vans on EU28 motorways:

- estimating total hours of delay;
- estimating total congestion costs;
- allocation of total congestion costs to the various vehicle categories.

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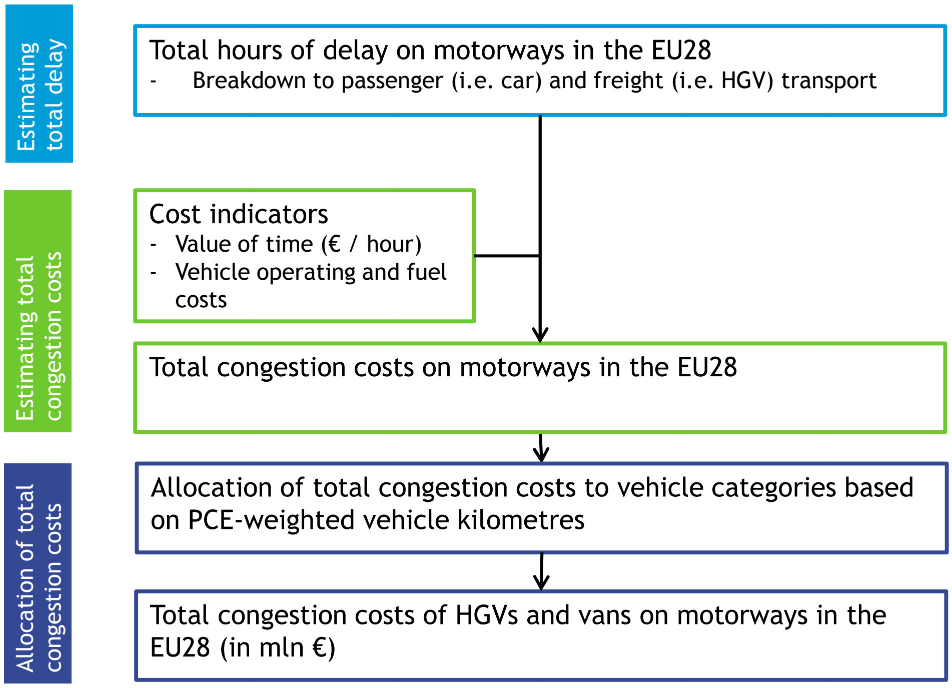
10 From the marginal cost perspective, congestion costs are external, since marginal cost are defined from the individual user perspective. An individual road user entering a (congested) road causes additional delays for the (individual) road users.

Figure 10 Methodology for estimating congestion costs



Estimating total hours of delay

Consistent EU-wide databases on congestion indicators are not publicly available. The estimation of the total hours of delay should therefore be based on extensive modelling exercises by a transport model. As this is out of the scope of this study, we make use of the results of model exercises done in CE Delft (2011). In that study, the hours of delay were estimated based on runs by the TRANS-TOOLS model, supplemented by results from a review of literature on road congestion costs. Detailed model results (not presented in the report of that project) are analysed to estimate the total number of delay hours on motorways in the EU28. To reflect the large uncertainty in the estimated number of hours delay, a bandwidth is applied for this indicator. The upper-bound of the bandwidth is fully based on the TRANS-TOOLS results, while the lower-bound is based on the results of the literature study.

Estimating total congestion costs

To estimate the total congestion costs, we first have estimated the total delay costs. This was done by multiplying the total number of hours delayed by the value of travel time. Value of travel time indicators reflect the willingness to pay of people/companies to reduce their travel time by a specific amount of time (e.g. one hour). These indicators are estimated in stated preference or revealed preference studies, and do vary between passenger and freight transport, trip purposes, trip distance, etc. In this study we use the same value of time indicators as CE Delft et al. (2011), which we have transferred to 2013 values by using PPP-adjusted GDP per capita values.

To estimate the additional vehicle operating and fuel costs due to congestion, the same cost indicators as in CE Delft et al. (2011) were used (again transferred to 2013 values by using PPP-adjusted GDP per capita values).

Allocation of total congestion costs to the various vehicle categories

The contribution of the various vehicle categories to the total congestion costs depends on their use of the scarce motorway capacity. This is reflected by Passenger Car Equivalent (PCE) weighted vehicle kilometres. Therefore, these are used to allocate the total congestion costs to the various vehicle categories. The PCEs used are shown in Table 12.

Table 12 **Passenger car equivalents**

Vehicle kilometre	Passenger Car Equivalent
Passenger car	1
Motorcycle	0.5
Bus	2
Van	1.2
HGV	3

2.7.3 Results

Table 13 presents the total congestion costs of HGVs and vans on EU28 motorways in 2013. For HGVs these costs are € 2.0 to € 6.8 billion, while for vans these costs are € 1.6 to € 3.9 billion. The rather large range in the congestion cost estimates reflects the uncertainty in the estimated number of delayed hours, which is mainly caused by the lack of an EU-wide consistent set of congestion indicators.

Table 13 **Total congestion costs of vans and HGVs on motorways in the EU28 in 2013 (billion €2013)**

Vehicle category	Total congestion costs
HGVs	2.0-6.8
Vans	1.6-3.9

2.8 Costs of upstream emissions

2.8.1 Defining the costs of upstream emissions

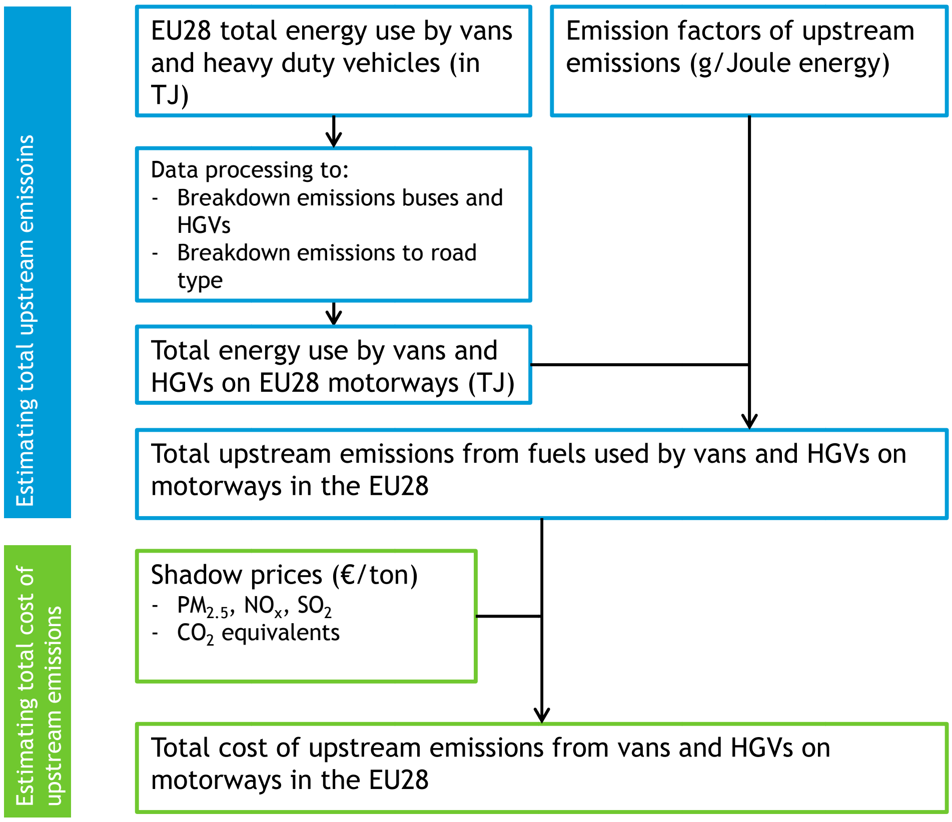
Road transport does not only directly cause negative effects, but also indirectly. The most important indirect effect of road transport includes the GHG and air pollutant emissions due to the extraction of raw materials and the production and transport of fuels[11]. These well-to-tank (WTT) emission lead to external costs, i.e. air pollution costs (health effects, etc.) and climate change costs. According to a life cycle view, the negative effects of these upstream emissions may be included in the total external costs of road transport. However, as these effects are only indirectly related to the road transport sector (e.g. the sector itself does not have the opportunity to mitigate these emissions), we present these costs separately and they are not added up in terms of total external costs of transport.

[11] In addition to fuel production, there are other sources of upstream (and downstream) emissions of road transport. The production, maintenance and disposal of road vehicles and road infrastructure lead to emissions (and external costs) too. However, these external costs have another dimension compared to the other external cost categories, because these costs are not directly related to the actual use of road vehicles. Therefore, we will not take the external costs related to these up/downstream processes into account.

2.8.2 Methodology

To estimate the external costs of upstream emissions, a similar two-step approach as for air pollution and climate change is applied (see Figure 11):
- estimating total upstream emissions;
- estimating total costs of upstream emissions.

Figure 11 Methodology to estimate the external costs of upstream emissions



Estimating total upstream emissions

Based on data reported by the EU Member States to the UNFCCC, the EEA presents an overview of total energy use by heavy duty vehicles and vans in the EU28. By the same approaches as applied for air pollutant and GHG emissions:
- the energy use by heavy duty vehicles is split between buses and HGVs;
- the total amount of energy used by HGVs and vans for kilometres driven on motorways is estimated.

To estimate the total upstream emissions from fuels used by HGVs and vans on motorways in the EU28, the total energy use is multiplied by relevant WTT emission factors for diesel and petrol (vans) (CE Delft, 2016). The resulting upstream emissions are shown in Table 14.

Table 14 Total upstream emissions from fuels used by HGVs and vans on motorways in the EU28 in 2013

Vehicle category	$PM_{2.5}$ (kton)	NO_x (kton)	SO_2 (kton)	CO_2 (Mton)
HGVs	0.3	3.0	8.7	2.2
Vans	1.4	1.1	3.3	0.8

Estimating total costs of upstream emissions

To estimate the total costs of upstream emissions, the same shadow prices as the ones used to estimate the external costs of air pollution and GHG emissions are applied (see Section 2.4 and 2.5). There is one exception: for PM emissions, a shadow price for emissions from industrial processes is used (from NEEDS, 2008) instead of a transport-specific shadow price. The SO_2 emissions were monetarised by using a shadow price from NEEDS (2008) as well.

2.8.3 Results

The total external costs from upstream emissions of fuels used by HGVs on motorways in the EU28 range from € 1.5 to € 4.5 billion. For vans, this range is € 0.6 to € 1.9 billion. The bandwidth results from the uncertainty in the CO_2 price, reflecting the use of different values for the CO_2 price.

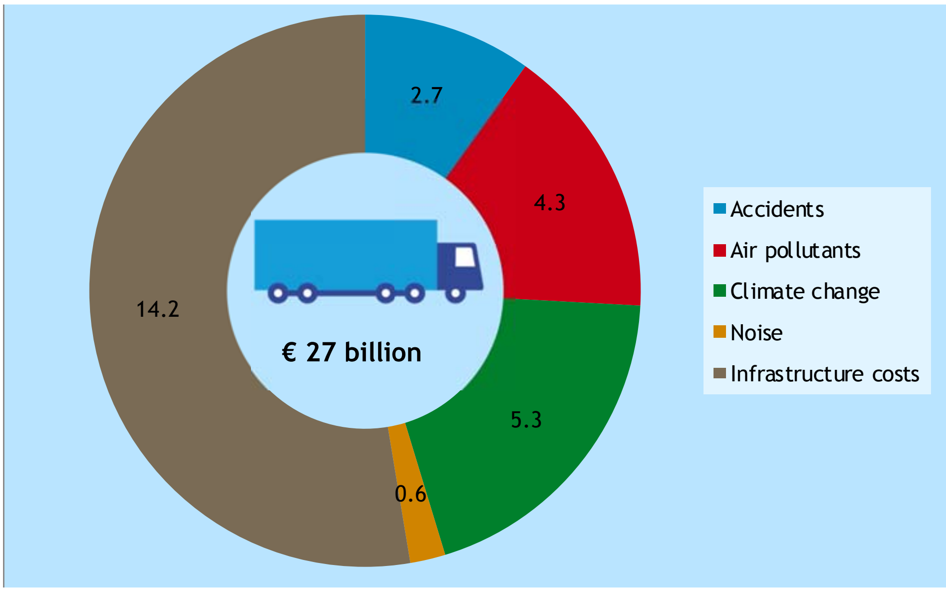
Table 15 Total costs of upstream emissions from fuels used by HGVs and vans on motorways in the EU28 in 2013 (billion €2013)

Vehicle category	Total costs of upstream emissions
HGVs	3.0 (1.5-4.5)
Vans	1.3 (0.6-1.9)

2.9 Conclusions

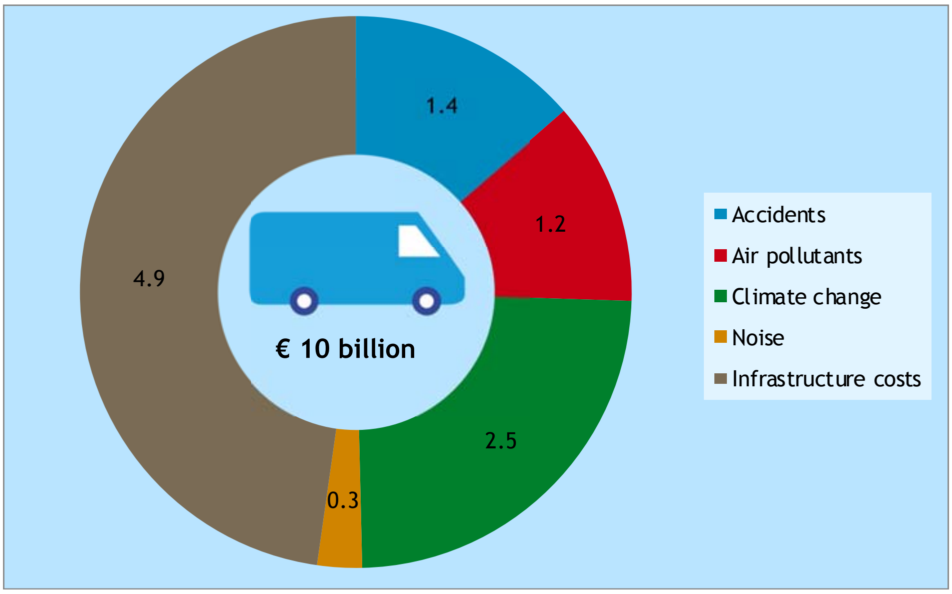
The total external and infrastructure costs of HGVs on EU28 motorways in 2013 are about € 27 billion (€ 22.5 to € 31.5 billion). Infrastructure costs are responsible for 53% of these costs. The main external cost categories are climate change and air pollution. The congestion costs of HGVs are about € 2 to € 7 billion, while the costs of upstream emissions equal € 1.5 to € 4.5 billion.

Figure 12 Total external and infrastructure costs (excluding congestion and upstream emissions) of HGVs on motorways in the EU28 in 2013 (billion $€_{2013}$)



The total infrastructure and external costs (excluding congestion and upstream emissions) of vans on the EU28 motorways in 2013 are about € 10.2 billion (€ 8 - € 12 billion). The main part of these costs are the infrastructure costs (about 48%), followed by the climate change costs. In addition to these costs, vans are responsible for congestion costs of about € 1.6 to € 4 billion, and costs of upstream emissions of € 0.6 to € 1.9 billion.

Figure 13 Total external and infrastructure costs (excluding congestion and upstream emissions) of vans on motorways in the EU28 in 2013 (billion $€_{2013}$)



3 Revenue from taxes and charges

3.1 Introduction

Various taxes and charges for road freight transport are applied in Europe. In this study we consider the following categories:
- vehicle taxes: registration tax, ownership tax, insurance tax;
- infrastructure charges: distance-based (tolls) and time-based (vignettes) charges;
- fuel taxes: fuel excise duty and EU ETS revenue.

In this chapter, we estimate the amount of revenue from these taxes, as far as they are related to kilometres driven by HGVs and vans on EU28 motorways in 2013. In this way, we address the first three sub questions of research question 2 (see text box below).

Research question 2

What is the amount of road tax/charge revenue related to the kilometres driven by road freight transport on EU28 motorways in 2013?

This question consists of four sub questions:

a What are the relevant taxes/charges applied in the EU28?
b What is the total revenue from these taxes/charges for HGVs and vans in the EU28 in 2013?
c What share of the total revenue can be allocated to kilometres driven on the EU28 motorways in 2013?
d What share of the revenue is earmarked for spending on road infrastructure or to mitigate the external costs of transport?

The Eurovignette Directive recommends that the revenue from road charges should be used to benefit the transport sector and optimise the entire transport system. However, there is no obligation on Member States to earmark tax/charge revenue. By addressing the fourth sub question of research question 2, we identify for each of the tax/charge categories, to what extent their revenues are earmarked.

Earmarked taxes in this study are defined as taxes for which (a share of) the revenue must be spent by law to investments in road infrastructure and/or to mitigate the external costs (e.g. CO_2, road safety) of road transport. These revenues are therefore not added to the general budget.

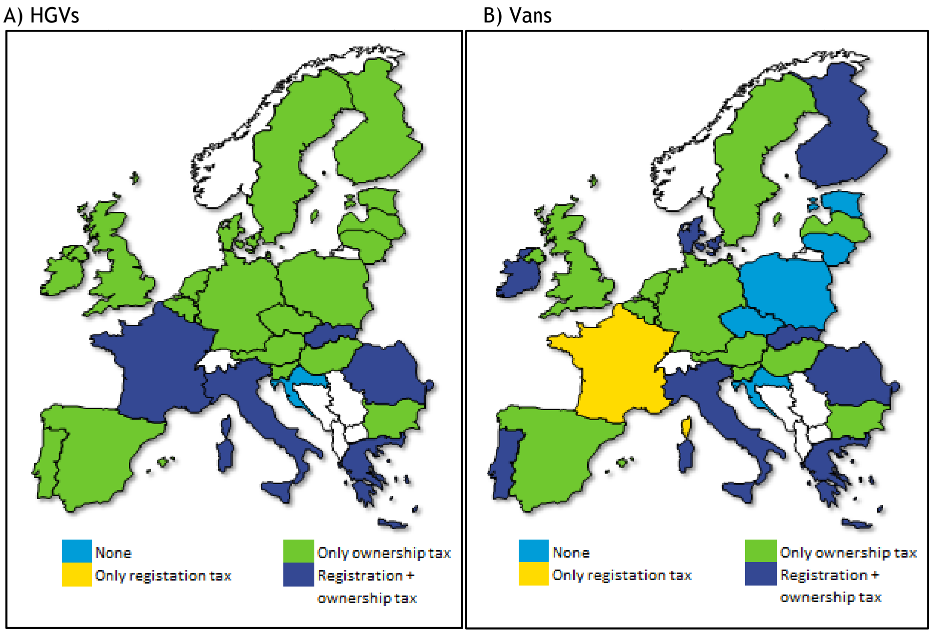
The methodology and sources used to estimate the share of earmarked revenues are described in Annex B. The results of the analysis are presented in the following sections.

3.2 Vehicle taxes

3.2.1 Vehicle taxes in the EU28

Three types of vehicle taxes are applied in the EU28: registration tax, ownership tax and insurance tax[12]. The registration tax is charged on vehicles (re)entering into the fleet. As shown in Figure 14, only a minority of the EU28 countries do levy a registration tax on HGVs and vans, and even then exemptions or reductions to zero apply in some of them (CE Delft et al., 2012). Weight and engine size are used most often as parameters for registration taxes. In contrast to registration taxes, periodic ownership taxes are levied on HGVs and vans in nearly all countries. For heavy goods vehicles above 12 tonnes, the Eurovignette Directive even sets common rules (including minimum rates) for an annual vehicle tax[13]. The most applied parameter for these taxes are vehicle weight, often combined with the vehicle's axle configuration and suspension type.

Figure 14 Vehicle taxes in the EU28 in 2013



Note: In The Netherlands private vans are charged a registration tax. However, the number of private vans in the Netherlands is negligible, and so is the revenue from this tax.

Finally, insurance taxes are levied in almost all EU Member States on the premiums paid for insurances (no mentioning of insurance taxes found for CZ, EE, HU, LV, LT, and PL). Next to insurance taxes, insurance premiums are considered as revenue in this study (as they internalise part of the accident

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12 It can be argued whether insurance taxes should be considered a specific transport tax. As insurance taxes are applied on all insurance premiums, it affects all economic sectors. Therefore, insurance taxes can be considered a general tax (like VAT), which does not affect relative prices on the transport market. However, insurance taxes can also be seen as a mark-up on the insurance premiums and hence as a direct internalisation measure of accident costs. Given this close relationship of insurance taxes with accident costs, we take the revenue from insurance taxes into account in this study.

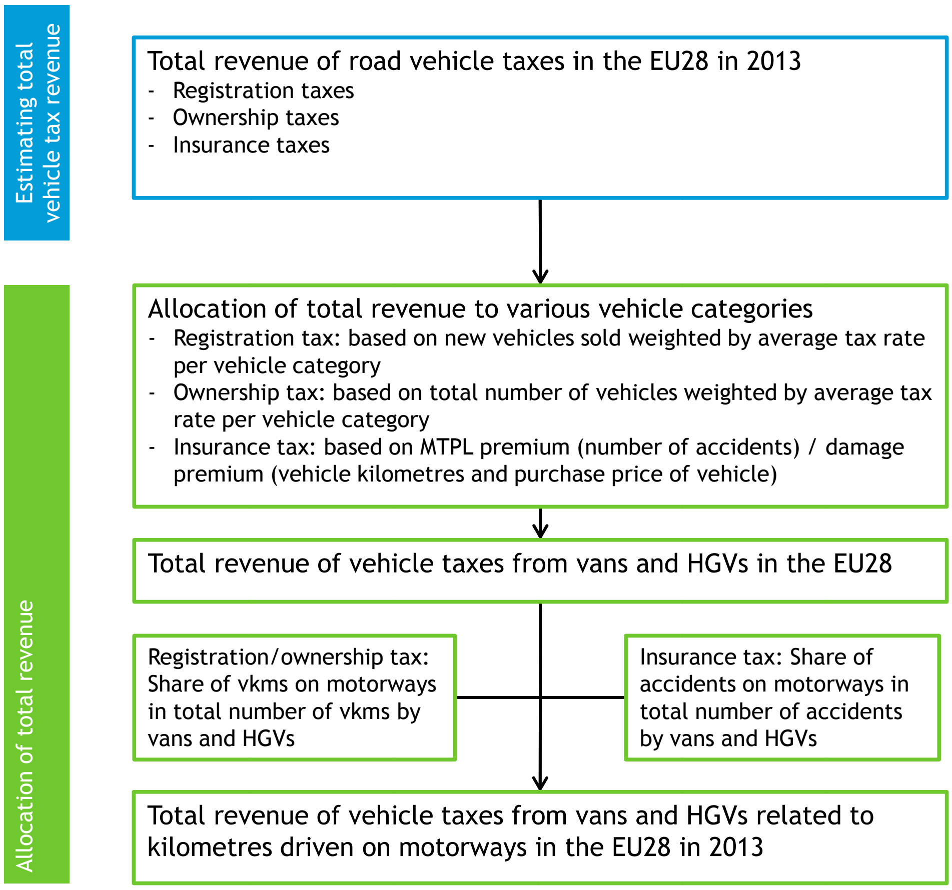
13 Croatia joined the EU mid-2013. As Figure 14 shows the situation by the beginning of 2013, no ownership tax for HGVs is indicated for Croatia.

costs). Insurance premiums are considered in Section 2.3, as we have lowered the accident costs with the premiums paid. In this chapter we therefore only consider the insurance taxes.

3.2.2 Methodology

As shown in Figure 15, a top-down approach is applied to estimate the vehicle tax revenue. This approach consists of two steps:
- estimating total vehicle tax revenue;
- allocation of total revenue.

Figure 15 Methodology to estimate the vehicle tax revenues



Estimating total vehicle tax revenue

The total revenue of registration and ownership taxes in the EU28 in 2013 has been mainly gathered from national accounts (national statistical agencies, Ministries of Finance and/or transport, car dealer associations), supplemented by data from Eurostat, the OECD and the ACEA. For most countries, only data on total revenues (for all vehicle categories together) was available.
For insurance taxes, the total premiums paid were taken from Insurance Europe (2015), while the tax rates were based on ACEA (2014) and CE Delft et al. (2012). By multiplying the total motor insurance premiums by the tax rates, the total insurance tax revenue was estimated.

Allocation of total revenue

To estimate the total revenue of vehicle taxes from HGVs and vans related to kilometres driven on motorways, two additional steps have been applied. First, the total revenues were allocated to the various vehicle categories.

For registration taxes this was done based on the number of vehicles sold per vehicle category, weighted by the average tax rates for these vehicles.
For ownership taxes the same approach was applied, but then the total number of vehicles in the fleet was used to allocate the revenue instead of total number of vehicles sold. For insurance taxes, we made a distinction between revenue from taxes on motor third-party liability[14] (MTPL) premiums and from taxes on damage[15] premiums. The allocation of the former category was based on the number of accidents with the vehicle type involved.
The revenue of taxes on damage premiums, on the other hand, were allocated based on the vehicle kilometres weighted by purchase prices (AEA, 2012).

In a second step, the revenue for HGVs and vans was allocated to various road types. For registration and ownership tax revenue, this was based on the number of vehicle kilometres driven on these road types. Insurance tax revenue was allocated based on the share of accidents by HGVs/vans on motorways compared to all roads.

3.2.3 Results

As shown in Table 16, the total revenue of vehicle taxes from HGVs and vans associated to kilometres driven on motorways in the EU28 in 2013 is € 1.3 and € 1.2 billion, respectively. The main part of these revenues is coming from ownership taxes (almost 70% for HGVs and about 60% for HGVs), followed by insurance taxes (about 30%). The revenue from registration taxes is limited, particularly for HGVs.

Table 16 Total revenue of vehicle taxes from HGVs and vans associated to kilometres driven on motorways in the EU28 in 2013 (billion $€_{2013}$)

Vehicle category	Total vehicle taxes	Registration taxes	Ownership taxes	Insurance taxes
HGVs	1.27	0.01	0.82	0.44
Vans	1.21	0.17	0.69	0.35

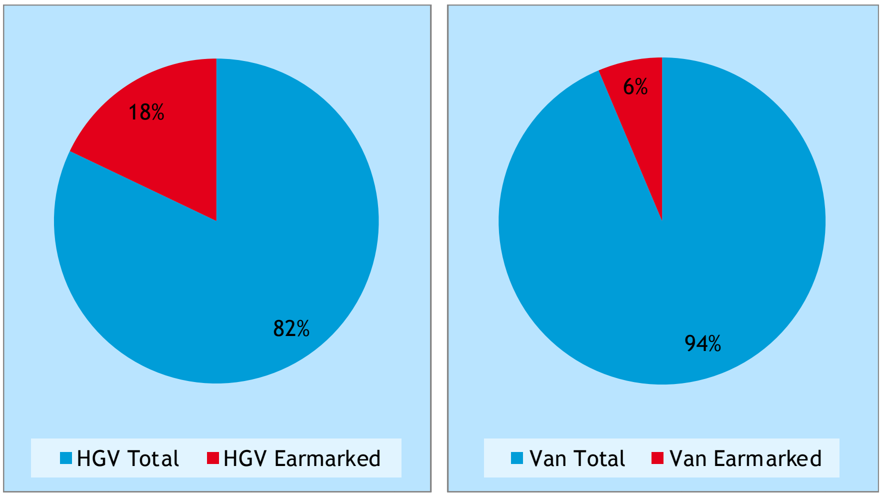
Earmarked vehicle taxes

Across the EU28, the revenue from vehicle taxes is rarely earmarked (see Figure 16). Exceptions are the registration tax in Romania (Environmental Fund) and ownership taxes in Czech Republic (infrastructure generally), France (Axle tax intended to offset the maintenance costs of roads), Latvia (Traffic road fund), Lithuania (Road Maintenance and Development Programme), and Luxembourg Climate and Energy Fund). Insurance taxes are sometimes earmarked, for Motor Insurer's funds (Cyprus, Greece, Romania, Spain, Ireland) or specific funds or services concerning road accident victims (Belgium, Italy, Portugal). Figure 16 shows the share of earmarked revenue in total revenue from vehicle taxes.

14 Liability for injury and damage sustained by others. This type of insurance is compulsory in the EU28 countries.

15 Own damage to the vehicle (i.e. damage caused directly by the insured driver), damage to glass parts, vandalism, natural forces and theft. This type of insurance is often optional.

Figure 16 Share of earmarked revenue in total revenue from vehicle taxes

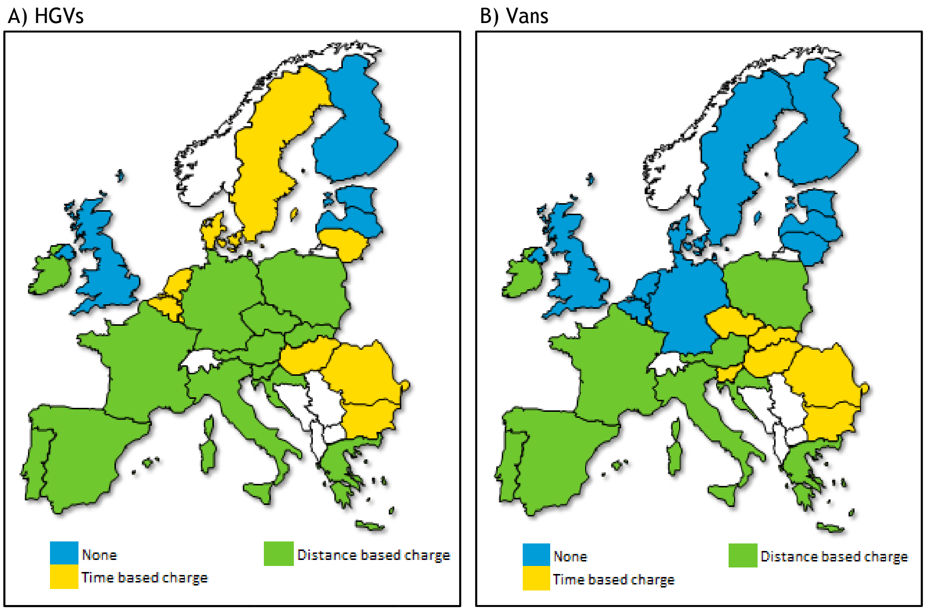


3.3 Infrastructure charges

3.3.1 Infrastructure charges in the EU28

In general, two types of infrastructure charges are applied in the EU28: distance-based (tolls) and time-based (vignettes) charges. Distance-based infrastructure charges, either electronic tolls or tolls with physical barriers, are applied for HGVs in thirteen EU countries in 2013 (e.g. the MAUT in Germany and Austria), while in nine countries these schemes covered vans as well (see Figure 17). Time-based infrastructure charges are applied in nine countries for HGVs and in six countries for vans. The prime example of a time-based infrastructure charge is the Eurovignette for HGVs with a gross vehicle weight over 12 tonnes. In 2013, this scheme was applied in Belgium, Denmark, Luxembourg, the Netherlands and Sweden.

Figure 17 Infrastructure charges in the EU28 in 2013



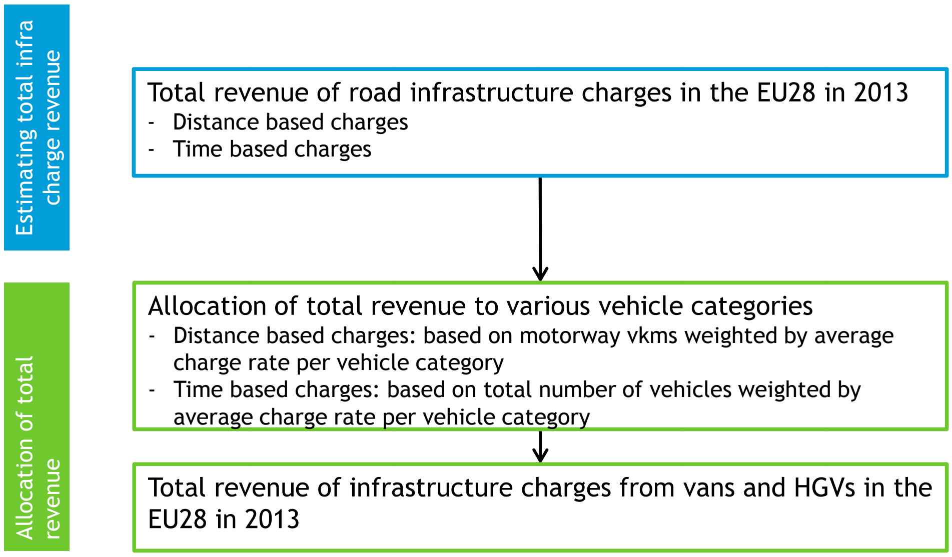
Note 1: This figure shows the situation in 2013. In the period 2013-2016, some changes have taken place. For example, in 2014, the UK introduced a vignette for HGVs.

Note 2: Local charging schemes (e.g. the M6 in the UK) are not shown.

3.3.2 Methodology

To estimate the infrastructure charge revenue, a top-down approach consisting of two steps is applied:
- estimating total infrastructure charge revenue;
- allocation of total revenue.

Figure 18 Methodology to estimate the total revenue from infrastructure charges



Estimating total infrastructure charge revenue

The total revenue of infrastructure charge revenue has been collected from national sources (national statistical agencies, Ministries of transport, road authorities, road charging scheme operators), the ASECAP country reports and the OECD environmental tax database. For most countries only data on the total charge revenues is available; a breakdown to the various vehicle categories is often missing. Furthermore, we have assumed that all infrastructure charges are applied on motorways only[16].

Allocation of total revenue

The total revenue of distance-based infrastructure charges has been allocated to the various vehicle categories based on the number of vehicle kilometres driven by the various vehicle types on the tolled motorways, weighted by the average charge rates applicable for these vehicles. For time-based infrastructure charges a slightly different approach is applied: the revenue of these charges is allocated based on the total number of vehicles per vehicle category in the domestic fleet, weighted by the average charge rate for these vehicles.

[16] In some countries infrastructure charges are applied on a small part of the trunk roads as well. Therefore, we probably slightly overestimate the total revenue from infrastructure charges on motorways.

3.3.3 Results

The total EU28 revenue of infrastructure charges in 2013 is about € 12.3 billion for HGVs and € 2.5 billion for vans (see Table 17). The major part (about 95%) of these revenues is coming from distance based charges. These charges are applied on a larger scale in the EU28. Furthermore, their average rates (in €/year) are higher than the time-based charge rates.

Table 17 Total revenue of infrastructure charges from HGVs and vans in the EU28 in 2013 (billion $€_{2013}$)

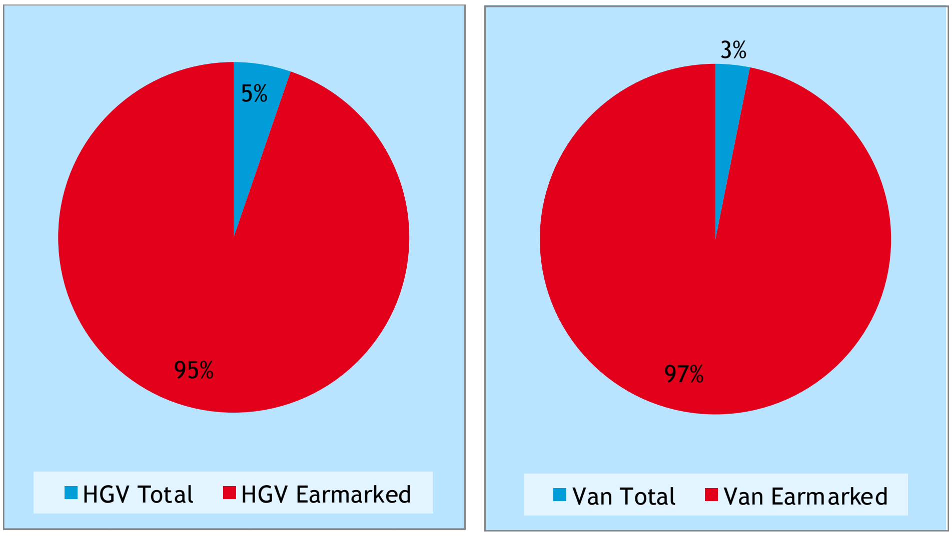
Vehicle category	Total infrastructure charges	Distance based charges	Time based charges
HGVs	12.3	11.7	0.7
Vans	2.5	2.3	0.2

Earmarked infrastructure charges

Regarding infrastructure charges, there seem to be two broad camps when it comes to the use of revenues from road charging (AEA, 2014). In the Eurovignette countries[17], the vignette is treated as any other tax and revenue is added to the general budget. In other countries revenue from vignettes is usually assigned to transport investments. The majority of Member States with road charging in place have elected to earmark revenue for transport-related investments. Toll revenue is often fully earmarked (Ricardo-AEA, 2014). In some countries (e.g. Italy) a fee to the state government needs to be paid, which is not earmarked. VAT on road tolls (also not earmarked) have been excluded from the revenue.

As shown in Figure 19, the main part of the revenue from infrastructure charges in the EU28 is earmarked. The revenue from the Eurovignette (which is not earmarked in any of the EU countries) is only small compared to total revenue. Furthermore, the main share of the revenue from other infrastructure charges is earmarked. Figure 19 shows the share of earmarked revenue in total revenue from infrastructure charges.

Figure 19 Share of earmarked revenue in total revenue from infrastructure charges



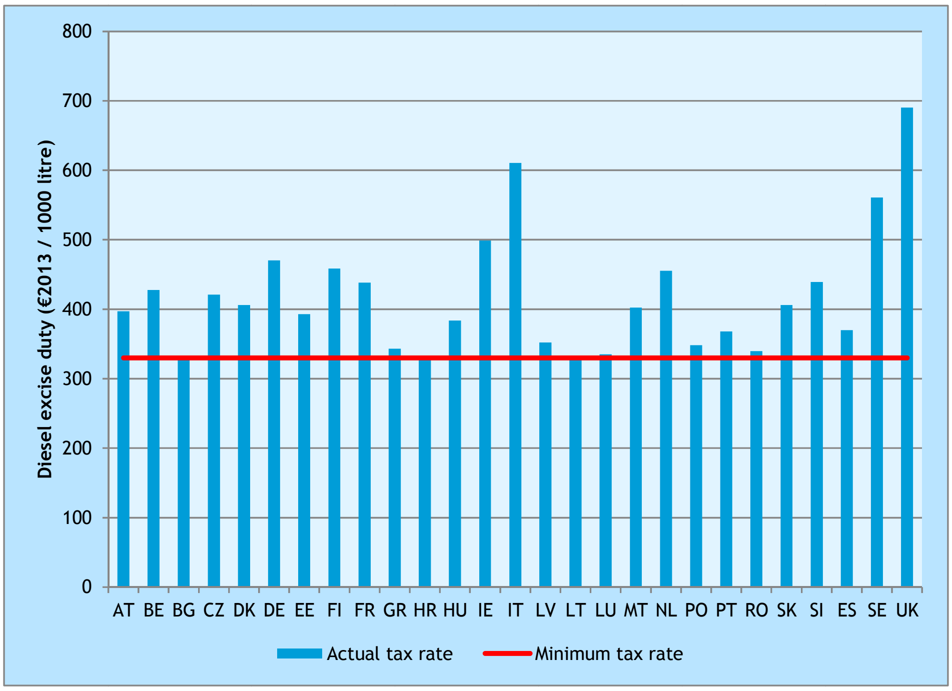
17 In the UK and the Netherlands, two of the Eurovignette countries, the revenue from (local) toll schemes is not earmarked as well.

3.4 Fuel taxes

3.4.1 Fuel excise duties in the EU28

All EU Member States levy excise duties on transport fuels. An overview of the 2013 tax levels for diesel is given in Figure 20. In all EU countries the diesel excise duty rates are equal to or above the minimum level set in Directive 2003/96/EC. The highest diesel excise duty rates are found in the UK, Italy and Sweden. In some EU countries (i.e. Belgium, France, Hungary, Ireland, Italy, Slovenia and Spain) a refund scheme for (part of the) diesel excise duty exist for HGVs. These schemes are taken into account in estimating the total revenue in the next sub-section.

Figure 20 Diesel excise duty rates in the EU28 in 2013



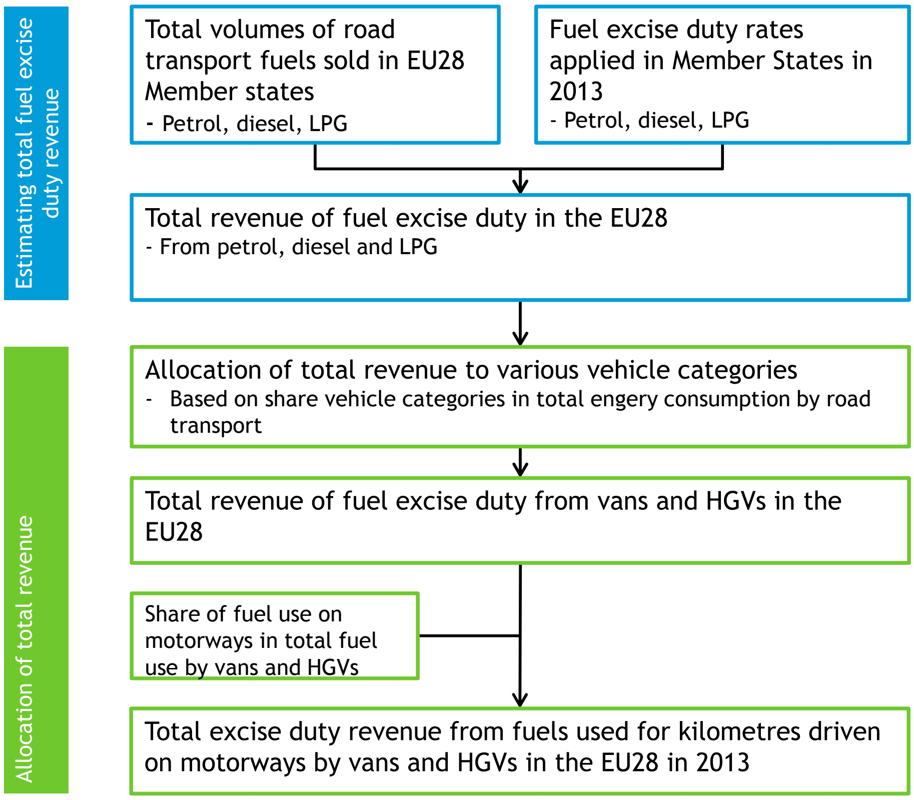
The CO_2 upstream emissions that are released by refineries are covered by the EU Emission Trading Scheme. The costs of the emission allowances purchased by the refineries are assumed to be passed through to the road transport sector (by a mark-up on the fuel prices). Therefore, the EU ETS costs are indirectly borne by the road transport sector and hence should be considered in scenarios which include the external costs of upstream emissions.

3.4.2 Methodology

A bottom-up approach is applied to estimate the revenue from the fuel excise duty for HGVs and vans in the EU28. This approach consists of two main steps (see Figure 21):

– estimating total fuel excise duty revenue;
– allocation of total revenue.

Figure 21 Methodology to estimate the total fuel excise duty revenue



Estimating total fuel excise duty revenue

The total EU28 fuel excise duty revenue is based on the total volumes of road transport fuels sold in the EU28 in 2013 (from Eurostat). These volumes are multiplied with the fuel excise duty rates applied in the various EU Member States in 2013 (from the DG Taxud Excise Duty tables) to estimate the total revenue.

Allocation of total revenue

To estimate the fuel excise duty revenue from fuels used for kilometres driven by HGVs and vans on EU28 motorways two additional steps have been carried out. First, the total revenue was allocated to the various vehicle categories based on the total energy consumption of these vehicles in 2013 (see Section 2.8 for the approach followed to estimate the energy consumption). Second, the share of fuels (and hence fuel excise duty revenue) used for kilometres on motorways was estimated, based on the number of motorway vehicle kilometres and motorway specific energy consumption factors.

EU ETS revenue

To estimate the EU ETS costs related to the CO_2 upstream emissions released by refineries, first the share of these emissions in total CO_2 upstream emissions was estimated (e.g. emissions from transport of fuels are excluded). In a next step, a price of € 4.46 per EU allowance of 1 ton CO_2 was taken to calculate the revenue (CE Delft, 2016).

3.4.3 Results

The total revenue of excise duty from fuels used by HGVs and vans for kilometres driven on EU28 motorways in 2013 is € 10.7 and € 5.3 billion, respectively (see Table 18).

Table 18 Total revenue of fuel excise duty from HGVs and vans associated to kilometres driven on motorways in the EU28 in 2013 (billion $€_{2013}$)

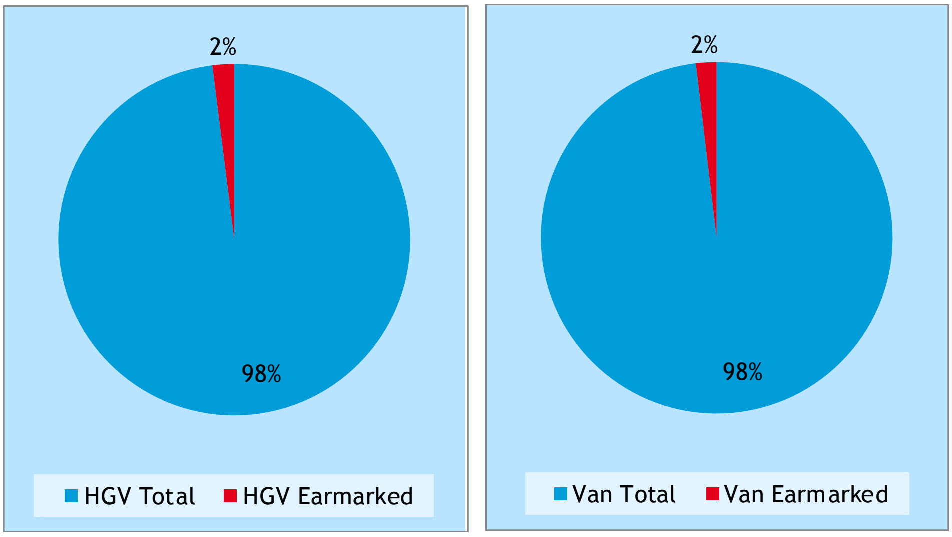
Vehicle category	Total fuel excise duty revenue
HGVs	10.7
Vans	5.3

The total revenue of EU ETS from CO_2 emissions of production and refining of fuels used by HGVs and vans for kilometres driven on EU28 motorways in 2013 is € 0.09 and € 0.04 billion, respectively.

Earmarked fuel excise duties

As shown in Figure 22, only a very small part of the revenue from fuel excise duties in the EU28 is earmarked[18]. Only in Lithuania, Czech Republic and Poland a significant share of fuel excise duties is earmarked (see also Annex A). Figure 22 shows the share of earmarked revenue in total revenue from fuel excise duties.

Figure 22 Share of earmarked revenue in total revenue from fuel excise duties

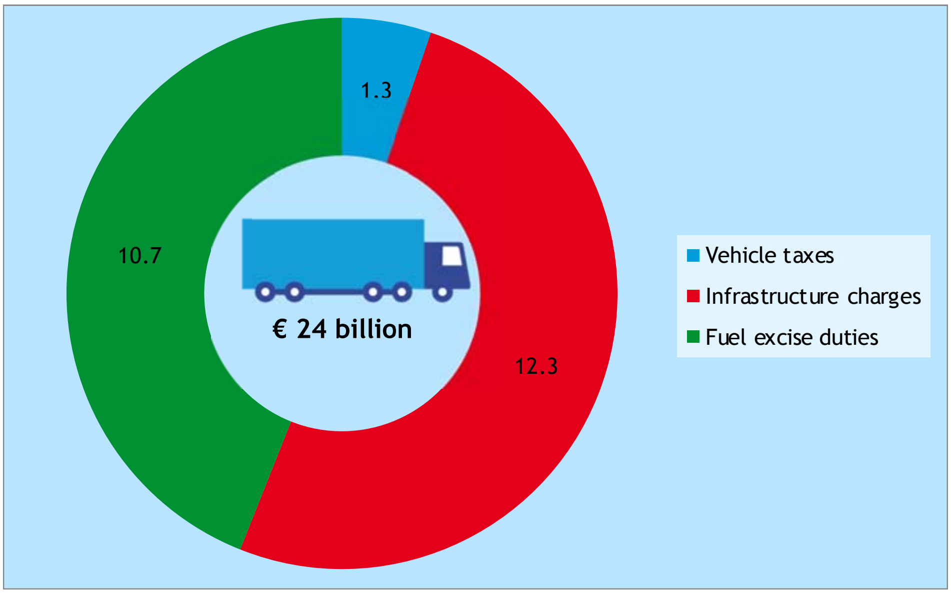


[18] Please notice that in our definition revenue is only considered earmarked as it must be spent in road infrastructure and/or to cover external costs. Therefore, the revenue from taxes or charges which are earmarked for other purposes (e.g. in the Netherlands, a small part of the fuel excise duty revenue is earmarked for strategic oil reserves) are not considered to be earmarked in this study.

3.5 Conclusions

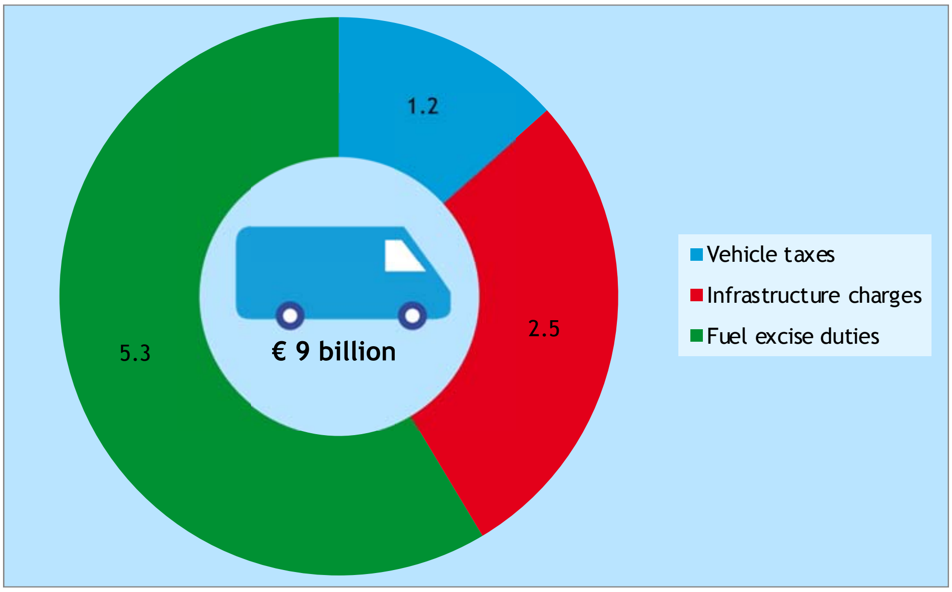
The total tax/charge revenue for HGVs is more than € 24 billion. As many European countries have implemented general or HGV specific infrastructure charging schemes, the main part of the revenues is from infrastructure charges (slightly more than 50%). Fuel taxes contribute about 43%, while vehicle tax revenue is only about 5% of total tax/charge revenue.

Figure 23 Total tax/charge revenue from HGVs associated to kilometres driven on motorways in the EU28 in 2013 (billion $€_{2013}$)



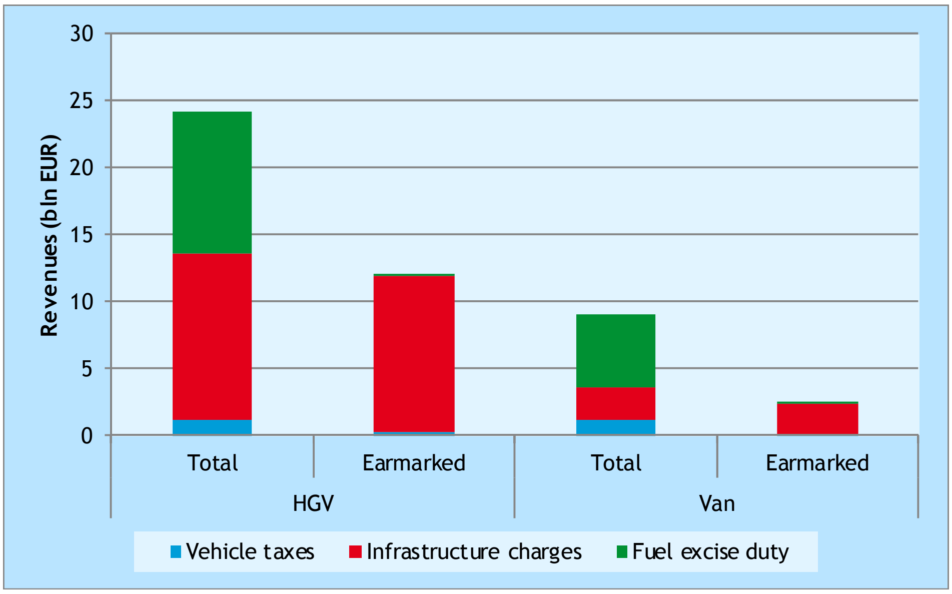
The total 2013 tax/charge revenue from vans associated to kilometres driven on EU28 motorways is about € 9 billion. The main part of this revenue is from fuel taxes (almost 60%), followed by infrastructure charges (about 30%) and vehicle taxes (slightly more than 10%).

Figure 24 Total tax/charge revenue from vans associated to kilometres driven on motorways in the EU28 in 2013 (billion $€_{2013}$)



As shown in Figure 25, only a limited part of the revenue from taxes and charges for HGVs and vans related to kilometres driven on motorways is earmarked for expenditures on road infrastructure or to investment in mitigation/adaptation measures addressing the external costs of transport. For HGVs, about 35% is earmarked, while for vans slightly more than 20% is earmarked. The earmarked revenue consists almost completely of revenue from infrastructure charges. As shown in Section 3.3, the majority of the infrastructure charge revenue in the EU28 is earmarked. The revenue from fuel excise duties or vehicle taxes, on the other hand, is earmarked in only a few countries in the EU28.

Figure 25 Share of earmarked revenue in total revenue from taxes/charges associated to kilometres driven by HGVs and vans on EU28 motorways in 2013



4 Cost coverage ratios

4.1 Introduction

This chapter seeks to compare how infrastructure and external costs of road freight transport compare to the tax/charge revenue they bring in (addressing research question 3, see below). We do this by providing cost coverage ratios, which show the share of the total infrastructure and external costs covered by the relevant taxes and charges. As the previous chapters, the analysis is focussed on the costs and revenue related to the kilometres driven on EU28 motorways.

The structure of this chapter is as follows: firstly, we briefly discuss the various scenarios we apply to compare the costs and revenue (Section 4.2). In Section 4.3, cost coverage ratios are presented for these scenarios.

> Research question 3
> *How are the total infrastructure and external costs compared to the total tax/charge revenue, both related to the kilometres driven by road freight transport on EU28 motorways in 2013?*
>
> This question consists of two sub questions:
> *a* *Which scenarios can be used to compare total costs and revenue?*
> *b* *What are the infrastructure and external cost coverage ratios for road freight transport on EU28 motorways in 2013?*

4.2 Scenarios for comparing costs and revenue

On request of the IRU, we have compared the total costs and revenue for several scenarios, which differ in the cost categories considered. In total five scenarios are assessed in this chapter:
- **Scenario 1**: comparison of total tax/charge revenue with total infrastructure costs.
- **Scenario 2**: comparison of total tax/charge revenue with total cost under the current Eurovignette Directive (infrastructure costs, air pollution, noise).
- **Scenario 3**: comparison of total tax/charge revenue with infrastructure and external costs (but excluding congestion and upstream emissions).
- **Scenario 4**: comparison of total tax/charge revenue with infrastructure and external costs (including congestion, but excluding upstream emissions).
- **Scenario 5**: comparison of total tax/charge revenue with all infrastructure and external costs.

To summarise, an overview of the cost categories considered in the various scenarios is given in Table 19.

Each scenario has been assessed for both HGVs and vans separately, but also for the entire road freight transport sector (HGVs and vans together).

Table 19 Overview of cost categories considered in the various scenarios

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Total revenues	X	X	X	X	X
Total infrastructure costs	X	X	X	X	X
Air pollution		X	X	X	X
Noise		X	X	X	X
Accidents			X	X	X
Climate change			X	X	X
Congestion				X	X
Upstream emissions					X

4.3 Results

This section presents the infrastructure and external cost coverage ratios for road freight transport on EU28 motorways in 2013. The cost coverage ratios are given for HGVs, vans and total road freight transport in the 5 scenarios as defined in the previous section. The cost coverage ratio is defined as the total revenue divided by the total costs in that scenario. Therefore a cost coverage ratio that is higher than 100% means that the revenue is higher than the costs. This is represented in the figures below by a thick line.

Figure 26 presents the cost coverage ratios for the defined scenarios for HGVs on EU28 motorways in 2013. The uncertainty concerning climate change costs and external costs from upstream emissions is represented by the uncertainty bars in the figure. Figure 26 shows that when infrastructure costs are compared to the revenue from HGVs on EU28 motorways, the revenues are significantly higher than the costs. When air pollution and noise are also included in the costs, the ratio is still above 100% (i.e. 127%). By adding accident and climate change costs, the cost coverage ratio falls below 100%. Including congestion (scenario 4) and upstream emissions (scenario 5) lowers the cost coverage ratio even further.

Figure 26 Cost coverage ratios for all scenarios for HGVs on EU28 motorways in 2013

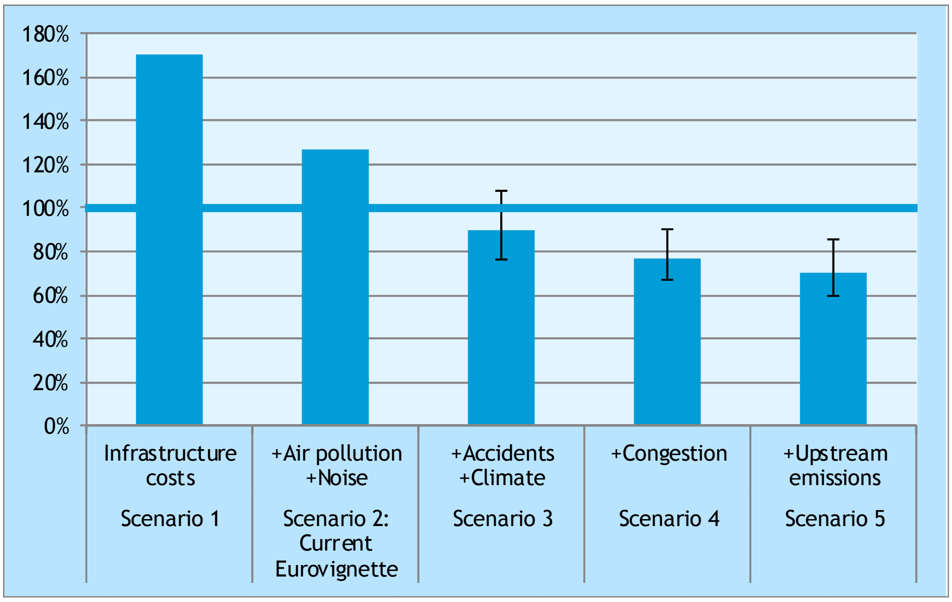
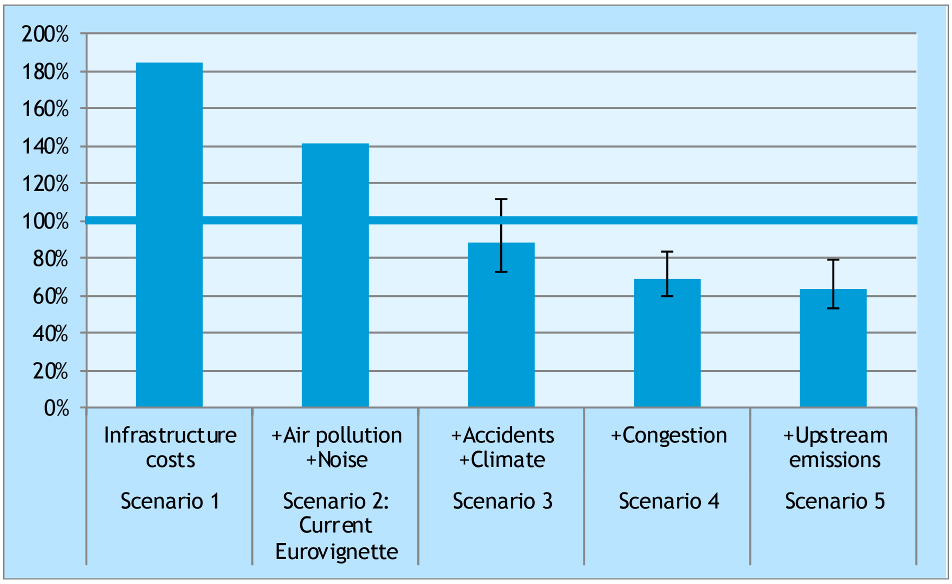


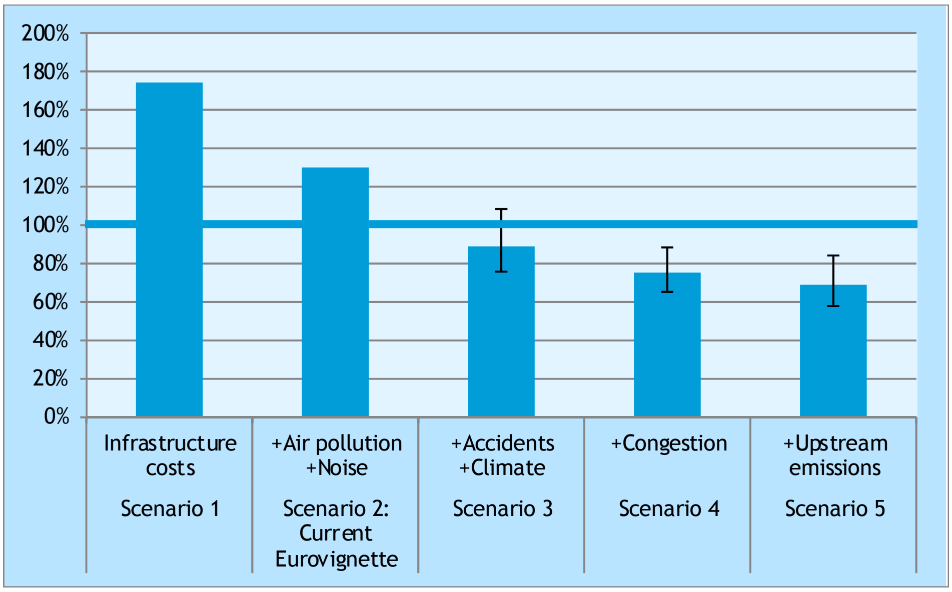
Figure 27 shows the cost coverage ratios for all scenarios for vans on EU28 motorways in 2013. The cost coverage ratios in scenario 1 and 2 are far above 100% (even slightly higher than for HGVs). The cost coverage ratios in scenario 3, 4 and 5 are below 100%, as was the case for HGVs. In general, the costs coverage ratios in these scenarios are slightly lower as for HGVs.

Figure 27 **Cost coverage ratios for all scenarios for vans on EU28 motorways in 2013**



In Figure 28 the cost coverage ratios for total road freight transport are displayed. Comparable results as for HGVs and vans separately can be drawn.

Figure 28 **Cost coverage ratios for all scenarios for total road freight transport on EU28 motorways in 2013**



Finally, all cost coverage ratios are summarised in Table 20.

Table 20 Cost coverage ratios for all scenarios for road freight transport on EU28 motorways in 2013

Scenario	Costs included	HGVs	Vans	Total road freight
Scenario 1	Infrastructure costs	170%	184%	174%
Scenario 2: Current Eurovignette	+ Air pollution + Noise	127%	141%	130%
Scenario 3	+ Accidents + Climate	90% (77-108%)	88% (73-111%)	89% (75-109%)
Scenario 4	+ Congestion	77% (67-90%)	69% (59-83%)	75% (65-88%)
Scenario 5	+ Upstream emissions	71% (60-86%)	63% (53-79%)	68% (58-84%)

5 Conclusions

5.1 External and infrastructure cost coverage ratios

The tax/charge revenue related to the kilometres driven on EU28 motorways by road freight transport exceeds the infrastructure costs of these roads. This revenue is 70% (for HGVs) to 84% (for vans) higher than the infrastructure costs. If also the external costs from air pollution and noise are included, in line with the current Eurovignette Directive, the cost coverage ratio is still higher than 100%. The revenue is 27-41% higher than the costs considered.

The findings of this study show, however, that in 2013 the total infrastructure and external costs of road freight transport on the EU28 motorways (including air pollution, noise, climate change, and accidents costs) exceed the relevant tax/charge revenue. For this scenario (scenario 3), the cost coverage ratio for HGVs is equal to 90%, while for vans it is 88%. Including congestion costs and/or upstream emission costs as well would lower these ratios even further.

5.2 Infrastructure and external costs

The total infrastructure and external costs related to kilometres driven by road freight transport on EU28 motorways in 2013 is estimated at about € 37 billion (excluding congestion costs and costs of upstream emissions). About 73% of these costs are caused by HGVs (€ 27 billion), while vans contribute for almost 27% to these costs (€ 10 billion).

The size of the total infrastructure and external costs is significantly affected by the shadow price applied for GHG emissions. If we apply a low CO_2 price (€ 10 instead of € 80 per tonne of CO_2 eq.), the total costs for road freight transport decrease to € 31 billion. On the other, in case we apply a high CO_2 price (€ 150 per tonne CO_2), the total costs increase to about € 44 billion. This relatively large variation in the results reflects the uncertainty in the economic valuation of the impacts of GHG emissions.

Infrastructure costs are the main part of the total infrastructure and external costs. About half of the total infrastructure and external costs (51%) are related to building and maintaining motorways (assuming the central CO_2 price of € 80 per tonne). Climate change costs contribute for about 21%, while air pollution costs are 15% of the total costs. Accidents contribute about 11%. Finally, the contribution of noise to the total infrastructure and external costs is relatively limited (about 2%).

In addition to the infrastructure and external costs discussed above, road freight transport is also responsible for congestion costs on the European motorways. For 2013, these costs are roughly estimated at € 7 billion (€ 4.4 and € 2.7 billion for HGVs and vans respectively). Finally, road freight transport indirectly causes external costs of upstream emissions, which are about € 4.3 billion (€ 2.1 - € 6.4 billion).

5.3 Revenue from taxes and charges

The 2013 total revenue from taxes and charges related to the kilometres driven by road freight transport on the EU28 motorways is estimated at € 33 billion. About 73% of this revenue is collected from HGVs, while the remaining part is from vans.

Fuel excise duties and infrastructure charges are the main contributors to the total revenue. For vans, the majority of the revenue is from fuel excise duties (59%), while infrastructure charges contribute 28%. As many European countries have specific HGV road charging schemes, the share of infrastructure charges in total revenue is significantly higher for this vehicle category (51%). Fuel excise duties contribute 44% to the total revenue from HGVs. The share of vehicle taxes in total revenue is limited for both HGVs (5%) and vans (13%).

The revenue from road freight transport taxes and charges are partly earmarked for investments in road infrastructure or mitigation measures for the external costs of road transport. Only 35% of the tax/charge revenue from HGVs and 20% from vans are earmarked for these purposes. These earmarked revenues almost completely consist of revenue from infrastructure charges.

5.4 Uncertainties

The external and infrastructure costs presented in this study have been based on the latest scientific evidence and methodologies. In general, the scientific basis for the various cost categories is quite advanced. The data basis is generally good, but differs per cost category.

The main uncertainties with respect to the estimation of external and infrastructure costs are:

- For congestion costs, no consistent European data on congestion indicators is available. As a consequence, these costs are mainly based on model exercises, which results in a rather high level of uncertainty.
- The valuation of GHG emissions is rather uncertain, which is closely related to the uncertain but potentially dramatic damages of climate change. By applying a bandwidth for the CO_2 price in this study, we have tried to show the impact of this uncertainty on the results. As discussed above, this impact is rather significant.
- For infrastructure costs, the availability of detailed data on infrastructure expenditures differs widely between EU countries. For some countries, no or only very limited data was available, and hence rough estimations had to be made. These data problems are reflected in the estimated infrastructure costs.
- For accident costs, the main uncertainties are related to the economic valuation of the immaterial costs of injured casualties, as for these types of casualties no specific valuation factors exist.
- For air pollution and noise costs, it is expected that the total costs are underestimated, as the state-of-the-art shadow prices for these external effects do not take all adverse health impacts into account. For example, although recent studies provide increasing evidence for negative health impacts of NO_2 and ultra-fine particles, these impacts are not yet taken into account in the most recent shadow prices.

For road transport taxes and charges, rather reliable data on total revenue is available for most countries. However, often no breakdown of the total revenue to various vehicle categories is available. Therefore, additional analyses were needed to allocate this revenue to HGVs and vans, which resulted in a modest level of uncertainty.

To conclude, although this study does contain quite some uncertainties, which have to be kept in mind when interpreting its results, the main conclusion are robust. Furthermore, the main results of this study do have the right order of magnitude.

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Annex A Detailed information on cost estimations

A.1 Introduction

In Chapter 2, the methodologies to estimate the various (external) cost categories are briefly discussed. For some of the cost categories, some more detailed information is provided in this Annex. Subsequently, information is provided for infrastructure costs (Section A.2), external accident costs (Section A.3), air pollution costs (Section A.4), and noise costs (Section A.5).

A.2 Infrastructure costs

In this section, some more detailed information on the estimation of infrastructure costs is presented.

A.2.1 Infrastructure expenditures

The data on motorway infrastructure expenditures in the various EU Member States has been collected from two main data sources (see Table 21):

- *National accounts*: for some countries data from national public accounts or national statistics have been gathered on investments and/or O&M expenditures. Any missing data have been supplemented by data from the International Transport Forum (ITF) or have been estimated (by extrapolation or interpolation, or by applying growth rates in expenditure levels in comparable countries).
- *International Transport Forum*; data on motorway infrastructure expenditures is presented for some EU countries by the ITF. Any missing data is estimated by the same approaches as described above.

Table 21 Primary data sources for expenditures on motorways[a]

Primary data source	Investments (enhancement and renewal expenditures)	Operation and maintenance expenditures
National accounts	Austria, Czech Republic, Denmark, Germany, France, Netherlands, Spain, UK	Austria, Czech Republic, Germany, France, Italy, Netherlands, Poland, Spain, UK
National accounts + ITF data	Italy, Poland	
ITF data[a]	Croatia, Hungary, Lithuania, Luxembourg, Portugal, Slovakia, Slovenia	Bulgaria, Estonia, Croatia, Hungary, Lithuania, Luxembourg, Portugal, Slovakia, Slovenia
Estimated	Belgium, Bulgaria, Estonia, Finland, Greece, Ireland, Romania, Sweden	Belgium, Denmark, Finland, Greece, Ireland, Romania, Sweden

[a] For most countries, ITF do not present data on operation expenditures. These expenditures have been estimated by determining a ratio of operation and maintenance expenditures (based on data from countries for which both types of expenditures are known) and multiplying the maintenance expenditures by this ratio to get a rough estimation of the operation expenditures.

As is shown in Table 21, for some countries no data was available on expenditures on motorway infrastructure. For these countries the expenditures have been estimated using average expenditure levels per kilometre motorway. These unit levels have been estimated based on the data available from the national accounts and the ITF database.

Information on the share of enhancement and renewal expenditures in total investments was only available for Austria, The Netherlands and Poland. Based on these data, we were able to estimate the average shares of enhancement and renewal expenditures in total investments (75% and 25%, respectively). These were used as default values for the countries for which this data was not available. The share of operation and maintenance expenditures in total O&M expenditures was only available for Austria, Germany, The Netherlands, Poland and the UK. Based on the average figures for these countries, default shares of operation and maintenance expenditures in total O&M expenditures (45% and 55%, respectively) were estimated for the other countries.

A.2.2 Assumptions used in applying the PIM

To estimate the enhancement and renewal costs the Perpetual Inventory Method (PIM) has been applied (see Section 2.2.2). Therefore, the following assumptions were used

- *Depreciation period;* the period over which the enhancement and renewal expenditures are depreciated depends on the assumed life expectancy of the infrastructure. Based on a detailed analysis in Fraunhofer ISI and CE Delft (2008), we assume an average depreciation period of 35 years for all enhancement and renewal investments.
- *Depreciation approach;* we used an annuity approach to estimate the enhancement and renewal costs, which assumes constant annual costs (depreciation + financing costs). As shown by CE Delft (2008), applying a linear depreciation approach would result in comparable cost estimates.
- *Interest rate:* an interest rate of 4% is used for all EU Member States.

A.2.3 Proportionality factors used to allocate the infrastructure costs

An overview of the specific proportionality factors applied in this study is given in Table 1.

Table 22 Applied proportionality factors

Cost category	Proportionality factor
Enhancement costs	– PCE kilometres (90%) – 4th power axle load kilometres (10%)
Renewal costs	– PCE kilometres (40%) – 4th power axle load kilometres (60%)
Variable maintenance costs	– 4th power axle load kilometres (100%)
Fixed maintenance costs	– PCE kilometres (50%) – Vehicle kilometres (35%) – Allocated to HGVs (15%)
Operation costs	– Vehicle kilometres (30%) – PCE kilometres (70%)

Different proportionality factors are applied for different types of infrastructure costs:

- *Enhancement costs* are assumed to be mainly (90%) capacity dependent, i.e. these costs are made to increase the capacity of the road network. This capacity dependent costs are allocated based on passenger car equivalent (PCE) weighted vehicle kilometres, as this proportionality factor reflects the capacity demand of the various vehicle categories. A small part of the enhancement costs (10%) is assumed to be weight dependent (e.g. the type and cost of pavement materials used depends on the assumed number of heavy duty vehicles using the road). These costs are allocated based on 4^{th} power axle load weighted vehicle kilometres.
- *Renewal costs* are assumed to be partly capacity (40%) and partly weight (60%) dependent as well. Therefore, these costs are also allocated based on PCE weighted vehicle kilometres and 4^{th} power axle load weighted kilometres.
- *Variable maintenance costs* are assumed to be fully weight dependent. These costs are therefore completely allocated based on 4^{th} power axle load weighted kilometres.
- *Fixed maintenance costs* are allocated based on the detailed approach developed by ProgTrans/IWW (2007) for Germany (and also applied by CE Delft (2008) and CE Delft and Free University Amsterdam (2014) for the Netherlands): 50% of the costs are allocated based on PCE weighted vehicle kilometres, 35% based on vehicle kilometres and 15% are allocated to HGVs.
- *Operation costs* are allocated based on vehicle kilometres (30%) and PCE weighted vehicle kilometres (70%).

A.3 Accident costs

A.3.1 Allocation of external accident costs

Various approaches can be applied to allocate the external accident costs to the various vehicle categories (CE Delft et al., 2011):

- *Monitoring perspective:* allocation according to involvement, casualties are allocated to the transport category they were using when the accident did take place (e.g. the costs of casualties in vans are allocated to vans).
- *Responsibility perspective (guilt);* external accident costs are allocated to the party ‘causing’ the accident. In other words, the costs are attributed to the party who is responsible for the occurrence of the accident.
- *Damage potential (intrinsic risk)*: allocation according to the damage potential of a certain vehicle. This means that all victims in a certain vehicle involved in a multiple party accident are attributed to the other vehicle involved.

In this study, we have applied the damage potential approach to allocate the total external accident costs to the various vehicle categories, in line with CE Delft and Free University Amsterdam (2014) and CE Delft et al. (2011). This allocation approach is based on the intrinsic risk the use of certain vehicles impose on other road users and hence best reflects the specific nature of external costs (i.e. the costs that are imposed on third parties by deciding to travel). Furthermore, all statistical data is available to apply this approach (in contrast to the responsibility perspective, as transport statistics do often not report on the responsible party for an accident).

A.4 Air pollution

A.4.1 Air pollution shadow prices

As mentioned in Section 2.4.2, shadow prices from NEEDS (NO_x) and HEATCO (PM emissions) are used to estimate the total air pollution costs. In our estimation we have applied country-specific shadow prices and total emission figures to estimate the total air pollution costs (HEATCO, 2006).
For illustrative purposes, we present the country specific shadow prices for Germany in Table 23.

Table 23 **EU28 average shadow prices for air pollutant emissions (in €$_{2013}$/ton)**

Air pollutant	Shadow price (€/ton)
$PM_{2.5}$	100,788[a]
PM_{10}	40,315[a]
NO_x	15,059

[a] HEATCO (2006) presents PM shadow prices differentiated by region type (i.e. metropolitan, urban and rural), reflecting the impact population density has on the damage caused by these emissions. Based on TREMOVE data, it is assumed in this study that all motorways are located in rural areas. Therefore, the shadow prices presented for $PM_{2.5}$ and PM_{10} are for rural areas.

A.5 Noise costs

A.5.1 Noise shadow prices

Shadow prices from HEATCO (2006) are used to estimate the total external noise costs (see Section 2.6.2). As for air pollution, country-specific total cost figures were estimated, which were summed to find the EU28 figures presented in Section 2.6.3. Therefore, we made use of country-specific shadow prices. For illustrative purposes we do present the figures for Germany in Table 24.

Table 24 **EU28 average noise costs per person exposed per year for 2013 (in €$_{2013}$)**

Lden (dB(A))	Noise costs per person per year
55-59	77
60-64	132
65-69	186
70-74	295
≥ 75	395

A.5.2 Noise weighting factors

The total external noise costs have been allocated to the various vehicle categories based on the vehicle kilometres on motorways. As the vehicle types differ in noise characteristics, the vehicle kilometres have been weighted by specific factors. The weighting factors (from CE Delft and Free University, 2014) used are shown in Table 25.

Table 25 **Noise weighting factors**

Vehicle category	Noise weighting factor
Passenger car	1
Motorcycle	4.2
Bus	3.3
Van	1.2
HGV	3.9

Annex B Earmarked revenue from taxes and charges

B.1 Introduction

Earmarked taxes in this study are defined as taxes for which (a share of) the revenue must be spent by law to investments in road infrastructure and/or to mitigate the external costs (e.g. CO_2, road safety) of road transport. These revenues are therefore not added to the general budget.

In this Annex, we present the methodology used to estimate to what extent the road freight transport taxes and charges have been earmarked (Section B.2). Detailed results of this assessment are presented in Section B.3).

B.2 Methodology

The estimation of the earmarked part in total tax/charge revenue has been based on a thorough literature review. The following sources have been analysed:
- ACEA (2014): Tax Guide 2013.
- CE Delft (2012) - An inventory of measures for internalising external costs in transport. In particular, the elaborated fact sheets in the Annex report has been studied, as they often mention whether the revenue of a specific tax/charge has been earmarked.
- OECD environmental tax database (2016): this database contains some explicit information on the earmarking of relevant taxes/charges.
- REVENUE (2006): EU project on Revenue Use from Transport Pricing, which contains a country overview table of revenue allocation schemes.
- Ricardo-AEA (2014) - Evaluation of the Implementation and Effects of EU Infrastructure Charging Policy since 1995: it provides an overview of Member States' stated approach for the use of revenues from road charging.
- Personal communication with country experts and/or national Ministries of Finance.

When a tax or charge revenue is not indicated in either of these sources to be earmarked, we have assumed that the taxes were not earmarked.

B.3 Results

The results of the assessment on earmarked tax/charge revenue are shown in Table 26.

Table 26 Share of tax/charge revenues that is earmarked per tax/charge and country

Country	Registration	Circulation	Insurance	Tolls	Vignettes	Fuel exise duty
Austria	-	0%[a]	-	100%	-	0%
Belgium	-	0%	28%	-	0%	0%
Bulgaria	-	0%	-	-	100%	0%
Cyprus	0%	0%	100%	-	-	0%
Czech Republic	-	100%	-	100%	100%	9%
Denmark	0%	0%	-	100%	0%	0%
Germany	-	0%	-	100%	-	3%
Estonia	-	0%	-	-	-	0%
Finland	0%	0%	-	-	-	0%
France	0%	100%	-	100%	-	4%
Greece	0%	0%	23%	100%	-	0%
Croatia	-	-	-	100%	-	0%
Hungary	-	0%	-	-	100%	0%
Ireland	0%	0%	40%	50%[b]	-	0%
Italy	0%	0%	45%	89%[c]	-	0%
Latvia	-	100%	-	-	-	0%
Lithuania	-	100%	-	-	100%	55%
Luxembourg	-	40%[d]	-	-	0%	8%[c]
Malta	0%	0%	-	-	-	0%
Netherlands	-	0%	-	0%	0%	0%
Poland	-	0%	-	100%	-	18%
Portugal	0%	0%	66%	100%	-	1%
Romania	100%	0%	100%	100%	100%	0%
Slovakia	0%	0%	-	50%[e]	50%	0%
Slovenia	-	0%	-	100%	100%	0%
Spain	-	0%	26%	100%	-	0%
Sweden	-	0%	-	100%	0%	0%
United Kingdom	-	0%	-	0%	-	0%

Note: "-" means that there are no revenues

[a] 50% of circulation tax revenues are spent on Public Transport. As these expenditures are not (indirectly) related to road freight transport, they are not considered earmarked revenues.

[b] Part of the toll revenue are allocated to private partners who have to spend it on the toll road network. Another part of the toll revenue is allocated to public partners and is not earmarked. The size of both shares is unknown. We assumed a 50/50 split.

[c] A fee needs to paid in Italy to the government, which is about 11% of the total revenue (excl. VAT). This fee is not earmarked.

[d] Shares of the annual vehicle tax and mineral oil tax are used to finance the country's climate mitigation efforts via the Climate and Energy Fund.

[e] Some part of the revenue is earmarked for reinvestment in the transport sector. It is not clear how much. We assumed 50%.