Annex 2

Direction technique
Infrastructures de transport et matériaux

Case followed by:

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Concerning: Memo External Environmental Costs

In the context of the Alpine Convention in the field of transport gathering the countries of the Alpine range (Germany, Austria, France, Italy, Slovenia, Switzerland), the French Ministry for Environment (DGITM/SAGS/MAP) commissioned from Cerema/DTecITM a bibliographical review on traffic-related external environmental costs (private cars, vans, HGVs, two-wheelers, buses/coaches). This review analysed the various calculation methods identified in a corpus of studies, in order to estimate the impact of traffic on external environmental costs. It also assessed the data used in the various studies. It cross-compared the values used in these studies, and checked them against the Eurovignette III Directive. The analysis also focused on mountainous areas and on how these had been factored in. Indeed, mountainous zones are more sensitive to traffic-related environmental impacts than are lowland areas. The topography of mountainous areas makes them less ventilated than lowlands and intensifies road traffic related resonance effects.

SUMMARY

This note, produced on behalf of the Mission des Alpes, addresses the question of external environmental costs incurred by heavy goods vehicles (HGVs). These external environmental costs are the impacts related to the use of transport and which are not accounted for in the costs paid by the agents who carry out or commission such transportation. Examples of the above are noise, atmospheric pollution or indeed climate change. These costs endured by society have a price (development costs for noise-limiting schemes, medical care related to pollution, action against GHG emissions, etc.). The current economic climate does not allow society to take on the entirety of these costs. Consequently, the Eurovignette III European Directive enables Member States to surtax vehicles in order to take into account the environmental impacts on noise and air pollution. This approach is based on the polluter-payer principle.

The aim of this review is to present the calculation methods encountered in a series of studies for estimating the impact of traffic on external environmental costs. A second objective is to identify the data used to estimate the impact of traffic on external environmental costs. Within this framework, 15 studies conducted between 2003 and 2015 have been analysed.

This review also compares the basic values arising from the 15 bibliographical references: by cross-referencing them and with the values recommended by the Eurovignette III Directive for atmospheric pollution and noise pollution.

The question of sensitive mountain zones is subject to particular focus. Their topography makes mountainous zones less aerated than lowlands and accentuates the resonance effects related to road traffic noise, making them more sensitive than lowlands.

<u>1) Comparison of methods and data sources used for calculating the external environmental costs:</u>

<u>- Air pollution:</u>

Out of the 15 documents analysed, 14 address the issue of atmospheric pollution. Particulate Matter – PM - (10 and 2.5) is the element incriminated in all the studies dealing with the issue of atmospheric pollution. Its dangerousness is linked to the particle size. The smaller the particles are (PM 2.5) the deeper they get inside the respiratory system. Some can contain toxic products such as metals or polycyclic aromatic hydrocarbons (PAH), which are considered to be carcinogenic. This is the reason why the cost per tonne of volatile particulate matter emitted is far more significant than for the other pollutants.

The most commonly encountered calculation method used to estimate the effects of atmospheric pollution emitted by road traffic is the IPA (Impact

Pathway Approach). Out of the 14 studies analysed, 11 employed it. The IPA method requires the use of 3 types of data: the transport demand (in vkm per year), the specific emission coefficients (in g per vkm) and the damaging factor per pollutant (in euros per tonne).

The database most often used to evaluate the transport demand is EUROSTAT. Other studies use transport models to which they add their own traffic data. Emission coefficients are obtained using traffic models. COPERT and TREMOVE are the most commonly used. The most used damaging factors per pollutant are mainly from HEATCO.

- Noise:

Out of the 15 documents analysed, 13 address the issue of noise. The majority of effects taken into account in the calculation of external costs due to noise are the cost of discomfort and effects on health. Out of the 13 studies analysed, 9 uses IPA method. This method requires the use of 3 types of data: data on exposure to noise, data on costs per person exposed and the breakdown of total external costs by vehicle category using weighing factors as a basis.

The data on exposure to noise is governed by European Directive 2002/49/EC. It makes noise maps compulsory for conurbations of more than 100,000 inhabitants or along roads bearing traffic of more than 3 million vehicles per year. As regards the data on costs per person exposed and the breakdown of total external costs by vehicle category using weighting factors, the majority of studies use HEATCO as a basis. Some of these studies implement correction factors to take account of their specific nature (For France: CGSP 2013 or La Transalpine 2008).

- Other external costs:

The Eurovignette III European Directive does not provide mean values imposed on HGVs for other external costs. Within the scope of the 15 studies, 9 provide further information on other external costs. It appears that the upstream downstream effects, accidents and climate change are analysed by most of the studies. Their impacts on the total of external costs vary considerably from one study to another. This is most likely to be linked to the introduction of factors and coefficients taking into account the scope studied, the development of engine power or the value of a year of human life. Other factors such as the calculation method and the databases used could explain such differences.

2) Comparison of basic values between the Eurovignette III Directive and the other studies:

- Air pollution:

To improve the comparison, the cost data per Euro standard presented in the European Directive has been averaged in accordance with the composition of the HGV fleet on the roads in France in 2015. On average, with Eurovignette III, an HGV driving along an urban road may be taxed at a rate of €0.04 per kilometre, as opposed to €0.03 per kilometre if it uses an inter-city road.

Only the CGSP 2013, Delft Infras 2011 and ALE 2012 studies (based on the results of Delft Infras 2011) provide values enabling a comparison with Eurovignette III. The aggregated values of the Eurovignette III Directive are generally lower than the values put forward by the other studies for an identical urban fabric. When compared with other studies, without applying the factor of 2 to mountainous zones, the Eurovignette III Directive underestimates the impacts of atmospheric pollution.

- Noise:

On average, with Eurovignette III, an HGV driving along an urban road in the daytime may be taxed at a rate of €0.011 per kilometre (€0,02 per kilometre during night-time whatever type if urban fabric. According to Eurovignette III, the noise impact due to the use of vehicles is approximately two times higher at night than during the day regardless of urban zoning. Only the CGSP 2013, Delft Infras 2011 and ALE 2012 studies (based on the results of Delft Infras 2011) provide values enabling comparison with Eurovignette III.

The costs of noise pollution according to the Eurovignette III Directive are much lower for urban areas than the values put forward by the studies that address the issue of noise cost in urban areas. The cost of noise pollution in the Eurovignette III Directive is much lower for rural areas then the values proposed by the studies that address the issue of noise cost in rural areas.

3) Comparison of basic values between the Eurovignette III Directive and the studies on mountainous zones:

- Air pollution:

METLTM 2003, GRACE 2006, La Transalpine 2008 and InterAlp 2013 are the studies that specifically assess mountainous zones or which use specific data for mountainous zones. To take account of external costs in mountainous zones, the Eurovignette III Directive recommends the use of a factor of 2 on the basic data. The GRACE 2006 study uses a factor of 5.15.

Applying a factor of 5.15 to the Eurovignette basic values makes it possible to approximate the values arising from the METLTM 2003 study. La Transalpine indicates much lower values.

- Noise:

METLTM 2003, GRACE 2006 and La Transalpine 2008 are the studies that specifically assess noise in mountainous zones. To take account of external costs in mountainous zones, the Eurovignette III Directive recommends applying a factor of 2 to the basic data. The GRACE 2006 study uses a factor of 5.15.

On comparing the Eurovignette III application of the “factor of 2”, its results converge with the two other studies on mountainous zones (METLTM 2003 and La Transalpine 2008). The values of Eurovignette III with a “factor of 5.1” are higher than the results of the studies addressing mountainous zones for urban areas.

Conclusion:

The result of this analysis shows that the basic values of the Eurovignette III European Directive are lower than those of the studies analysed within the scope of this paper.

According to the studies addressing mountainous zones, the use of a factor of 2 appears to be insufficient to take account of their sensitivity to air pollution. The application of a factor of 5.15 for air pollution to Eurovignette III provides values that are close to those in the studies on mountainous zones.

Concerning noise pollution, the factor of 2 proposed by the Directive is fairly close to the results of the studies addressing mountainous zones.

I - WHAT IS AN EXTERNAL COST?

External costs are effects related to the use of transport that are not taken into account in the costs paid by the agents using transportation. These effects are, for example, noise, congestion, pollution, accidents, etc. These costs are borne by society (care in the case of accidents, insurance, medical costs linked to pollution, etc.).

1) External environmental costs:

External environmental costs can be distinguished from overall external costs. **External environmental costs are the secondary effects** (noise, air pollution, health, climate change, biodiversity, etc.) **that solely have an impact on the environment.**

2) External costs included in this study:

In this study, two major external environmental costs are singled out: air pollution and noise.

It is more difficult to quantify some of the other environmental impacts, such as impacts on biodiversity, nature and landscapes, water and soils, etc.

II - BIBLIOGRAPHICAL ANALYSIS: HOW EXTERNAL COSTS ARE CALCULATED

This chapter focuses on the analysis of the methods used to calculate external environmental costs based on the bibliographical analysis of the 15 studies referenced in the annex.

1) Air pollution:

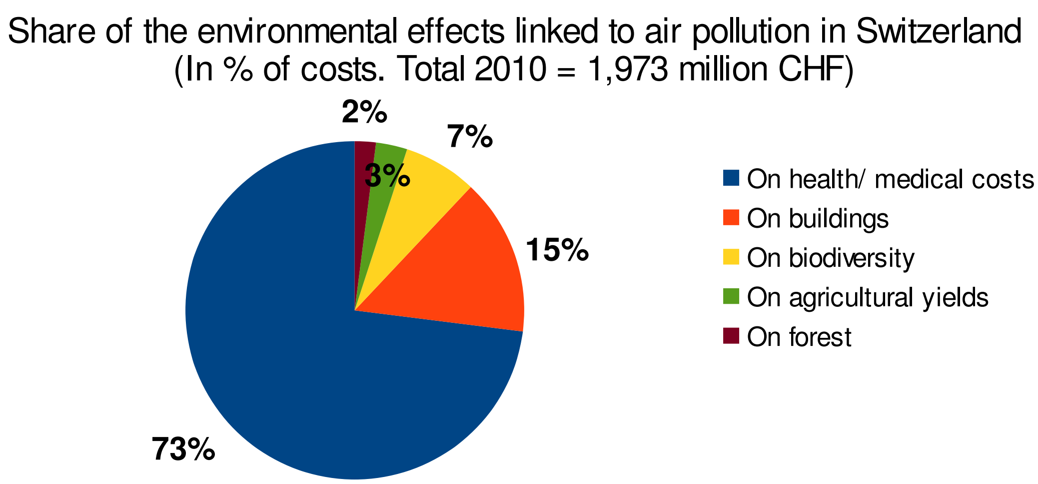
This section describes the methods used to calculate external costs related to air pollution, as observed in the bibliographical analysis. Out of the 15 documents analysed, 14 address the issue of air pollution. This section focuses first on the environmental effects factored in by the different methods to calculate air pollution. Thereafter, analysis is made of the pollutants taken into consideration and their impacts on health. The last part will address the method employed and the data sources used to calculate air pollution.

a) The effects taken into consideration:

In the analysis of the 14 studies, the majority of effects taken into consideration in the calculation of external costs are the health/medical effects (all the studies), the effects on buildings (8 studies), the effects on biodiversity (6 studies) and the effects on agricultural yields (5 studies).

To a lesser extent, 3 studies (ARE 2014, Ecoplan 2014 and Ricardo-AEA 2014) take into consideration the effects on forests and on wildlife.

Illustration 1: Share of the environmental effects linked to air pollution in Switzerland drawn from ARE (2014)



A Swiss study (ARE 2014) monetised the effects of air pollution on different impacts for all transport modes. The share of costs concerning health/medical fees linked to air pollution is considerable.

It is therefore understandable why all the studies we analysed take that into consideration. The other costs account for part of it but to a lesser extent (less than 15 %).

b) Pollutants taken into consideration:

Particulate matter (PM 10 and 2.5) is the element incriminated in atmospheric pollution by all the studies.

Eleven studies incorporate nitrogen oxide (NOx) for measurement of atmospheric pollution, 8 integrate sulphur dioxide (SO2) and 8 include Non-Methane Volatile Organic Compounds (NMVOC).

To a lesser extent, the other elements taken into consideration are ozone (O3), ammonia (NH3), carbon monoxide (CO), carbon dioxide (CO2) and tetrahydrocannabinol (THC). Most of the documents assign the impacts below to the pollutants in the following way:

Elements	Name	Effects
PM 10 and 2.5	Particulate matter	On health and buildings
NOx	Nitrogen oxide	On forests, agriculture and biodiversity
SO2	Sulphur dioxide	On agriculture and biodiversity
NMVOC	Non-Methane Volatile Organic Compounds	On agriculture and biodiversity
O3	Ozone	Combination of NOx + NMVOC. Effects on agriculture and biodiversity
NH3	Ammonia	On biodiversity and acidification of soils
CO	Carbon monoxide	On health and biodiversity
THC	Tetrahydrocannabinol	No data

Table 1: Effects of different atmospheric pollutants

The impact of each pollutant on the environment was monetised by some of the studies, per country. These results are summarised in graphical form below.

Illustration 2: Cost of atmospheric pollution in € per tonne of pollutant emitted in rural areas - drawn from the Ricardo-AEA study (2014)

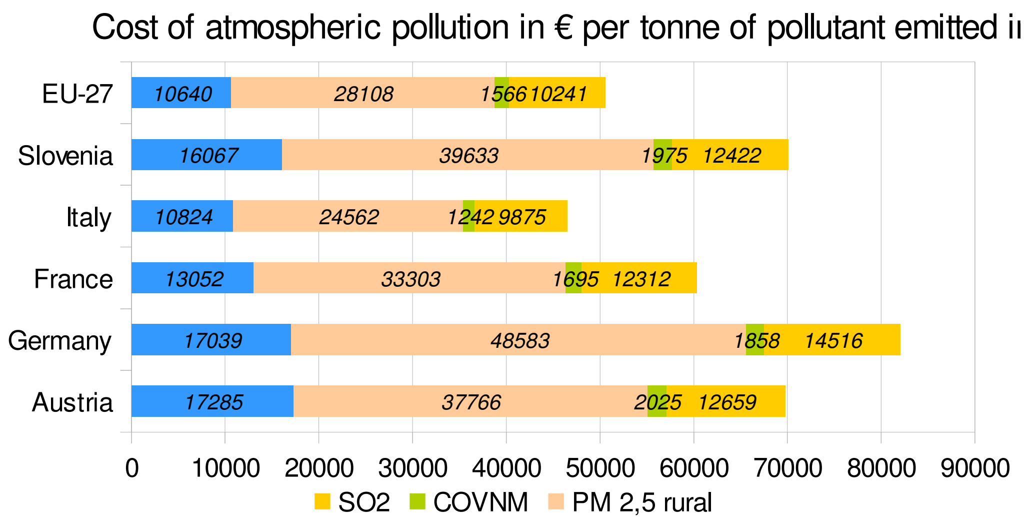
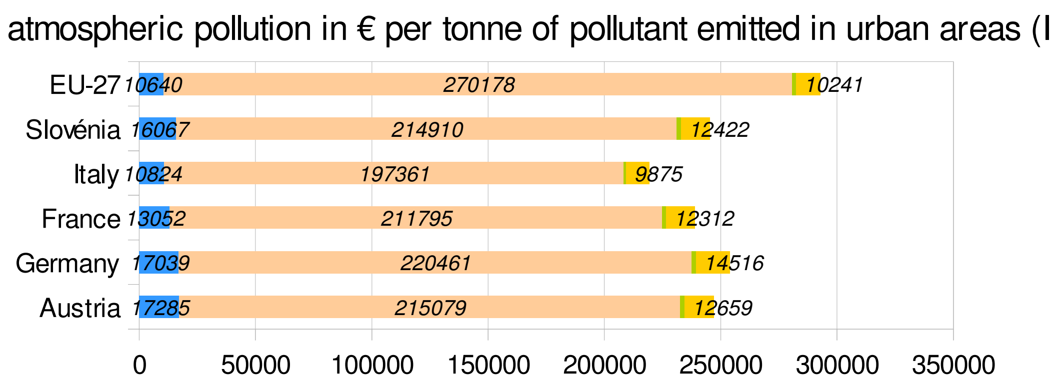


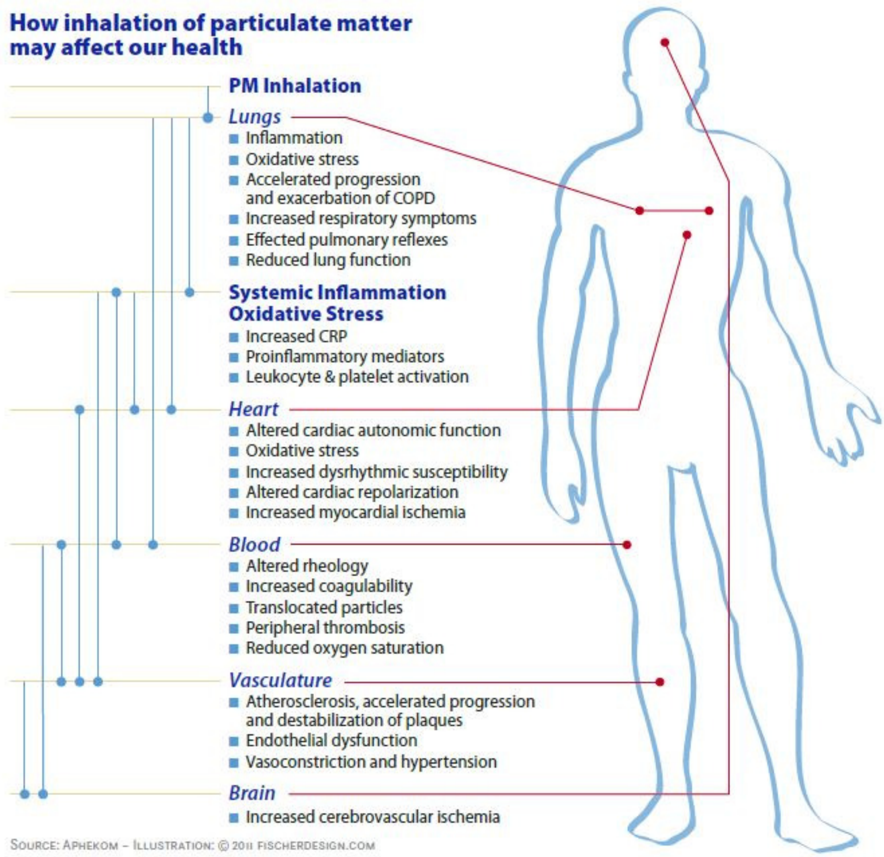
Illustration 3: Cost of atmospheric pollution in € per tonne of pollutant emitted in urban areas - drawn from the Ricardo-AEA study (2014)



Remarks on the graphs: *We only selected the countries among the 27 EU Member States that are signed up to the Alpine convention. In urban areas, the cost of a tonne of emitted pollutants is higher than in rural areas. Even if there are considerable disparities between the countries concerning rural areas, disparities lessen in urban areas.*

These graphs make it possible to grasp the significance of particulate matter's impact on the environment. As can be seen in illustration 1, **human beings are the primary beings vulnerable to**

particulate matter. The particulate matter penetrates deeply into the lungs and transports carcinogenic compounds. The smaller the particles (PM 2.5), the deeper they penetrate. The diagram below describes and pinpoints the impacts of particulate matter in human beings.



Source: Based on Pope and Dockery, 2006, cf. Aphekom project.

Illustration 4: Based on the EEA study (2010)

This is why the cost per tonne of particulate matter emitted is much higher than for any of the other pollutants.

c) Methods and data sources used to calculate air pollution:

IPA (Impact Pathway Approach) is the most commonly used calculation method for the assessment of the impacts of air pollution generated by road transport. Out of 14 studies analysed, 11 use this method. IPA is a “bottom-up”[1] method inspired by the ExternE study (2005). The IPA method calls for the use of 3 types of data:

- - Assessment of transport demand (in vkm per yr);
- - Specific emission coefficients (in g per vkm);
- - Damage factors by pollutants (in € per tonne).

Only two out of all the studies analysed, use the top-down method:[2] Reports InterAlp 2013, INFRAS 2004 and METLTM 2003.

- **Assessment of transport demand**

To assess transport demand in view of calculating air pollution impacts, the most commonly used tools are EUROSTAT, ALPINFO, SECTEN and TREMOVE. Each of their specificities is described below:

Name	Description
EUROSTAT	Soon after it was created, the EU developed a Statistical Office in 1953, thus providing the EU with statistics on Europe. EUROSTAT offers an important range of statistical data (9 main themes including transport), mainly for public authorities. In the wider family of transport data, this indicator is defined as the share, expressed as a percentage, of each transport mode out of the total number of transportation systems inside the EU, measured as ton-kilometre (). This indicator includes road, railway, inland waterways and oil pipeline transportation.
ALPINFO	Database managed by the Swiss Federal Transport Office with contributions from Austria, France and Switzerland. ALPINFO lists all road and railway traffic at the main Alps crossings.

Table 2: Traffic database

Name	Description
TREMOVE	The EU’s DG Environment developed this transport model within the framework of European Programme CAFE (Clean Air For Europe). This tool is used for the implementation of policies aimed at reducing air pollution and climate change impacts generated by transport systems. This model encompasses both passenger and freight transport systems in 31 countries, and covers years 1995 to 2030.

Table 3: Traffic model

1 Bottom-up: Upward approach – based on vehicle emissions (fleets of vehicles; engine power; etc.), assesses impact on health of exposed individuals.

2 Top-down: Downward approach – breaks down total cost of pollution between the various vehicles (engine capacities, car categories, etc.) at macro (or national) level.

Nom	Description
SECTEN	Inventory conducted by CITEPA for the Ministry for Environment. The **SECTEN** report (Economic SECTors and ENergy) is updated each year and includes 6 to 8 main sectors (including transport), in which emissions of over 50 compounds are monitored.

Table 4: Inventory for pollution assessment

- ### Emission coefficients (data related to incriminated elements)

HBFEA, COPERT and TREMOVE are the databases used to obtain the emission coefficients that served as a basis to calculate the effects of air pollution. The specificities of this data are described below:

Name	Description
COPERT	Tool used to calculate air pollutant emissions and greenhouse gas emissions generated by road transport. Built with the participation of the European Environment Agency (EEA), COPERT was developed in preparation for road transport emissions inventory in the EEA Member States. It can however be used for all relevant scientific research and academic applications.
HBFEA	Database stemming from "The Handbook Emission Factors for Road Transport (HBEFA)", which provides emission factors for all categories of vehicles (LPVs, HGVs, LCVs, bus, motorcycles), motorizations (diesel, gasoline), loading weight and road cross-section.
TREMOVE	The EU's DG Environment developed this transport model within the framework of European Programme CAFE (Clean Air For Europe). This tool is used to implement the policies aimed at reducing air pollution and climate change impacts generated by transport systems. This model encompasses both passenger transport systems and freight in 31 countries, and covers years 1995 to 2030.

Table 5: Databases of emission coefficients

- **Damage factors per pollutant (monetarisation of emissions)**

Several studies served as a source for databases used to monetise the impacts of pollutant emissions. These studies are: NEEDS, HEATCO, CAFE CBA, ALPINFO and TRENDS. CGSP (2013), in particular, is based on HEATCO data. The specificities of this data are presented below:

NEEDS	The aim of this report is to assess the costs and benefits of future energy policies and systems in each country and at EU level. This implied advanced research results for: - Life cycle analysis (LCA) of energy technologies; - Monetary assessment of externalities related to energy generation, transport, transformation and use; - Integration of LCA and information externalities in the definition of policies and development of scenarios.
CAFE CBA	This report is part of the Clean Air for Europe – CAFE – programme, which aims at developing an integrated and long-term strategy to fight against air pollution and protect human health and the environment against the impacts of this pollution. The existing community measures and proposals aimed at improving air quality define target values for air quality, as well as national threshold values to fight cross-border air pollution. They also provide integrated pollution reduction programmes in concrete areas, as well as specific measures for the limitation of emissions or improvement of products quality.
HEATCO	European project based on the assessment of transport projects in Europe by analysing current practices in EU countries and Switzerland. It suggests guidelines for the assessment of inter-European transport projects, focusing on specific elements such as evaluation techniques for non-market values (risks, impacts of non-monetised values, updating…), evaluation of traffic and congestion, time value, accidents and environmental costs (air pollution, noise, global warming, maintenance costs and infrastructure operation).
ALPINFO	Database managed by the Swiss Federal Transport Office with contributions from Austria, France and Switzerland. ALPINFO lists all road and railway traffic at the main Alps crossings.

Table 6: Monetisation of emissions

In some cases, the data is used to take account of certain impacts in a specific way. **Some studies use multiplying factors to factor in the density of the impacted population** (Delft Infras 2011, CGSP 2013, Ricardo-AEA 2014, TransAlpine 2008 and GRACE 2006). Other studies, such as EEA 2013, ARE 2014 and Ecoplan 2014, provide no value per vehicle -.

2) Noise:

Based on the bibliographical analysis, the objective of this section is to analyse the methods used to calculate external costs related to noise. This section will focus first on the environmental effects factored in by the different methods to calculate noise, and second, on the methods and data sources used for calculation. Thirteen of the studies analysed tackle the noise issue.

a) Effects taken into account:

In the analysis of those 13 studies, the majority of effects integrated in external costs calculation generated by noise were related to disturbance costs (10 studies) and health consequences (11 studies).

Housing value depreciation due to noise is only included in 3 studies (ARE 2014, ECOPLAN 2014 and METLTM 2003). To some extent, they can be considered as also reflecting the cost of disturbances and health consequences, since people take them into account in their choice of a location to settle. The ARE 2014 and ECOPLAN 2014 studies monetise the effect of noise on people (physical and psychological illnesses) based on epidemiological studies[3]. The EEA 2010 survey only tackles the impact of noise pollution on health. The impact of noise was not monetised.

Out of the 13 studies analysed, 6 provide information on the marginal cost of noise, including 4 providing values for this marginal cost of noise depending on which population is impacted and on the time of day.

b) Methods and data sources used to calculate air pollution:

The most commonly used calculation method to assess the effect of noise generated by road traffic stems from the IPA (Impact Pathway Approach). 9 out of 13 studies analysed use it. The IPA is a bottom-up method inspired by the ExternE study (2005). The IPA method calls for the use of three types of data:

- Noise exposure data;

- Data related to the cost per exposed person and distribution of total external costs between the various categories of vehicles, based on weighting factors.

3 We were not able to analyse those epidemiological studies.

- **Noise exposure data**

The assessment of the number of people impacted by noise is important data to understand the number of people impacted at their place of residence. **This assessment is conducted based on strategic noise maps, in compliance with the requirements of the European Directive 2002/49/EC applying to all Member States.**

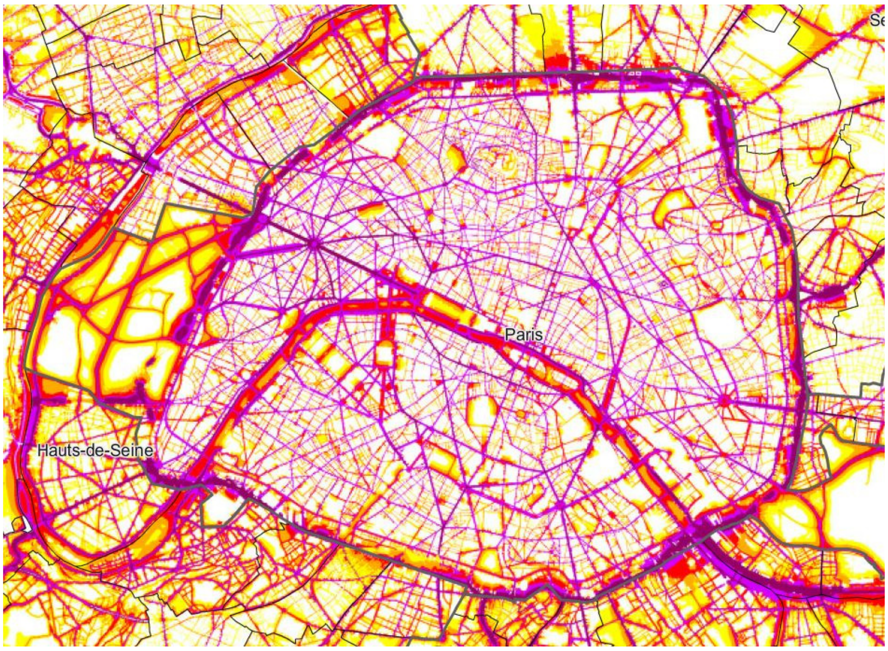


Illustration 5: Source: BruitParif (2016)

This map applies to conurbations of over 100,000 inhabitants or to roads with traffic levels exceeding 3 million vehicles per year. Given the compulsory character of the Directive, all studies analysed recommend its implementation, except the Swiss studies (ARE 2014 and ECOPLAN 2014), and one study, METLTM 2003, which uses a top-down method.

This map has its limits: it does not cover all territories (conurbations of less than 100,000 inhabitants and roads travelled by less than 3 million AADT). A threshold at 45dB was chosen by scientific researchers to take account of noise pollution.

All these limitations led certain studies to use a different method to calculate the cost of noise. Two studies use an alternative method rather than the method in the European Directive:

The UBA 2015 report, noise calculations were computed using LIMA, mapping software from Germany. This programme uses the V-BUS sound pollution calculation method. This method allocates a sound absorption level to buildings governed by population density.

Name	Description
LIMA	Noise calculation software to calculate noise levels and their impacts on the environment. It creates, calculates and displays maps showing the effects of noise. It integrates the European Directive as well as other methods (V-BUS, etc.).
V-BUS	VBUS is a preliminary noise calculation method for noise generated by road traffic. It is a German method used for acoustic calculations and the development of strategic noise maps. The Lden noise index (24h weighting, average value) and Lnight one were calculated based on a step size of 10 m x 10 m with a sensor located at 4m above ground.

Table 7: German method serving as an alternative to the European Directive's strategic maps

When no noise map is available and traffic levels are known, the CGSP 2013 report offers a similar method to take account of noise disturbances. Various samples, that had been used to develop strategic maps, were measured to obtain these values.

- **Data related to the cost per person exposed and distribution of total external costs between the various categories of vehicles based on weighting factors**

Out of 13 studies analysed, 8 studies provide information on this data and 3 studies (Delft Infras 2011, ALE 2012 and CGSP 2013) used data drawn from the HEATCO 2006 study.

3) Other costs (excluding noise and air pollution):

This section aims to analyse other external costs for which the Eurovignette III European Directive does not provide average values for HGVs. This section focuses first on other external costs (excluding noise and air pollution) included in other studies. Second, this section presents a comparison between the different studies based on the share of each impact in the total sum of external costs. 9 studies are analysed in this section.

a) External costs factored in

As far as other external costs are concerned, the Eurovignette III European Directive provides no average values enforceable on HGVs. However, out of 15 studies, 9 provide us with extra information regarding other external costs. These studies are[4]:

Illustration 6: Other environmental costs factored in

	Nature & landscape	Water & soil	Upstream Downstream	Accidents	Urban	Biodiversity	Climate change	Mountain areas	Congestion
ARE (2014)	X	X	X	X	X		(**)		
ALE (2012)			X	X			(**)		
CGSP (2013)			X	(X)			(**)		(X)
Delft-Infras (2012)	X	X	X	X	X	X	X		
ECOPLAN (2014)	X	X	X	X	X		X		
GRACE (2006)			(°)	(°)			(°)	X	(°)
INFRAS (2004)	X		X	X	X		(**)		(*)
RICARDO AEA (2014)			(°)	(°)			(°)		(°)

For each environmental cost, analytical methods vary from one study to the other, as well as unitary values (million €, CHF or in € per 100 HGV.km). **It appears that most studies analyse the upstream and downstream[5], accidents, and climate change impacts.**

The CGSP 2013 study considers that accidents and congestion are not to be included in external environmental costs, whereas the other studies incorporate them.

The issue of climate change is tackled in different ways depending on the study. Indeed, they allocate a varying value to each tonne of CO2 emitted and their scenarios (high and low levels) are based on these values. This CO2 value also has an impact on the results showing upstream-downstream effects.

4 (*) Congestion costs calculated by measuring the loss of surplus due to inefficient infrastructure use - (**) Cost of avoidance of each tonne of GHG emitted, according to different scenarios (high and low levels). High-level scenario selected for studies - (°) case studies where externalities are analysed independently - (X) Not integrated as external environmental costs.

5 ups and-downstream effects: composed of three externalities: those related to the generation of energy and its delivery, those related to the production of vehicles and those related to the life cycle of the infrastructure

So as to measure the share of environmental costs in the total of all external costs, we have analysed the share of each cost in the total sum. Some studies, because of their specificities, present costs that we will not be able to subsequently analyse. For instance, GRACE 2006 and Ricardo-AEA 2014 process each external cost independently for each specific location (or specific values).

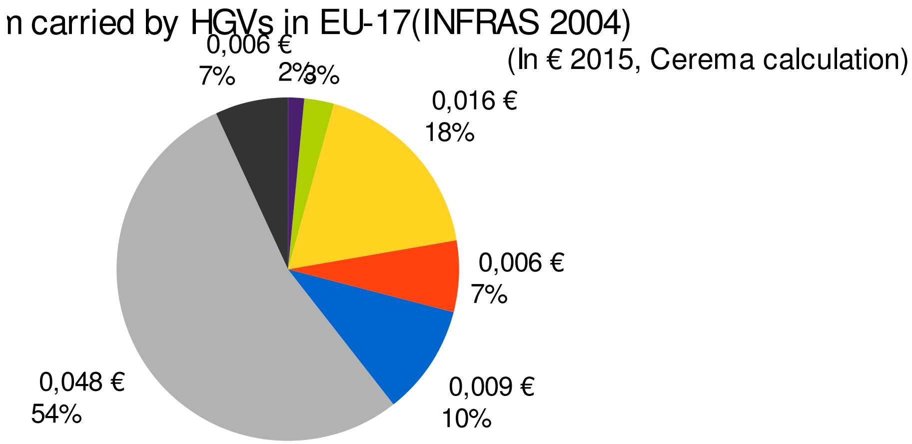
b) Share of each impact out of the total sum of external costs:

Concerning HGVs, we analysed the share of each environmental impact out of the total cost, whenever the data was available. Two analyses thus were conducted:

- Share of each external cost out of the total cost, expressed in million € (or CHF);

- Share of each external cost in € per 100 HGV.km.

- **Share of each external cost out of the total cost in euros per tonne.km:**[6]



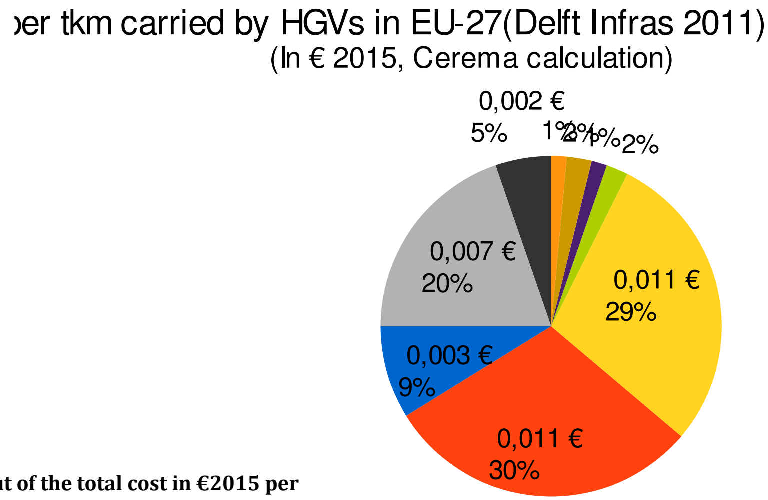
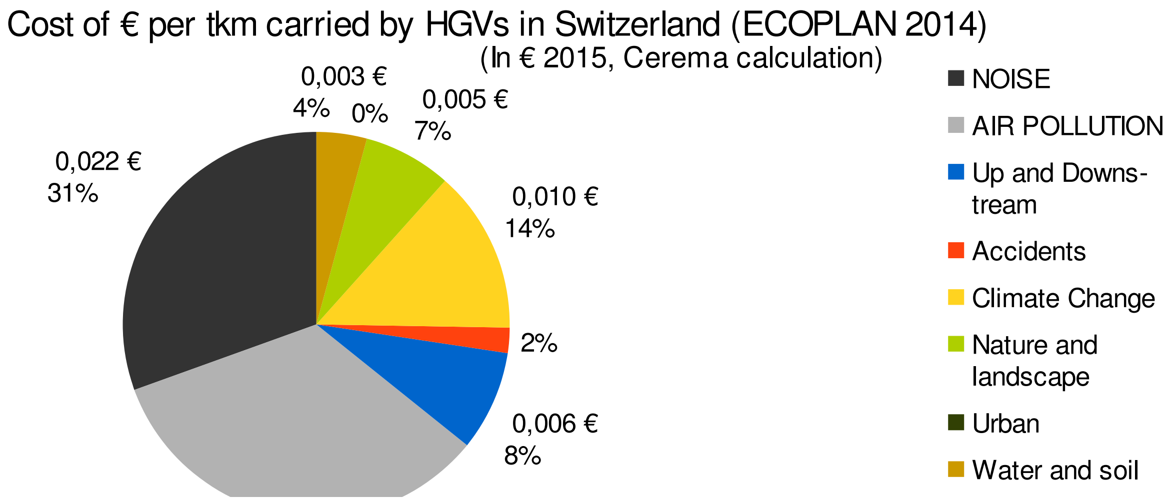


Illustration 7: Share of each external cost out of the total cost in €2015 per tonne.km



Updating monetary values in 2015 euros. For EU INFRAS 2004, updating 2000 euros in 2015 euros (Inflation at €1.243). For Delft Infras 2011 updating of 2008 euros in 2015 euros (Inflation at 1.09). For ECOPLAN, switching from CHF 2010 to 2010 euros with 1 CHF2010 = €0.72. Updating of 2010 euros in 2015 euros (Inflation at €1.07).

Expect for the upstream-downstream effects and climate change impacts, the 3 graphs show values that are quite different. This most likely has to do with calculation methods. Differences between INFRAS 2004 and Delft Infras 2011 are quite substantial. Several potential explanations of these differences between Infras 2004 and Delft Infras 2011 are presented below:

- **Scope of countries covered:** this has an impact on the various cost values (revenues, cost of healthcare, lower GDP per inhabitant).

The scope of both studies (moving from 17 States in 2004 to 27 States in 2011), by including Eastern European countries, most of which have lower average cost values compared to Western Europe. These lower costs give rise to lower calculation factors and coefficients, to take account of revenue levels, healthcare costs and generally lower GDP per inhabitant compared to Western Europe.

- Development of motorization: cleaner in 2008 than in 2000

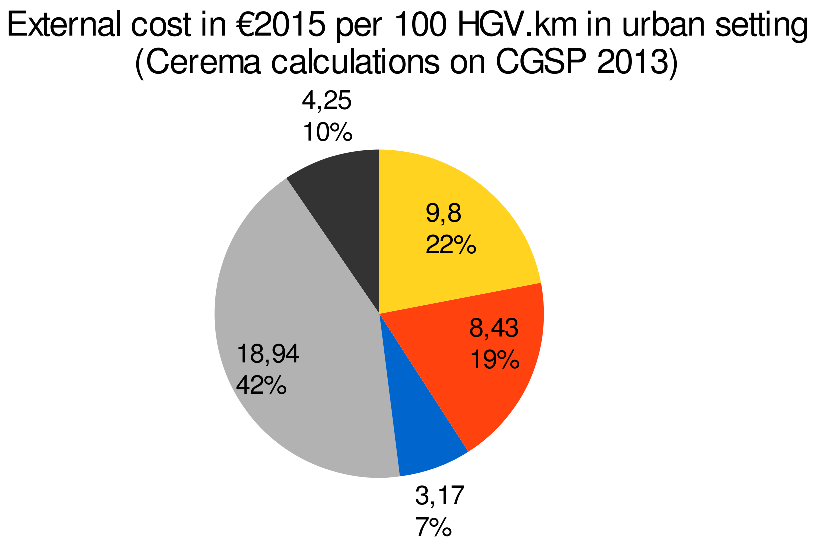
The Euro standard policy reduces the emissions of HGV engines, which is factored in Delft Infras 2011 and shows "cleaner" HGVs than those on the roads in 2000.

- Avoidance of death value changes: higher in 2008.

- Accident assessment method: takes account of the risk of damage in the event of an HGV accident.

As for accidents, a new calculation method was developed in Delft Infras 2011. It takes into account the cost of accidents (…) as well as the potential damage that could be caused by heavier vehicles (HGVs) on other road users. The risk of fatalities and injuries due to an HGV accident is higher than with cars. This is reflected in a factor, which is higher for HGVs compared to cars. Therefore, the impact of HGV accidents in Delft Infras 2011 is higher than in the other studies.

- **Share of each external cost in € per 100 HGV.km**



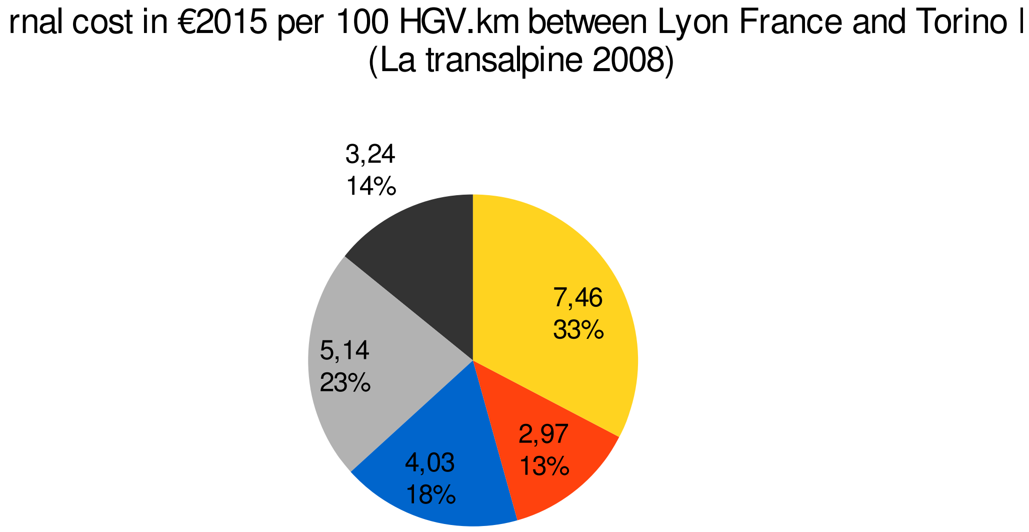
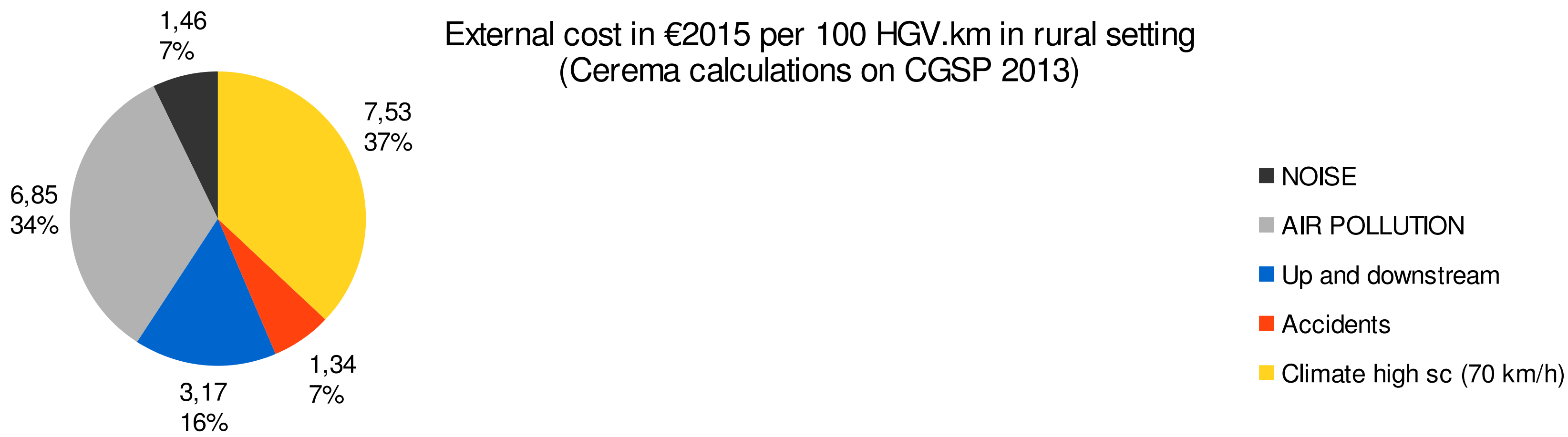


Illustration 8: Share of each external cost out of the total cost in €2015 per 100 HGV.km



Values provided by CGSP 2013 integrate noise, air pollution and upstream-downstream effects in external costs. As far as accident rate values are concerned, we listed all accidents involving an HGV in 2014, applied monetary values for each type of accident (material damage, light injuries, injuries with hospitalisation, fatalities), and analysed this in view of the number of HGVs circulating in France in 2014. As far as climate change is concerned, we selected the high-value scenarios for CO2 (100 € per tCO2) and calculated emissions for an HGV running at 35 kph in urban areas and 70 kph outside urban areas. These are indicative values to illustrate orders of magnitude.

The study entitled “La Transalpine” focuses on a Lyon - Torino journey. Several impacts are integrated. So as to compare it with CGSP 2013, we selected the following impacts: noise, air pollution, upstream-downstream effects, accident rates and climate.

CGSP 2013 values in rural areas are lower than those in urban areas, except for upstream-downstream effects. The calculation method used in CGSP 2013 provides a single value for upstream-downstream effects, irrespective of population densities (rural, urban areas), whereas all other indicators do, depending on the urban context. This is the reason why the share of upstream-downstream effects rises when moving from urban to rural areas.

The values provided by “La Transalpine” appear much lower than the values of CGSP 2013. This has to do mainly with the values related to climate change. CGSP 2013 selects the high-level scenarios to account for climate change. The value of each ton of CO2 is €100, which tends to increase the share of climate change in the total cost.

Overall, the results are mixed and changes in the scope of studies, engine types and human life value may probably not fully explain this variability. Other factors such as the calculation method and the databases employed might explain such differences.

With regard to other external costs for which Eurovignette III does not show cost values, accidents, climate change and upstream-downstream effects represent quite a significant percentage of external costs.

None of the studies account for accidents in their external costs. In fact, some studies define external environmental costs as being just those costs that have an impact on the environment. Indeed, accidents would not be included because they have a direct impact on equipment, the resources implemented to treat accidents (minor and serious injuries; human life value) and only accident victims.

Despite the weighting allocated to climate change, the latter is an external cost with a global impact beyond the scope of a section of road or a community. A tonne of CO_2 emitted in a mountainous area has just as much of an effect on global warming as if it had been emitted in another area.

In terms of upstream-downstream effects, we have identified 3 externalities: those related to energy production and its transportation, those related to vehicle production and those related to infrastructure life cycle. The majority of studies only take into account some of the effects related to energy transportation and distribution.

Hence, for mountainous areas, the other external costs to be analysed are related rather more to those that have a direct local impact: nature and landscape, urban, biodiversity and water and soil.

III MONETISATION OF EXTERNAL COSTS

In Chapter II, the top-down (Impact Pathway Approach) calculation methods and data sources used are almost identical. However, it is difficult to make comparisons between values taken from different bibliographical sources. There are great disparities due to the use of specific data, particularly for traffic and speed, as well as specific coefficients to take account of population density and topographical features.

This Chapter III tackle comparing the base values taken from 15 studies analysed with the Eurovignette III Directive values. This comparison will start with addressing air pollution and follow on with noise pollution.

1) Air pollution:

In this section, the Eurovignette III European Directive values for air pollution will be compared with the values from the other studies included in the bibliographical analysis. Out of the 14 studies addressing the issue of air pollution, few values could be used for this comparison. Only the results of the GRACE (2006), CGSP (2013), Delft Infras 2011 and ALE 2012 (based on Delft Infras 2011) studies could be compared with the European Directive.

This section will first address the objective and method used for the comparison. Then we shall analyse the results of the comparison between Eurovignette III and the other studies for an urban and a rural fabric.

a) Objective and method:

The objective of this analysis is to compare the values taken from Eurovignette III with the 14 studies analysed. To improve the comparison, the data for costs by European standard in the European Directive have been averaged according to the HGV fleet on French roads in 2015.

We thus obtain the average cost for HGVs according to Eurovignette III from the HGV fleet on French roads in 2015.

Density	Urban	Inter-urban
€ per 100 HGV.km	44.2	34.2

Table 8: Eurovignette III Directive aggregated according to French HGV fleet in 2015

On average, using Eurovignette III, an HGV travelling on an urban road may be taxed at a level of €0.04 per kilometre, as against €0.03 per kilometre if travelling on an interurban road.

Only the values available (i.e. from studies that provide euro per vehicle values) will be compared with Eurovignette values, i.e. the following studies:

CGSP 2013, Delft Infras 2011 and ALE 2012 (based on the results of the Delft Infras 2011 study).

The other studies (Ecoplan Infras 2014, ARE 2014 and a GRACE 2006 case study) either provide values for a given year (million CHF in 2014 for ARE 2014 and Ecoplan Infras 2014 and million € for InterAlp 2013), or include other costs under air pollution (climate change for the GRACE 2006 case study). INFRAS 2004 was not been used, because it was updated by the Delft Infras 2011 study.

Other studies provide us with a range of values by HGV tonnage (Ricardo-AEA 2014 and UBA 2015) or only provide values in euros per tonnes of pollutants emitted (EEA 2013).

For all these studies, the exercise to reduce them to identical unit values (€ per 1,000 HGV.km) within the time allowed appeared too complex to perform. This is the reason why we shall not use them for a comparison with the Eurovignette III Directive.

b) Comparison between Eurovignette III Directive, CGSP 2013, Delft Infras 2011, ALE 2012 and GRACE 2006[7]:

In € per 1000 HGV.km	**URBAN**	**RURAL**
Eurovignette III	44,2	34,2
Delft Infras 2011 (in € 2008)	83,4	64,3
CGSP 2013 (in € 2010)	177	94
GRACE 2006 (Prague in € 2006)	83	
GRACE 2006 (Copenhagen in € 2006)	82	
GRACE 2006 (Berlin in € 2006)	94	

Table 9: Comparison of air pollution between the Eurovignette III European Directive and other studies

The aggregated values of the Eurovignette III Directive are lower overall than the values proposed by other studies for an identical urban fabric. Compared with the other studies, by not applying a factor of 2, the Eurovignette III Directive underestimates the impact of air pollution.

In an urban environment, the CGSP 2013 values are 4 times higher than the Directive and the Delft Infras 2011 values are almost twice as high. The case studies taken from GRACE are around 88% higher to twice as high for Berlin.

In a rural environment, the CGSP 2013 values are 3 times higher than the Directive, whilst the Delft Infras 2011 values are almost twice as high as the Eurovignette III Directive.

The CGSP calculation method applies a correction factor of 2.5 to take account of changes in the annual human life value (HLV) between Delft Infras 2011 (€115,000) and the HEATCO and HBEFA reports (€46,000). Other factors are allocated according to the density of population living close to the infrastructure and the urban fabric. This is the reason why the CGSP values are quite high.

2) Noise:

In this section, the Eurovignette III European Directive values for noise will be compared with the values from the other studies included in the bibliographical analysis. Out of the 13 studies addressing the issue of noise pollution, few values could be used for this comparison. Only the results of the CGSP (2013), Delft Infras 2011 and ALE 2012 (based on Delft Infras 2011) studies could be compared with the European Directive.

7 Values taken from Delft Infras for "urban" and "suburban" apply in this report to "urban" and "rural" respectively. Values taken from CGSP for "urban" and "rural" apply in this report to "urban" and "rural" respectively.

This section will first address the objective and method used for the comparison. Then we shall analyse the results of the comparison between Eurovignette III and other studies for an urban and a rural fabric.

a) Objective and method:

The objective of this analysis will be to compare the values taken from Eurovignette III with the 13 studies analysed. The Eurovignette III Directive sets out the maximum cost that can be charged to road users:

€ per 100 HGV.km	Day	Night
Urban	11	20
Inter-urban	2	3

Table 10: Eurovignette III Directive for noise values

On average, applying Eurovignette III, an HGV travelling on an urban road in the daytime may be taxed at a level of €0.011 per kilometre and €0.02 per kilometre if travelling on the same road at night. According to Eurovignette III, noise impacts due to vehicle use are about twice as high at night as during the day, whatever the urban area.

Only the values available (i.e. from studies that provide euro per vehicle values) will be compared with the Eurovignette values, i.e. the following studies:

Quinet 2013 (average values on national and regional roads), Delft Infras 2011 (average HGV values) and ALE 2012 (based on the results of Delft Infras 2011).

The GRACE 2006 and Ricardo-AEA studies only provide us with marginal costs for noise.

The Ecoplan 2014, ARE 2014, InterAlp 2013 and UBA 2015 studies provide values for a given year (million CHF in 2014 for ARE 2014 and Ecoplan Infras 2014 and million € for InterAlp 2013 and UBA 2015). Therefore they are not reduced to identical unit values.

EEA 2010 only gives us noise levels and their effects on human health. INFRAS 2004 was not used, because it was updated by the Delft Infras 2011 study.

This is the reason why we shall not use them for a comparison with the Eurovignette III Directive.

b) Comparison between Eurovignette III Directive, CGSP 2013 (national and regional), Delft Infras 2011 and ALE 2012:

This table summarises the data available in terms of noise pollution cost[8]. We are then going to compare the values for urban and inter-urban.

€ per 1000 HGV.km		Day	Night
Eurovignette III	Urban	**11**	**20**
	Rural	**2**	**3**
Delft Infras 2011 (in € 2008)		19.4	
CGSP 2013 (in € 2010)	Urban	39.7	
	Rural	13.6	

8 In Delft Infras the costs for urban and light rural are in italics because they relate to the cost of a vehicle when traffic is light. It is logical that this cost is higher, because the impact of vehicle in an area where there is little or no traffic is greater than that of the additional vehicle in an area with very high traffic.

Table 11: Comparison of noise pollution between the Eurovignette III European Directive and other studies

Noise pollution costs in the Eurovignette III Directive are much lower for urban areas than the values proposed by studies addressing the question of noise cost in urban areas. The table below gives the difference in noise cost for urban zones between the European Directive and other studies.

Overall, the values taken from Delft Infras 2011 and CGSP 2013 are generally greater than the costs recommended by Eurovignette III.

It is noted that the Eurovignette III European Directive values are lower than those from case studies or those calculated on a national scale.

We conducted the same operation for rural areas. Noise pollution costs in the Eurovignette III Directive are much lower for rural areas than the values proposed by studies addressing the question of noise cost in rural areas. The table above gives the difference in noise cost for rural areas between the European Directive and other studies.

IV MOUNTAINOUS AREAS

Chapter III has enabled us to observe that there are significant differences between Eurovignette III values and the other studies. The application of a factor of 2 to Eurovignette III barely enables us to get close to the base values of the other studies.

The purpose of this Chapter IV is to analyse the results of studies in mountainous areas and to compare them with the recommendations of the Eurovignette III European Directive for mountainous areas. The methods and results of calculations of external environmental costs will therefore be analysed for mountainous areas only, based on 15 bibliographical resources, referenced in the annex.

a) Air pollution in mountainous areas:

In this section, the Eurovignette III values in mountainous areas for air pollution will be compared with the values in the other studies addressing the issue of mountainous areas. Out of the 14 studies addressing the issue of air pollution, only 4 studies address the question of mountainous areas (METLTM 2003, GRACE 2006, La Transalpine 2008 and InterAlp 2013).

This section will first of all set out the methods for calculating external costs in mountainous areas and then compare its results with Eurovignette III for an urban and a rural fabric.

1) Method for calculating external costs in mountainous areas:

Only 4 studies (METLTM 2003, GRACE 2006, La Transalpine 2008 and InterAlp 2013) specifically assess mountainous areas. If we consider Switzerland as a mountainous area, this takes the number of studies to 6. The studies use databases specific to their case study, particularly for mountainous areas (GRACE 2006, MELTM 2003, La Transalpine 2008 and InterAlp 2013), or specific data from their case study (ARE 2014 and Ecoplan Infras 2014).

METLTM 2003 and InterAlp 2013 use a top-down method. GRACE 2006 and La Transalpine 2008 use a bottom-up method.

METLTM 2003 has produced models for population spread around infrastructures and for pollutants dispersing specific to valleys, taking containment effects into account. Slopes have not been taken into account. According to an ADEME study, the slope impact on HGV consumption is estimated at a factor of 1.5 to 2.1 (Boiteux II Report of June 2001).

InterAlp 2013 has taken account of slope incline effect and HGV load impact on consumption. This points to the fact that slopes have a significant effect on consumption. A half-loaded HGV (Euro 5) ad travelling at 50kph consumes 272g of fuel per kilometre for a 0% slope. This vehicle consumes 1015g for a 6% upward slope (i.e. 3.7 times more than on flat ground) and 19.6g (i.e. 13 times less) on a 6% downward slope.

The conclusions for nitrogen oxide are quite similar. A half-loaded HGV (Euro 5) travelling at 50kph emits 3gpkm of NOx. On a 6% upward slope, it emits 9.5gpkm of NOx (i.e. 3.2 times more than on flat ground), and on a downward slope, it tends toward zero emission.

For particulate matter (PM), the conclusions are less clear-cut. A half-loaded HGV (Euro 5) travelling at 50kph emits 0.03gpkm. On a 6% upward slope, it emits 0.05gpkm of PM (i.e. 0.6 times more than on flat ground) and on a downward slope, almost 0.01gpkm (i.e. twice as little as on flat ground).

The GRACE 2006 study concentrating on mountainous areas has used the IPA method. To take better account of mountainous areas, it has typified emissions (due to altitude and to temperature inversions), concentration (due to topographical and weather conditions) and impacts (population density). No specific points had been identified with regard to infrastructure costs. The GRACE 2006 results come from the collection of knowledge based on different specific research projects in various specificities (MONITRAF-project). The difference coefficient for air pollution between lowland and Alpine areas turns out to be around 5.15 for HGVs.

The external unit costs used in the La Transalpine 2008 study were based on HBFEA 2008 and adapted to the specificities of France-Italy cross-border hauling. These values apply to the HGVs (Euro 5 standard). A factor of 2 for the road was applied to the 2008 HBFEA values that were used. Concerning the impact of traffic congestion, differences were introduced to take account of day and night, peak times or slack periods but the calculation results did not detail them.

2) Comparison between Eurovignette III Directive and GRACE 2006, La Transalpine 2008 and METLTM 2003 studies in mountainous areas for air pollution:

According to the Eurovignette III Directive, *"The table 1 values can be multiplied by a maximum of 2 in mountainous regions, insofar as the slope of the road, altitude and/or temperature inversions allow".* The Directive therefore leaves scope for allocating a factor of 2 to Eurovignette III values in mountainous regions. We have applied this factor to compare it with the two results from mountain studies.

The pricing study of external transport costs in mountainous areas conducted by METLTM in 2003 indicates much higher values than those of Eurovignette III factor of 2 (mountainous areas).

The results taken from the La Transalpine 2008 study are close to Eurovignette III "Factor of 2". This study uses values taken from HBEFA 2008, to which a factor of 2 has been applied to certain impacts and to take account of mountainous areas.

A mountainous area case study conducted in the GRACE 2006 report concludes that, for HGV emissions, a factor of 5.15 must be applied to take account of the impact of the topographical constraints of mountains compared to lowland areas. This factor has been applied to the Directive under the name of "Eurovignette III factor of 5.15".

€ per 1000 HGV.km	Urban mountain roads	Interurban mountain roads
Eurovignette III (in € 2008)	*44.20*	*34.20*
Eurovignette III factor of 2 (in € 2008)	**88.40**	**68.40**
METLM 2003 (in € 2000)	230	200
La Transalpine 2008 (in € 2006)	45.5	
Eurovignette III (factor of 5.15)	227.63	176.13

Table 12: Comparison of air pollution in mountainous areas between the Eurovignette III European Directive and other studies We note that the METLTM 2003 values are 3 times higher than the Eurovignette III (factor of 2) values for inter-urban roads in mountainous areas.

For urban roads in mountainous areas, the METLTM 2003 values are 2.6 times higher than the Eurovignette III (factor of 2) values.

Compared with the La Transalpine 2008 study, the values are lower than Eurovignette III (factor of 2) values.

By applying factor of 5.15 taken from the GRACE 2006 study to the values of the Eurovignette III Directive, the METLTM 2003 values are 14% higher than the Eurovignette III (factor of 5.15) values for inter-urban roads in mountainous areas. For urban roads in mountainous areas, the values of METLTM 2003 and Eurovignette III (factor of 5.15) are almost identical (Eurovignette III (factor of 5.15) being 1% lower).

For the La Transalpine 2008 study, the factor of 5.15 is 5 times higher.

With regard to air pollution, the base values of Eurovignette III are too low for the factor of 2 to allow the sensitivity of mountainous areas to be taken into account.

b) Mountainous areas and noise: *In this section, the Eurovignette III values in mountainous areas for noise will be compared with the values of other studies addressing the issue of noise in mountainous areas. Out of the 13 studies addressing the question of noise pollution, only 3 studies address the issue of mountainous areas (METLTM 2003, GRACE 2006 and La Transalpine 2008).*

This section will start by setting out the methods for calculating external noise cost in mountainous areas and then compare its results with Eurovignette III for an urban and rural fabric.

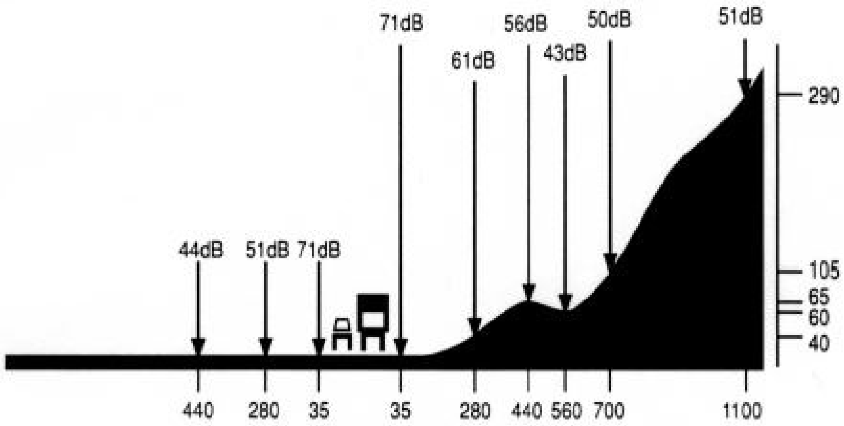
1) Method for calculating external noise costs in mountainous areas:

Only 3 studies (METLTM 2003, GRACE 2006 and La Transalpine 2008) specifically assess noise in mountainous areas. If we consider Switzerland as a country in a mountainous zone, this takes the number of studies to 4. The studies use databases specific to their case study, particularly in the case of mountainous areas (GRACE 2006 and MELTM 2003) or specific data from their case study (ARE 2004, Ecoplan 2014 and INFRAS 2004).

METLTM 2003 studies use the top-down method based on the noise avoidance cost approach; METLTM distributed the amount of known work between the various network sections concerned. Only networks taking traffic of over 50,000 vehicles per day and the urban characteristics of the section were selected. From this calculation comes a cost per kilometre closer to reality. Cost is charged by adopting the following equivalence coefficient: 1 HGV = 10 LPVs.

METLTM 2003 produced models for population spread around infrastructures. In addition, it used the noise-spread model developed by AEE in 1999, which is based on distance from the motorway.

Figure 2: Noise spread in mountainous areas compared to lowland areas



Distance from the motorway in [m]

Source: GRUBER (1994), cit. in BMVIT (1999)

Illustration 9 : from the METLTM study 2003

The values used per type of vehicle stem from the average calculation of damage on the A43 motorway due to noise, i.e. €0.03 per HGV*km.

The GRACE 2006 study measured noise impact by including temperature inversion and resonance effects in mountainous areas. Such effects required greater distance from the road in order to reduce their impact. A number of the Swiss, German and Austrian studies - Scheiring (2000) and Weissen (1996), factored in those impacts.

By factoring in both density of exposed population and increase of the noise impact, the report recommends a factor of 5.1 for HGVs.

The external unit costs used in the La Transalpine 2008 study were based on HBFEA 2008 and adapted to the specificities of France-Italy cross-border hauling. These values apply to the HGVs (Euro 5 standard). A factor of 2 for the road was applied to the 2008 HBFEA values that were used. Concerning the impact of noise, differences were introduced to take account of day and night, peak times or slack periods but the calculation results did not detail them.

<u>2) Comparison between Eurovignette III Directive and mountain-oriented studies - GRACE 2006, La Transalpine 2008, and METLTM 2003 Noise:</u>

According to the Eurovignette III Directive: “Table 2 values can be multiplied by 2 at the most, in mountainous regions, if the slope of the road, altitude and / or temperature inversions justify it.” The Directive therefore allows applying a factor of 2 to Eurovignette III values in mountainous regions. We applied this factor to compare it with the 3 sets of results of the mountain studies.

The study on the pricing of external transport costs in mountainous regions carried out by METLTM in 2003, as well as the Lyon-Torino link done by La Transalpine 2008, and case study in mountainous areas included in the GRACE 2006 report, concluded that a factor of 5.1 should apply to take into account the impact of topographical constraints in mountains versus lowlands. This factor was allocated to the Directive under the designation of “Eurovignette III factor of 5.1”.

<table>
<tr><td colspan="2">€ per 1000 HGV.km</td><td>Day</td><td>Night</td></tr>
<tr><td rowspan="2">Eurovignette III</td><td>Urban</td><td>11</td><td>20</td></tr>
<tr><td>Rural</td><td>2</td><td>3</td></tr>
<tr><td rowspan="2">Eurovignette III "factor of 2"</td><td>Urban</td><td>22</td><td>40</td></tr>
<tr><td>Rural</td><td>4</td><td>6</td></tr>
<tr><td rowspan="2">METLTM</td><td>Sensitive area (high assumption)</td><td colspan="2">30</td></tr>
<tr><td>Sensitive area (low assumption)</td><td colspan="2">30</td></tr>
<tr><td>La Transalpine</td><td>Lyon-Torino</td><td colspan="2">28.7</td></tr>
<tr><td rowspan="2">Eurovignette III "factor of 5.1"</td><td>Urban</td><td>56.1</td><td>102</td></tr>
<tr><td>Rural</td><td>10.2</td><td>15.3</td></tr>
</table>

Table 13: Sound pollution in mountainous areas: Comparison between European Eurovignette III Directive and other studies

When comparing Eurovignette III “factor of 2”, those results converge with the two other mountain-oriented studies (METLTM 2003 and La Transalpine 2008).

The Eurovignette III “factor of 5.1” values are higher that the results from mountain-oriented studies on urban areas.

V ASSESSMENT

The analysis of the fifteen bibliographical references points to similarities between them, particularly the calculation methods and data sources that were used. The differences mostly concern coefficients allocated to take account of average speed, urban fabric or value per tonne of pollutant emitted.

Our analysis has brought out the fact that the base values from the European Eurovignette III Directive are lower than those in the studies we analysed.

Out of the fifteen bibliographical references, only four took account of mountainous areas. According to these four (METLTM 2003, GRACE 2006, Transalpine 2008 and InterAlp 2013), resorting to a factor of 2 seemed insufficient to account for the additional sensitivity to atmospheric pollution, of mountainous areas.

Project GRACE 2006 recommends applying a multiplication factor, i.e. 5.15 for air pollution and 5.1 for noise. A similar factor is indicated in the METLTM 2003 report for air pollution. For noise pollution, the factor of 2 as per the Directive is fairly close to the results produced by the other studies examining mountainous areas.

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Glossary

Upstream-downstream effect:

Composed of 3 externalities: those related to energy generation and its delivery; those related to the production of vehicles; and those related to the life cycle of the infrastructure.

External cost:

External costs are effects related to transport use, not taken into account in the costs paid by those agents using transportation.

External environmental cost:

Secondary effects impacting the environment exclusively.

Particulate Matter (or PM):

Particulate matter (PM) suspended in the air are called aerosol. Their toxicity applies essentially to particulate mater smaller than 10µm in diameter (PM 10 and PM 2.5). Their effect on health depends first on their grain size (the smaller their diameter, the deeper they get inside the respiratory system), and second on their chemical composition. Some could contain toxic products such as metals or polycyclic aromatic hydrocarbons (PAH) considered as carcinogenic. The larger ones are stopped and disposed of by the nose and upper respiratory tract (source: *dictionnaire-environnement.com*).

Non-methane volatile organic compounds (NMVOC)

Non-methane volatile organic compounds (NMVOC) are due mostly to transportation and industrial activities. They are produced in large quantities by road vehicles burning fossil fuel. Beyond this direct impact on health, they are part of the ozone production process in the lower atmosphere (source: *dictionnaire-environnement.com*).

Bottom-up:

Upward approach - based on vehicle emissions (fleets of vehicles; engine power; etc.); assesses impact on health of exposed individuals.

Top-down:

Downward approach – breaks down total cost of pollution between the various vehicles (engine power, car categories, etc.) at macro (or national) level.

Life Cycle Analysis (LCA):

The LCA measures all the resources required to manufacture a product or give access to a service, followed by the quantification, on the environment, of all the potential impacts of this manufacturing. According to ISO, it is the “compilation and evaluation of energy inputs, the uses of raw materials and discharges into the environment, as well as the evaluation of the potential impact on the environment associated to a product, to a process, or to a service, over the total life cycle.” The life cycle of a product, process or service extends from the manufacturing and the processing to the use and final disposal. This method is based on a 4-step approach: the goal and scope definition phase; the inventory analysis phase; the impact assessment phase; and the interpretation phase against the initial objectives. (https://www.iso.org/obp/ui/#iso:std:iso:14044:ed-1:v1:en).

Impact Pathway Approach (IPA):

The physical pathway of a specific pollutant is followed from its emission to the damage it causes to the outside environment (final impacts). This leads to the assessment of the different types of pollution and their related risks.

Two-wheelers:

Motorcycles

Acronyms

PM: Particulates Matter - PM 2.5 and PM 10

NMVOC: Non-Methane Volatile Organic Compounds

CO2: Carbon Dioxide

O3: Ozone

Nox: Nitrogen oxide

SO2: Sulphur dioxide

LCA: Life Cycle Analysis

IPA: Impact Pathway Approach

V-BUS: Vorläufige Berechnungsmethode für den Umgebungslärm an Straßen

HGV: Heavy Goods Vehicle

Cerema: French Centre for Studies and Expertise on Risks, Environment, Mobility and Urban and Country planning

DtecITM: Technical Division for Transportation and Materials Infrastructures at Cerema

LPV: Light Passenger Vehicle

LCV: Light Commercial Vehicle

Two-wheeler: Motorcycle

DGITM: Directorate General for Infrastructures, Transport and the Sea (Direction générale des infrastructures, des transports et de la mer)

SAGS: General Administration and Strategy Department at DGITM

MAP: Mission des Alpes et des Pyrénées

CHF: Swiss Franc

HBFEA: Handbook Emission Factors for Road Transport.

DG: Directorate General

CAFE: Clean Air For Europe

EEA: European Environment Agency

kph: Kilometre per hour

gpkm: gram per kilometre

GHG: Greenhouse Gases

HEATCO : Harmonised European Approaches for Transport Costing and Project Assessment

Table Index

Illustration Index

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