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Effect measurement of (goods) transport noise

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1. Introduction

Noise as defined by the Environmental Noise Directive (2002/49/EC) means "unwanted or harmful outdoor sound created by human activities, including noise emitted by means of transport, road traffic, rail traffic, air traffic, and from sites of industrial activity [...]." Furthermore, one might add, this sound or these sounds are of duration, intensity or other quality which cause physiological or psychological harm (CE Delft, Handbook).

Noise is second only to air pollution in the impact it has on the health of EU citizens. It is estimated that over half of Europe's population is exposed to unacceptable noise levels. Noise from road transport is the major source, followed by aircraft and rail-way noise (T&E). Noise emissions from transports by ship are regarded as rather low and therefore negligible, as most activities take place outside populated areas (CE Delft, Handbook). This might look different for harbors, though, as some of Europe's biggest harbors are located close to larger cities (example Gothenburg) and have a noise impact on people living there, not only on people working there.

In its 6th Environmental Action Program (2002-2012) the EU has set itself the objective of substantially reducing the number of people regularly affected by long-term average levels of noise. The aim of reducing noise exposure to acceptable levels has been repeated in the renewed Sustainable Development Strategy as well as in the transport White paper and its mid-term review. Despite all efforts in this direction, however, experts claim that EU policy does not seem to recognize that noise is a major environmental health issue (CE Delft 2007), as existing noise limits for vehicles for example have not been revised since 1995, and even then they did not bring about the benefits expected.

This was largely because the method used to work out a vehicle's noise was based on test conditions, which differed considerably from real-world driving (T&E), leading in practice to even weaker limits (CE Delft 2007). Cars are about as noisy today as they were when the first regulation came into force nearly 40 years ago. This is also because each tightening of the limit values was accompanied by a change in the test method, which allowed vehicles to appear to be quieter than they really are. Aside from the vehicle noise standards, increasing traffic and a trend towards larger, heavier and more powerful vehicles also mean that Europe's roads continue to get louder.

In their present form, legislation on vehicle noise and tyre/ road noise are said to be too liberal to have any significant effect. The new standards will apply to new vehicles only, so it will take a long time for the effect of this legislation to make a widespread difference (T&E). Thus, the number of people exposed to ambient noise is consequently expected to increase rather than decline (CE Delft 2007). Yet, traffic noise could be halved with existing technologies and if more stringent limits were adopted (T&E).

2. Effects of noise on human health

Community noise[1], including traffic noise, is already recognized as a serious public health problem by the World Health Organization, WHO, who published their "Guidelines on community noise" in 1999. These guidelines present noise levels above which a significant impact on human health and/or well-being is to be expected. In 2007 an extension of the guidelines was published, focusing on the health impacts of night-time noise (Night noise guidelines for Europe).

- Threshold according to WHO for "serious annoyance" and onset of negative health effects: 55 dB(A)
- Nervous stress reactions caused by noise levels > 60 dB(A)
- Hearing damage caused by noise levels > 85 dB(A)

Below the level of 30 dB $L_{night, outside}$[2], no effects on sleep are observed except for a slight increase in the frequency of body movements during sleep due to night noise. There is no sufficient evidence that the biological effects observed at the level below 40 dB $L_{night, outside}$ are harmful to health. However, adverse health effects are observed at the level above 40 dB$L_{night, outside}$, such as self-reported sleep disturbance, environmental insomnia, and increased use of somnifacient drugs and sedatives. Above 55 dB the cardiovascular effects become the major public health concern, which are likely to be less dependent on the nature of the noise. Closer examination of the precise impact will be necessary in the range between 30 dB and 55 dB as much will depend on the detailed circumstances of each case.

Night noise guideline (NNG)	$L_{night, outside}$ = 40 dB
Interim target (IT)	$L_{night, outside}$ = 55 dB

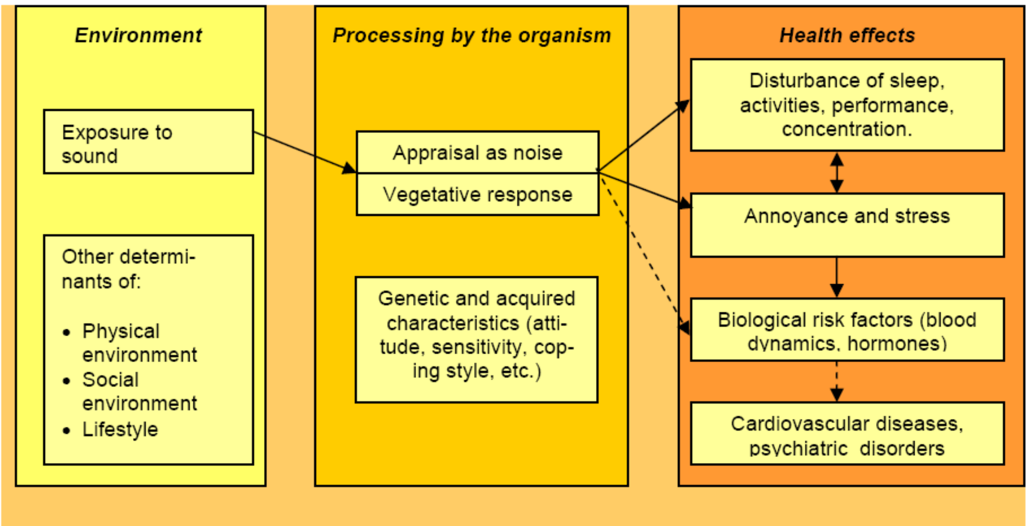
WHO 2007: Recommended night noise guidelines for Europe

An interim target (IT) of 55 dB $L_{night, outside}$ is recommended in the situations where the achievement of NNG is not feasible in the short run for various reasons. It should be emphasized that IT is not a health-based limit value by itself. Vulnerable groups cannot be protected at this level. Therefore, IT should be considered only as a feasibility-based intermediate target which can be temporarily considered by policy-makers for exceptional local situations (WHO 2007 Night noise guidelines for Europe).

[1] Defined in 1995 by WHO as noise emitted from all noise sources except noise at the industrial workplace (WHO 1999).

[2] Refers to the EU definition in Directive 2002/49/EC: equivalent outdoor sound pressure level associated with a particular type of noise source during night-time (at
least 8 hours), calculated over a period of a year. The same value is mentioned as a limit for indoor environments (WHO, Night noise guidelines for Europe, p. 111).

The mechanisms of noise-induced health effects



(CE Delft 2007)

Especially traffic noise has a variety of adverse impacts on human health:

- Of all the adverse effects of traffic noise the most widespread is simply annoyance. For example, about 57 million people are annoyed by road traffic noise, 42% of them seriously.
- There is also substantial evidence for traffic noise disturbing sleep patterns, affecting cognitive functioning (especially in children) and contributing to certain cardiovascular diseases. For raised blood pressure, the evidence is in-creasing. For mental illness, however, the evidence is still only limited.
- The health effects of noise are not distributed uniformly across society, with vulnerable groups like children, the elderly, the sick and the poor suffering most.
- In 2000, more than 44% of the EU25[3] population (about 210 million people) was regularly exposed to over 55 dB of road traffic noise, a level potentially dangerous to health. In addition, 35 million people in the EU25 (about 7%) are exposed to rail traffic noise above 55 dB.
- A preliminary analysis shows that each year over 245,000 people in the EU25 are affected by cardiovascular diseases that can be traced to traffic noise. About 20% of these people (almost 50,000) suffer a lethal heart attack, thereby dying prematurely.

[3] EU25 refers to EU27 except Cyprus and Malta.

- The annual health loss due to traffic noise increased between 1980 and 2000 and is expected to increase up to 2020. In contrast, traffic safety has improved, following implementation of a variety of policy measures.

- At a conservative estimate, the social costs of traffic noise in the EU22[4] amount to at least € 40 billion per year (0.4% of total GDP). The bulk of these costs (about 90%) are caused by passenger cars and lorries (CE Delft 2007).

Poorer people are more likely to suffer the health effects of transport noise than the better off. This might be explained by lower quality housing with poor noise insulation and the proximity of housing for lower income groups to noisy transport infrastructure (CE Delft 2007).

[4] EU22 refers to EU27 except Cyprus, Estonia, Latvia, Lithuania and Malta.

3. Measurement of effects

Measuring noise:

Noise levels are generally specified on the decibel, or dB, scale, which is defined in terms of the sound pressure (in Pascals) by the equation:

$$Noise\ level = 20.\log_{10}\left[{Sound\ pressure}\Big/{20\mu Pa}\right]$$

(ExternE)

Noise is measured in decibels. The decibel scale is logarithmic, so a three-decibel increase means a doubling of the volume of sound, and a 10-decibel increase means the sound is 10 times louder. For example, an aircraft passing overhead is likely to be 20 decibels – or 100 times – louder than a normal conversation. Levels of environmental noise are often reported as averages over a sustained period.

The short form for decibels is generally dB but noise is often given in dB(A) units. The (A) is added to denote that the scale has been adapted for the human hearing range. 20dB(A) equates to a gentle breeze or a soft whisper. Sounds that are louder than 120dB(A) – the level of noise when a military aircraft takes off – can make people feel fear and sometimes pain.

Other important characteristics of noise include its sound wave frequency (pitch), whether it's continuous or intermittent, how long it lasts, what time of day it occurs at, and even any thoughts associated with it. In general, an intermittent sound, such as one passing lorry on an otherwise quiet road, is often more disturbing than a constant background noise, such as a busy road.

Here are some examples of sounds associated with a 10-140 decibel scale:

10 dB(A) Breathing

20 db(A) Broadcasting studio

30 db(A) Bedroom at night

40 db(A) Refrigerator

50 db(A) Rainfall

60 db(A) Normal conversation

70 db(A) Washing machine

80 db(A) Vacuum Cleaner

85 db(A) Heavy traffic (standing next to a busy road)

90 db(A) Shouting

100 db(A) Electric drill

110 db(A) Car horn

120 db(A) Emergency siren

130 db(A) Car racing

140 db(A) Plane taking off

(T&E 2008a)

Denmark has statutory orders which require noise levels (L_{Aeq})[5] of:
< 45 dB(A) for all neighbouring properties, and
< 40 dB(A) in residential areas and other noise sensitive locations;

The Netherlands has advisory levels (L_{Aeq}) for all industrial noise of:
< 40 dB(A) in rural areas,
< 45 (day), 40 (evening), 35 (night) dB(A) in quiet residential areas, and
< 50 (day), 45 (evening) and 40 (night) dB(A) in all residential areas;

Germany has recommended levels (L_{Aeq}) of:
< 65 (day) and 50 (night) dB(A) in commercial areas,
< 60 (day) and 45 (night) dB(A) in mixed areas,
< 55 (day) and 40 (night) dB(A) in general residential areas,
< 50 (day) and 35 (night) dB(A) in pure residential areas.

(ExternE)

Measuring noise effects on health:

Disability-adjusted life years (DALY) is a measure used to quantify the overall 'burden of disease' on a population. It does so by combining the impact of premature death (mortality; life years lost) and disability (morbidity; life years lived with disability or disease) into a single, comparable measure. DALYs represent the total number of years of life lost due to

5 There are many variants of this scale to allow for the fluctuations of noise levels over time, notably the L_{Aeq} scale, which is the level equivalent to the mean sound energy level (ExternE).

premature death and of years lived with a reduced level of health, weighted by the seriousness of the health impairment suffered (CE Delft 2007).

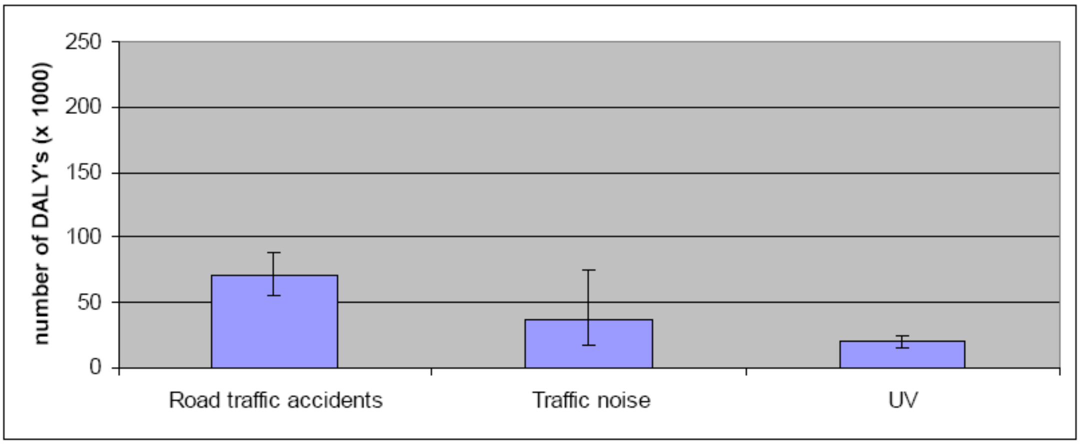
DALYs are calculated by adding YLD (Years Lived with Disability) and YLL (Years of Life Lost): DALYs = YLD + YLL.

One DALY is equivalent to one year of healthy life lost.

It is recommended to estimate health effects by default values according to WHO guidelines on Noise Burden on Disease. In addition, it is recommended to take vulnerable groups, like children and elderly, into account (CE Delft Handbook).

The WHO is currently working on an estimate of DALYs for traffic noise for Europe. To date, however, there is only one country for which such an estimate is publicly available: the Netherlands (CE Delft 2007).

Burden of disease due to several problems in the Netherlands in 2000, in DALYs



Note: The 90% prediction intervals around the respective DALY values are indicated by a band width. The figures for traffic noise include road, rail and air traffic noise.

RIVM (2005)

Ca. 1 to 1.6 million healthy life years are lost every year from traffic noise in the EU cities. Sleep disturbance and annoyance related to road traffic noise comprise the main burden (WHO/JRC 2011).

4. Calculation of the external costs of noise

In general, two types of negative impacts of transport noise can be distinguished: Costs of annoyance and health costs. The annoyance costs are usually economically based on preferences of individuals (by stated or revealed preference methods), whereas health costs (especially due to increased risk of heart attacks) are based on dose response figures (CE Delft Handbook).

The costs of noise relate to the type and characteristics of the vehicle used, the time of day when it is used, the receptor density close to the emission source and the existing noise levels (CE Delft 2008, CE Delft Handbook).

In addition to these general cost drivers, there also some mode-specific cost drives.

Road:
- Sound of propulsion system
- Sound of rolling
- Speed
- Vehicle type (e.g. share of heavy trucks)
- Kind of tyres
- Vehicle's state of maintenance
- Vehicle age
- Slope of the road
- Kind of surface (including presence of noise walls)
- Driving behaviour (in urban areas)

Rail:
- Rolling surface of the steel wheel on the steel track
- Train speed
- Coach/wagon type
- Surface conditions of both wheel and rail
- Type of track including level of maintenance
- Type of brakes
- Length of train
- Presence of noise walls

For air transport, important drivers are the noise classification the aircraft type[6] and type of engine, the movements (mainly landing or takeoff) and time of day. Currently, landing charges differentiated to noise emissions and/ or time of day are widely applied. In some

[6] A noise classification system could easily be derived from certified noise levels published at the web of the European Agency on Safety of Aviation which is the EU body responsible for issuing aircraft noise certificates.

situations, surcharges are levied to finance insulation or property acquisition (CE Delft 2008, CE Delft Handbook).

For air transport an additional negative impact of transport noise can be identified. In many cases governments establish 'cordons sanitaires' around large noise sources such as airports. In these cordons sanitaires land use is restricted; for example, it may not be permitted to build new houses. This restricts use of land within this area compared to a situation without noise and indirectly also limits choices elsewhere, which lead to welfare losses. These costs are only partly related to actual flight movements. Also other aspects, like land prices and future potential flight paths, influence these costs. These aspects cannot be influenced by airlines. Therefore, effective internalization strategies should also take other actors (e.g. air traffic control, spatial planning institutions) into account (CE Delft Handbook).

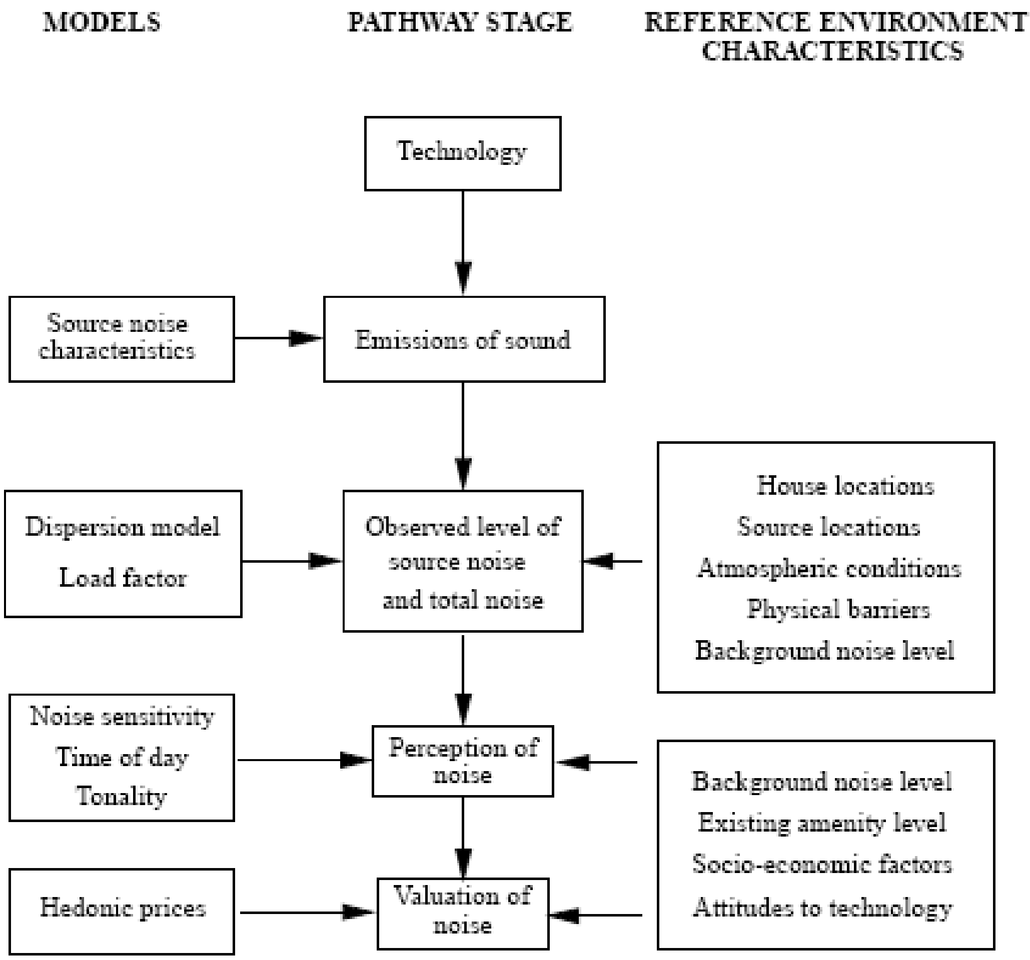
The marginal noise costs[7] due to maritime shipping and inland waterways are assumed to be negligible, because emission factors are comparably low and most of the activities occur outside densely populated areas (CE Delft Handbook).

For marginal external costs in general and for the calculation of marginal noise costs in particular two approaches do exist:

- A top-down approach: The starting point in this approach forms the macro level, most times a whole geographical unit and a country for example. For such a unit the total noise costs (for example an estimation of health costs, and building damages) is determined. This cost is then divided by the total amount of activity leading to this externality. In practice allocation is based on the shares of total noise emissions, in the vehicle mileage etc. In the end average costs result (no marginal costs) and the average costs thus obtained do in general not account for the differences in locations and conditions.

- A bottom-up approach: The starting point of this approach is the micro level, i.e. the traffic flow on a particular route segment. The marginal external costs of one additional vehicle then are calculated for a single trip on this route segment. This is done by modeling the path from noise emission to impact and costs. This involves modeling noise emissions, dispersion of emissions, estimation of impacts (e.g. on health), and finally applying monetary values to these impacts. In practice this method is called 'the impact pathway approach' and was developed in the ExternE-project (CE Delft 2004).

[7] Marginal noise costs are defined as the additional costs of noise caused by adding one vehicle to the existing traffic flow. If the existing traffic levels are already high, adding one extra vehicle to the traffic will result in almost no increase in the existing noise level (DE Delft Handbook).



Impact pathway for noise (ExternE Vol. 2)

With regard to the valuation of noise the most popular method is hedonic pricing, but studies have also used contingent valuation, abatement costs, avoidance costs and productivity loss to estimate the external costs of noise (CE Delft 2004).

Contingent valuation method:

Starting point is the willingness to pay (WTP) or willingness to accept (compensation) for more silence and health effects. These unit values are then multiplied with the national data on noise exposure for different noise classes (CE Delft Handbook).

The contingent valuation method involves directly asking people, in a survey, how much they would be willing to pay for specific environmental services. In some cases, people are asked for the amount of compensation they would be willing to accept to give up specific environmental services. It is called "contingent" valuation (CV), because people are asked to state their willingness to pay, contingent on a specific hypothetical scenario and description of the environmental service.

The contingent valuation method is referred to as a “stated preference” [SP] method, because it asks people to directly state their values, rather than inferring values from actual choices, as the “revealed preference” [RP] methods do.

(http://www.ecosystemvaluation.org/contingent_valuation.htm)

The strength of the RP is that it relies on actual behavior in the housing market where WTP for noise and other environmental externalities can be observed. A disadvantage of this method is that it is very hard to isolate noise from other environmental problems (e.g. air pollution).

Methods based on SP are generally easier to implement. The extents to which SP techniques are capable of providing valid and reliable estimates depend very much on the survey design and analysis. Both methods are generally accepted to use obtaining an estimate for valuation of costs of noise exposure (CE Delft 2004).

Hedonic pricing:

Hedonic pricing is the preferred method for quantification of amenity losses due to noise; the Noise Depreciation Sensitivity Index (NDSI) tool, which applies this method, gives an average percentage change in property prices per decibel; thus there is a lower value of properties exposed to higher noise levels (CE Delft Handbook).

An estimate done by EEA is that house prices lose 0.5% (range: 0.2% - 1.5%) of their value per decibel over 50-55 dB L_{den}[8] (EEA 2010).

Generally, external noise costs are calculated by multiplying the specific noise emissions with the number of people affected, then multiplying this number with damage per dB(A).

For many European countries exposure numbers were not available until recently. This has changed with the introduction of the strategic noise maps required by Directive 2002/49/EC[9]. These maps provide data on exposure to noise (number of people per band of noise levels) in every agglomeration with more than 250,000 inhabitants, roads with more than 6 million vehicles per annum, railways with more than 60,000 trains per year and major airports within their territories (Directive 2002/49/EC).

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8 “den” stands for day, evening and night.

9 These maps were required by June 30, 2007 at the latest. No later than June 30, 2012, additional strategic noise maps are required for all agglomerations and for all major roads and major railways within the territory of the Member States (Directive 2002/49/EC).

Calculation method for simplified approach

The simplified approach that CE Delft (2004) propose for noise is a cost allocation approach and consists of the following four steps:

- Step 1: Define the cut-off value (this is the noise level below which the nuisance is regarded as negligible).
- Step 2: Determine per mode the number of people/households that are exposed to a certain noise level, do this for several noise level groups (e.g. 56-60 dB(A), 61-65 dB(A), 66-70 dB(A), 71-75 dB(A) and > 75 dB(A)).
- Step 3: Financial valuation per mode and area.
- Step 4: Allocation to vehicle classes within each mode.

This approach calculates the average transport noise costs (the top-down approach). The calculation of the marginal costs requires a detailed analysis of noise emissions, dose-response relationships and natural geographic features such as hills or building design features (double-glazed windows). These data are often unavailable or incomplete and such an approach is deemed too complicated to serve as a simplified approach. It should be known though, that the resulting estimates for average costs are generally higher than the marginal costs. Average cost can be 2 (for aviation) up to 6 to 8 (road transport) times higher than marginal cost. This also holds for densely populated areas (CE Delft 2004).

Furthermore CE Delft (2004) propose to distinguish between the noise cost within urban areas and those outside of urban areas. If statistics on the number of exposed people are differentiated with respect to location, this distinction can be accounted for in step 2, if not, this should be incorporated in step 3.

The approach is identical for all modes, except for the cost allocation to vehicle classes.

<u>Step 1: Definition of cut-off value (road, rail, air)</u>

The nuisance people experience of noise depends on the source of noise. Rail noise is less annoying than the road noise, because of the low frequency of the sound and it continuous character. On the other hand, aircraft noise is experienced as more annoying than road traffic, because the passage of an aircraft creates fear feelings with people.

The difference in nuisance is the reason that the often cited 'bonus of 5 dB' is given to rail. Based on a 'State-of-the-art in noise valuation' workshop, organized by DG Environment of the European Commission in 2001 (European Commission, 2002) and international literature, CE Delft propose to use the following cut-off values for noise.

Road	55
Rail	60
Air	55

The thresholds above which noise is considered a nuisance are somewhat arbitrary. In some studies 50 dB(A) is adopted to define a reasonable level of noise, while other studies choose 55 dB or even 60 dB(A)[10]. The impact of the threshold on marginal noise costs is substantial. The European Conference of Ministers of Transport in 1998 showed that changing the threshold from 50 dB(A) to 55 dB(A) reduces the average results for cars by almost 50% (CE Delft Handbook).

The cut-off values above imply that below these noise levels, no damage cost are taken into account in the simplified approach. There is, however, some discussion that the cut-off levels should be lower, since below the cut-off values, people can still be annoyed. Also, noise reduction measures can be underestimated with the proposed cut-off value (CE Delft 2004).

As a refinement of the proposed simplified approach, additional noise cut-off values could be defined for night hours. Since people are more sensitive to noise during night hours, it could be argued to set night time cut-off levels five to ten dB(A) lower than the aforementioned cut-off levels.

<u>Step 2: Determination of number of exposed households / people (road, rail, air)</u>

To determine the total noise cost for a country, estimates for the number of exposed households (or individuals) per noise level group are indispensable.

These statistics need to be collected for each country.

<u>Step 3: Financial valuation of noise (road, rail, air)</u>

Although there is some evidence that the WTP for noise reduction increases slightly with the level of existing noise, this change is not statistically significant. CE Delft (2004) therefore propose to use one value per decibel noise (above the cut-off value), independent of the initial noise level. In CE Delft's Handbook, the recommended value is an annual WTP-value equal to 0,09% – 0,11% of capita income per dB (see also HEATCO 2006 below).

A value of 50,000 – 75,000 € for a life year lost is recommended. These values correspond to a Value of a Statistical Life (VSL) of ca. 1.0 Mill €.

[10] For the values recommended by WHO, see page 3 of this report.

Finally, there is a high agreement on the values for the medical costs. In the table below, values provided by UNITE, 2003b (based on ExternE) are presented.

Monetary values for impacts due to noise (€$_{2000}$)

Myocardial infarction (non-fatal, 8 days in hospital, 24 days at home)	
Medical costs	4,700
Absentee costs	2,800
WTP	15,000
Total per case	**22,500**
Angina Pectoris (severe, non-fatal, 5 days in hospital, 15 days at home)	
Medical costs	2,950
Absentee costs	1,750
WTP	9,400
Total per case	**14,100**
Hypertension (hospital treatment, 6 days in hospital, 12 days at home)	
Medical costs	1,800
Absentee costs	1,575
WTP	550
Total per case	**3,925**
Medical costs due to sleep disturbances (per year)	200

Note: Corrected for GDP per capita development by CE Delft (GDP per capita in PPP consumer price index from http://epp.eurostat.ec.europa.eu).

CE Delft Handbook

For the average noise costs per person per dB(A) per year CE Delft recommends the values from HEATCO (2006). As an example the values for Germany are presented in the table below. Values for other countries can also be found in HEATCO (2006). These values are a weighted average over day, evening and night.

Noise costs for Germany per person exposed per year (in €2002)

Lden (dB(A))	Road	Rail	Aviation
≥ 51	9	0	14
≥ 52	18	0	27
≥ 53	26	0	41
≥ 54	35	0	54
≥ 55	44	0	68
≥ 56	53	9	82
≥ 57	61	18	95
≥ 58	70	26	109
≥ 59	79	35	122
≥ 60	88	44	136
≥ 61	96	53	149
≥ 62	105	61	163
≥ 63	114	70	177
≥ 64	123	79	190
≥ 65	132	88	204
≥ 66	140	96	217
≥ 67	149	105	231
≥ 68	158	114	245
≥ 69	167	123	258
≥ 70	175	132	272
≥ 71	233	189	334
≥ 72	247	204	354
≥ 73	262	218	373
≥ 74	277	233	393
≥ 75	291	248	412
≥ 76	306	262	432
≥ 77	321	277	451
≥ 78	335	292	471
≥ 79	350	306	490
≥ 80	365	321	509
≥ 81	379	336	529

Source: CE Delft Handbook.

The noise cost per mode per noise level group can be estimated by multiplying the number of households within a certain noise level group with the average noise exposure above the cut-off value for this group with the costs of noise per dB per household per year. Total noise costs per mode are obtained by summing the outcomes over the different noise level groups.

To determine the total noise cost within / outside city limits one can either use the distribution of the households in the noise level groups (households within urban areas contribute to total noise cost within urban areas), or in case detailed statistics are unavailable, a default value could be used. For the Netherlands, 80% of noise costs are estimated to fall within urban areas, and 20% outside (CE Delft 2004).

Use of these values is a second best option, since clearly the distribution of noise cost in urban and non-urban depends of the urbanization level of a country and could best be based on the number of households disturbed inside and outside city limits.

<u>Step 4: Cost allocation</u>

Road and rail

After determining the total noise cost per mode, both inside and outside city limits, the allocation to different vehicle types has to be determined. CE Delft (2004) distinguish two approaches:

- Allocation based on vehicle kilometers.
- Allocation based on weighted noise vehicle kilometers[11].

An allocation based on vehicle kilometers would pass over the differences in noise emission between vehicles. Clearly an HGV causes more noise than a passenger vehicle, as do freight trains compared to passenger trains.

The noise cost per vehicle kilometer can be calculated by the following formula:

Noise cost per vehicle kilometre = noise cost for vehicle category / total vehicle category kilometres

Where:

Noise cost for vehicle category = total noise cost * (vehicle weight factor * total vehicle category kilometres) / Σ (vehicle weight factor * total vehicle category kilometres)

with the summation over all vehicle categories. Depending on the noise cost in an urban area of outside of city limits is being calculated, the total noise cost apply to the total noise cost within urban areas or outside. The appropriate weighing factors should be used (CE Delft 2004).

For allocating average noise costs to various modes, the weighting factors presented in the table below are recommended. Weighting factors for aircraft noise can be found in CE Delft (2004).

[11] Weighted noise kilometers are the weight factors of a certain vehicle category multiplied by the vehicle kilometers for this category.

Unit values for marginal costs for different network types (€ct/vkm) for road and rail traffic

	Time of day	Urban	Suburban	Rural
Car	Day	**0.76** (0.76 – 1.85)	**0.12** (0.04 – 0.12)	**0.01** (0.01 – 0.014)
	Night	**1.39** (1.39 – 3.37)	**0.22** (0.08 – 0.22)	**0.03** 0.01 – 0.03
MC	Day	**1.53** (1.53 – 3.70)	**0.24** (0.09 – 0.24)	**0.03** (0.01 – 0.03)
	Night	**2.78** (2.78 – 6.74)	**0.44** (0.16 – 0.44)	**0.05** (0.02 – 0.05)
Bus	Day	**3.81** (3.81 – 9.25)	**0.59** (0.21 – 0.59)	**0.07** (0.03 – 0.07)
	Night	**6.95** (6.95 – 16.84)	**1.10** (0.39 – 1.10)	**0.13** (0.06 – 0.13)
LGV	Day	**3.81** (3.81 – 9.25)	**0.59** (0.21 – 0.59)	**0.07** (0.03 – 0.07)
	Night	**6.95** (6.95 – 16.84)	**1.10** (0.39 – 1.10)	**0.13** (0.06 - 0.13)
HGV	Day	**7.01** (7.01 – 17.00)	**1.10** 0.39 – 1.10	**0.13** (0.06 – 0.13)
	Night	**12.78** (12.78-30.98)	**2.00** 0.72 – 2.00	**0.23** (0.11 – 0.23)
Passenger train	Day	**23.65** (23.65 – 46.73)	**20.61** 10.43 – 20.61	**2.57** (1.30 – 2.57)
	Night	**77.99**	**34.40**	**4.29**
Freight train	Day	**41.93** (41.93 – 101.17)	**40.06** 20.68 – 40.06	**5.00** (2.58 – 5.00)
	Night	**171.06**	**67.71**	**8.45**

Central values in bold, ranges in brackets.

Note: The lower limit of the bandwidth is based on dense traffic situations, while the upper limit is based on thin traffic situations. Central values (in bold) chosen based on the predominant traffic situation in the respective regional cluster: urban: dense; suburban/rural: thin.

The weighing factors for rail originally stem from INFRAS/IWW (1995). Weighing factors for road transport were calculated from noise reference values for light, medium heavy and heavy vehicles presented in the Dutch instruction for measuring and calculating road traffic noise. Such reference values can normally be found in governmental instructions for calculating traffic noise, and could be used to determine country specific noise weighing factors (the first best approach).

Air

The noise costs of air traffic depend heavily on local factors (e.g. population density around airports), flight path, aircraft type and technology, and time of the day (see above). Therefore, it is not possible to present some general (range of) value(s) that can be applied for all situations. CE Delft recommend to apply specific case studies to obtain these costs on individual airports. In this way airport-specific data, such as population density, flight paths, and aircraft type and technology could be taken into account (CE Delft Handbook).

Below, the marginal cost estimates for various airports are presented (CE Delft Handbook).

Marginal noise costs at Frankfurt Airport (€ per LTO)

Aircraft type	07L (easterly traffic)			25R (westerly traffic)		
	Day	Evening	Night	Day	Evening	Night
737-800	32.4	77.0	240.8	29.0	69.0	216.4
747-200	71.6	170.0	524.0	55.8	132.4	412.6
747-400	128.0	304.0	934.0	113.6	269.4	836.6
767-300	42.6	101.2	316.0	34.6	82.0	257.2
A 300-62	77.8	184.6	572.0	76.6	181.6	567.8
A 319	14.6	34.4	108.8	12.8	30.6	96.6
A 320	26.0	61.8	194.4	23.2	54.8	193.0
A 340	51.6	122.4	385.8	54.0	127.8	403.4
ATR 72	7.2	17.2	53.8	1.6	3.8	11.8
DHC 8	2.6	6.2	19.6	0.2	0.4	1.4
EMB 145	7.0	16.6	52.0	2.2	5.2	16.2
MD 82	9.2	21.8	68.6	3.4	8.2	26.2

Source: Ökoinstitut/DIW (2004).

Marginal noise costs of aviation per LTO

		40 seater	100 seater	200 seater	400 seater
CE Delft, 2002	Fleet average technology	180	300	600	1,200
	State-of-the-art technology	90	150	300	600

Marginal noise costs at Heathrow London

Aircraft type	Marginal noise costs (€ per LTO)
A210	92.3
A340	111
Bae146	21.6
B737-100	326
B737-400	49.1
B747-400	242
B757	63.5
B767-300	77.9
B777	47.6
F100	17.3
MD82	70.7

Source: TRL (2001).

Marginal noise costs of aviation per LTO

		40 seater	100 seater	200 seater	400 seater
CE Delft, 2002	Fleet average technology	180	300	600	1,200
	State-of-the-art technology	90	150	300	600

An important factor explaining the wide ranges in marginal noise costs estimates for aviation is aircraft type. Also the population density around airports is an important driver of noise costs.

To allocate noise cost to specific aircraft, the relative performance of aircraft with respect to noise is required. At first sight, the categorization the noise limits set by ICAO appears a good option. However the categorization and the noise limits set depend on MTOW and the number of engines. So it is possible that a small aircraft belongs to a noisier class than a larger aircraft emitting less noise (CE Delft 2004).

CE Delft (2004) therefore propose to allocate the noise cost to aircrafts on the basis of the actual noise level (instead of the noise limit) they produce according to the instruction in Annex 16 to the ICAO convention, Chapter 3.

These noise levels, measured in EPNdB[12] (EPNdB = dB(A)+13), are known for three different measuring points: take-off, sideline and approach. Based upon these noise levels, weighing factors can be calculated. The weight factor of a B747 for example, with respect to an aircraft of reference, can be calculated as illustrated in the following formula:

Weight factor B747 in comparison with aircraft of reference = $(10^\wedge((EPNdB_{B747}-13)/10) + 10^\wedge((EPNdB_{B747}-13)/10) + 10^\wedge(EPNdB_{B747}-13/10))\ /\ (10^\wedge((EPNdB_{REF}-13)/10) + 10^\wedge((EPNdB_{REF}-13)/10) + 10^\wedge((EPNdB_{REF}-13)/10))$

CE Delft 2004

Weighing factors for a limited number of aircraft are presented by CE Delft (2004). The Fokker 100 has been used as the aircraft of reference. From the table it can be found that noisy aircrafts (B747-400) produce about 12 times as much noise as the silent Fokker 100. Aircraft with a MTOW[13] of less than 9,000 kg are not taken into account since their contribution to the total noise production is minimal.

12 Aircraft noise is measured in Effective Perceived Noise level (EPNdB).

13 MTOW = Maximum Takeoff Weight.

The cost per LTO of a specific aircraft can be calculated by allocating the total costs on the basis of the number of LTO's and the calculated weighing factors, as in the following formula.

Noise cost per LTO for specific aircraft = total noise cost * aircraft weight factor / Σ (aircraft weight factor * number of LTO's of aircraft)

The summation in the formula is over all aircraft visiting the airport.

This approach requires detailed information about the aircraft movements (airport dependent) and noise levels of different aircraft. The latter can be derived from the airlines that call in at airports CE Delft (2004).

5. Legislative development

In the Commission Work Program 2011, a number of important initiatives with regard to noise were included, in particular:

- The *White Paper on Transport* which provides a roadmap until 2050 to, amongst many other objectives, contribute to the reduction of noise pollution from transport (e.g. action to develop "vehicle standards for noise emission levels");

- The revision of *Directive 2002/30/EC* on airport noise which will, as part of the airport package, improve noise mapping on the basis of an internationally recognized method and data, and drive towards the adoption of cost-effective noise mitigating measure, taking into account internationally agreed standards to streamline the relationship between the airport noise directive and the END[14]. It will also update the definition of noisy aircraft ("marginally compliant aircraft") in line with the current composition of the aircraft fleet.

- The next revision of *noise from motor vehicles* (see also subchapter 5b) with at least four wheels will, on the basis of an improved test procedure, assess the possibilities of introducing tighter limits ensuring that quieter vehicles are actually being put on the market. This may include a proposal for a regulation relating to the permissible sound level and the exhaust system of motor vehicles. The main objective of the initiative is aiming at reducing the negative impact of noise exposure of European citizens caused by motor vehicle traffic.

- The revision of the *Outdoor Noise Directive* will evaluate the scope of equipments covered and revise the noise requirements to reflect the current state-of-the-art technology. At the same time related administrative requirements will be simplified.

(Report from the Commission to the European Parliament and the Council On the implementation of the Environmental Noise Directive in accordance with Article 11 of Directive 2002/49/EC)

a. Environmental noise

Environmental noise as defined by the Environmental Noise Directive (2002/49/EC) means "unwanted or harmful outdoor sound created by human activities, including noise emitted by means of transport, road traffic, rail traffic, air traffic, and from sites of industrial activity [...]."

[14] END = Environmental Noise Directive.

Currently, Directive 2002/49/EC (Environmental Noise Directive) works with indicators called L_{den} to measure noise impacts: "The selected common noise indicators are L_{den}, to assess annoyance, and L_{night}, to assess sleep disturbance. It is also useful to allow Member States to use supplementary indicators in order to monitor or control special noise situations."

"den" stands for day, evening and night, which are defined by the Directive as follows:

- day (7-19),
- evening (19-23)
- night (23-7)

The day-evening-night level L_{den} in decibels (dB) is defined by the following formula:

$$L_{den} = 10 \lg \frac{1}{24}\left(12 * 10^{\frac{L_{day}}{10}} + 4 * 10^{\frac{L_{evening}+5}{10}} + 8 * 10^{\frac{L_{night}+10}{10}}\right)$$

in which:

- L_{day} is the A-weighted long-term average sound level as defined in ISO 1996-2: 1987, determined over all the day periods of a year,
- $L_{evening}$ is the A-weighted long-term average sound level as defined in ISO 1996-2: 1987, determined over all the evening periods of a year,
- L_{night} is the A-weighted long-term average sound level as defined in ISO 1996-2: 1987, determined over all the night periods of a year.

(Environmental Noise Directive (2002/49/EC))

Strategic noise maps currently required by Directive 2002/49/EC provide data on exposure to noise (number of people per band of noise levels) in

- agglomerations[15] with more than 250,000 inhabitants,
- roads with more than 6 million vehicles per year,
- railways with more than 60,000 trains per year,

[15] An agglomeration is part of a territory, delimited by the Member State, which has a population in excess of 100 000 persons and a population density such that the Member State considers it to be an urbanised area.

- airports with more than 50,000 movements per year.

b. Vehicle noise

The most recent tightening of vehicle noise limits took place in 1995. In 2011, the European Commission is due to finally present a proposal for new noise standards (see above), which has been repeatedly delayed.

Noise emissions from motor vehicles are regulated by the World Forum for Harmonization of Vehicle Regulations (WP.29), a body of the United Nations Economic Commission for Europe (UN ECE) based in Geneva.[16] The European Community is a signatory, as well as individual EU Member States, meaning that UN ECE vehicle regulations are directly applicable in EU and national law.

The World Forum for Harmonisation of Vehicle Regulations within the UN ECE has developed Regulation N°51 on road vehicles sound emissions, which is deemed to be equivalent to EU Directive 70/157/EEC on motor vehicle noise, both of are to be revised from 2011 onwards. The Regulation for technical approval of new vehicles currently sets

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[16] WP29 is supported by several technical working parties (groupes rapporteurs), which largely consist of technical experts specialized in particular fields:

- GRPE: Working Party on Pollution and Energy
- GRSG: Working Party on General Safety Provisions
- GRRF: Working Party on Brakes and Running Gear
- GRE: Working Party on Lighting and Light Signalling
- GRSP: Working Party on Passive Safety
- *GRB: Working Party on Noise* – which meets twice per year in Geneva and has been supported by the work of several "informal working groups".

The working parties consist of national delegations and non-governmental organisations from industry, standardisation bodies (e.g. ISO) and other stakeholders. Technical experts on the working parties are expected to give recommendations on the basis of technical expertise rather than national preferences or commercial interests. However, national delegations often include automotive industry employees (e.g. A Ferrari representative is part of the Italian delegation, Saab for Sweden), and experts from test houses and type-approval authorities. Test house and type-approval experts (privatized or semi-privatized in most countries) in practice often support the position of their customers, the automotive industry, especially those from car producing countries.

WP29 works according to the principles of the '1958 Agreement', which provides procedures for establishing uniform standards regarding new motor vehicles and equipment and for reciprocal acceptance of approvals for vehicle parts, systems and equipment issued under Regulations issued under this agreement. There are 38 contracting parties to the 1958 Agreement, of which 33 are European UNECE member countries. The others are: the European Community, Japan, Australia, South Africa and New Zealand.

The Working Party on Noise (GRB) is currently working on an amendment to this regulation through modifications to the test procedure, with a view to better reproducing the sound levels generated by vehicles during normal driving in urban traffic. The current noise test (known as R51.02) measures noise emissions at a specific speed, in a low gear, at low reverse. However, some vehicles (particularly high-powered cars and vans, and sports cars) were found to perform dramatically worse in different gears, at higher speeds and higher reverse. A new, additional method for 'Additional Sound Emission Provisions' (ASEP) has been under development since 2005 to test under a broader range of operating conditions. Both methods combined are supposed to enable more effective vehicle noise reduction.

noise emission limits of 74dB(A) for passenger cars and 80dB(A) for trucks (T&E Briefing 2009).

As the tyre/road contact begins to dominate the noise emission above 30km/h for passenger cars and above 50km/h for lorries, it was deemed necessary to regulate tyre/road noise separately as well as its role in overall vehicle noise. Therefore Directive 2001/43/EC complements the vehicle noise standards by setting a test procedure and noise limit values for tyre rolling noise (T&E website).

The overall potential for traffic noise reduction from newly manufactured tyres given today's available technology is 2-4 decibels. Every noise reduction of 3 decibels means that volume is halved: the same noise effect as halving road traffic (T&E Briefing 2009).

The complete research and development renewal cycle for car tyres is five years, so introduction of a second phase of standards in 2017 seems reasonable whilst minimizing additional costs, and providing planning certainty for manufacturers. It is desirable to tackle the trend towards larger and noisier models by reducing the limit value differential between size classes (T&E Background briefing 2008).

Legislation on rail noise (Directive 96/48/EC on high speed and 2001/16/EC on conventional trains) only came into effect at the start of the last decade, and even then only for trains operating in two or more member states. It shall be revised from 2011 onwards. Noise limits are included in the railway interoperability directives for new and modernized vehicles in both high-speed and conventional rail, but they are easily met by existing technology. The real problem lies with the existing fleet. Rail rolling stock has a typical lifespan of up to forty years, so the vast majority of the current fleet dates from before the legislation and can be very noisy (T&E report2010).

Existing WHO guidelines are useful for policy-makers, but:

- WHO Night Noise Guidelines (2009) is only for night noise;
- WHO Guidelines for Community Noise (1999) needs update;
- No guidelines address new issues like wind turbine noise.

WHO will work with the EU and the Member States to develop suitable guidelines on noise following up the Parma Declaration[17].

To safeguard environmental protection in a way which is compatible with internal market requirements, Directive 2002/30/EC was adopted in March 2002 on the establishment of

[17] The Parma Declaration was set up during the 5th Ministerial Conference on Environment and Health in 2010. It takes up several challenges related to factors like health and environmental risks of climate change, socioeconomic and gender inequalities, health risks to children and other vulnerable groups, burden of noncommunicable diseases (transport is mentioned explicitly, though not noise) etc. (Parma Declaration 2010).

rules and procedures with respect to the introduction of noise related operating restrictions at Community airports.

This Directive implements in European Community legislation the so called "balanced approach" to managing aircraft unanimously agreed and recommended by ICAO since October 2001. The approach comprises four principal elements, including reduction of airplane noise at source, land-use planning and management measures, noise abatement operational procedures and operating restrictions. The first of these elements is addressed by the ICAO recommended technical design standards to which aircraft engine combinations are independently certificated prior to entry into service. The current standard 'Chapter4' formally came into force on 1 January 2006.

Directive 2002/30/EC has put in place a harmonized definition of marginally compliant aeroplanes (aeroplanes that have a cumulative margin of no more than 5 decibels in relation to the ICAO Chapter 3 certification limits). In addition, the Directive contains principles and rules on how to carry out a noise assessment process which is mandatory prior to the introduction of noise related operating restrictions.

On 15 February 2008 the Commission adopted a Report on the implementation of Directive 2002/30/EC.

c. Motor vehicle type approval

Within Europe, two systems of type approval have been in existence for over 20 years. One is based around EC Directives and provides for the approval of whole vehicles, vehicle systems, and separate components. The other is based around ECE (United Nations) Regulations and provides for approval of vehicle systems and separate components, but not whole vehicles.

Type approval is the confirmation that production samples of a design will meet specified performance standards. The specification of the product is recorded and only that specification is approved.

Automotive EC Directives and ECE Regulations require third party approval - testing, certification and production conformity assessment by an independent body. Each Member State is required to appoint an Approval Authority to issue the approvals and a Technical Service to carry out the testing to the Directives and Regulations. An approval issued by one Authority will be accepted in all the Member States (http://www.vca.gov.uk/vca/index.asp).

If a vehicle is produced in a very small quantity (e.g. category M1[18] maximum 75 per year), single EU Member States can grant exception on a discretionary basis, however the validity of the Type Approval is limited to the boundaries of those nations which concede to it.

[18] Vehicles designed and constructed for the carriage of passengers and comprising no more than eight seats in addition to the driver's seat (Directive 2007/46/EC).

Cornerstones of the Type Approval process are:

- Application by the vehicle or component manufacturer
- Testing by a technical service
- Granting of the approval by an Approval Authority
- Conformity of Production by the manufacturer in agreement with the Approval Authority
- Certificate of Conformity by the manufacturer for the end-user (www.wikipedia.org)

With regard to sound levels, Directive 70/157/EEC suggests the following restrictions:

Vehicle categories		Values expressed in dB(A) (decibels(A))
2.1.1.	Vehicles intended for the carriage of passengers, and comprising not more than nine seats including the driver's seat	74
2.1.2.	Vehicles intended for the carriage of passengers and equipped with more than nine seats, including the driver's seat; and having a maximum permissible mass of more than 3,5 tonnes and:	
2.1.2.1.	with an engine power of less than 150 kW	78
2.1.2.2.	with an engine power of not less than 150 kW	80
2.1.3.	Vehicles intended for the carriage of passengers and equipped with more than nine seats, including the driver's seat; vehicles intended for the carriage of goods:	
2.1.3.1.	with a maximum permissible mass not exceeding 2 tonnes	76
2.1.3.2.	with a maximum permissible mass exceeding 2 tonnes but not exceeding 3,5 tonnes	77
2.1.4.	Vehicles intended for the carriage of goods and having a maximum permissible mass exceeding 3,5 tonnes:	
2.1.4.1.	with an engine power of less than 75 kW	77
2.1.4.2.	with an engine power of not less than 75 kW but less than 150 kW	78
2.1.4.3.	with an engine power of not less than 150 kW	80

In the amendment of 2007, these values were completed as follows:

- For vehicles of categories 2.1.1 and 2.1.3, the limit values are increased by 1 dB(A) if they are equipped with a direct injection diesel engine,

- for vehicles with a maximum permissible mass of over two tons designed for off-road use, the limit values are increased by 1 dB(A) if their engine power is less than 150 kW and 2 dB(A) if their engine power is 150 kW or more,

- for vehicles in category 2.1.1, equipped with a manually operated gear box having more than four forward gears and with an engine developing a maximum power exceeding 140 kW/t and whose maximum power/-maximum mass ratio exceeds 75 kW/t, the limit values are increased by 1 dB(A) if the speed at which the rear of the vehicle passes the line BB' in third gear is greater than 61 km/h (Commission Directive 2007/34/EC).

The tyres approval requirements stated in Regulation 661/2009 were updated in 2009 but they are regarded as far from adequate. A revised standard will enter into force in 2012. A labeling system, Regulation 1222/2009, was agreed to give consumers, fleet managers and public authorities an opportunity to choose between tyres that are the best and worst performers. The labels will be on all tyres for sale in Europe (cars, vans, trucks and buses) from 2012.

6. Measures against noise

There are basically two kinds of measures used in order to decrease or stop noise:

1. Stop the noise – known as "at-source measures" (quieter engines, tyres/wheels, quieter brakes on trains, quieter road surfaces, noise walls and windows, etc.),

2. Stop people hearing the noise – known as anti-propagation measures (sound insulation in buildings, or erecting embankments and walls to put a barrier between people and the source of the noise) (T&E report 2010).

At-source measures that reduce overall emissions are preferable to noise exposure measures reducing imissions at the local level, like insulation of houses or construction of noise barriers (CE Delft 2007).

The greatest reduction potential comes from technical measures to reduce noise emissions from vehicles, tyres and road surfaces. The abatement impact of these various measures is presented in more detail below (CE Delft 2007):

	Vehicle		Speed reduction	Road surface	
	Engine	Tyre		Thin/dense	Porous
5 year perspective	1-2	1-2	1-3	1-3	2-4
10-15 year perspec-tive	2-4	2-4	-	3-5	6-8
Effect of measure	international	international	local	local	local
Who pays?	Industry/polluter	Industry/polluter	Industry/polluter	Road owner/society	Road owner/society

Of these measures, the cost effectiveness of quieter tyres is greatest, as several studies report that tyre/road noise reduction comes at zero cost. A study by FEHRL[19] indicates that the cost effectiveness of a reduction of tyre/ road noise is significantly better than the figure reported above. FEHRL estimates the benefits at € 48-123 billion, while the costs are only € 1.2 billion. The main cost item for industry would be discontinuation of production of the noisiest tyres. Research costs would be very limited, as quieter tyres have already been developed and are already on sale on the European market (CE Delft 2007).

One disadvantage of at-source measures at the vehicle level, however, is that penetration of the vehicle fleet takes several years for tyres and almost a decade for motor vehicles. Local measures like speed reduction and low-noise road surfaces are therefore also needed. Given the very long life spans of railway rolling stock, this is even truer of railway noise reduction measures. The optimal strategy will need to comprise a mix of local and at-source measures, including noise barriers at hotspots (CE Delft 2007).

Complementary local noise prevention measures could include: Environmental zones or Low Emission Zones (access restrictions for heavy/ noisy vehicles), nighttime driving or flight bans, reduced speed limits and transport demand management including the promotion of (quiet) public/ collective transport, cycling and walking (T&E website Transport noise sources and solutions).

A conservative estimate of the social [=external?] cost of traffic noise is €40 billion per year across the EU, of which 90% is from cars and trucks. That represents a loss of 0.4% of total EU GDP each year - equivalent to about one-third of the societal [= external?] cost of road accidents. This includes reduced property values in affected areas and the costs to local authorities of erecting noise barriers or installing insulation. However, the toll on health, sick leave, lost productivity and quality of life are not included, neither are the latest WHO findings. Estimates in a study for the UK government suggest that noise pollution produced costs, in England alone during 2008, in excess of GBP9billion (around 11 billion EUR) including GBP 5-9 billion in annoyance costs, GBP 2 billion health costs and a further GBP 2 billion (around 2.5 billion EUR) of productivity losses (T&E Quiet please).

An EU study looking into the benefits of stricter new standards for vehicle noise has concluded that strict standards to produce an effect equivalent to that of halving traffic,

19 FEHRL (2006): Tyre/road noise: final report, Brussels: TUV Nord, BAST, TRL, VTI, 2005.

would outweigh the costs of developing and introducing quieter vehicles by over twenty times (TNO 2011):

"The social impact in terms of numbers of highly annoyed people and highly sleep disturbed people is significant. For the current situation (Option 1) an estimated 55 million people are highly annoyed by road traffic and 27 million are highly sleep disturbed. These numbers are reduced to 44 / 22 million for Option 4[20] and 41 / 22 million for Option 5[21]. The economic impact consists of benefits to society due to reduced traffic noise and costs for the vehicle industry due to reducing noise levels of vehicles, in particular the powertrain noise, as tyre noise will be reduced due to the tyre directive. The impact on the vehicle industry consists primarily of additional development and production costs due to extra reduction of powertrain noise on vehicles. For Option 4 the accumulated costs amount to 4 billion Euros and 6 billion Euros for Option 5. These additional costs are for development and production, incurred over a period of 10 years and consisting mainly of additional production costs. If the indicative additional costs for the tyre industry related to the reduction of rolling noise of tyres are added the total costs for Option 4 amount to 8.7 billion Euros and for Option 5 to 10.8 billion Euros.

The accumulated benefits for society consist of hedonic pricing, healthcare savings and savings on noise abatement on road infrastructure and dwellings. By far the largest benefits are due to hedonic pricing related to perceived value of noise reduction, followed to a lesser extent by healthcare savings and relatively smaller savings on noise abatement costs. Together, these benefits are in the order of 103 billion Euros for Option 4 and 123 billion Euros for Option 5 over the period 2010-2030. The benefits outweigh the costs for industry by a factor 26.2 for Option 4 and a factor 20.6 for Option 5. The environmental and social benefits may be reduced by half if traffic growth continues at current rates. If the assumed additional costs of the tyre industry are included over the period 2010-2013, then the benefits still outweigh the costs by a factor 11.8 for Option 4 and a factor 11.4 for Option 5."

7. Conclusion

All in all, there are relatively solid methods and data available for the measurement of external costs of noise. Especially CE Delft has worked over many years with research in this area, and we recommend following the guidelines as outlined in their respective Handbook of 2008. At the same time, it is important, as for all measurements, to keep track of on data improvements and to always use the most current data available, for example from the "noise maps" which continuously need to be improved according to the Environmental Noise Directive (2002/49/EC). Furthermore, we recommend follwoing EU legislation with regard to new standards for vehicles noise, which were expected to be renewed during 2011.

[20] New method – new limit values with noise reduction potential.
[21] New method – new limit values with noise reduction potential in two step approach.

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