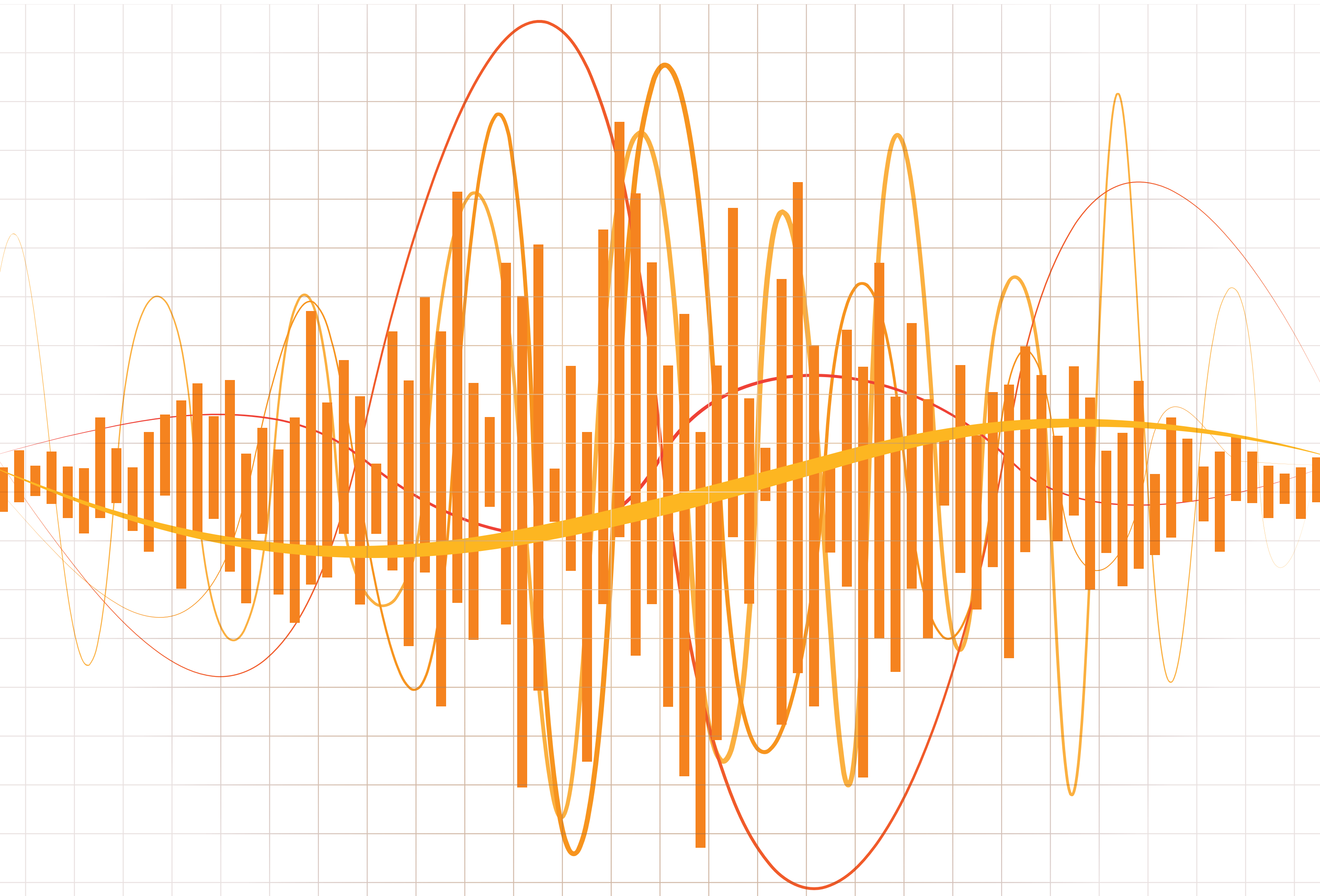
INTERNATIONAL UNION
OF RAILWAYS

Exploring bearable noise limits and emission ceilings for the railways

Part I: National and European legislation and analysis of different noise limit systems

UIC Project 'Bearable limits and emission ceilings'



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Summary

The question 'What are bearable limits for environmental noise?' is discussed regularly in different forums on a national scale and on a European level. This report gives the results of a feasibility study on bearable limits for railway noise.

Two developments put pressure on limits for railway noise:

1. Noise emission ceilings are announced by the European Commission to prevent increasing noise if rail freight traffic grows.
2. The World Health Organization (WHO) and civil initiatives to restart the debate about lower noise reception limits.

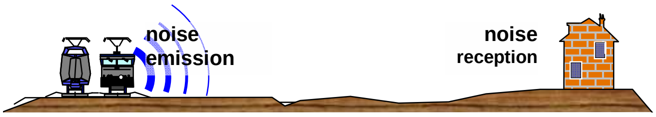

Figure 1: Noise Emission and Noise Reception.

European noise policy

EU noise policy distinguishes the *sources of noise* (emission) and the *exposure to noise* (reception). The *sources* (cars, trains, aircraft) and their noise emission are addressed by DG MOVE. One of the intended EC policy instruments for railway noise control is 'noise emission ceilings'. *Noise reception* is primarily the domain of the Member States. Many countries already have noise reception limits.

Health effects of noise

The WHO has issued guideline values for environmental noise. The most stringent guidelines address night noise. An Interim Target of 55 dB L_{night} and Night Noise Guideline of 40 dB L_{night} are proposed. The question 'What level of exposure to railway noise is bearable?' cannot be answered by looking at the WHO guidelines only. Choosing acceptable noise limits is a political consideration.

National noise legislation

A survey of current noise legislation in European countries reveals an enormous variation in legal protection of residents that live close to new or existing lines, either in residential or mixed zones, in flats or detached houses. Different noise indicators imply sometimes cultural differences. The European policy instrument of noise emission ceilings is inspired by specific Swiss and Dutch ceiling legislation.

Noise reception limits

Noise reception limits have impact on spatial planning, current residents, infra manager and the train operator. Without noise measures, nightly reception levels will be above 40 dB up to 1 000 m or more from the busy railway lines. Levels above 55 dB are found up to 500 m. Reduction of reception levels to 55 dB means average additional cost for barriers of € 0.3 to 0.5 million per km railway line (Western Europe). Reduction to 40 dB will increase these cost with at least a factor 4. Measures additional to retrofitting are necessary to comply a limit value of 55 or 40 dB. Operational measures like speed reduction and traffic reduction are contra productive. While these measures have little impact on railway noise reduction they will cause a modal shift towards road, thereby increasing noise annoyance of road and rail together. A night-time reception limit of 40 dB can only be achieved with large cost and a massive impact on the transport and the spatial environment.

Economic techniques like monetization or valuation can answer the question 'what noise reception levels are bearable?' from the point of view of society. These methods show that the equilibrium noise reception level will always be higher than the threshold level of 50-55 dB. A big issue is how to arrange that the benefits will flow to the same party that paid for the noise measures.

Noise emission ceilings

Noise emission ceilings are already in force in Switzerland and the Netherlands. They have a direct impact on the infra manager and train operators. The initial height of the noise ceiling can be fixed at the actual noise level or at a future expected level. Additionally one can take into account the combination of the effect of retrofitting (decreasing the ceiling) and the possible growth of rail transport (increasing the ceiling). Also a certain margin will be required to accommodate small yearly fluctuations in train service.

A ceiling system combined with monitoring will show whenever ceilings are trespassed. In case of a trespassed ceiling, different levels of intervention can be chosen: Mild (notification only), more stringent (warn and to ask for further investigation in order to decide whether or not to take measures) and most stringent (immediate action). The decision for measures can be supported by legal cost-benefit instruments.

Trespassing a noise ceiling can start a process of balancing interest of the railways and the involved inhabitants. This process can be organised with legal instruments like participation procedures and cost-benefit schemes. The notification system and the warning system give room for a balance between interests.

Harmonization of instruments gives railway undertakings that act cross-border simple regulations and equal opportunities. On the other hand it limits room for national government to optimize the noise control system, due to cultural and historical differences. Harmonization of ceilings seems to be possible in combination with predefined margins to adapt the system to national needs.

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1 EU Noise Policy and Health Effects

1.1 EU Noise policy

1.1.1 Introduction

Annoyance due to environmental noise is regarded an important issue for which a European approach has been developed over the years. According to the European Commission (EC) about 10% of the population is exposed to railway noise levels above the threshold for “serious annoyance” [1]. Besides this, road traffic noise causes an even larger number of seriously annoyed: 30%. This insight has lead to a number of European policy intentions and directives addressing environmental noise and its various sources.

Three different departments within the EC are responsible for the development of European noise policy. An overview is drawn in Fig. 1.

- Directorate General Mobility & Transport (DG MOVE, formerly called DG TREN) is developing policies for the creation (or emission) of transportation noise. DG MOVE addresses the source of the transportation noise: the vehicles, tracks, roads, aircraft.
- DG ENTR (Enterprise and Industry) is responsible in cases where industrial standards for the European market are involved: noise emission standards for tyres, motor cycles, recreational boats, et cetera.
- In contrast with these two source-related departments, DG ENV (Environment) is responsible for noise reception and exposure. The environmental noise policy will shortly be described and all other EC policy fields regarding noise will be mentioned. The railways noise policy will be discussed in details in the next section.

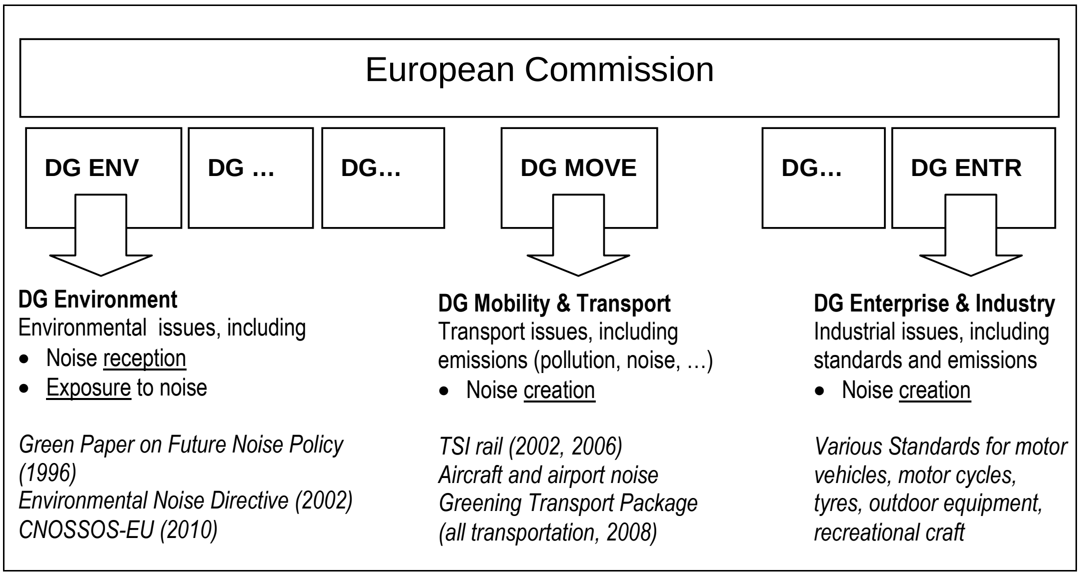

Figure 2: The departments involved in EC noise policy.

The 1996 Green Paper on Future Noise Policy [3] declared the basic goal of EC noise policy: 'no person should be exposed to noise levels which endanger health and quality of life[1]'.
At that time, the Commission considered that the lack of accurate and standardized data on noise exposure was to be solved first before further coherent actions could be taken. Several EU Working Groups were formed to assist the Commission in the development of its noise policy. The 2002 Environmental Noise Directive (END) would provide the necessary data in a standardized way, and besides that, it would also require Member States to evaluate noise exposure and draw up action plans. By the writing of this report, the evaluation of the results of the first round of noise mapping is still on-going. Nevertheless, it has been decided already that further standardization of the calculation method (so-called CNOSSOS-EU method) is essential to obtain more reliable and better comparable European figures on exposure.

Besides the END there are various other European Directives on noise: outdoor machinery, road vehicles, tyres, subsonic aircraft, operating restrictions for airports, regulations for noisy aircraft, TSI high speed + conventional rail, and recreational boats[2]. They have in common that they address the sources of noise.

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[1] *Article 6 of the Lisbon Treaty puts this more generally: "The Union shall have competence to carry out actions to support, coordinate or supplement the actions of the Member States. The areas of such action shall, at European level, be: (a) protection and improvement of human health; […]"*
[2] *An useful overview is found here: http://ec.europa.eu/environment/noise/sources.htm*

1.1.2 Railway freight noise policy of the EC

Inspite of its environmentally friendly image, rail transport encounters substantial public opposition to noise in some European regions. The Commission believes that "if no remedial action is taken, this could lead to restrictions in rail freight traffic along the most important European rail corridors. A possible modal shift from rail to road on these corridors would lead to increasing environmental impacts." [1]. Retrofitting 370 000 freight wagons is the main objective to avoid this scenario. This objective should be achieved by a combination of three policy instruments:

1. Noise-differentiated track access charges (NDTAC);
2. Noise emission ceilings;
3. Voluntary commitments (railway undertakings could pass NDTAC benefits to wagon owners, rail sector could start individual retrofitting programmes).

The above combination of policy instruments (abbreviated DEV) was selected after an impact assessment [2] by PriceWaterhouseCoopers which revealed slightly better results as compared to an alternative set of instruments (SOV): direct funding (subsidies for retrofitting), operating restrictions and (other) voluntary commitments. According to PwC the DEV option will provide incentives to minimize retro-fitting costs and it is not discriminatory – the SOV option would require governments to pay subsidies to certain private companies. The implementation of harmonized noise-differentiated track access charges [6] requires a revision of Directive 2001/14 on track access charging, which is expected no earlier than 2012/2013 [7]. However, the rail sector has strong considerations whether the proposed system of NDTAC will work at all [8, 9].

The noise emission ceilings are proposed as a second step to prevent an increase of noise, "after the initial retrofitting programmes have been completed" [1]. The Commission wants to move towards a trans-European rail network giving priority to freight [5]. The Technical Specification for Interoperability (TSI) for conventional rail should provide the technical basis for a well-functioning network. The TSI also sets limits for the noise creation per vehicle. It contains maximum values for the A-weighted Leq and/or Lmax for individual vehicles under different operating conditions.

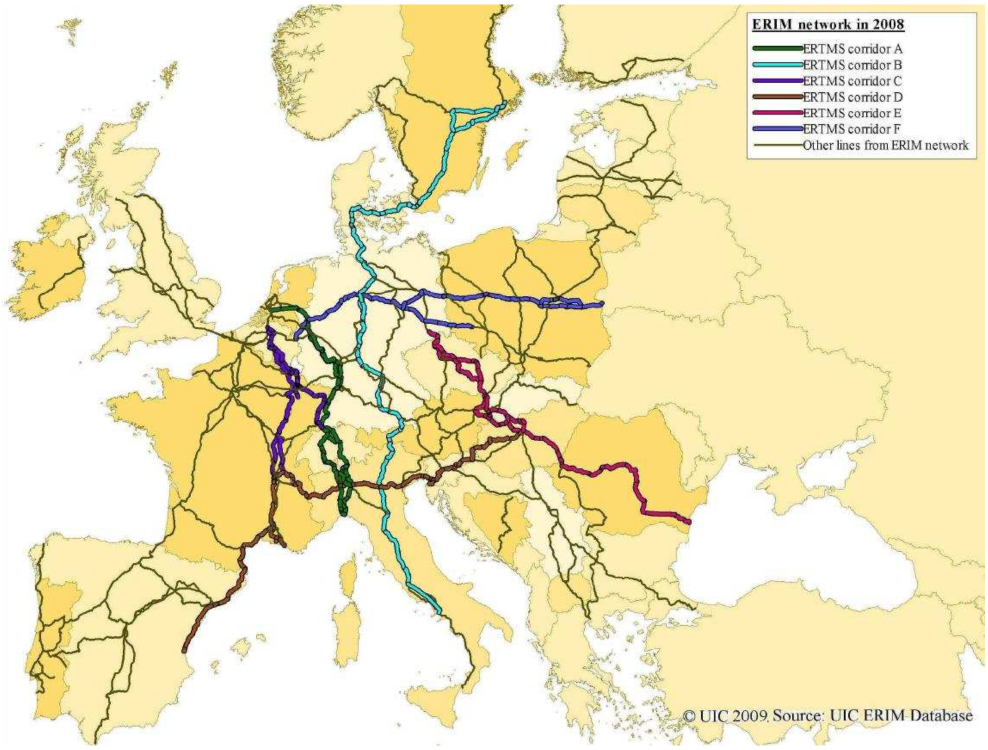

Figure 3: The rail freight oriented network and the main corridors (UIC Atlas 2008 of Infrastructure in the ERIM Network).

1.1.3 Noise limits

In the previous sections a distinction is made between limits for noise emission (or creation) and noise reception[3]. To understand the noise legislation in different countries of Europe (Chapter 2) a further subdivision is necessary. Table 1 and Figure 4 show the four basic positions where limits can be defined for transportation noise.

Table 1 Positions where noise level can be compared with legal limit.

noise	position has a certain relationship with	legal framework	what can be monitored?
I. creation or emission	source sound power	TSI, source definition	the daily average level but also single vehicle levels
II. reception at monitoring point	emission + propagation (includes effect of barrier)	(Dutch) warning system	the daily average level

[3] the word “immission”, as an alternative for “reception”, is not used in English.

noise	position has a certain relationship with	legal framework	what can be monitored?
III. reception at façade	impact, dosis, exposure	reception limits, environmental effects	the daily average level
IV. reception inside building (interior)	impact, dosis, exposure, sleep disturbance, façade and window insulation	interior noise	the daily average level

Most countries have defined a set of noise reception limits at the façade (position III) which are meant to protect residents from high noise exposure levels. Generally only new situations (new or renewed railway lines, new buildings) are governed by these limits, while the severe noise impact of existing lines is reduced on a long-term basis by noise abatement programmes. Apart from some exceptions, interior noise limits (position IV) are only considered in case window insulation is involved.
Position II is added for completeness. This monitoring position will be applied in the future Dutch "noise production ceilings", which is actually a warning system rather than a rigid ceiling. This system will be discussed in detail in Section 2.4.3.

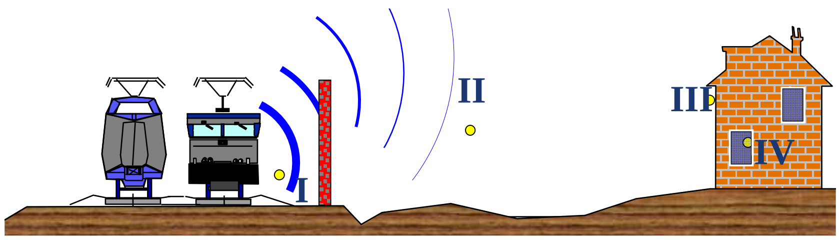

Figure 4: Noise limits are defined at different spots between source and receiver.

So far, the environmental noise policy of the EU (basically the END) does not interfere with existing national reception limits and abatement programmes[4]. The only compulsory European regulations are the TSIs, which focus on the noise emission per vehicle (position I) and are restricted to trans-national transport.

Noise emission ceilings

The future possible EC policy instrument of noise emission ceilings needs more consideration, because it is likely this instrument will interfere with the national systems of noise reception limits, depending on how such ceilings will be defined. The WG Railway Noise (1999-2003), who were asked by the EC to evaluate strategies and priorities for railway noise abatement, considered the Swiss and Dutch emission ceilings in their 2003 position paper [10]:

[4] *The END does not impose any limits, nor do the action plans require actual progress in abatement. Nevertheless, some Member States have voluntarily implemented noise remediation programmes.*

A majority of the WG rejects this instrument and gave it a low priority. The noise emission ceiling should be related to and combined with targets for noise reception levels and noise abatement programmes. Then it provides a better protection against unacceptable noise exposure than mere reception limits.
Next, the PwC impact assessment study [2] reconsidered the noise emission ceilings as an additional instrument to NDTAC and voluntary commitment. The ceilings were chosen in favour of operating restrictions, because operating restrictions in combination with NDTAC would put too much of a burden on the railway undertakings. The PwC concept of noise emission ceilings is cited in Appendix 2 and commented in Appendix 3. Their concept is mainly based on the Swiss ceiling system, but it requires two additional features: identification of noisy wagons and penalizing the railway undertakings (Figure 5).

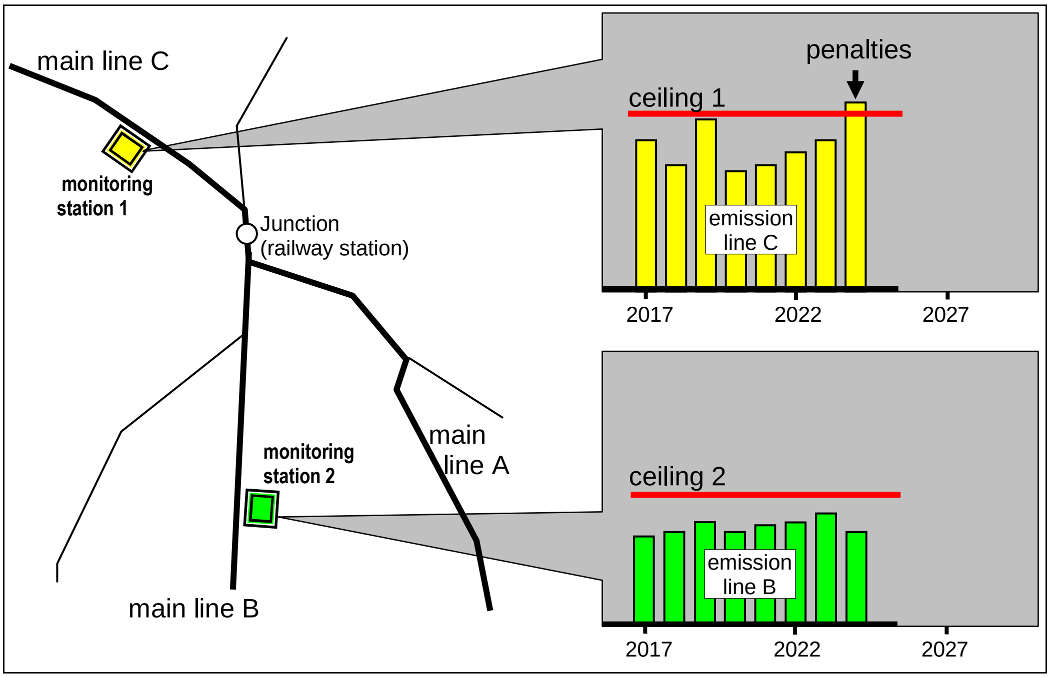

Figure 5: Noise emission ceilings at selected main freight lines, as in PwC 2007 study [2].

The only official EC statement about noise emission ceilings is given in [1]. The cite and comment of the complete text are as following:

4.2 Introduction of noise emission ceilings as a second stap

The noise emission ceiling limits the average emissions within a determined period at a certain location along the line. For example, current noise emission could be taken as a limit to prevent increasing noise if rail freight transport grows. Under Directive 2002/49/EC, Member States are legally competent to set such limits on environmental noise.

> Not clear how "current" would match with an introduction "after the initial retrofitting programmes".

> Member States may set ceilings now, but will probably need to adapt their system, once the EC enforces mandatory ceilings.

The noise emission ceiling leaves it to the rail sector to find optimal solutions: the railway undertaking may use vehicles with lower emissions to increase the number and/or speed of trains without exceeding the noise limits. The noise emission ceiling therefore gives an incentive to use low-noise vehicles. Noise emission ceilings could directly address noise "hot spots" in the European network as well as the sensitive evening and night periods. Infrastructure-related measures are also covered by this instrument, leading to a holistic approach to rail noise reduction.

> Ceilings might work as an incentive for retrofitting, but not when introduced too late.

> There is no common definition of "infra-structure related". Does it or does it not cover noise barriers?

In order to maintain the noise reduction achieved by retrofitting, the European Commission recommends Member States to introduce noise emission ceilings for major rail freight lines as a second step after the initial retrofitting programmes have been completed. However, cost-benefit analyses should be carried out prior to the introduction of this instrument considering the noise reduction already achieved by retrofitting and other means at that date.

> Not clear. This could mean that introducing noise emssion ceilings will not be (cost-)effective anymore if retrofitting has turned out to be successful.

This description of emission ceilings is rather provisional. This concept of emission ceilings could eventually result in very mild or very restrictive system. These extremes should be kept in mind when the railways wish to prepare themselves for the introduction of emission ceilings.

Noise reception limits

This text does not explain if mandatory reception limits will be integrated in the emission ceilings. As far as noise emission ceilings are solely considered as a means to support the retrofitting goals and to protect against future noise *growth*, there is indeed no need to introduce (or adjust existing) reception limits. This view is supported by the fact that noise reception limits as a European policy instrument were considered by WG Railway Noise[5] and the PwC impact study [2], but were rejected. The only existing European legislation dealing with noise reception is found in the Environmental Noise Directive, but therein no specific limit values are

[5] *WG Railway Noise recommended reception limits only for the case of new dwellings along existing lines.*

recommended. However, following this Directive, the EC made a declaration relating to the development of a long-term EU strategy [11] :
Therefore, and in accordance with the Treaty establishing the European Community, the Commission will evaluate the need to come forward with new legislative proposals, reserving its right to decide as and when it would be appropriate to present any such proposals.
At present DG ENV has no intention to introduce or harmonize European reception limits [12]. It should be noted that noise reception limits would only be effective if they are put in place for all relevant environmental noise sources, not only for railway noise. It does not make sense to protect people against noise from a faraway railway corridor without considering nearby road traffic. A European system of noise reception limits for environmental noise will take a long preparation and negotiation period, in which many stakeholders are involved.
The recent END review report [29] explains that mandatory EU-wide noise reception limits would raise issues of proportionality and subsidiarity. For example, it is considered unlikely that such legislation would be more successful at EU level than at national level:
If national legislation does not generate sufficient legal imperative to overcome technical and budgetary restraints to addressing noise, this suggests that the same drivers would impair implementation of any EU level objectives.

1.1.4 EC policy for other modes of transportation

Ships

There is no separate Directive dealing with the noise emission of ships on inland waterways, but a noise limit is included in a general directive dating back to 1982, stating that inland waterway vessels should not emit more noise than 75 dB measured at 25 m from the side. It is not foreseen that this limit value will change in the near future – the directive has only been revised in 2006 without adjusting this limit (2006/87/EC).

Aircraft

Unlike noise of ships, aircraft noise is a big issue in Europe. Aircraft noise is bound by international regulations (ICAO) and, besides this, the main European airports operate on a global market. For these reasons, the Commission seeks ways to reduce the noise impact in European agglomerations without affecting the international competitiveness of airports and operators. There is a voluntary legal framework for European airports to refuse admission to (old) aircraft that just marginally meet international requirements regarding noise emission (2002/30/EC). Airports are legally competent to ban noisy airplanes from 2013.

Road

Road noise is the main source of noise annoyance due to transportation. A cost-effective way to reduce road noise would be to set tighter industrial standards for new vehicles and tyres. So far, due to major objections from the European automotive (and tyre) industry and due to inappropriate type testing methods, only small steps forward have been made. The Greening Transport Package [4], which includes all existing directives and policy developments to reduce negative environmental effects of all modes of transportation, contains no direct measures to reduce the impact of road noise. There could be some effect on noise after the announced revision of Directive 1999/62/EC on road charging, but this instrument mainly addresses air pollution and congestion. Differentiating road charges for different environmental goals might not work here: the best period to drive a car from the perspective of air pollution and congestion would be at night – and that is the very period where noise is considered most harmful.

1.2 Health and annoyance

1.2.1 WHO Guidelines

There are two WHO Guidelines regarding noise. The first one, *Guidelines for Community Noise*, was issued in 1999 [13]. It summarizes scientific knowledge on health impact of noise and formulates guidelines for governments to develop strategies to reduce environmental noise. The second report, *Night Noise Guidelines for Europe*, was published in 2009 [14] to serve as guidance for action plans under the Environmental Noise Directive. Again, scientific findings are the basis, but in this case the guidance concentrates on the European situation relating to night noise. The final text was reviewed and agreed upon by stakeholders from industry, governments and NGOs.

It is important to note that the guidelines do not specify one single noise target value, but provide a range of threshold values depending on the situation. As a consequence, there is a tendency that different stakeholders cite only those values that fit them well.

The WHO realizes that implementing the recommended noise targets takes time and money:

- Governments should adopt the health guidelines for community noise as targets to be achieved in the long-term.
- Cost-effectiveness and cost-benefit analyses should be considered as potential instruments when making management decisions.

The guideline values that are relevant for environmental noise sources are listed in Table 2.

Table 2 WHO guideline values for the living area.

outside reception levels (incident sound) in dB	LAeq (16h)	Lnight (8h)
Serious annoyance, day and evening (WHO 1999)	55	-
Moderate annoyance, day and evening (WHO 1999)	50	-
“Night Noise Guideline” (WHO 2009)	-	40
“Interim Target” for night noise (WHO 2009)	-	55

WHO proposes to adopt the Night Noise Guideline (NNG, 40 dB) as a limit for new projects (road/rail/residential areas), while the Interim Target (IT, 55 dB) can be used for existing cases. The Interim Target, however, is not based on health considerations but on feasibility. Therefore, the NNG should be used as long-term goal.

For the issue of noisy freight trains and bearable limits, the night-time values are probably more restrictive than the day-time values. While it will be shown in Chapter 2 that the Interim Target of 55 dB is comparable to legal limit values in most countries, the stringent NNG value of 40 dB needs further exploration.

Regarding the process that leads from the scientific results to NNG value of 40 dB the following can be remarked.

- The round number of 40 dB is apparently based on an unrounded value of 42 dB. Namely, this value of 42 dB equals the threshold level of the five non-biological factors for which sufficient evidence is available (Table 1 of [14]), the only exception being the non-biological factor “Use of somnifacient drugs and sedatives”. For this latter factor 40 dB is listed, but there is not much justification in Guideline Section 4.5.8 to specify *exactly* 40 dB as threshold for sleeping pills. Hence, a level of 42 dB would result if the final guideline values were not rounded. This difference of 2 dB seems rather small, but it represents an enormous amount of additional costs for noise abatement measures in Europe.
- The non-biological effects that support this unrounded NNG value of 42 dB are almost exclusively based on research of road and aircraft noise[6]. For railway noise, often much higher thresholds are observed than for road and aircraft noise. As demonstrated in the next section of this report, railway noise has in some cases 6 to 12 dB higher levels for the same percentage of affected people than road noise. Therefore, based on the same scientific material as referred to in the 2009 Guideline, one could argue for a separate *higher* NNG value for railway noise. Before giving a better founded NNG value for rail noise, further

[6] *Considerably less research is done on rail noise than on road and aircraft noise, obviously because the noise problem (people affected) is much bigger for road and aircraft noise than for railway noise.*

research is necessary on rail noise health effects for which insufficient evidence is available at present.

1.2.2 Health and annoyance research

Well-known effects of environmental noise are annoyance and sleep disturbance. These occur already at fairly low levels. Besides these effects, also hypertension and ischemic heart disease and decreased school performance have been reported [15]. The evidence for cardiovascular risks and other physiological effects has increased during the past decade [16,17], but the WHO 2009 guideline rates this evidence still as 'limited' [14]. This means that this evidence was not used in deriving the final guideline values.
Besides acoustical factors, annoyance is also influenced by many non-acoustical factors such as the extent of interference experienced, ability to cope, expectations, fear associated with the noise source, noise sensitivity, anger, and beliefs about whether noise could be reduced by those responsible influence annoyance responses [16]. The annoyance effect depends strongly on the source of the noise: road, rail or else. Based on a review of field and laboratory test Möhler [18] concluded that at the same energy equivalent A-weighted level, railway noise is preferred to road traffic noise. In other words, the dose-response functions (that relate the percentage annoyed to the noise exposure level) for railway noise are lower than for road noise and aircraft noise. Miedema and Vos [19] established the annoyance dose-effect relationships for L_{den} that form the backbone of the position paper of the EU Working Group Dose/Effect in 2002 [20]. These relationships were derived from a meta-analysis including over 50 original reports and articles. Two years later, another position paper was issued on dose-effect relationships for night-time noise L_{night} [21].

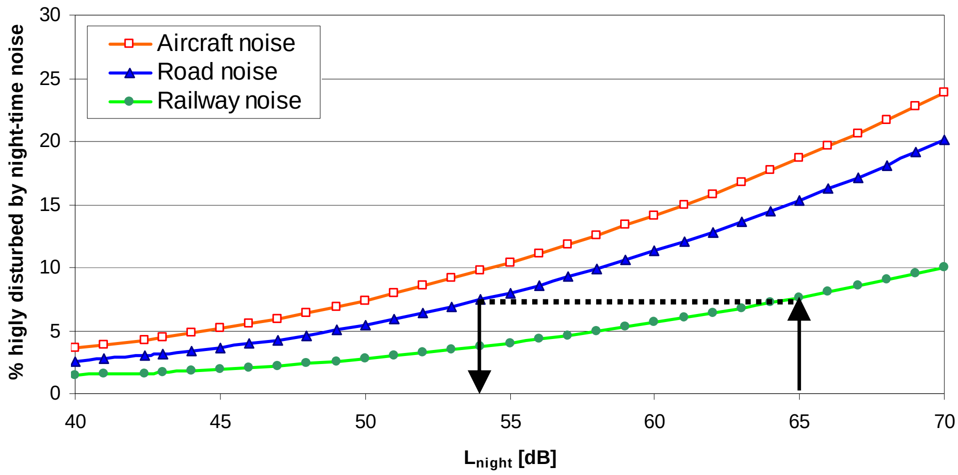

Figure 6: Percentages of highly disturbed when exposed to aircraft, road and railway traffic noise [21].

Noise annoyance correction factor

The dose-effect relationships for noise annoyance and sleep disturbance are generally used as a basis for the noise annoyance correction factor[7]. This factor can be derived by looking at the horizontal differences between the dose-effect curves of Figure 6. For example, railway noise of 65 dB generates the same amount of sleep disturbance (7.5%) as road noise of about 54 dB. A correction factor of about +11 dB (= 65 – 54) could thus be applied to road noise in order to compare the impact of railway noise to road noise. It can be seen from the different slopes of the road and railway dose-effect relationships that this correction factor will vary slightly with the noise level.

If one would subtract the dose-effect responses of rail noise and road noise, an advantage for rail is found of 8-12 dB for sleep disturbance (L_{night}) and 6-8 dB for annoyance (L_{den}), see Figure 7.

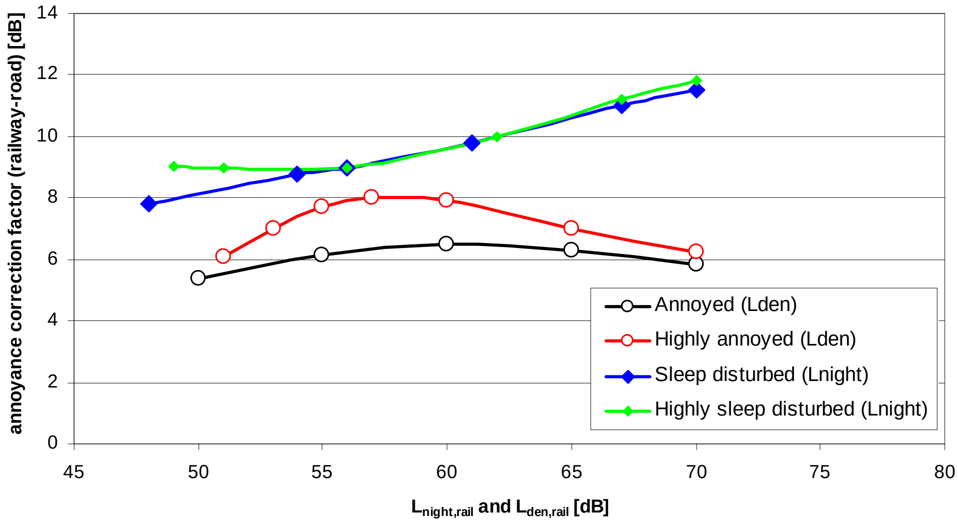

Figure 7: The correction factor (railbonus) derived from the difference between railway and road dose response relationships [20,21].

The L_{night} and L_{den} are are not the only indicators that influence annoyance. The L_{max} value and the train frequency (number of events) are also important. With higher train frequencies the difference between road noise an railway noise will decrease.

There is no clear understanding of the mechanisms that create differences in annoyance between railway noise, road noise and aircraft noise. An interesting explanation is proposed recently by De Coensel *et al.* [26]. They argue that noise events (road, rail or aircraft) are only noticed when they exceed a certain *varying* inner threshold level of exposed people. This time-varying threshold depends on

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[7] *sometimes referred to as 'rail bonus'*

the relative level of the noise events above the background noise, but also on psychological processes like attention, habituation, gating. By using literature values for all these factors, as well as the output of an acoustical calculation model for a large region like Flanders, the researchers were able to predict that railway noise causes less noticed noise events than road noise. If one adopts their hypothesis that self-reported annoyance is proportional to the energy of all events that were really noticed, one finds 7-8 dB difference between rail and road, similar to what is found in real life.

The principle to use this advantage as a noise annoyance correction factor in legal reception limits is sometimes questioned, especially in Germany [22,23,24]. For example, Schreckenberg *et al.* [22] demonstrated in a field study (8 areas with 1600 respondents in total) that railway noise may affect the ability to communicate more than road noise does. In the same study, however, road noise led to more ‘general annoyance’ and more ‘total annoyance at night’.
Very few studies compare the noise effects of different types of trains. A recent French study [25] reveals that freight trains may produce higher cardiac response than passenger trains, probably due to their longer pass-by duration. In a second paper [25b] the same researchers describe that, in the long run, sleep fragmentation due to nocturnal railway noise tends to decrease and also habituation occurs with respect to cardiovascular responses.

In order to draw general conclusions about railway noise in comparison with road noise, a meta-analysis of many single field and laboratory tests, is required. This is because single experiments and specific situations cannot be considered sufficiently representative to serve as a basis for noise mitigation policy.

1.3 Conclusions

EU noise policy distinguishes the *sources of noise* and the *exposure to noise*. While the primacy of EU noise legislation is at the source (which moves through Europe thus requiring standardized specifications), Member States are mainly responsible for legislation with respect to noise exposure. Figure 8 shows the influence of three organisations on different elements of noise control.

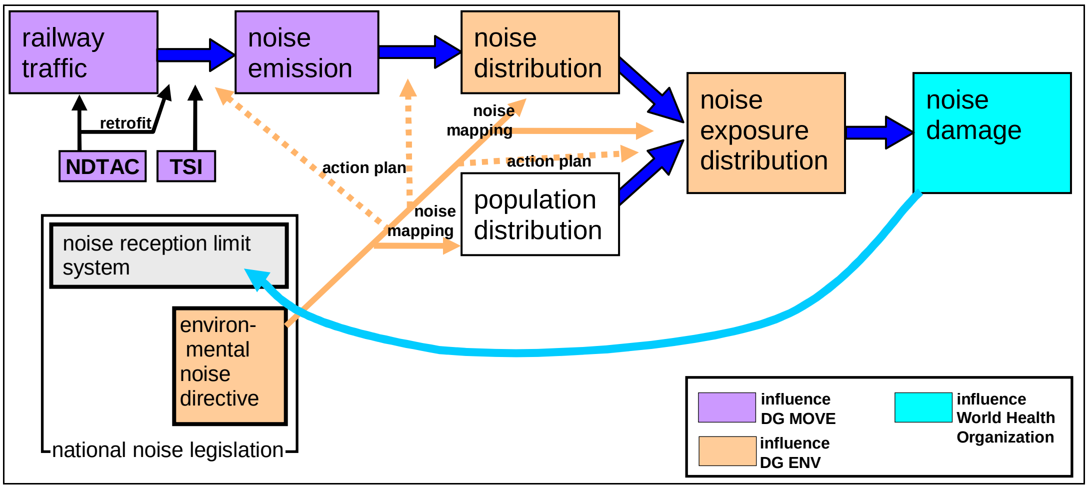


Figure 8: Policy of DG MOVE, DG ENV en WHO act on various positions in the railway noise chain.

The *sources* (cars, trains, aircraft) and their noise emission are addressed by DG MOVE:

- The Technical Specification for Interoperability (TSI) provides the technical basis for a well-functioning railway network. Among other things, the TSI sets limits for the noise creation per vehicle. The TSI contain maximum values for the A-weighted L_{eq} and/or L_{max} for individual vehicles under different operating conditions. There are no specifications for the total daily or nightly emissions on (part of) the network.
- The Greening Transport Package is a bundle of policy strategies of DG MOVE that includes all existing directives and policy developments to reduce negative environmental effects of all modes of transportation. As to railway noise, the most important policy target is to retrofit noisy freight wagons, in order to strengthen the position of rail freight transport in Europe. In order to achieve this, three policy instruments have been selected by the Commission, one of them being the idea to introduce so-called noise emission ceilings as a second step.
- The idea of *noise emission ceilings* has not been worked out yet. It is clear, however, that these ceilings do not require noise reception limits to be installed (or adjusted). This is because mandatory European reception limits for the railways would also require reception limits for all other environmental sources: it does not make sense to protect people against noise from a faraway freight corridor without considering nearby road traffic. Besides that, the purpose of ceilings is to prevent noise growth, not to guarantee a certain degree of protection against railway noise exposure.

Noise exposure is primarily the domain of the Member States. Many countries already have noise reception limits for new and upgraded infrastructure, and noise abatement programmes for existing lines, see the next chapter. Though the

Environmental Noise Directive (by DG ENV) attempts to stimulate Member States to develop (further) noise abatement strategies, this directive does not compel Member States to develop (or adjust) noise reception limits.

The Member States' primacy on noise exposure legislation may change through on-going European integration, but mandatory EU-wide reception limits are not considered yet. Nevertheless, considerable national and international pressure is felt by the railways to accept lower reception limits, while the current limits are already threatening railway operations and planning.

The new WHO *Night Noise Guidelines for Europe* propose a night-time noise reception target of 40 dB, which is much lower than present standards in Europe. It is also much lower than the Interim Target of 55 dB, proposed in the same report as a target that is feasible for the short term. It can be demonstrated however that the 40 dB target is

- a rounded value; the unrounded value being 2 dB higher;
- not readily applicable to railway noise; a higher value for railway noise is defensible.

More health research is required to establish a substantiated *health-related* target level for the railways.
Summarizing this, the question 'what level of exposure to railway noise is bearable?' cannot be answered by looking at the WHO recommendations. The WHO guidelines themselves reveal considerable ranges between different guideline values, and seem not to handle effects of railway noise properly. Finally, even the WHO recognizes that 'cost-effectiveness and cost-benefit analyses should be considered as potential instruments when making management decisions'. It will therefore remain a political choice.

2
Noise legislation in European countries

2.1 Introduction

In the previous chapter shows an overview of the noise policy of the European Union. The policy of DG MOVE and DG ENTR address the sources of noise, while DG ENV is responsible for noise exposure and reception. Table 3 gives an overview for railway noise.

Table 3 Overview of the European and the national noise policy for railway noise.

Aspect	Acoustics	Responsibility	Legislation
sources of noise	noise creation, noise emission	1. DG MOVE	in force: Technical Specifications for Interoperability in development: Harmonized noise-differentiated track acces charges (2013), Noise emission ceilings (2017-2020?)
		2. Member States	Voluntary commitments and national programmes that stimulate noise reduction at the source, as far as these do not affect the internal EU market negatively
exposed population	noise reception	1. Member States	reception limits for existing / upgraded / new infrastructure reception limits in urban planning noise abatement programmes
		2. DG ENV	in force: Environmental Noise Directive (2002/49/EC) in development: CNOSSOS-EU as a harmonized method for noise mapping under the END (2010-2011)

While the primacy of EU noise legislation is at the source (which moves through Europe, thus requiring standardized specifications), Member States are responsible for legislation with respect to noise exposure. This primacy of the Member States may change under the pressure of on-going European integration. In order to be prepared when a discussion on noise reception limits and emission ceilings starts, this report will describe the existing noise legislation on railway noise in a limited number of countries throughout Europe. This is done by means of interviews.

2.2 Set-up of the interviews

In order to acquire information on the present situation and noise legislation in Europe, representatives of national railways and/or infrastructure management organizations were interviewed. This inventory involved the 7 countries shown in Figure 9.
The first page of Appendix 1 gives an overview of the interviewed persons and the questions that were asked. In case of the Polish and Swedish inventories, use was made of e-mail and telephone rather than visiting. An attempt was made to engage Italy (Trenitalia) as well, but after an initial promising contact by phone, in which it was agreed to proceed by e-mail, no response followed.

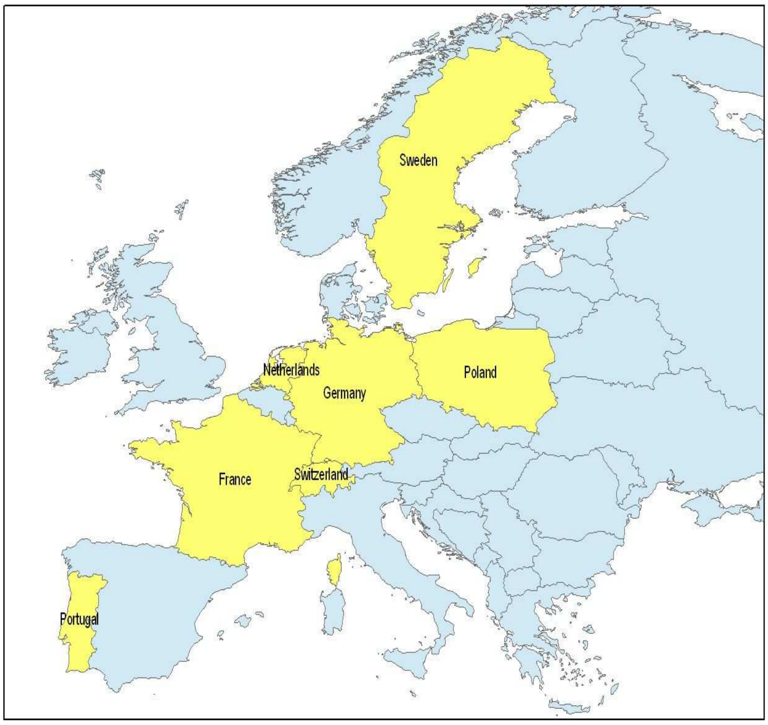


Figure 9: Countries involved in the inventory.

2.3 Summary of the interview results

Appendix 1 contains factsheets with detailed information per country. This information is summarized and compared here.

Legislation

All countries surveyed have a certain degree of noise protection, either by law, or by decree or by voluntary agreements. Since the previous inventory of European noise legislation features in 2001 [28], all EU countries have amended their legislation in order to implement the Environmental Noise Directive. In some cases other amendments were also made.

In most countries different noise legislation is applicable to new lines, lines that are being upgraded, and existing lines. The lowest reception limits apply to new lines and the highest to existing lines. The reception target levels for upgraded lines are in some countries equal to those for new lines while in other countries they follow existing lines. In Poland and Portugal, all situations are treated equally by law, but in practice priority is given to lines that are being upgraded. In France, lower reception limits apply to high speed lines.

Zoning and sensitivity

All countries in the survey, except two, have classified their residential areas into distinct sensitivity zones, to which different reception limits apply. The exact definition and number of zones varies, but generally speaking a low noise level applies to recovery and residential areas, while in city centres and/or industrial zones higher level are accepted. France applies two zones, the others have four zones. From the surveyed countries only Sweden and the Netherlands do not have zones.

Stakeholders

The ministries of environmental affairs and/or the ministries of transport are responsible for the noise legislation and enforcement. The infra management organizations are responsible to take action if limits are exceeded. In France, a slightly different situation exists. Here, maintenance and new projects are subcontracted from infrastructure manager RFF to SNCF. In each of these countries the former national railways are mostly (still) the main railway undertakings for passenger transport, but for freight transport many different companies have emerged.

Railway network

The railway network in most countries of our survey is standard gauge. Part of the Swiss network is narrow gauge, while the entire Portuguese network is broad gauge (like in Spain). The lines on the main network are ballasted tracks with (increasingly) concrete sleepers. The average network usage is shown in Figure 10. From the countries of our survey, Switzerland, Germany and Poland have the highest density of freight trains on their network.

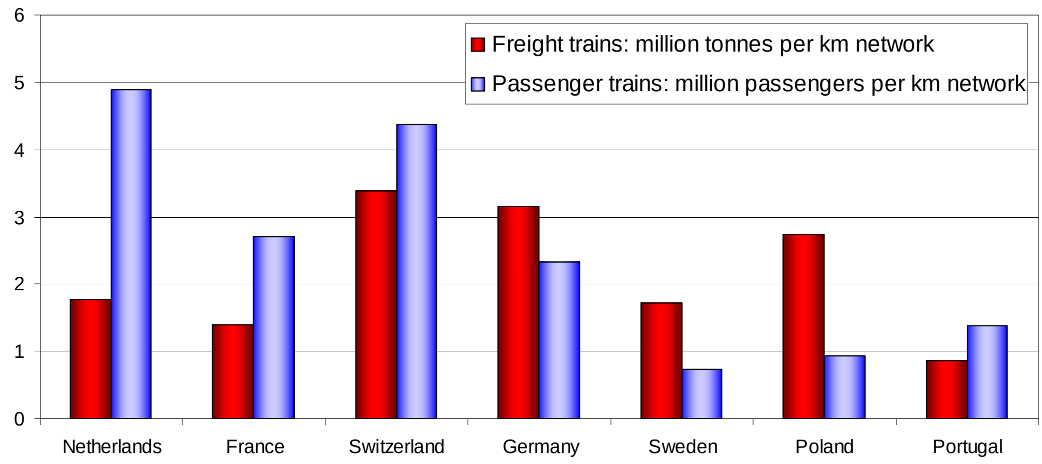


Figure 10: Network usage. Performance divided by network length for the countries surveyed (Eurostat, 2006). Countries in order of appearance in Appendix 1.

Rollings stock

The majority of freight wagons currently in operation have cast-iron braking blocks, even in Switzerland where advanced retrofitting programmes are almost completed. Of the seven surveyed countries Portugal forms an exception because of its broad gauge network: almost all freight trains nowadays are equiped with K-blocks (the same applies for Spain).

Noise abatement

Noise abatement or remediation takes various forms. Generally it means that the noise situation on existing lines is investigated and that noise measures are applied where reception limits for existing lines are exceeded (*Sanierung*, *protection anti-bruit*). Such abatement programmes cover many years and involve enormous investments [27]. This generally requires that a priority list is made of the most urgent situations.

Calculation methods

In some countries different noise calculation methods are used by the railways and by the authorities that are responsible for END noise mapping. This has led to some complications. For example, in Germany the difference between the legal noise indicator (which features a noise annoyance correction factor) and L_{night} becomes visible. In Switzerland there is a pressure to replace SEMIBEL with sonRAIL, which is used on behalf of the Ministry of Environment in regular noise mapping. In France the EU interim method RMR2002 is used for the additional noise abatement programme, while the current programmes are based on NMPB. This leads sometimes to confusion.

Also in the other countries the legal noise calculation methods are reconsidered. Poland uses RMR2002 but has not yet modified it to the Polish fleet. In Sweden the Nordic method of 1969 is not yet replaced with Nord2000.

Noise indicators

France, Germany, Poland and Switzerland apply day-time limits (usually $L_{Aeq,6\text{-}22h}$) as well as night-time limits (usually $L_{Aeq,22\text{-}6h}$).
Portugal has converted the original $L_{Aeq,6\text{-}22h}$ and $L_{Aeq,22\text{-}6h}$ limits into the END standards L_{den} and L_{night}, without changing the limit values. Also the Netherlands have converted their old L_{etmaal} indicator into L_{den}. This latter conversion involved a modification of all limit values by subtracting 2 dB. A separate night-time limit is considered unnecessary in the Netherlands.
Sweden applies L_{max} limits in addition to $L_{Aeq,24h}$. Besides outside limits also interior noise reception limits are in force[8].

Comparing noise reception limits

A comparison of the noise reception limits between these countries is a most tempting idea, but it will not be meaningful due to a number of factors:

- complexity of the legislation behind these limits;
- the different definition of zones ('residential' in one country could mean 'mixed' in another);
- the different definitions of when a line is considered to be upgraded;
- the different noise indicators (L_{den} levels cannot be transfered to $L_{Aeq,6\text{-}22h}$ levels);
- the different purpose or function of the 'limit' (threshold, target, absolute maximum).

This means that with a slightly different definition of a certain situation to be compared between countries, limit values may jump considerably. The legal limit values of the surveyed countries are listed in Table 4.

[8] *Interior noise limits are applicable in many countries, but then they are only considered after the outside noise limit is exceeded (in noise abatement programmes and building new houses). The difference is that the Swedish interior limits should be observed at any time (independent of the façade level).*

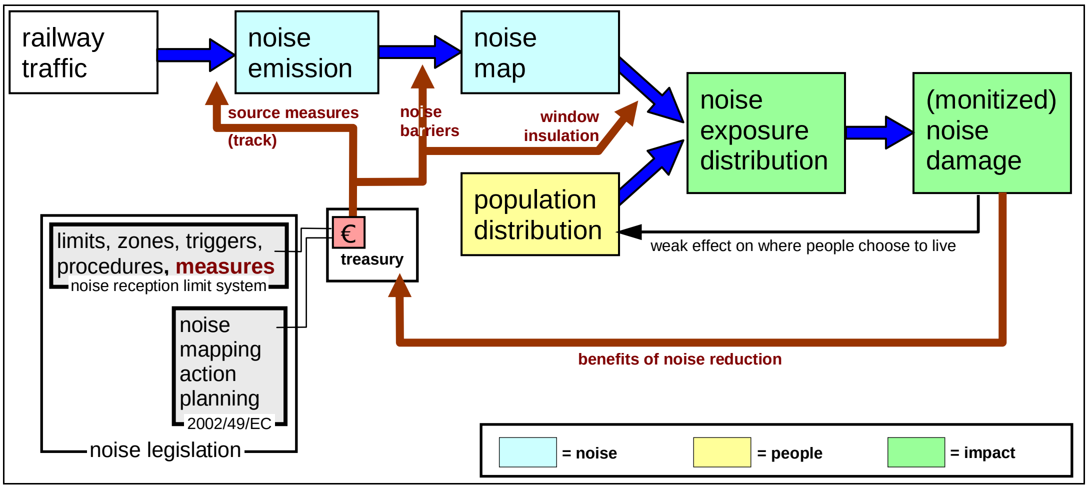


Figure 11: National noise legislation defines actions at various positions in the railway noise chain.

Table 4 Overview of the European and the national noise policy for railway noise.

country	line[a]	applicable situation built-up environment[b]	'Day' limit[c]	Night limit[d]	for com-parison[e]	remarks
Nether-lands	Ex.	dwellings	L_{den}=70	-		'NoMo-sanering'
	Up.	dwellings, schools and hospitals	$\Delta L \leq 0$	-		objective
	New		L_{den}=71	-		upper limit
		dwellings (2 dB lower limit for schools and hospitals)	L_{den}=55	-		objective
		dwellings, schools and hospitals	L_{den}=68	-		upper limit
France[f]	Ex.	all	L_{den}=73	L_{night}=65		'points noirs'
	Up.	all	$\Delta L \leq 0$	$\Delta L \leq 0$		objective
	New		68	63	Δ_{inc}=-3, Δ_{rail}=+3	upper limit
		zone with moderate noise levels	63	58		
		zone with more than moderate noise levels	68	63		
Switzer-land	Ex.+	recreational or recovery areas (I)	55	45	Δ_{rail}=+5 up to +15	
	Up.	residential areas, areas for public buildings & facilities (II)	60	50		
	New	residential and commercial zones, agricultural zones (III)	65	55		
		industrial zones (IV)	70	60		
		recreational or recovery areas (I)	50	40		

country	line[a]	applicable situation built-up environment[b]	'Day' limit[c]	Night limit[d]	for com-parison[e]	remarks
		residential areas, areas for public buildings & facilities (II)	55	45		
		residential and commercial zones, agricultural zones (III)	60	50		
		industrial zones (IV)	65	55		
Germany	Ex. Up.+ New	hospitals, schools, sanatoriums and nursing homes (1); residential areas and small settlements (2)	70	60	Δ_{rail}=+5	'Lärmsanierung'
		in central areas, village areas and mixed areas (3)	72	62		
		commercial and industrial areas (4)	75	65		
		hospitals, schools, sanatoriums and nursing homes (1)	57	47		'BImSchG'
		residential areas and small settlements (2)	59	49		
		in central areas, village areas and mixed areas (3)	64	54		
		commercial and industrial areas (4)	69	59		
Sweden	Ex. Up.+ New	inside the building (in the bedroom)	-	L_{max}=55		
		outside the building (in the garden or patio)	$L_{Aeq,24h}$=70	-		
		inside the building (in the bedroom)	$L_{Aeq,24h}$=30	L_{max}=45		
		outside the building (in the garden or patio)	$L_{Aeq,24h}$=55 L_{max}=60	-		
Poland	Ex.+ Up.+ New	health resorts and hospitals outside city	50	45		
		single-family houses, city hospitals	55	50		
		multi-family houses, recreation areas, farms	60	50		
		city centres above 100 000 inh.	65	55		
Portugal	Ex.+ Up.+ New	sensitive zone (residential, hospitals, schools)	L_{den}=55	L_{night}=45		
		mixed zone; sensitive zone close to existing major line	L_{den}=65	L_{night}=55		
		areas not yet classified by municipality	L_{den}=63	L_{night}=53		
		line projected when approving sensitive zone	L_{den}=60	L_{night}=50		

a. Existing lines (Ex.), lines being upgraded (Up.) and new lines (New).
b. Limits apply to the façade of the building, unless otherwise stated (Sweden).

c. Limit value as cited in the law (or decree or regulation). This value is expressed in LAeq,6-22h (dB), unless otherwise stated in this table. '$\Delta L \leq 0$' means that the objective is to avoid an increase of noise after upgrading.
d. Night limit expressed in LAeq,22-6h, unless otherwise stated. Limits expressed in Lnight are equal to limits expressed in LAeq,22-6h.
e. For comparability, some of the listed values must be raised or lowered. These limits generally apply to incident sound from railways. If this not the case, Δinc and/or Δrail are given (to be added to the legal limit value for comparison with the other countries). For example, in France -3 dB and +3 dB result in 0 dB addition. Note that limits expressed in Lden cannot be transferred to LAeq,6-22h.
f. The listed French limits are for conventional lines. For high speed lines mostly 3 dB lower limits apply.

2.4 Swiss and Dutch ceilings in use

2.4.1 What is meant by 'noise emission ceiling'?

A noise emission ceiling sets a maximum to the noise that is emitted on a daily basis by a certain railway line. Noise emission, and its synonym noise creation, refers to an amount of noise produced by the source, irrespective of whether the environment contains dwellings. This common definition for noise emission implies the following properties:

1. A high noise emission does not necessarily imply high exposure levels, because the latter depends on the actual distance of the dwellings;
2. An increase of the noise emission level will result in an (almost) equal increase in the noise reception levels;
3. As a consequence of properties 1 and 2, setting a ceiling to noise emission does not protect the population against high noise reception levels, but against *increasing* noise reception levels;
4. A noise emission ceiling sets constraints to the combination of traffic volume, the standard emission per vehicle (at reference speed), the maintenance of the infra and the train speed.

The purpose of a noise emission ceiling is to prevent further growth of noise exposure.

Switzerland and the Netherlands have developed quite similar systems of emission ceilings. The main difference lies in the definition of the source: whether or not to include barriers in the noise emission level (Figure 12). This is explained in more detail in the next sections. The Swiss and Dutch ceilings have in common that they are backed up by a legal framework of noise reception limits, which existed already in these countries long before the ceilings were established. In both countries, different ceilings apply to different railway lines. Besides railway noise also roads noise is controlled by ceilings. The annual noise emission along the network is monitored and if it somewhere exceeds the ceiling permanently, action is required. In that case the legislation regarding upgraded lines is applicable. In Appendix 3 gives an analysis of the PriceWaterhouseCoupers concept of emission ceilings and more similarities and differences of Swiss and Dutch ceilings are given.

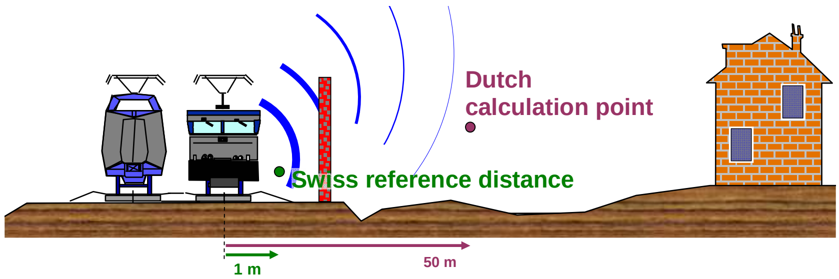


Figure 12: Noise ceilings in Switzerland and the Netherlands.

2.4.2 Swiss ceilings

The Swiss abatement programme that started in 2000 is based on emission ceilings for the railway network, called Emission Plan 2015. Distinct ceilings are defined at about 6 500 track sections of variable length (between 1 meter and 20 km) along the entire railway network.
The Swiss ceilings are monitored by a combination of measurements and calculations [27b]. The measurements, carried out continuously at six locations along the network, mainly aim at monitoring the progress of the vehicle retrofitting programme (Figure 13). Additional calculations are required to check if the actual noise emission on the whole network is still compliant with Emission Plan 2015. A calculation tool using operational data is now being developed for this purpose.

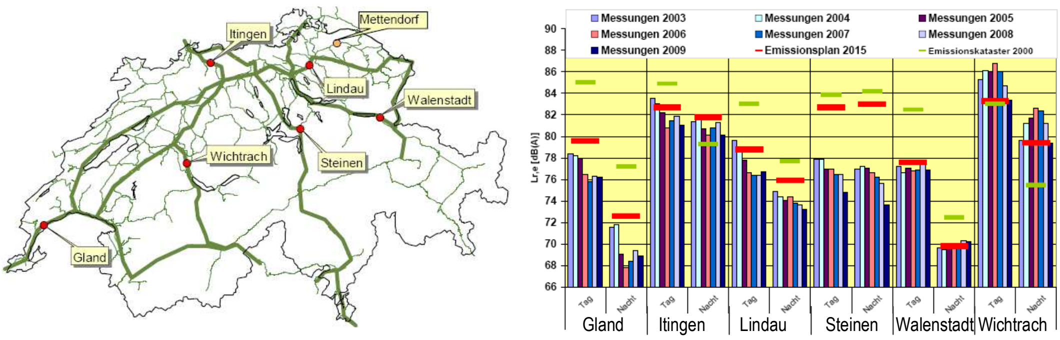


Figure 13: Swiss monitoring of actual emission level, compared to Emission Plan 2015 (▬).
Source: www.bav.admin.ch.

During the first years of the monitoring programme the ceiling was locally exceeded at Wichtrach. The track at Wichtrach had not the correct rail roughness.

Since a few years the track condition has improved. In 2009 the emission level is just in line with the ceiling.

If the ceilings are exceeded in the long term, the infrastructure manager is responsible for further noise abatement. The track section under consideration is then treated as a track being upgraded and noise measures are taken near dwellings in accordance with the legal cost-benefit scheme. The legal framework for this intervention is laid down in article 37a of the Swiss ordinance on noise protection. Such a situation has not yet occurred.

At present, the ceilings of Emission Plan 2015 are not restrictive for railway operations. It can be seen in Figure 13 that headroom is increasing on most of the six lines as a result of the retrofitting programme, allowing for a certain growth. Note that 1 decibel headroom corresponds to 26% more traffic.

The Swiss ceilings are compliant with the EC text (see section 1.1.3) on noise emission ceilings, but not with the concept of monitoring described in the PwC impact assessment (Appendix 2). This because the Swiss monitoring stations do not (yet) identify retrofitted vehicles.

2.4.3 Dutch ceilings

The Dutch ceilings for the main roads and railways were developed during a period of more than 10 years[9]. The idea to introduce ceilings is defended by environmentalist and by the railway sector. The advantage for the railway sector is that under the new law a small change in the track lay-out does not require lengthy noise procedures as long as the local ceilings are respected (for example by installing rail dampers). The advantage for the environment is that the ceilings prevent gradual year-by-year noise growth.

The Dutch ceilings are established at many reference points (every 100 m, see Figure 14). The noise impact at these points is monitored every year by calculation. Similar calculation software is used on a daily basis by the traffic capacity management department. If a railway undertaking applies for a new train path (for example a new daily freight service between station A and B), the capacity manager will check the available noise headroom along that path. If the ceiling would be exceeded at a certain bottleneck location along the path, the capacity manager needs to take further action. This could result in temporary or conditional permission for the railway undertaking. If a permanent capacity increase is expected, the track section under consideration is treated as a track being upgraded and noise measures are taken near dwellings in accordance with the legal cost-benefit scheme. Source measures like rail dampers and acoustical grinding are

[9] *The new legislation is accepted by the Dutch Parliament on June 30th, 2011. It is treated by the Senate by the end of 2011 and is expected to be put into force on July 1st, 2012.*

stimulated by the fact that the procedural workload is less heavy compared to noise barriers.

Reference points

The reference points are meant as a warning system. They have been defined in such a way to act as a warning system if the reception limits of dwellings could be at stake:

- *Spacing is 100 m*. This is a compromise between keeping the number of points low while avoiding 'leakage' of noise through the gaps between subsequent reference points without giving a warning. This requirement leads to 60 000 reference points along the Dutch network (3 000 km).
- *Distance is 50 m from the outer track*. At this distance the effect of a noise barrier is accounted for.
- *The reference points are situated in imaginary free field.* The monitoring model does not include other objects than noise barriers. Including houses would lead to an unnecessary increase of administration. Houses are only taken care of once a ceiling is surpassed. In that case, the dwellings and other objects in the vicinity of the surpassed ceiling points are included in the acoustical model. If, in spite of an increase of noise emission, the noise level at these dwellings does not exceed the reception limit, the ceiling level at the reference points in that area will be raised and the case is considered solved.
- The *initial ceiling level* at each reference point is fixed at its present level (2008) plus a headroom of 1.5 dB. This headroom is not meant to accommodate capacity growth, even though it corresponds to 41% more traffic. This margin is required to provide sufficient preparation time if a ceiling is approached (noise procedures, studying alternatives) and to allow for annual time-table modifications.
- It is intended to use a few measurement stations to check the retrofitting claims of railway undertakings. This may be done by tag reading (silent wagons should be tagged) in combination with noise measurements.

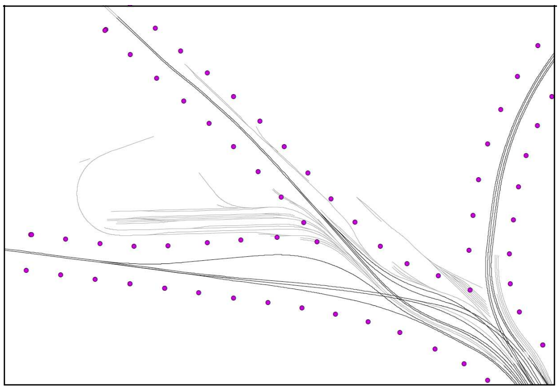


Figure 14: Dutch ceilings are defined at 60 000 reference points near the main lines.

Assessment studies for Dutch ceilings

The initial height of the ceilings, the present level + a headroom of 1.5 dB, has been chosen after a number of assessment studies between 2005 and 2008. The assessments concentrated on long-term and short-term bearability of different headroom settings (0 dB, 0.5 dB, … 3 dB). The long-term effects refer to financial aspects for measures and incentives for retrofitting. The costs of the ceiling system in the long run are compared to the base system (no change of legislation). The short-term effects relate to operational consequences (network capacity, annual time-table).

- If too much headroom is granted (>2 dB), the ceiling would initially not be felt and there would be no incentive for retrofitting. This would lead to a scenario where retrofitting does not take place[10]. Costs would initially be zero (less than the base system), but would rapidly increase when after 5-10 year the ceilings are eventually exceeded. Because retrofitting did not take place in this scenario, the final cost could be even higher than under the base system (in which gradual growth does not always lead to costs).
- If 0 to 0.5 dB headroom is taken, the annual time-table adjustments cannot take place any more and train services would be frozen, also logistically (slightly noisier trains cannot be exchanged any more with less noisy trains from a different line).
- A headroom of 1 dB would allow most of the usual time-table adjustments, but the infrastructure manager is unable to anticipate capacity growth: when a ceiling is approached, noise procedures have to be started up and this takes time.

Finally a choice for 1.5 dB as headroom has been agreed, for the railways and for the roads.

The Dutch ceilings are compliant with the EC text (see section 1.1.3) on noise emission ceilings. Though much more reference points have been defined than considered necessary in the EC text, this is not necessarily a contradiction. For various reasons, however, the Dutch ceilings are not in line with the concept of monitoring described in the PwC impact assessment (Appendix 2).

2.5 Conclusions

A comparison of the current noise legislation in some European countries has shown large differences with respect to

- treatment of new / upgraded / existing railway lines;
- noise reception limits in different zones (residential / mixed / others) or housing types (detached house / single family house / flat);
- noise indicators (L_{den} / $L_{Aeq,6\text{-}22h}$ / L_{night} / L_{Amax});
- legal noise measures (only noise barriers are a standard measure everywhere);

[10] It should be mentioned that part of the Dutch passenger fleet still has cast-iron blocks. Retrofitting is therefore also cost-effective for railway lines where mainly passenger trains are running.

If for a specific situation the noise limits of the various countries are compared, large differences can occur between the highest and lowest level of protection. Sometimes the differences are due to cultural aspects. For example in Sweden levels inside dwellings are relevant, while in Portugal only the outside level plays a role.

Two countries have developed a concept of noise emission ceilings. These countries do so in a very different way, but there are also similarities. The EC idea of noise emission ceilings has been based on these examples. The Swiss ceilings are defined in a fairly simple way. Ceilings are guarded using measurement stations, but the main purpose of these stations is to obtain an overview of the progress on retrofitting noisy wagons. The Dutch ceilings are very detailed and serve as a warning system: they ensure that local reception limits will not be exceeded without noticing.

The European policy instrument of noise emission ceilings for the railways does not necessarily interfere with existing national noise legislation. Because the concept of ceilings is not yet very specific, it is currently not possible to take a position. It is clear from the foregoing that the more explicit these ceilings will be defined, the greater the risk of unintended interaction with existing national noise policy.

3

General features of noise limit systems

3.1 Introduction

This chapter provides a general framework of noise legislation. This framework attempts to cover existing legislation and possible future European legislation.
It is meaningful to distinguish at least five different 'systems' of noise limits, based on the position where the noise level is to be determined. These possible positions are shown as yellow dots in Figure 15 and are described in Table 5.

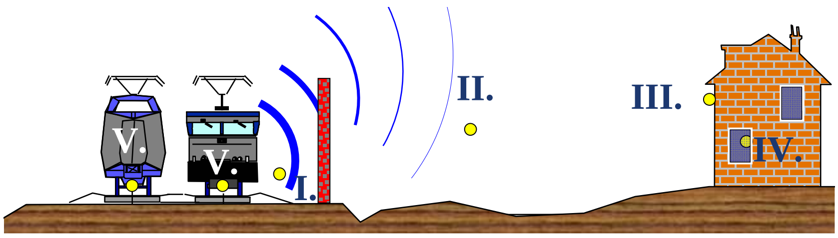


Figure 15: Positions where noise limits can be enforced.

Table 5 The five principal systems of noise limits.

No.	System name	Description
I	noise creation limits	This system limits the average yearly noise creation level, which is determined close to the track and train. Installing noise barriers does not affect this creation level. System I is used in Switzerland in addition to system III to guarantee that the reception level set by the noise abatement plans is not exceeded without notice.
II	noise reception limits at reference points	This system limits the average yearly noise level at reference points. These reference points are situated at some distance from the source. Installing noise barriers will reduce the noise level at reference points. System II is proposed in the Netherlands in addition to system III to guarantee that the reception level set by the noise abatement plans is not exceeded without notice.
III	noise reception limits at façades of dwellings	This system limits the average yearly noise near dwellings. This noise level is determined in front of the façade. This system is used in most European countries.

No.	System name	Description
IV	noise reception limits inside dwellings	This system limits the average yearly noise inside dwellings. The noise level is determined inside the houses. These interior noise limits are often considered in conjunction with system III, for example when window insulation is applied as a noise measure. In Sweden, interior noise limits (bed-room) have the same status as exterior noise limits.
V	a tight TSI for all vehicles + traffic capacity limits	This system is an alternative to system I. It is nowhere in use (yet). This system limits noise creation in a different way than system I does, by 1. maximizing the standard noise creation level of each rail vehicle (new and existing, national and transnational), and at the same time 2. maximizing the yearly number of vehicles that run on a railway line.

It is important to realize that some of the systems can co-exist with other systems. For example in Switzerland, systems I and III are in use, while the Netherlands combined system II and III. In Sweden systems III and IV are applicable. In most other countries system III is the main system, backed up by system IV when window insulation is to be applied.
System V is an alternative noise creation limit system. It is simpler, because the noise level is not to be controlled by measurements, but regulated by Technical Specifications[11] that set limits to noise emission of all existing vehicles (not only those that operate on the trans-European network). Under this system, it is just a matter of counting traffic volumes in order to prove that a ceiling is not exceeded. However, as (long as) not all rail vehicles have the same noise creation, this system does not accurately predict the noise creation of a railway line.

Other aspects

Besides the position where the noise level is controlled, there are many other aspects that determine how effective noise will be controlled.

- Different 'functions' of a noise limit. A noise limit may work like:
  - A signal or warning, requiring attention but not necessarily direct action. Action could depend on the seriousness of the situation, future expectations and/or abatement priorities.
  - A trigger for action, meaning that the situation should be investigated and reported. Various solutions are possible and the choice may depend on cost-effectiveness.
  - An rigid upper limit, above which levels are illegal and need to be solved. In extreme cases, such an upper limit implies that dwellings need to be

[11] *TSI is not the appropriate term here, because 'interoperablility' is not its purpose. These Technical Specifications refer to national regulations that sets limits to all vehicles, even those that never cross national borders.*

demolished in order to comply with noise legislation (if other local solutions are more expensive).

- The method and/or moment of monitoring. A noise limit can only have effect if there is a requirement to determine the actual noise level. This requirement may be:
  - Periodically, for example monitoring every year or (in the EU) every five years.
  - Event-driven, linked to a physical change of the railroad or a significant change of traffic (amount and composition).
  - Complaint-driven, leading to ad-hoc investigations.
- The legal status of a limit. The status depends on the level of legislation that mentions the limit values: law, decree, regulation, decision. Among others, this determines how easy limits can be modified or refined by the government and also which rights residents have to demand action or to appeal against a decision.
- Relative or absolute limit. A noise limit is commonly thought of as an absolute level (e.g. 55 dB). But a limit may also be set relative to the present noise level, for example 'an increase over 2 dB is not allowed without taking noise abatement measures'.

It should be remarked that noise limits are sometimes accompanied by certain (lower) target values. Such a target value is the preferred noise level to be reached by noise abatement measures. A target value is only relevant if the respective noise limit is exceeded. Therefore, exceeding a target value has no meaning. Confusingly, such target values are sometimes also referred to as 'noise limits'.

While systems III and IV consist of noise reception limits, systems I, II and V will act like noise emission ceilings. These will be further outlined in Sections 3.2 and 3.3.

3.2 General features of noise reception limits

- The fact that the effects of noise disturbance in humans are gradual [34] and indirect makes it difficult to answer the question 'what level is acceptable from the perspective of health?'. According to the WHO study [14], already at fairly low reception levels around 32 dB (at the façade) the first effects in humans (inside the bedroom) become measurable (see Figure 16). The number and severity of effects, and also the percentage of harassed people, increases progressively with the noise level. Ultimately, extreme exposure to noise can be fatal, namely through cardiovascular or respiratory disorders [33]. As a consequence of this gradual scale of effects, a precise value for an acceptable noise level cannot be given.

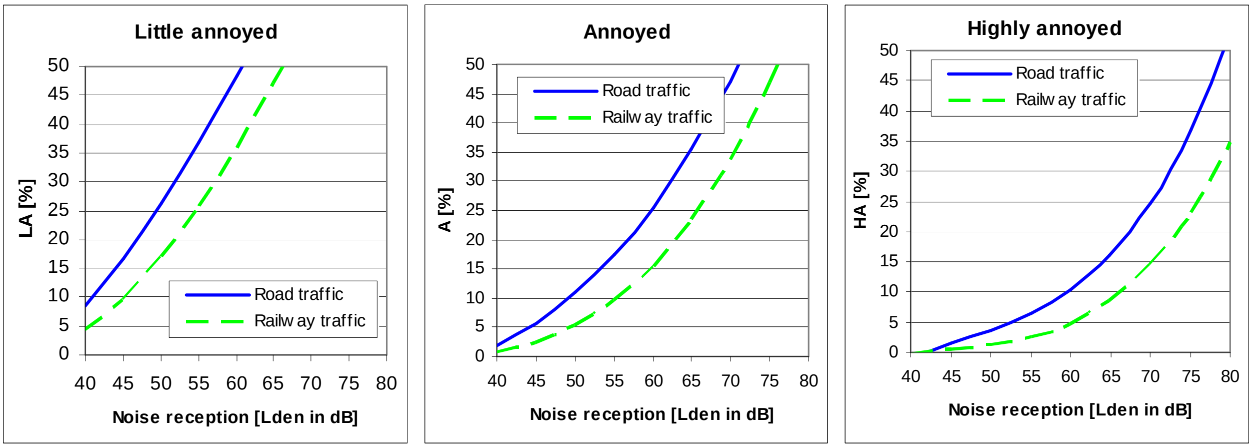


Figure 16: Annoyance from road and railway traffic noise [34].

- The height of the noise reception limit is not only based in health issues, but also on economical aspects. The height will therefore be the result of a trade-off between economical and health-related effects[12]. If both effects are expressed in money terms (monetization), in principal a certain equilibrium noise limit value can be assessed [30-31]. Though it can be criticized if a decision on noise abatement strategies and noise limits should only be based on monetization models, using such models would directly imply that noise limits will differ between different economies in Europe.
- Many countries have certain sensitivity zones where different noise levels apply (see Figure 17). This can be thought of as a local equivalent of the trade-off between economical and health-related effects. Assessing the bearability of noise limits at this local scale will require a description of the relevant differences between zones.

[12] *This trade-of was probably made implicitly or intuitively by looking at feasibility, when the first noise limits were established in the 1970s and 1980s (see Appendix 1). The systematic approach towards monetization and life cycle assessment, starting in the 1990s, allows for an explicit trade-off assessment, See also Appendix 4.*

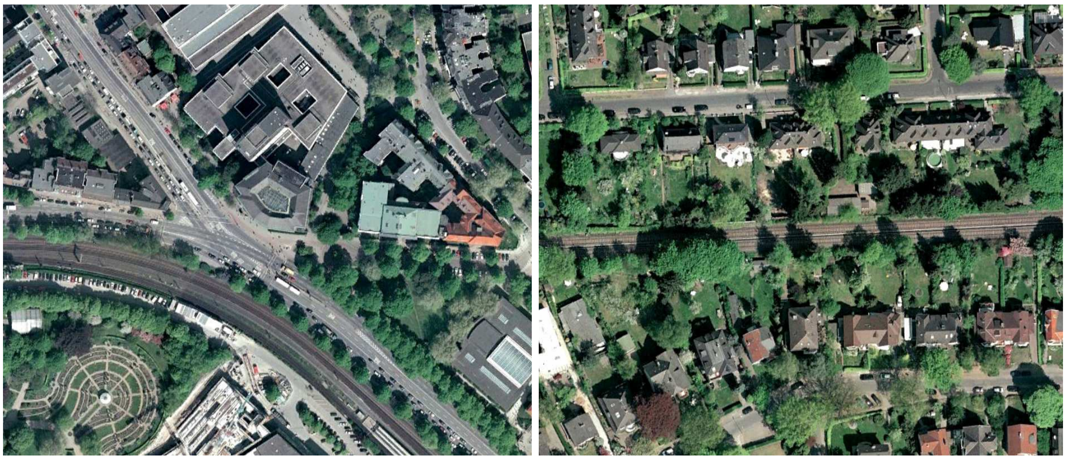


Figure 17: Example of two zones 'mixed zone' (left) and 'residential area' (right).

- While assessing a bearable noise limit, not only the present situation but also the future situation should be considered. Low noise limits have a considerable effect on spatial planning (see Figure 18), because large areas along railways and roads may become unusable for new residential areas. Among others, this will affect the revenues of municipalities, as land prices depend strongly on their use.

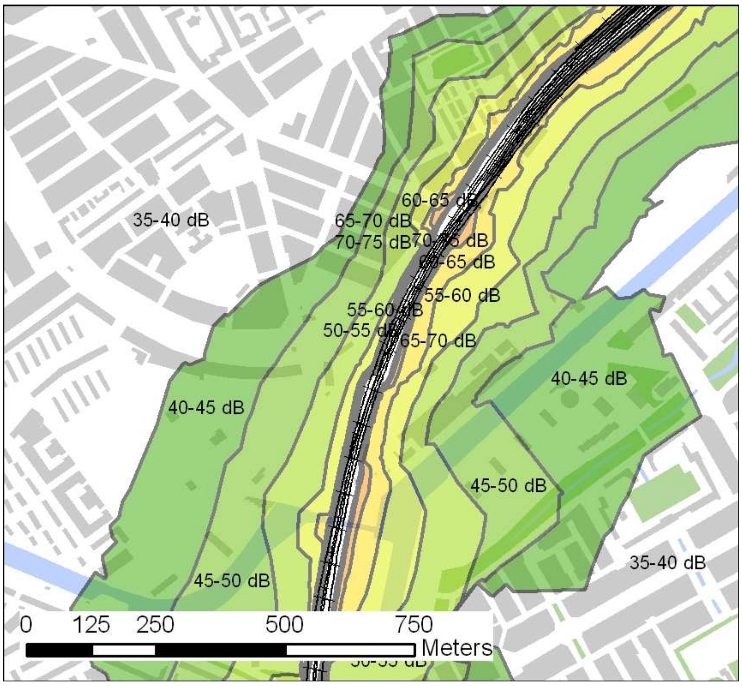


Figure 18: Example of distance of railway noise levels for present situation (**L_{night}**).

- As the purpose of a noise limit is to provide protection against exposure to noise, the whereabouts of the exposed inhabitants play an important role. A noise reception limit inside a house is not useful if people stay outside most of the time to relax and recover (see Figure 19). An assessment of bearability requires these and other cultural differences to be taken into account.

Figure 19: Cultural differences will effect bearability of different systems of noise control.

3.3 General features of noise emission ceilings

- Noise emission ceilings cannot replace noise reception limits. Emission ceilings set limits to the source (track and train), but do not limit the absolute noise reception level. However, relative changes to the source lead to corresponding changes at the façade of dwellings, therefore noise emission ceilings control the growth of noise.

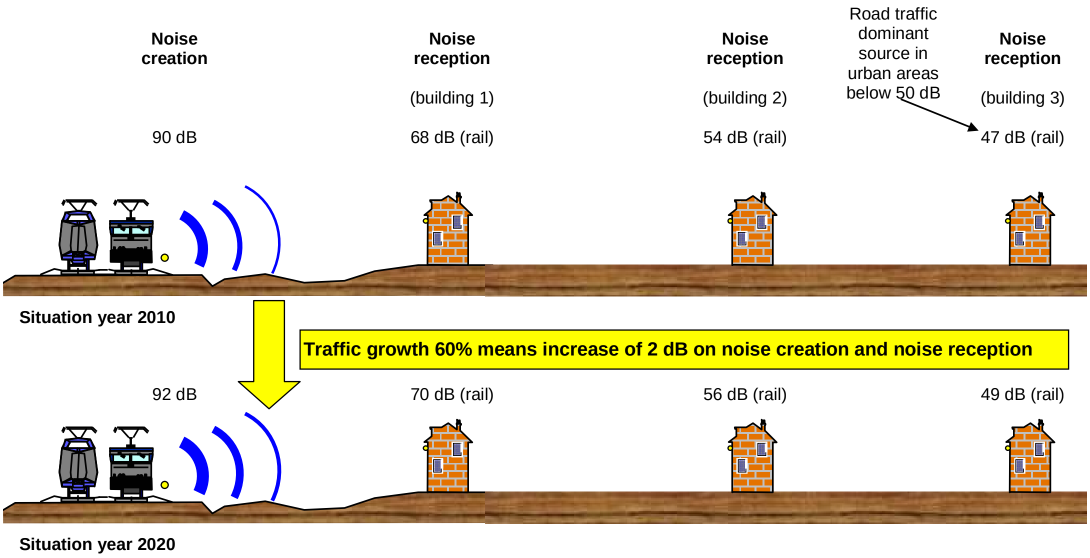


Figure 20: Relative changes in the source lead to corresponding changes at the façade of dwellings. In urban areas reception levels are dominated by road traffic if the levels caused by railways is below 50 dB.

- Because of this relative nature of emission ceilings, establishing one and the same ceiling level along the whole network makes little sense.
- The ceiling height can basically be chosen relative to the present source emission level or based on the future traffic situation.
  - Choosing a ceiling below the present situation is not a practical choice for the short-term, as the only way to comply with such ceilings would be to reduce speed or cut down traffic numbers.
  - Choosing a ceiling slightly above the present emission reflects the need that ceilings should not impede small yearly fluctuations in train services. Examples are a cargo train that will vary year to year, trains that will start half an hour more early and therefore will start during the night period instead of the day period, or temporarily operation with different rolling stock. This idea has been the basis for the Dutch ceilings that were set 1.5 dB above the present emission, creating a working space.
  - Choosing a ceiling well above the present emission would allow for a certain growth of railway traffic.
  - Alternatively, a ceiling height can be based on future expectations about traffic numbers and the development of noise creation of trains. This can be accompanied by a noise abatement plan, like in Switzerland. This plan can be thought of as a special case of track upgrading, as it prepares for upgrading the whole network.

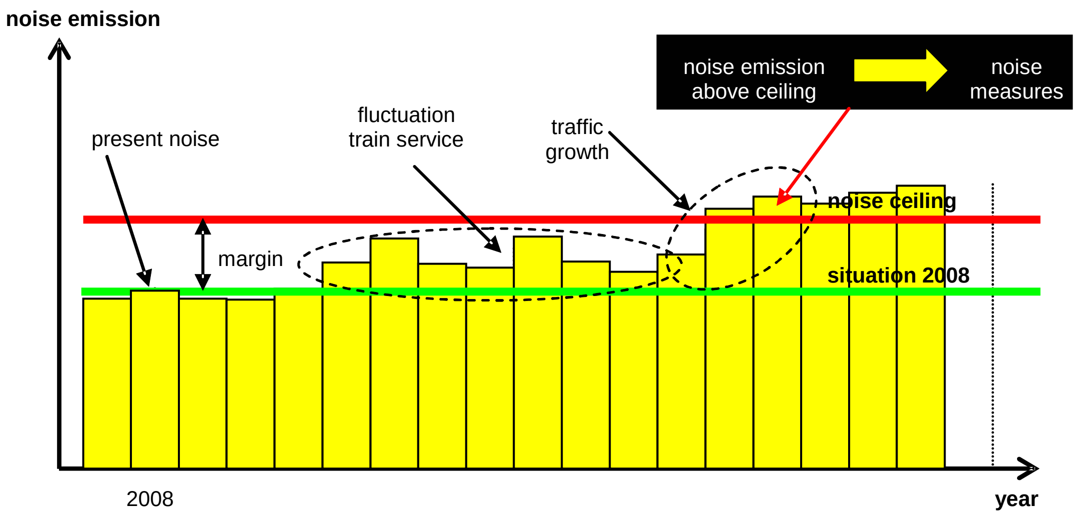


Figure 21: Graphical presentation of the ‘Dutch system’ of noise emission ceilings. The margin is 1.5 dB on the whole network.

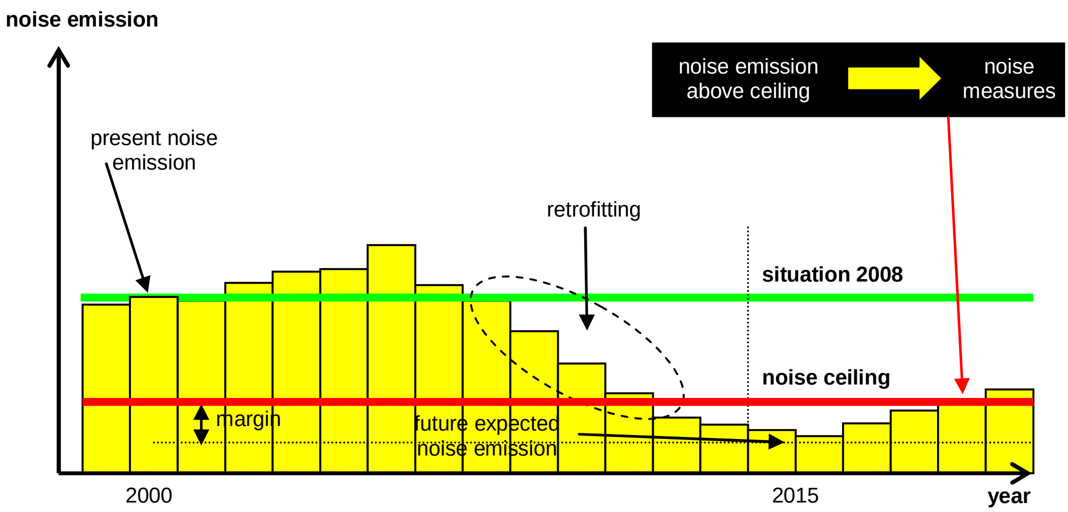


Figure 22: Graphical presentation of the ‘Swiss system’ of noise emission ceilings. The margin is different for different railway lines, based on a traffic prognosis for each line.

- If noise emission ceilings are chosen relative to the present emission, noise monitoring is essential to make ceilings effective. The frequency of noise monitoring can be fixed, but it can also depend on the (local) margin that is left before the ceiling is trespassed.

- Monitoring can be done by counting, by measuring or by calculating, or by a combination of these. Measuring is probably most convincing for the public, but it requires that the local track condition is representative[13] for the railway line segment it represents. This requires additional cost for frequent monitoring of rail roughness by measurements. And in case of exeedance additional cost for rail grinding. Calculating has the advantage of covering the whole network accurately, but it therefore requires an enormous amount of precise traffic data as input.
- The effectiveness of noise emission ceilings as a means to control noise growth depends strongly on how much margin (relative to the present level) is taken, how fast to respond to exceedance, and the actions and stakeholders involved thereby.
- A system of noise emission ceilings may take advantage of the fact that protection is only required in the vicinity of dwellings.

In the previous chapter shows an overview of the noise policy of the European Union.

[13] *Local rail roughness and track decay rate may deviate from average conditions, thereby varying in time.*

4 Cost of noise reduction

4.1 Introduction

This chapter provides general information about the cost of noise reduction. Section 4.2 describes the assumptions. The studies is based on the noise calculation model RINGS that is used for strategic noise legislation calculations for the Dutch railways and ministries. Section 4.3 gives results for cost for reduction of $\mathbf{L_{den}}$ noise reception levels from 80 dB until 50 dB.

4.2 Assumptions

The calculations of this study is based on the noise calculation model RINGS. RINGS is used for strategic noise cost benefit analyses for the Dutch railway network. The RINGS software system contains information of:

- Dutch railway network (about 3.000 km of length);
- Track construction, speed and number of trains;
- All the dwellings within 1.500 m of the railway lines;
- Noise reduction by existing barriers;
- Noise reduction by urban areas;

RINGS support the Dutch railways (ProRail) and the ministry of Infrastructur & Environment by the development of Dutch noise legislation of the Dutch noise ceilings. Since 2003 many studies have done with RINGS. An important study is the combination of budgets for reduction of railway noise of the former ministries of Infrastructure and the ministry of Spatial Planning and Environment [43]. The results of this study have been updated in September 2010. The update contains more recent information about number of trains.

This Section reports the result of additional calculation based in the information of this study of 2010.

The noise levels represent the average situation for the years 2006 – 2007 – 2008 including a future traffic increase of 41%. This 41% gives an additional 1,5 dB. For situations that currently have a low number of trains, this increase of 41% is possible without network adaptations. Additional noise measures are calculated that needs to be installed with noise reception limits of 50, 55, 60, 65, 70, 75 and 80 dB $\mathbf{L_{den}}$. Notice that levels are calculated within 1.500 m of the railway lines only. Noise reception levels below 60 dB can go beyond 1.500 m. Therefore the cost for noise measures for limit values below 60 dB is under estimated.

4.3 Results

These results of the additional calculations are summarized in Figure 23. It is important to know, when assessing the costs and the benefits of noise control, who is paying the costs and who is receiving the benefits. Concluding that noise abatement is profitable for society as a whole is, by itself, not enough to make noise abatement happen [32].

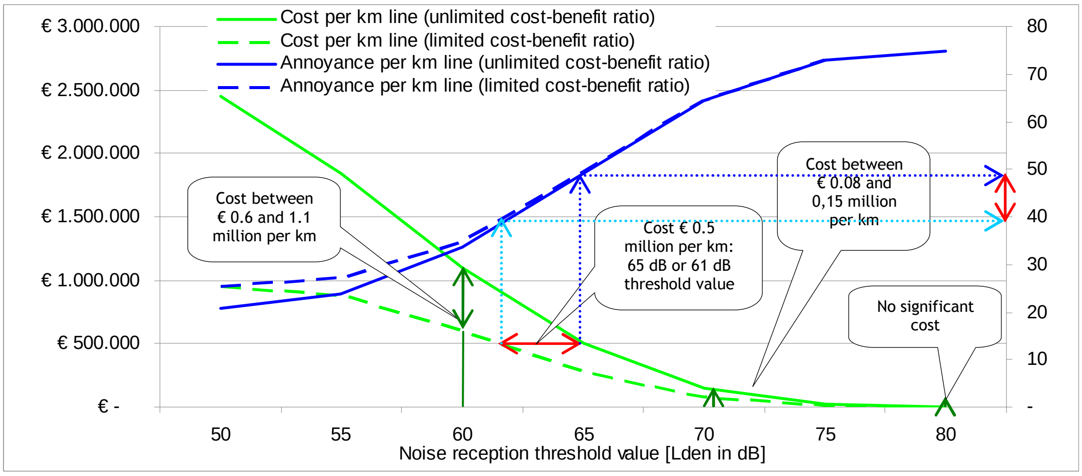


Figure 23: Cost for noise control and annoyance for different threshold values per km railway line.

One can derive from Figure 23 that:

- Noise control measures with 80 dB limit values at façades of dwellings do not bring significant costs. Investment cost will increase with limit values of 70 dB (€ 80 000 to 150 000 per km railway line). With limit values of 60 dB the cost will increase to € 600 000 to 1 100 000 per km railway line. The number of measures and therefore the cost to comply noise limits, will increase with lower threshold values.
- Without a cost-benefit ratio the cost for noise measures will increase a factor 2. Effects of cost-benefit ratio on annoyance are small. Situations with noise problems in rural areas or high building blocks close to the track can be very hard to solve. Costs for noise reduction are relative expensive. By using a cost-benefit ratio cost for noise reduction can be saved for ineffective situations. For example
  - Without a cost-benefit ratio the cost for noise reduction on a threshold value of 65 dB is € 500 000. These measures will reduce annoyance to a value of 49 people per km railway line.
  - With a cost-benefit ratio the cost for noise reduction on a threshold value of 61 dB is € 500 000. These measures will reduce annoyance to a value of 35 people per km railway line.

- Willingness to pay becomes small for very stringent threshold values. Noise control with 80 dB limit values on the façade do not bring significant costs. The average cost for noise reduction per reduction of one annoyed person is € 7 500 to 14 000 with limit values of 70 dB. With limit values of 60 dB the cost will increase to € 15 000 to 27 000. The cost increases to € 20 000 to 45 000 with limit values of 50 dB. Figure 24 shows the result of a study based on the Dutch situation, with the assumption of an average number of persons per house of 2.3.

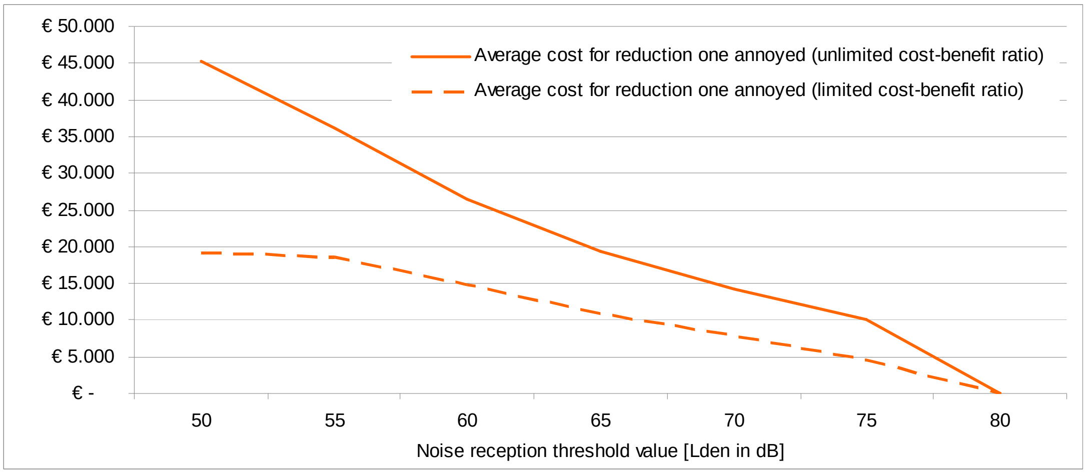


Figure 24: Average cost for noise reduction of one annoyed person for different threshold values relative to a threshold value of 80 dB.

- As described in the previous section, the height of a noise reception limit is not the only factor that determines the actual degree of protection against noise. It is important to consider these other factors in relation to the limit value, before drawing conclusions on what noise limit is bearable. A statement like ‘a noise reception limit of 50 dB offers a good protection’ is quite meaningless by itself.

5 Noise reception limits – what is bearable?

5.1 Introduction

More knowledge is required to give insight in the bearability of noise limits, or in other words: what is an acceptable (dis)satisfaction level for all stakeholders? The research goal is not to end up with one specific noise reception level that is considered bearable for all European railways, but to provide sufficient background information that enable the railways to make their own assessment of this question.

One method to find an equilibrium level of bearability for all stakeholders is to monetarize all different effects and then to equate all marginal costs and marginal benefits. If it would be possible to express all negative effects of noise exposure into economical losses, a technique called monetization or valuation, and if all costs related to noise abatement would be calculated, one could assess an economical equilibrium for noise levels.

A few starting remarks can be made:

- An important aspect of valuation studies is that there is a threshold level, typically between 50 dB (road) and 55 dB (railway), below which economical effects of traffic noise are unmeasurable [31, 35–38]. In other words, it is highly uncertain what economic value is to be attributed to such low levels of noise exposure. So, prior to a cost-benefit analyses (CBA) study it can already be concluded that an equilibrium railway noise level will be above 55 dB (L_{Aeq}).
- Only a few studies are dedicated to railway noise, and some of them transfer results and assumptions that are valid for road noise to railway noise without any justification [35,36].
- Various CBA studies reveal an enormous spread of results: the price of a decibel would lie somewhere between 2 and 200 euro per household per year [39].
- After the economic equilibrium noise level has been found, the next step would be to find an equilibrium *noise reception limit*. The difference between the two will depend on the (legislative and technical) aspects that determine how effective noise is controlled, see Section 3.1.

5.2 Effects of railway noise control

What is the effect of a low threshold for noise? This section describes the impact in terms of:

- Spatial planning.
- Residents who currently live along a railway line.
- Noise control by the infra manager.

- Noise control by the operator.

Two examples are worked out. An example of an urban area and an example of a rural area. These examples focus on the **L**$_{night}$ level. The WHO guidelines gives values of 40 dB and an interim target level of 55 dB. In general the **L**$_{night}$ level is about 7 tot 8 dB below the **L**$_{den}$ level. The difference depends on the relative distribution of the number of trains during the day, evening and night.

These examples are based on two railway lines: A cargo line and a mixed line with cargo and passenger traffic. Figure 25 illustrates the noise reception levels for these two railway lines. The above figure shows the **L**$_{den}$ level and the figure below the **L**$_{night}$ level. In this example the difference between the **L**$_{den}$ level and the the **L**$_{night}$ level is 7 dB.

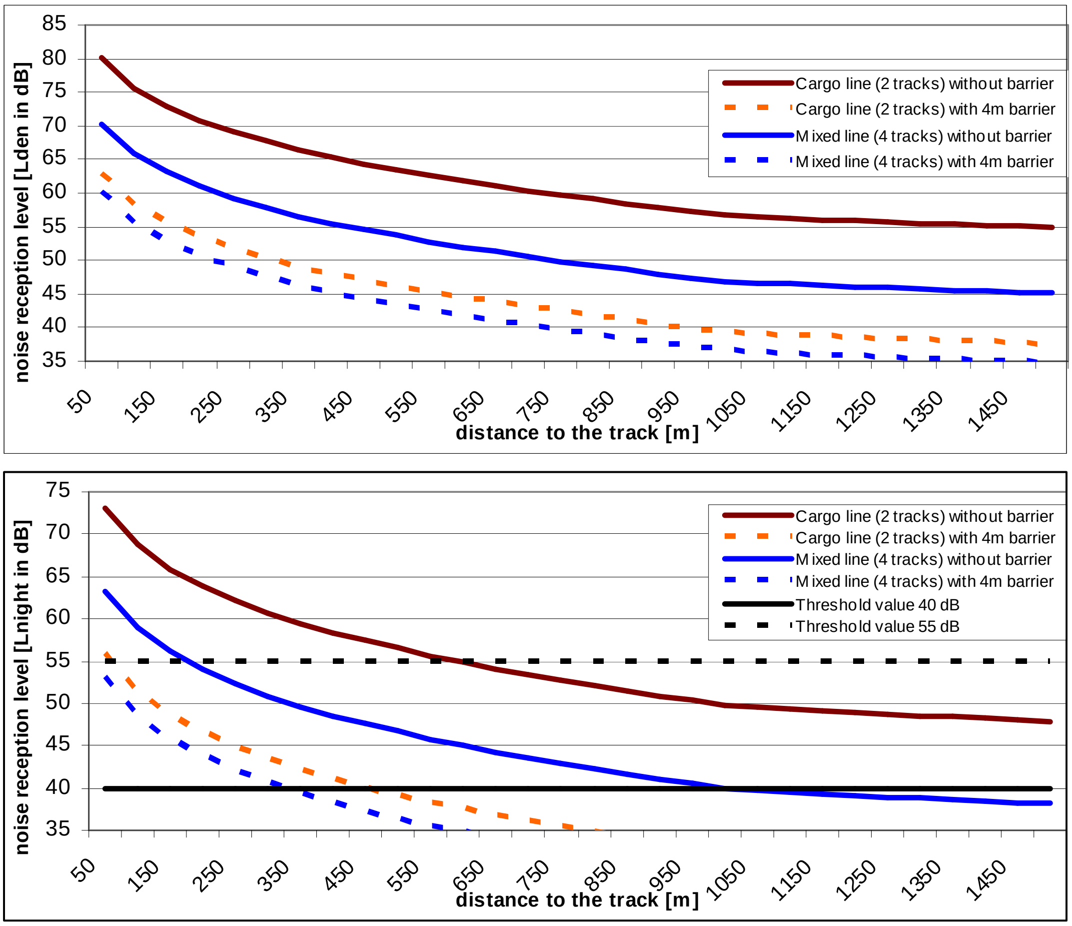


Figure 25: Example of noise reception levels relative to the distance to the track for a cargo line and a mixed passenger/cargo line. Above the **L**$_{den}$ value and below the **L**$_{night}$ value.

The results show **L**$_{den}$ levels above 70 dB close to the track until 40 dB levels until a distance of 800 m or more. For **L**$_{night}$ levels until 40 dB reach to 350 m or more.

The calculation is based on these assumptions for number of trains in both directions together:

- Cargo line: Day: 11 freight trains / hour
  Evening: 17 freight trains / hour
  Night: 11 freight trains / hour
- Mixed line: Day: 14 passenger and 1,0 freight trains / hour
  Evening: 7 passenger and 1,3 freight trains / hour
  Night: 1 passenger and 0,8 freight trains / hour

Freight trains are with cast iron tread brake and passenger wagons are disc braked. Passenger train speed is 130 km / hour. Freight train speed is 85 km / hour. The cargo line is representative for the Rhine Valley in Germany.

Effects of very low limits for an urban area

Figure 26 illustrates a typical example of noise reception levels within an urban area. Large fluctuations are observed due to reduction of noise by buildings and noise barriers. This example is not based on the same train numbers as given above.

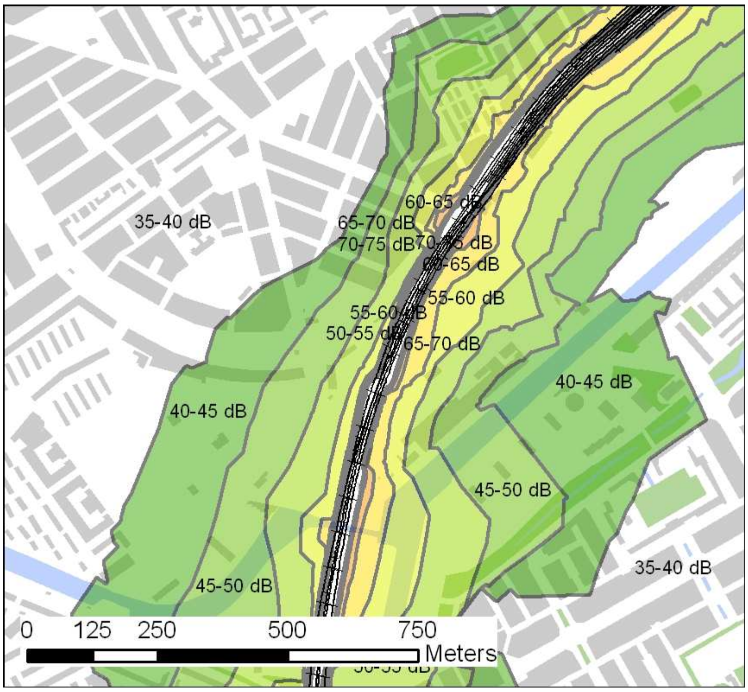


Figure 26: Example of distance of railway noise levels (**L**$_{night}$) for the present situation. The number of trains used in this figure does not match the number of trains in Figure 25.

The effects of low noise limits for an urban area as reflected in Figure 26 are:

- Spatial planning: Development of housing within a distance of at least 500 m from the railway line exceeds the 40 dB level. Development is only possible with additional noise measures. Until 150 m of the railway line noise levels are up to 55 dB.
- Residents who currently live along a railway line: A large number of dwellings and a large part of the city does not meet the 40 dB limit for railway noise. Levels of 40 or 55 dB reach until 150 and 750 m from the railway line. Reduction of noise reception levels up to 40 dB is only possible with additional measures. Railway lines through city centres should be equipped with barriers up to 8 or 10 m height. With limit values of 40 dB, situations with apartments near the railway line should be improved with tunnels or special barrier constructions above the railway line. Road traffic noise within an urban area is in most cases above 40 dB. Therefore road traffic will dominate in most cases the noise levels and annoyance near dwellings. This is illustrated in Figure 27.

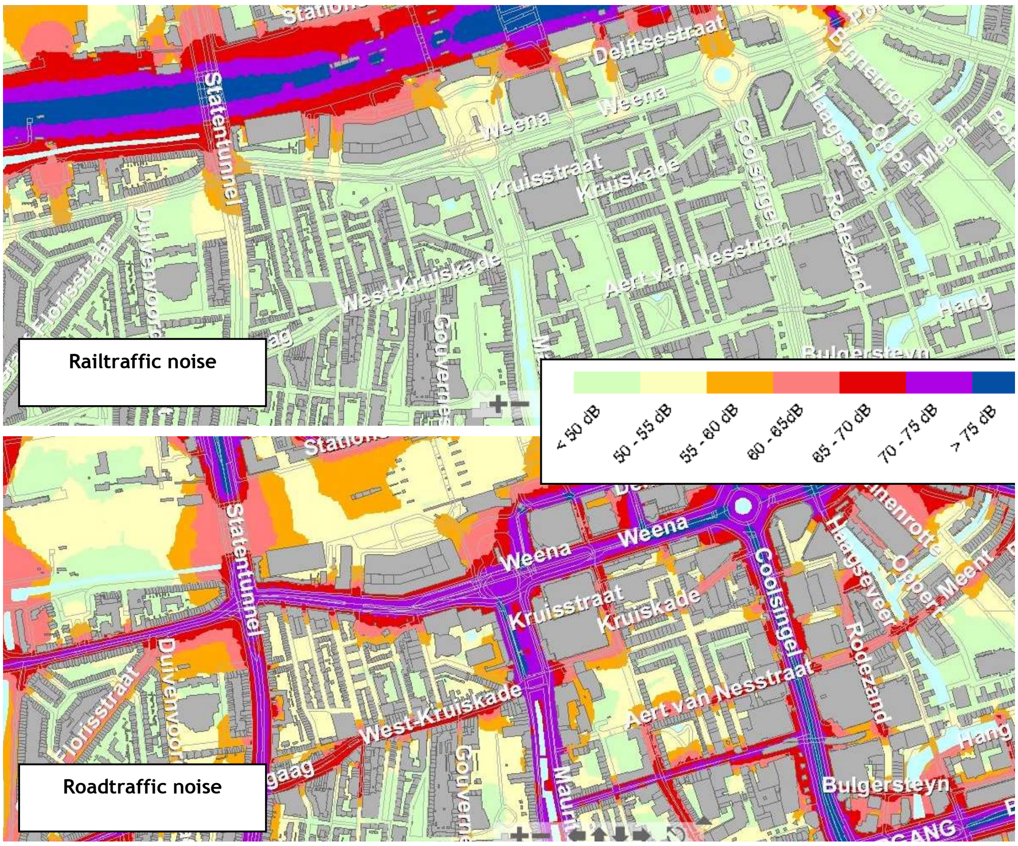


Figure 27: Example railtraffic noise and road traffic noise in urban areas (both L_{den}). This example is the EU noisemap of Rotterdam (2006).

Figure 28: Example of the effect of noise barriers on the spatial environment in urban areas.

- Noise control by the infra manager: Noise control with barriers up to 10 m will reduce reception levels with 20 to 25 dB. Noise control with track measures (for example rail dampers and smooth rail surface) will reduce reception levels with 2 tot 5 dB. Noise reduction up to 40 dB is possible by construction of tunnels.
- Noise control by the operator: Introduction of low noise trains (smooth wheels) will reduce reception levels with 5 tot 10 dB. Speed reduction from 140 to 80 km/h reduces reception levels up tot 4 dB. A further speed reduction to 50 km/h reduces an additional 4 dB. A decrease of the number/volume of trains with 50% reduces an additional 3 dB.
- Speed reduction affects also the network capacity. Based on information from DB AG, speed reduction from 100 km/h to 50 km/h reduces network capacity with 50%. Therefore large speed reduction has a dramatic effect on the market position of the railway (travel time for passengers and goods) and the efficiency of the network use (capacity per km railway line).
- Cost for noise control will increase to at least € 5 million per km railway line, if reception limits have a threshold value of 40 dB (Figure 23). The cost for a country like The Netherlands with a network length of 3 000 km will increase to € 15 000 million. These costs estimate does not include cost for tunnels.

Figure 29 shows the maximum reduction of noise measures by:

- The infra manager only.
- The operator only.
- Both the infra manager and the operator.

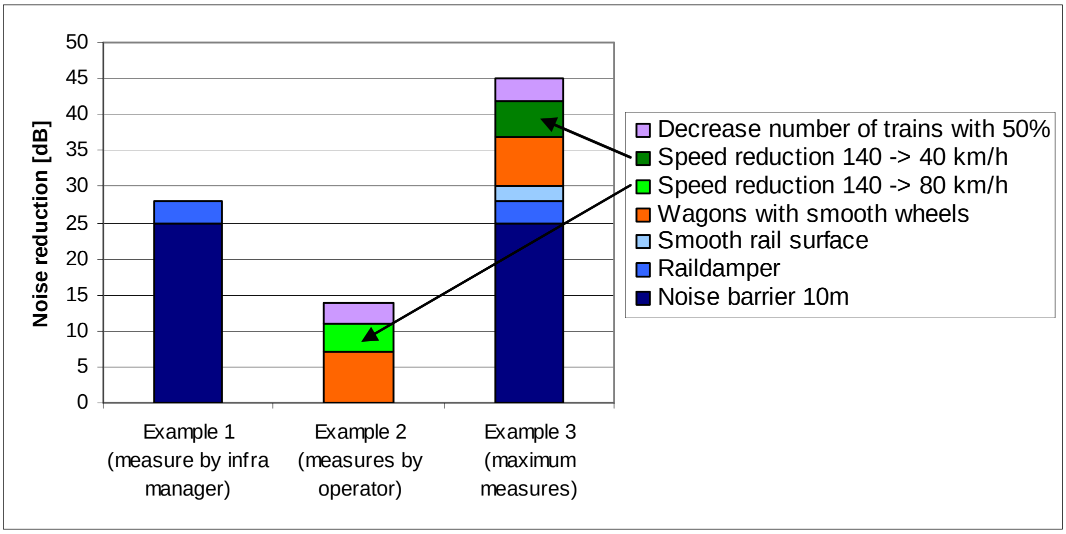


Figure 29: Effect of different noise measures on the reduction of railway noise.

Figure 30 shows the effect of noise barriers to the noise reduction relative to the distance of the track. To meet the 40 dB reception levels for dwellings within 600 m of the cargo line, barriers need to be installed up to 8 m height. Near mixed cargo/passenger lines barriers up to 8 m need to be installed when dwellings are within 200 m of the railway line. The need for barriers is up to more than 1 500 m distance of the track.

Limit values of 55 dB need smaller barriers up to 4 m of height near cargo lines. There is no need for barriers from a distance of 600 m of more.

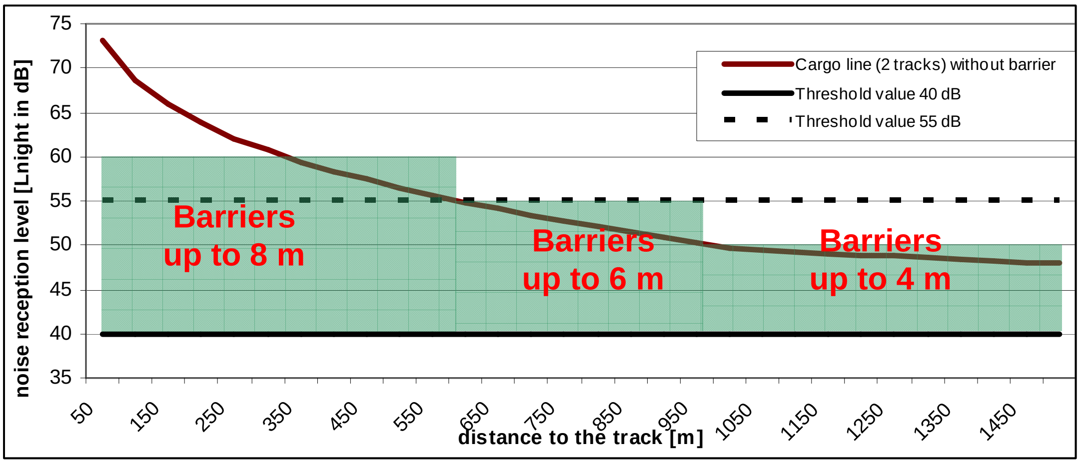


Figure 30: To reduce noise reception levels to 40 dB (L_{night}) requires high barriers up to large distance of the track for cargo lines.

Limit values of 55 dB need smaller barriers up to 4 m of height near mixed lines. There is no need for barriers from a distance of 200 m of more.

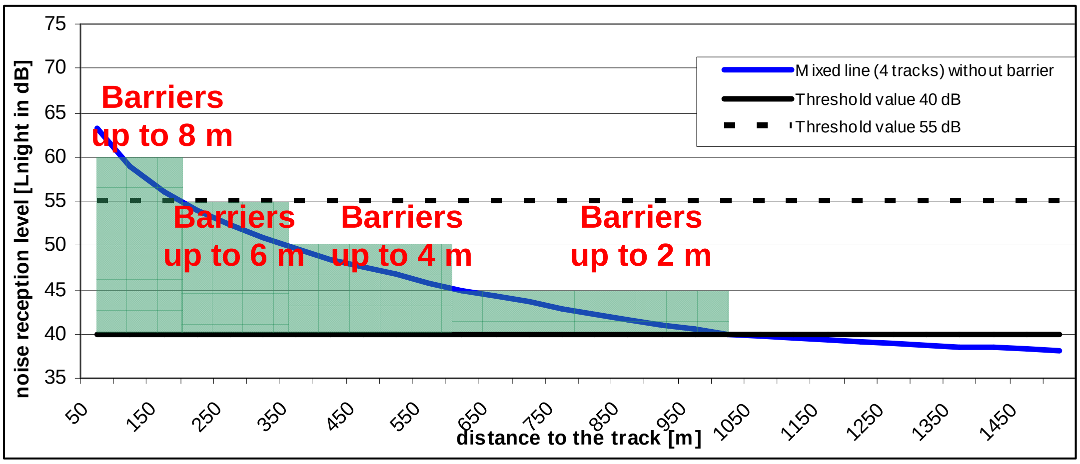


Figure 31: To reduce noise reception levels to 40 dB (L_{night}) requires high up to large distance of the track for mixed lines.

Figure 32 shows the effect of noise measures by the operator to the noise reduction relative to the distance of the track. Without additional barriers operators can only meet the 40 dB reception levels with a large reduction of number of trains. Although introduction of low noise freight wagons do reduce noise levels significantly, reductions of 7 to 10 dB are by far not enough. Even a reduction of 50% of the number of trains is in most of the situations near cargo lines not enough.

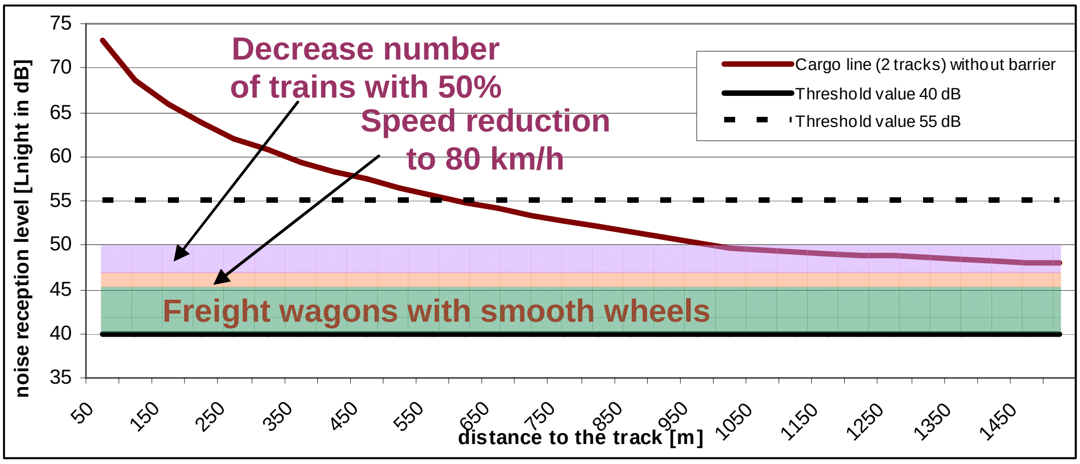


Figure 32: To reduce noise reception levels to 40 dB requires substantially operational measures. Even for large distance to the track these measures will not reduce enough.

The secondary effects of noise reception limits of 40 dB are that:

- Redevelopment of urban space near railway lines with dwellings is less attractive. Redevelopment plans will transform more and more locations with dwellings into locations with offices, hotels, factories and shopping centres.
- Railway lines support urban segregation. The massive barriers through city centres will separate connections in between city centres.
- The cost for existing and new railway lines will increase because of the large cost for additional noise measures like barriers and operational measures. Therefore cost for transport by road will become more attractive relative to cost for transport by rail. This will support a shift transportation from rail to road transport. On the other hand, freight transport by rail has a noise advantage of around 4 to 8 dB over carriage of the same load at the same speed by road [40]. Therefore this shift will increase the noise creation by transport and therefore will increase the combined noise annoyance from rail and road transport.

Effects of very low limits for a rural area

Figure 33 gives a typical example of noise reception levels within a rural area. Because of the absence of noise reduction by buildings, noise levels reach to large distances of the railway line.

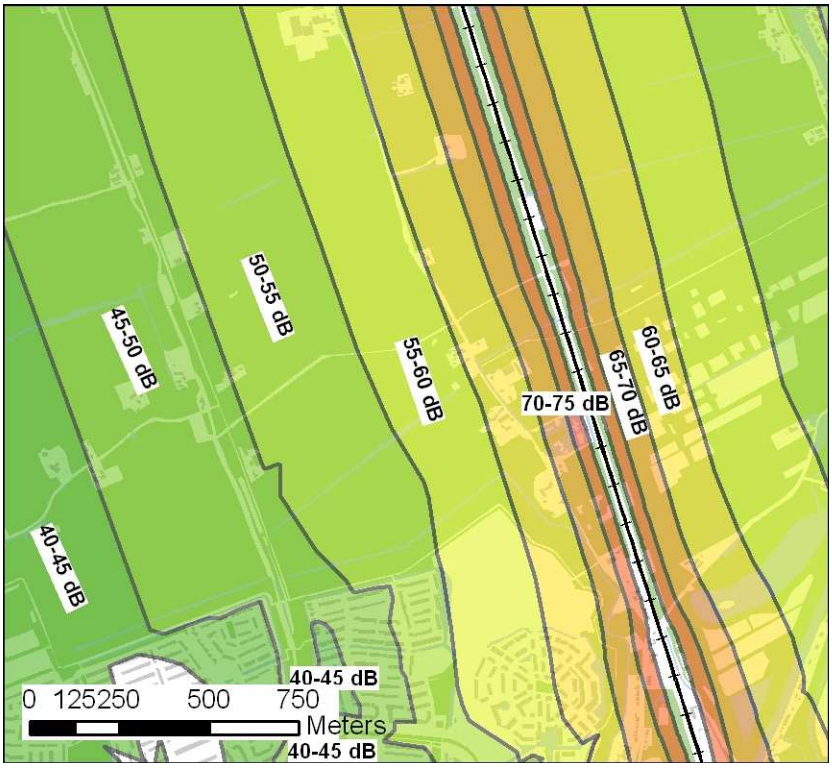


Figure 33: Example of distance of railway noise levels (**L_{night}**) for present situation. The number of trains used in this figure does not match the number of trains in Figure 25.

The effects of low noise limits for rural area as reflected in Figure 33 are:

- Spatial planning: Development of housing within a distance of at least 1 000 m from the railway line exceeds the 40 dB level. Development is only possible with additional noise measures. Until 500 m of the railway line noise levels are up to 55 dB.
- Residents who currently live along a railway line: A large number of dwellings does not meet the 40 dB limit for railway noise. Levels of 40 or 55 dB reach until 500 and 1 050 m from the railway line. Reduction of noise reception levels up to 40 dB is only possible with additional measures. Railway lines through rural areas should be equipped with barriers up to 8 or 10 m height. Large barriers determine the view to an open landscape. In many situations in rural areas railway lines are parallel to motor ways. Road traffic noise is in many cases far above 40 dB. Therefore road traffic noise will dominate in most cases the reception levels and annoyance near dwellings. This is illustrated in Figure 27.

Figure 34: Example of the effect of noise barriers on the spatial environment in rural areas.

- Noise control by the infra manager: The choice for reduction measures is the same for the situation in urban areas. The cost for noise reduction per dwelling will increase because of the low population density in rural area. For example: Consider a situation with one house on a distance of 200 m from the track and with a noise reception level of 60 dB. Noise barriers of about 8 m height and 800 m length are necessary to reduce noise levels to 40 dB. The cost for these barriers is about € 3.5 million for one house. Noise reduction above 40 dB is possible by construction of tunnels. If the cost for noise measures per dwelling exceeds acceptable levels, a large number of dwellings must be removed. This will influence conditions for farmers who want to live close to their agricultural land. An alternative is to allow a large number of exceptions to the 40 dB reception limit within rural area. The cost for noise reduction to 55 dB is still large, but far below the cost for a 40 dB limit value. The cost is large because in rural areas the population density is low. Therefore less people benefit from the noise measures.
- Noise control by the operator: The choice and reduction measures is the same for the situation in urban areas. The effect of train speed to noise reduction is relative small compared to the effect on railway capacity. Therefore a small noise reduction has large effects on capacity.

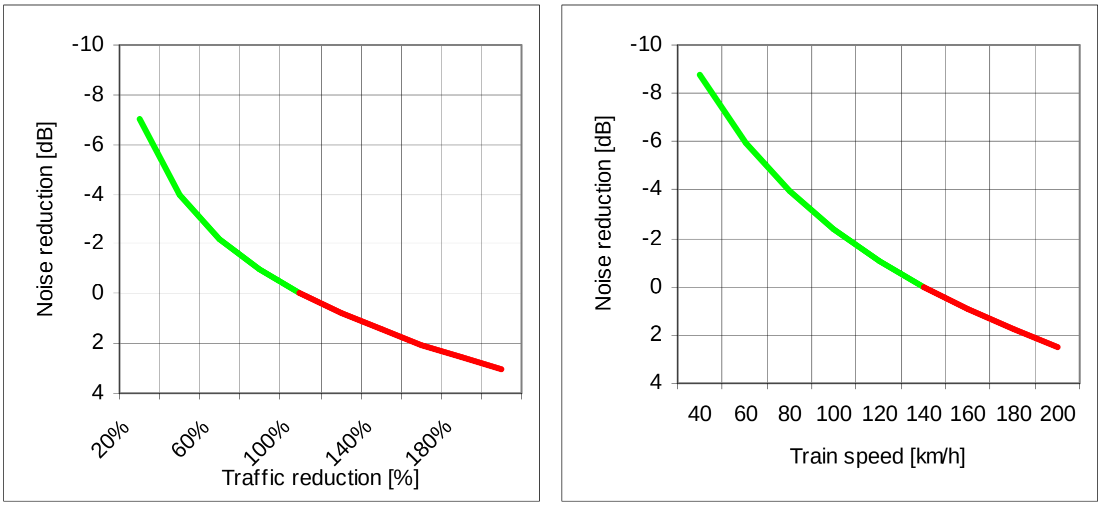


Figure 35: Substantially operational measures like traffic reduction and reduction of train speed do have a relative small impact noise reduction.

- Cost for noise control depends on the number of dwellings within 1 500 m of the railway line. The cost for noise control can increase to at least € 1 million per dwelling.

The secondary effects of noise reception limits of 40 dB are that:

- Increase of people that move from the country side to urban areas. Development of new houses in small villages and near farms becomes more expensive.

Positive effects of living in the vicinity of railways

Besides negative effects from railway traffic noise, people living close to railway stations also experience positive effects from transport accessibility. It is estimated for the region of Amsterdam that houses in a geographical range of 1.1 km of a railway station have 3 to 5 percent higher prices because of station proximity [41]. Other studies found measurable positive effects on house prices up to 2 km from stations. The negative pricing effects due to noise were found within a distance up to 500 m from the railway line [42]. From this point it is clear that these positive effects are only found in a relatively small area around stations, not in the much larger areas between railway stations.

Discussion

This section provides a basis for taking a position by assessing the pros and cons and by giving arguments, i.e. describing several options for each of the following conditions or propositions:

- Do policy goals like growth of freight traffic fit with goals for noise reduction?
  PRO

+ Technological solutions are available to implement noise reduction. The potential noise reduction is more than the possible noise increase by traffic growth. Exceptions are railway lines that are rarely used now and will be used frequently in the future.

CON

- Reduction of noise reception values to 40 dB requires low noise trains, track measures and noise barriers on a large scale. On heavy use railway lines additional decrease of number of trains and speed reduction is needed.
- The cost for available noise measures is high, as is for homologated measures like K-blocks and wheel dampers.
- The cost for measures like LL blocks is probably fairly low. The stakeholders (wagon owner / operator) that will shoulder the cost will not benefit (at this moment) for the noise reduction.

• Noise limits may not influence rail capacity and cost for operation (relative to competitor).

PRO

+ At present the infra manager shoulder the cost for most commonly used noise reduction measures like barriers and track measures. This infra manager is mainly supported by the national governments and does not work in a competitive market.

CON

- The operator works in a competitive market. The market competition is between train operators and with operators that transport on the road. Noise measures on existing rolling stock will influence the cost for operation. Except if compensation for this additional cost is available like future Europe wide NDTAC.

• Set limit on calculated noise (not on measured noise).

PRO

+ The system of noise ceilings has to prevent an increase of noise reception levels by an increase of traffic. The most direct way to monitor this increase is to count number of wagons and calculating noise emission. Noise monitoring by measurements introduces an inaccuracy. This inaccuracy comes mainly from the spread of noise creation by individual wagons, meteorological effects and effects of rail condition. The inaccuracy is at least 1 dB, which equals an increase of traffic of 25%. Noise measurements are therefore not very effective to monitor the increase of traffic.

CON

- Inhabitants near railway lines ask for noise measurements. Inhabitants do not trust ‘difficult’ noise calculation. To correct for specific circumstances like meteorological effects and rail condition there is a need for additional calculations to express a noise measurement value to a useful value. Therefore even noise measurements end up with noise calculations.

• A noise limit should act as a trigger for action, not a rigid limit;

PRO

+ The system of noise limits can contribute to transparency. It can answer the question if the situation becomes worse or not for the inhabitants.
+ A trigger for action can contribute to transparency in the decision process. The responsible authority is forced to explain how to handle different interests of different stakeholders. It helps to support this authority with legal instruments, like a participation procedure and a cost – benefit scheme for noise measures. This scheme answers the question until what price it is reasonable to invest in noise measurers.
+ A trigger function in combination with a cost – benefit scheme makes noise control more cost effective. A rigid limit is cost ineffective and therefore only bearable if the level of this limit is very high. A rigid limit will protect inhabitants for noise levels, even if the costs for measures are excessive. This removes budget for situations below this high limit that could be solved easily.

CON

- A trigger function can be the start to a reasonable decision process. A rigid limit can lead to situations and solutions that are not desirable. Like the need to remove dwellings (even if the inhabitants accept a situation that becomes worse than now), the need to decrease the number of trains and the need for speed reduction.
- A trigger function will not give any guarantee. A rigid limit therefore will guarantee the protection level of inhabitants.

5.3 Conclusion

From the point of view of society (inhabitants and government), the question ‘what noise reception **limits** are bearable?’ is a composition of two questions:

1. What **average** noise reception **level** is bearable? and
2. How to achieve this average by **establishing** noise reception **limits**?

The first composing question can be answered by economic techniques like monetization or valuation. These techniques attempt to express negative effects of noise in money terms, and show that investments in noise reductions can certainly be cost-efficient for society as a whole. An example assessment described in Appendix 4 demonstrates a method that can be used to assess an equilibrium noise reception level in a certain region or zone. An important conclusion is that there is a certain sensitivity threshold in these economic techniques around 55 dB. Because of this, the equilibrium noise reception level will always be higher than this threshold of 55 dB. A big issue is still how to arrange that the benefits will eventually flow to the same party that paid for the noise measures.
The answer to the second question requires that not only **limit values**, but all other features of the reception limit system are taken into account: frequency of monitoring, types of measures, annual resources for abatement, sensitivity zones, difference between existing/upgrading/new lines.

Also from the point of view of the railways (infra managers, operators) the bearability issue cannot be answered without looking at all other legislative features that determine the effectiveness of the limits under consideration. Stringent noise limits can be very ineffective if the actual reception levels are rarely monitored, while weak limits may require a lot of procedural effort from the infra manager. However, the following is very clear:

- Speed and capacity reduction is hardly effective in terms of decibels
- A noise limit of 40 dB, as proposed by the WHO night noise guideline,
  - Would require noise reductions of more than 20 dB, which is impossible with today's and future source measures
  - Would therefore require a completely new approach towards urban planning and infrastructure
  - Is only sensible if all noise sources, including road, air and industrial are equally quiet in the end.

6 Noise emission ceilings – what is bearable?

6.1 Introduction

More knowledge is required to give insight in the bearability of noise emission ceilings, or in other words: what is an acceptable (dis)satisfaction level for all stakeholders? As mentioned in Section 4.1 the research goal is not to end up with one specific system of noise emission ceilings that are considered bearable for all European railways, but to provide sufficient background information that enables railways to make their own assessment of this question.

A few starting remarks can be made:

- A system of noise ceilings should be based on the existing situation plus a certain margin. The margin supports a fluctuation of train service.
- The height of the ceiling has to take into account a certain retrofitting status or executed renewal of the fleets and a potential reduction by future retrofitting.
- A system of noise ceilings is not meant to replace any existing noise reception limits, but to complement them. It should prevent an unnoticed future noise increase.
- The height of the noise ceiling should be adjusted (under conditions) if future policy goals reflect more or less transport.
- The height of the noise ceiling should be adjusted (under conditions) if future policy goals reflect the need for more urban areas close to the railway line.

6.2 Assessment of ceiling systems

This assessment provide a basis for taking a position for ceiling system. The assessment describes pros and cons of:

1. Ceiling system I, II and V (see description in Section 3.1).
2. Negative, neutral or positive margins.
3. Different intervention levels (notification, warning, immediate action).

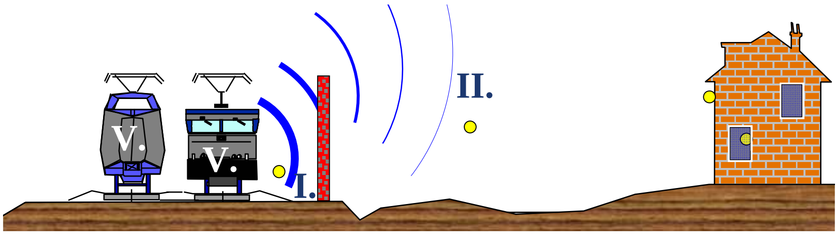


Figure 36: Positions where noise ceilings can be enforced.

Table 6 gives the pros and cons of ceiling system I, II or V.

Table 6 Pros and cons for the choice of ceiling system I, II or V.

Ceiling system I	Ceiling system II	Ceiling system V
+ System gives overall value of noise emission. + Almost all relevant parameters like track construction, train speed, train type and number of trains per hour are involved before check exceed limit. + Simple calculation method. - Noise barriers do not influence the noise creation before check exceed limit.	+ System gives overall value of noise emission from the railway line including barriers. + All relevant parameters like track construction, train speed, train type, number of trains per hour and barriers are involved before check exceed limit. - Noise reduction effect of barriers depends on location dwelling relative to the track. I.e. reduction is low for apartments close to the track and high for dwellings with a roof height below barrier height. - Calculation method becomes more complex, especially in hilly areas. System needs more general assumptions.	+ Use existing TSI system for noise creation of a train type. + Simple calculation method. - Source measures on the track do not influence TSI noise emission. Ceiling system needs additional correction. - Train speed does not influence TSI noise emission. Ceiling system needs additional correction. - Noise barriers do not influence the noise creation before check exceed limit.

Table 7 gives the pros and cons of a margin value below, on or above the noise ceiling.

Table 7 Pros and cons for the choice of a margin.

Negative margin	Neutral margin	Positive (small) margin
Immediate check of noise creation to ceilings (Dutch system)		
+ Decrease of annoyance for the people that live along railway line. - Immediate check of actual noise creation gives exceedance of the ceiling. Direct need for additional measures on a large scale. - No room for small yearly fluctuations in train service that result in a small noise increase.	-/+ No increase or decrease of annoyance for the people that live along railway line. - Immediate check of actual noise creation gives on a large scale exceedance of the ceiling. Direct need for additional measures. - No room for small yearly fluctuations in train service that result in a small noise increase.	- (Small) increase of annoyance for the people that live along railway line. + Immediate check of actual noise creation doesn't give a large scale exceedance of the ceiling. No direct need for additional measures. + Anticipation is possible for research en installing measures on future locations with exceedance of the ceiling. + Room for small yearly fluctuations in train service that result in a (small) noise increase.
Not an immediate check but a future check of noise creation to ceilings (Swiss system) can include expectations of future retrofit within ceiling		
-/+ Within this (Swiss) system a combination of retrofit and traffic growth can be chosen, with a negative margin. Effect for capacity and environmental impact depends on balance within this choice.	-/+ Within this (Swiss) system a combination of retrofit and traffic growth can be chosen, with a negative margin. Effect for capacity and environmental impact depends on balance within this choice.	-/+ Within this (Swiss) system a combination of retrofit and traffic growth can be chosen, with a negative margin. Effect for capacity and environmental impact depends on balance within this choice.

Table 8 gives the pros and cons of the different intervention levels when monitoring shows an exceedance of the noise ceiling.

Table 8 Pros and cons for the choice of intervention with notification, warning or immediate action.

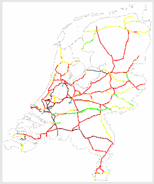
Notification	Warning	Immediate action
The system notifies that the ceilings are exceeded. No further action is required.	The system gives a warning when the ceilings are exceeded. Further action is required to investigate the need for measures.	The system detects that the ceilings are exceeded. Immediate action is required to prevent increase of noise for the environment.
+ The system gives information to all stakeholders involved. With this information the system supports transparency around increase or decrease of railway noise. + The system doesn't enforce need for further action for the responsible organizations. - The system doesn't enforce need for further action for the people that have a negative impact of the noise increase. -/+ The system doesn't guide people and organizations involved in the process for further action. The system provides information that stakeholders involved can use by working out solutions for the new situation. Solution can be a mix of acceptance of the situation with more noise and take measures to reduce the noise levels. - The system can lead to dissatisfaction when the outcome of this 'open process' is mainly the acceptance of the situation with more noise. The system supports senseless discussions	+ The system gives information to all stakeholders involved. With this information the system supports transparency around increase or decrease of railway noise. + The system requires further action to for the responsible organizations. This action can be for example: Research to the environmental impact. Research to the impact on noise measures. Make a balance between those two points and decide for further action. In The Netherlands the responsible stakeholders are supported with a legal system for this decision process. The outcome is: No further action if no dwellings have an impact of noise increase (above 55 dB). Further action with measures is forced when a significant number of dwelling have an impact of noise increase (above 55 dB). Some further action if the situation is in between two mentioned points.	+ The system enforces immediate noise measures for the people that have a negative impact of the noise increase. The system leads to satisfaction for those people. - The system enforces immediate noise measures by the responsible organizations. These measures can decrease the rail capacity. - The system can lead to an unintended growth of (cost for) measures to prevent exceedance of the noise ceilings. Therefore the system can lead to unbearable cost for the railway sector.

Notification	Warning	Immediate action
between organizations like local and national governments, infra managers and operators. -/+ The system supports the need for additional agreements and rules in situations with notification of a ceiling exceedance.	-/+ The system enforce in specific situations further action for the responsible organizations. -/+ The system enforce in specific situations further action for the people that have a negative impact of the noise increase. + The system guides people and organizations involved in the process for further action. The system forces legal needs for further action in specific situations. + The system prevents for specific situations dissatisfaction. The system prevents senseless discussions between organizations like local and national governments, infra managers and operators. - Dissatisfaction will remain for those who doesn't get compensation in situation with in increase of noise.	

6.3 Administrative costs and workload

Any new administrative system for controlling noise ceilings will impose costs. This section presents an estimate of these costs (Table 9), identify which stakeholders bear them and assess performance of different administration systems that allow for control of noise emission ceilings.

Table 9 Administrative costs and workload for a noise control system.

Noise control system	Example	Initial costs	Yearly costs for infra manager
1. Network-wide noise creation calculations 	as in Netherlands (3000 km network length)	0.5 mln € per network to use available traffic counting systems and make them match (rough estimate). 3-4 mln € per network if highest ICT quality standards apply (ProRail).	0.1-0.5 mln € to keep track and traffic data up-to-date and to deliver annual report of noise creation.
2. Continuous measurement stations on specific lines 	as in Switzerland and as proposed in PwC study [2]	10-30k € per monitoring station if standard equipment is sufficient. 50-150k € per monitoring station if dedicated software is needed (video system, train recognition, veh. no. reading).	5-15k € maintenance costs per monitoring station (calibration, debugging, fixing). Additionally: hardware depreciation over 5 years. 10-25k € for reporting.
3. Noise calculation points on specific lines	one point per line, as a direct alternative to measuring	5-10k € per line if traffic composition is known Otherwise, add costs of item 4	1-5k € per line if traffic composition is known Otherwise, add costs of item 4
4. Counting trains and type 	Using axle counter to estimate total number of vehicles. The ratio loud/silent among freight vehicles can perhaps be assessed manually (using a statistically relevant sample).	5-10k € per installed axle counter (incl. of permission and administration)	5-10k € per line for accurate estimation of traffic composition (freight vehicles). Long lifetime (hardware depreciation irrelevant)
5. Other ways to convert existing	For member states of the EU, the relevant traffic information (volumes and composition) for lines which have more than 60 000		

Noise control system	Example	Initial costs	Yearly costs for infra manager
operational data into usable noise creation indicators	train passages per year is already available under the END (2002/49/EC). Further more, each country has its own systems to manage trains, register freight tonnes, administrate charges, et cetera. These can be used to acquire additional information to calculate the noise emission. Alternatively, European freight vehicles can be labeled with electronic transponders (RFID tags). Silent vehicles (K-block, disc braked or retrofitted) could be registered as such in the tag number database. Tag readers could be installed at different points along the freight corridors. If also the (national and transnational) passenger trains are tagged, the noise emission could be calculated and progress on retrofitting could be followed. This would require a uniform tag system throughout Europe. However the costs for such a system would be enormous. Safety issues (information could be misused) and reliability (fraud) should be addressed.		

Stakeholder costs

The infra manager (or government) will be the main party that will bear these costs. Depending on the chosen solution, also other stakeholders could be involved at some point in delivering traffic information.

Measuring or counting and calculating?

Given the fact that most traffic information is already be available under the Environmental Noise Directive (2002/49/EC), the main purpose of setting up an administrative system for noise monitoring will probably be to proof to the public that noise is controlled well.
For purposeful traffic capacity management (additional) calculations are essential. In the Dutch ceiling system the infra manager checks the noise capacity before approving the timetable. Occasional or temporary train paths are only granted if it is expected that ceilings are not trespassed. Also in the Swiss ceiling system, emission calculations are being set up while the year 2015 is approaching [27b].

If the EC will opt for measuring as a means to control noise emission ceilings, costs will highly depend on the system specifications. All-purpose noise measurement stations are not expensive, but these are unable to identify the source of noise events, hence to provide information to manage noise capacity. There are no ready-to-market solutions to count freight vehicles accurately, nor to handle mixed freight trains correctly (with silent and noisy vehicles mixed). For these purposes, dedicated (expensive) measurement systems need to be developed and finally a standardization process should be started (CEN/ISO).

Apart from this, noise measurements at one location along the line can be influenced strongly by changing rail roughness and track decay rate over time. But even if these two disturbing factors would be absent, noise measurements have an accuracy range of typically 1 dB, which is equivalent to a change in traffic volume by 25 percent. Therefore, noise measurements are unsuitable to base capacity allocation or legal procedures on.

6.4 Other aspects of ceilings

Correction of ceiling value and the choice 'who gets the benefit of the advantage' Trespassing noise ceilings can lead to a decision whether or not to compensate the noise impact with noise measures. The new situation depends on the intervention level (notification, warning or immediate action). In some situations no further noise measures are taken. In other situations noise measures are taken. The height of the ceiling needs to be corrected after the decision process of the new situation is finished. This correction is needed to prevent repeated interventions about situations that have been handled before.

Two examples are described below for situations without noise measures and with noise measures on the track. Appendix 5 describes more examples with retrofitting and with noise barriers.

No noise measures after increase of noise

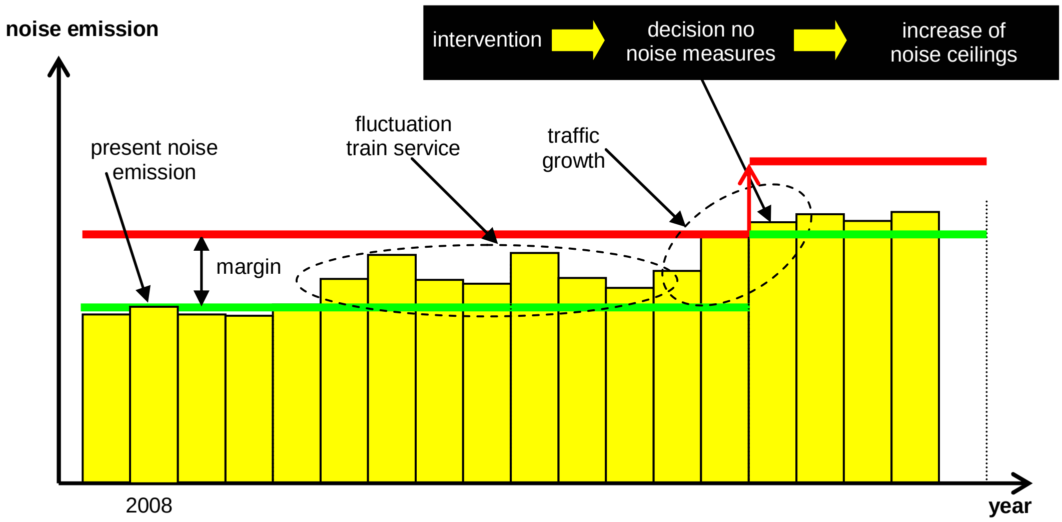


Figure 37: Graphical presentation of a situation where is decided not to take noise measures after trespassing the noise emission ceilings.

This example describes a decision, not to take noise measures to compensate the growth of noise. An increase of noise above the initial limit value is left. The decision not to compensate this increase can be accompanied with a voluntary or a legal participation procedure. After this moment the height of the emission ceiling is accepted.

Noise measures on the track after increase of noise

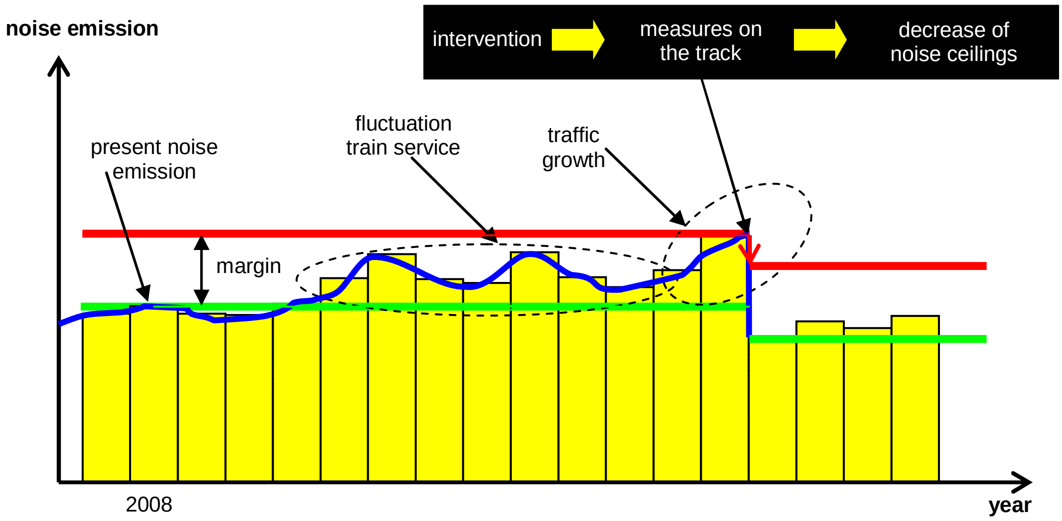


Figure 38: Graphical presentation of a situation where is decided to take noise measures after trespassing the noise emission ceilings and to give a part of the benefit to the residents along the railway line.

The second example describes a situation where the noise measures more than fully compensate the growth of noise. A small decrease (relative to the initial noise emission) is left. After the decision process of the new situation is finished a small decrease of the height of the emission ceiling is accepted. The advantage of the extra noise reduction is donated to the residents along the railway line. This example prefers in situation with very high noise levels around the railway line and a relative minor interest in extra capacity on the railway line.

Harmonization of instruments or national policy choices?

Is there a necessity for harmonization on European scale? As noise emission ceilings are proposed by the EC as a policy target to 'strengthen the position of rail freight transport', ceilings should not be restrictive for operations on the freight corridors.

The three major systems that have an impact on future noise reception levels and are:

- Noise differentiated track access charge.
- Noise ceilings.
- Noise reception limits.

The pros for harmonization are simplicity of regulations for companies that act cross border and equal opportunities for countries and companies within the European Union. The cons for harmonization are the disturbance of a national legal and economical system. Countries which currently have systems that are much different from the harmonized systems need to implement large adaptations. Very stringent harmonization sometimes leaves few options to adapt cultural and historical differences.

Harmonization could also leave room for differences between European countries. A harmonized system can give recommended values and a bandwidth for national adaptation.

An example of a harmonized system with national choices is:

- For noise ceilings: The European recommendation is no increase of the noise creation more than 1 dB relative to 2010 and a bandwidth of + 2 dB. This means that countries can decide to implement noise creation ceilings in their national legislation between +1 and +3 relative to the situation 2010.
- For noise reception limits: The European recommendation is an $\mathbf{L_{night}}$ value of 55 dB and a bandwidth of + 10 dB. This means that countries can decide to implement noise reception limit in their national legislation between 55 and 65 dB

6.5 Conclusion

Noise emission ceilings can be a policy instrument to control traffic noise. They can complement existing noise legislation. If a noise ceiling is exceeded, action is required to avoid a further increase of noise. This could lead to a decision to put noise measures in place, but only if reception limits at façades of dwellings are exceeded as well. In this respect, noise emission ceilings are nothing more than a trigger to start legal procedures for upgrading a railway line.
The level of the ceiling could be based on the existing situation plus a certain margin. This margin or headroom is required to absorb yearly fluctuations in traffic volumes. Alternatively, the initial ceiling height can be based on the expected state of retrofitting or executed renewal of the fleets. In that case the system can be accompanied by a noise abatement plan, like in Switzerland.

Noise emission ceilings should not be cast in concrete. This would severely damage the position of the railways, especially if no similar ceilings are installed for other modes of transport. Adjustment of ceilings over the years should be made possible, upward and downward, to account for developments that cannot be foreseen.
Noise measurement stations are not suitable to accurately monitor if ceilings are trespassed. This is because noise, in general, cannot be measured accurately enough – an uncertainty of 1 dB accounts for 25% change of traffic intensity. For legal purposes, only calculated noise levels have value.

National governments should be given the choice of how monitoring emission ceilings. In this way, they can efficiently use available sources of information to monitor traffic volume and composition. The required data for calculations is the same as that needed every five years for the Environmental Noise Directive. Therefore, for yearly monitoring of emission ceilings one could use the same data infrastructure, keeping administration costs to an acceptable level. If, however, specific monitoring systems are imposed on a European level, costs may increase dramatically.

Appendix 1 Factsheets national noise legislation

Interviews

	Country	date	Involved
A	Netherlands	April 2010	dBvision: Frank Elbers, Edwin Verheijen, Wiebe van Golde
B	France	17 May 2010	Franck Poisson SCNF, Pascal Belingard SNCF, Anne Guerrero RFF
C	Switzerland	19 May 2010	Jakob Oertli SBB
D	Germany	21 May 2010	Martina Fleckenstein DB, Bernhard Koch DB Netz, Rolf Gessner DB
E	Sweden	early June 2010	Karin Blidberg Banverket
F	Poland	25 May 2010	Krzysztof Polak PLK, Damian Trojnara PLK
G	Portugal	20 May 2010	Diogo Vasconcelos REFER

Questionnaire

<u>The actual situation of the railways</u>

1. Who are the (main) train operators in your country? Freight? Passengers?
2. International traffic? Train operators? Rolling stock used?
3. Can we have a digital map of the main railway lines in your country?
4. Who are the entities in the regulation of railway noise? (Ministry? Municipalities?)
5. Is there a (legal) noise difference between ballasted track with concrete and wooden sleepers? Is so, what’s their share (km) on the total network?
6. Can I have a graph showing the developments regarding noisy and silent rolling stock?
7. Is there a track access charge (€/km)? Different for passengers and freight? NDTAC (as proposed by the EU)?

<u>Existing noise legislation</u>

8. Please explain what noise legislation there is, and since when?
   a. Are there (different) noise limits for new houses near existing tracks or for existing houses near new tracks?
   b. Are there different railway noise limits for urban/rural cases?
   c. Is your noise legislation an important part of the procedures required to build a new railway track?
   d. Is there different legislation for rail traffic compared to depots/shunting yards?
   e. In case of local complaints about railway noise, does your noise legislation require investigation and action?
   f. Are there gaps in the noise legislation which cause problems to the infra manager?
   g. How would you describe the public opinion regarding railway noise? Is this different for freight transport, for passenger transport, TGV?
   h. Is there special care for existing dwellings with high noise levels due to trains?
   i. Is it obliged to check the calculated noise of newly built lines by measurements?
9. What’s your legal noise computation model? Has it been changed over the years? Is noise being monitored (apart from obligations due to the END)?
10. What kind of noise measures are taken?
    a. Retrofitting of noisy trains, rail dampers, rail grinding, noise barriers, insulation of façades?
    b. Why are measures taken? Is there an obligation (policy/legislation)?
    c. How do you decide which measure is taken (cost benefit analysis)? Who pays?
    d. What entities take part in this decision making?
    e. Has there been a development in time of the noise measures that are applied?
11. Noise mapping and action plans (END)
    a. Who produced the noise maps?

b. Is it possible to obtain these documents?
c. Is it possible to obtain GIS files of railway lines and noise contours (in a later stage of our project)? Preferably shape files or other data format which is supported in GIS software for further analysis.

Important future developments

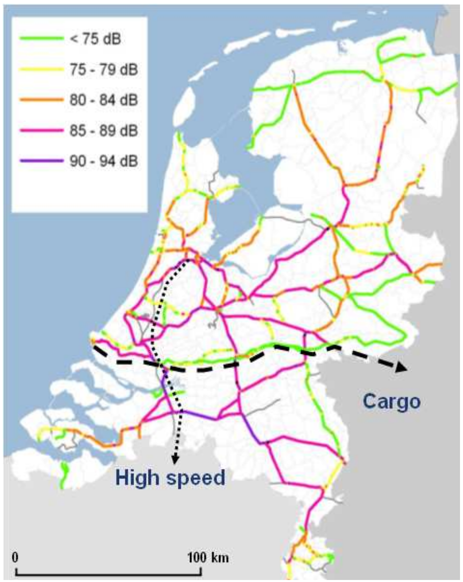
12. What developments are foreseen to the future?
    - Silent trains? Changes in traffic? New lines?
    - International lines? High speed?
13. Is future legislation/policy being prepared?
14. What do you expect from noise emission ceilings?

A. FACTSHEET NETHERLANDS

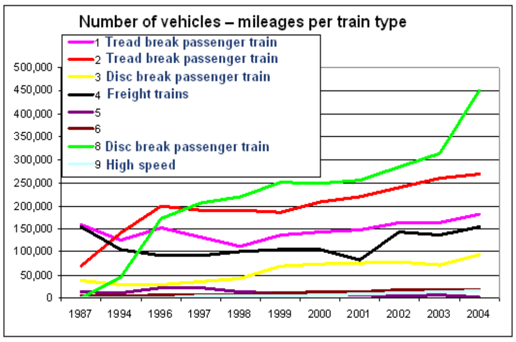
The infra manager of the Dutch railway network (3 000 km) is ProRail. For passenger traffic, the network is one of the most intensively used in Europe. There are dedicated lights for freight (Rotterdam – Emmerich (D), since 2007) and for high speed traffic (Amsterdam – Antwerp (B)).

Passenger transport NS (=main), Arriva, Veolia, Syntus
Freight transport DB Schenker, Rail4chem, ACTS, ERS, and others.

ProRail is responsible for railway noise, including the production of END noise maps and action plans. The railway superstructure consist of jointless track (>95%) with an almost equal share of concrete and wooden sleepers. Experience with LL-blocks was gained in the national 'Innovatieprogramma Geluid' 2002-2007. During this programme also Noise-Differentiated Track Access Charges were investigated and, finally, introduced (2008). Two types of rail dampers were homologated in 2007. ProRail is planning to apply 35 km of rail dampers until 2012.
Acoustical grinding has been prepared in legislation, but is as yet only in effect on the high speed line. This is because because there are still too much trains with cast-iron blocks (see graph).



Railway network. Colour scale refers to so-called 'Noise creation value', as defined in Dutch calculation scheme



Still a considerable number of passenger trains with cast-iron blocks (type 1 and 2) is running on the Dutch network.

Noise legislation The 'Noise annoyance act' of 1979 came into full force for the railways in 1987. There are noise reception limits for new lines and upgraded lines, which are expressed in Lden. There are no separate night-time noise limits. The reception limit for new lines is 55 dB Lden (incident sound level). This limit also applies for urban planning. Besides a physical modification also a traffic volume increase may require starting up the procedures for upgraded lines. The trigger for a more detailed noise study is a 1.0 dB increase of the noise creation value in populated areas along the railway line, compared to the average value of the preceding three years. In that case, the noise reception levels at the dwellings are calculated. Further action is only required if 63 dB Lden is exceeded or if dwellings in the range 55-63 dB would be exposed to an increase of 3 dB or more. Only then, the line is regarded as 'being upgraded', requiring ProRail to set up a noise abatement plan. A legal cost-benefit scheme determines if rail dampers and/or noise barriers and/or façade insulation are applied, in that order. The target for the reception values is ‘stand-still’, but in many cases different levels are allowed depending on cost-effectiveness, the interior noise level, the historical level in 1987, and the rights granted during preceding track upgrading.

Noise abatement The 1987 based noise abatement programme involves 73 000 dwellings that had a noise reception level above 65 dB(A) L_{etmaal} (≈ 63 dB Lden). Due to lack of annual budget, only 30% of these cases is solved now. Recently, as a result of the END Action Plans, a new programme for ‘hot spots’ (>70 dB Lden) is set up. At present, both programmes are integrated, receiving a budget of 0.5 billion euro until 2020.

Noise issues There is no protection for a gradual growth of noise due to traffic growth (<1 dB per year). The communities do not accept this. There is a huge working load due to noise regulations, even for minor track improvements. Noise procedures take 2 – 4 years, while politicians ask for a fast network capacity increase.
There is no debate at all about reducing the noise reception limits or abolishing the limit differences between road and rail (7 dB). The WHO guidelines have not yet led to discussions.

Future As a solution to the above problems, new legislation on ‘noise production ceilings’ has been prepared and is close to being adopted. Ceiling levels are based on the current levels + 1.5 dB headroom. Present reception limits remain unchanged. The ceilings will function as warning system to prepare action.

B. FACTSHEET FRANCE

The infra manager of the French railway network (29 200 km) is RFF. The first high speed line was opened in 1981 (Paris-Lyon) and the TGV network is still being extended.

Passenger transport mainly SNCF
Freight transport SNCF and 9 others (Veolia, Eurocargo, Europort, VFLI, TSO, …)

RFF is legally responsible for the railway network. SNCF maintains the infrastructure under contract of RFF, including new projects and line upgrading. The government is responsible for END noise mapping, based on data delivered by RFF. SNCF manages the stations.
The main lines have basically concrete sleepers, while the regional lines have mainly wooden sleepers. Rail dampers have been homologated in 2007 but their usage is still under consideration, as normally noise measures should reduce the noise by 5 dB or more. Wheel damper homologation is in progress. Low barriers and barrier tops are considered.
Most of the new passenger trains run on the regional and suburban lines, also on high speed lines. Freight traffic (29.7 tonnes km in 2008) consists partly of transit traffic (3.5 million tonnes km).

Noise legislation The 'Law on Noise Abatement' of 1992 sets the following limits for new and upgraded lines.

LAeq*	New conventional lines		New high speed lines		Upgraded lines**	
Sensitivity sectors	Day (6-22h)	Night (22-6h)	Day	Night	Day	Night
Residential (moderate noise levels)	63	58	60	55	'stand-still' if existing levels lower than the limits to the left, else	
Mixed (higher noise levels)	68	63	65	60		
					68	63

* For comparison with limits of other countries, subtract 3 dB for the façade reflection and add 3 dB for the noise annoyance correction factor
**A noise study is required if the noise would increase by more than 2 dB.

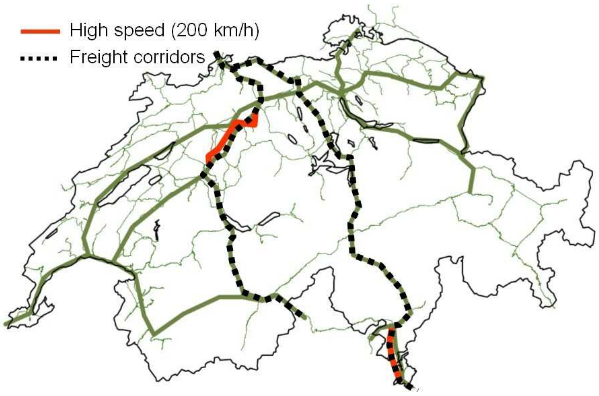
For the purpose of urban planning and noise abatement, lines are classified:
a. <50 trains per day: no noise limits for new dwellings, not included in noise abatement programme
b. >50 trains per day in interurban areas, >100 in urban areas

Noise abatement A 2001 based noise abatement programme involves railway lines of class b. Hot spots are defined as locations where L_{den} >73 dB and/or L_{night} > 65 dB for conventional lines, and L_{den} > 68(A) dB and/or L_{night} > 62 dB for high speed lines. The noise should be reduced to 68/65 dB in daytime (6-22h) and 63/60 dB at night (22-6h), respectively. The costs are normally shared between government (25%), RFF (25%) and the municipalities (50%). Within the framework of the END action plans, an additional hot spots programme (3 years) is developed, in which the governmental organization Adème pays 80% of the costs and RFF 20%. At present, façade insulation is applied more often than noise barriers.

Noise issues The complexity of the noise policy is difficult to explain to the public (during consultations). There is a mismatch between the national abatement programme and the END action plans, in time (20 years vs. 3 years) in place (involving different tracks) and in problem definition (French calculation method vs. EU interim method). The progress of the national abatement programme suffers from the fact that half of the costs should be contributed by the municipalities. Station noise is not clearly defined in legislation. The noise limits are not in line with WHO recommendations.

Future An update of the calculation method NMPB is expected, regarding the source definition (source height).

C. FACTSHEET SWITZERLAND



The Swiss railway network has a size of 5 000 km, of which 3 700 km is standard gauge. Of this standard gauge network, about 3 000 km is managed by SBB and 345 km by BLS. The rest of the network is managed by many so called private railways.
The network is one of the most intensively used in Europe.
There are short stretches of high speed lines. Two important freight corridors cross the Alps: Basel - Domodossola and Basel - Chiasso.

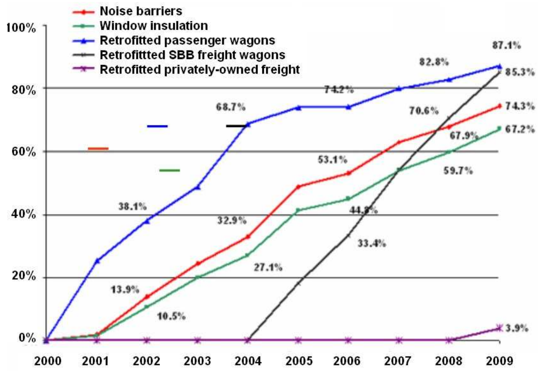
Passenger transport mainly SBB and BLS, also RhB, SOB, SZU, …
Freight transport SBB, BLS and others

The Ministry of Transport and SBB are responsible for implementing noise control. The Ministry of Environement is responsible for noise mapping. Monitoring is undertaken by the Ministry of Transport with measurements and by the Ministry of Environment with calculations.
Legal noise measures are: retrofitting passenger and freight vehicles, noise barriers and window insulation. Rail dampers and acoustical grinding are considered.

Noise legislation Noise abatement measures were applied since about 1980 when new lines were built or when lines were upgraded. Major noise legislation was enacted in 1987 and 2000. The reception limits are:

LAeq*	New lines		Existing lines + upgrading		Priority cases (abatement)	
Sensitivity zones	Day	Night	Day	Night	Day	Night
Recovery	50	40	55	45	65	60
Residential	55	45	60	50	70	65
Mixed	60	50	65	55	70	65
Industrial	65	55	70	60	75	70

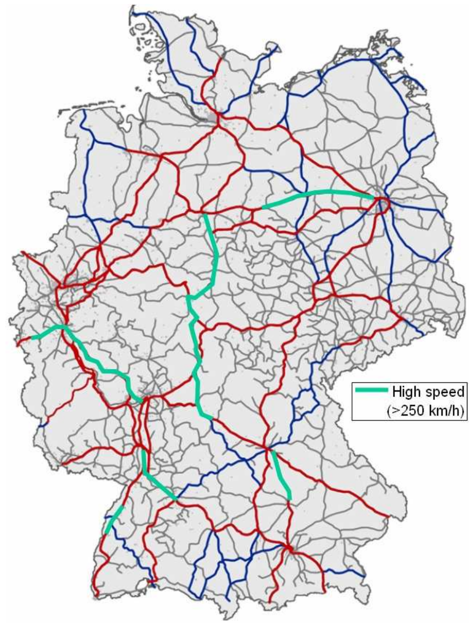
Noise abatement The noise abatement programme consists of (1) a retrofitting plan for the existing passenger and freight fleet. Where necessary, also (2) noise barriers are installed. If these are not cost-effective, (3) window insulation is applied. Noise-differentiated track access charging has been introduced around 2002. The abatement programme is based on emission ceilings for the railway network, called *Emissionsplan 2015*. If the ceilings are exceeded, SBB is responsible to further noise abatement.
The Ministry of Transport monitors the progress on retrofitting at six locations on the network, using measurement stations.



Progress on noise abatement. Most targets are almost achieved. Retrofitting of the private freight vehicles has only just started.

Noise issues Foreign freight wagons are still noisy (70% of traffic on corridors is from abroad). There is discussion about allocation of resources that were saved during the present abatement programme (0.5 Billion CHF). The legal definition of idling trains is not clear (traffic or industrial noise). The German discussion about WHO guidelines and abolishing the noise annoyance correction factor is noticed in Switzerland, but it is not subject of debate (yet).

Future There are two programs for new rail capacity: ZEB (2020) and Bahn 2030. The new calculation model SonRAIL is just finalized. It includes roughness, weather, multiple reflections. SonRAIL will be used for specific situations requiring detailed calculations, while standard calculations will continue with SEMIBEL.



D. FACTSHEET GERMANY

The infra manager of the German railway network (34 000 km) is DB Netz. The network has dedicated high speed lines and important European freight corridors.

Passenger transport Long-distance lines: DB
Regional lines: mainly DB, also Veolia, …
Freight transport DB Schenker (45%), Arriva, Rail4chem (and 300 others

EBA (under authority of the Ministry of Traffic) is responsible for railways. They also produced the END noise maps. DB is responsible as infra manager (DB Netz) and main operator.
Most of the main lines consist of ballasted tracks with concrete sleepers, except in tunnels (slab track).
Most of the passenger trains have disk brakes or K-blocks. The noise problem is mainly due to freight, of which the great majority has cast-iron blocks. There are 150 000 German-owned wagons.
Legal noise measures are noise barriers, acoustical grinding (*BüG*) and façade insulation.
Noise measures considered for future use: rail dampers, high speed grinding and low barriers.

Noise legislation The 'State immision protection law' *BImSchG* of 1974 sets reception limits for new and upgraded lines. These limits are shown in the non-shaded (middle) columns of the following scheme.

LAeq*	New and upgraded lines (*BImSchG*)		Existing lines (abatement threshold)	
Type of area	Day	Night	Day	Night
Hospitals and Care	57	47	70	60
Residential area	59	49	70	60
Mixed area	64	54	72	62
Industrial area	69	59	75	65

A unique noise measure under *BImSchG* is the specially monitored track (*BüG*), where a reduction of 3 dB is applied in the noise calculation model for rails of which the roughness is kept low by an acoustical grinding regime.

Noise abatement The national noise abatement policy for existing lines is based on a voluntary agreement of 1998. The abatement thresholds are shown in the shaded columns of the above table. The annual funding of 100 million euro is used to build barriers (so-called 'active' measures) and to install noise-insulated windows ('passive' measures). The planning is based on a priority list. DB's target is to half the railway noise impact by 2020.

Noise issues Nightly freight trains are the main cause of noise annoyance. The increase of freight capacity on the corridors is heavily criticized by the communities, who refer to the low reception limits proposed in the WHO guidelines. At a governmental level, the debate about abolishing the rail bonus revived in 2009. DB has an obligation to maintain noise reception limits near upgraded lines during 30 years, but this is not yet implemented firmly in the German law.

Future The rail sector has proposed a simplified scheme for noise-differentiated track access charges to the government, avoiding massive administrative load. DB intends to retrofit 90% of noisy freight wagons by 2020. A start is being made by retrofitting 5000 freight wagons in the program Silent Rhine (*Leiser Rhein*, 2012). As new version of the calculation model Schall03 is finalized but not in force yet. The research project *LZarG* (silent trains on realist track, 2007-2010) aims at investigating how future noise reduction can be realised on track and vehicle components.

E. FACTSHEET SWEDEN

The new infra manager of the Swedish railway network (13 000 km) is Trafikverket (Swedish Transport Administration), after the railway and road administrations were integrated in April 2010. There is exchange of traffic with Norway and Denmark.

Passenger transport SJ (65%), and various regional operators
Freight transport Green Cargo (60%), also Hector Rail, TGOJ Trafik, MTAB (ore transport)

Trafikverket should comply with target values decided by the Swedish Parliament and limit values according to decisions by the Environmental Court of Appeal. The Ministry is responsible for proposals on noise legislation which is adopted by the Swedish Parliament.

Most passenger trains are equipped with disked brakes. The majority of freight trains have cast-iron blocks.

Noise measures are mainly noise barriers and window insulation. Rail grinding (maintenance) is also a noise measure: a special project on acoustical rail grinding is planned. Tests with rail dampers are being conducted. The calculation method is still the Nordic method of 1969; the 2000 version is evaluated.

Noise legislation Noise protection is applied since the 1970s. The current law is the Swedish Environmental Code 1 of January 1999. The environmental objective is: “by 2010 the number of people who are exposed to traffic noise in excess of the guide values approved by Parliament for noise in dwellings will have been reduced by 5% compared with 1998”.
Target values decided by the Parliament for new and upgraded lines and urban planning (non-shaded column):

situation	metric	new and upgraded lines [dB]	existing [dB]
inside the building (bedroom)	LAeq,24h	30	
during the night inside the building (bedroom)	Lmax	45	55
outside the building (garden or patio)	LAeq,24h	55	70
outside the building	Lmax	60	

The shaded column gives the limits for existing lines (decisions by the Environmental Court of Appeal).

Noise abatement The noise abatement programme for existing lines has provided window insulation for 22 300 houses (50 million euro, already finished). Window insulation and barriers were applied near 1850 houses and 420 school and hospitals the like. There is a new budget every year from 2008 to 2015.

Noise issues Freight traffic noise is less accepted in the public opinion than passenger traffic noise. Old freight rolling stock is very noisy. Some operators use noisy diesel locomotives that rapidly exceed the Lmax limits.

Future Freight traffic is increasing. The network is upgraded by building new lines for passenger traffic and use existing lines for freight traffic. Trafikverket has a positive attitude towards (1) more stringent limits for existing vehicles, and (2) noise-differentiated track access charging if this supports to use of silent vehicles.
There is a need for revision and a user manual for the Nord2000 method.

F. FACTSHEET POLAND

The infra manager of the Polish railway network (19 600 km) is PLK. The main railway freight corridor (purple on the map) runs from Gdanks via Warszawa to Brno(CZ)/Bratislava(SK).

Passenger transport mainly PKP InterCity
Freight transport mainly PKP Cargo

PLK responsible for keeping noise below the limits.
Ministry of Environment responsible for noise regulations.

Noise is controlled by rail grinding (maintenance), noise barriers, anti-vibration pads, replacing wooden sleepers by concrete ones, exceptionally also window insulation. There is a tendency towards source measures.

Noise legislation There is no separate legal act concerning noise in Poland. The legal framework for environmental noise issues is established by the Environment Protection Law (*Prawo Ochrony Środowiska*) of 2001.

LAeq	Existing and new railway lines	
Type of area	Day (6-22h)	Night (22-6h)
Health resorts areas, hospitals outside cities	50	45
Single-family houses and city hospitals	55	50
Multi-family houses, single-family houses with craft services, recreational areas outside cities, farm buildings	60	50
City centres above 100 000 inhabitants, with close buildings and with concentration of administrative, commercial buildings	65	55

The same limits apply to noise from depots and shunting yards. New dwellings should observe the interior limits laid down in the Building Acoustics regulation: 40 dB during day time (most adverse 8 hours of 6-22h) and 30 dB during night (most adverse 1 hour between 22-6h). Periodic monitoring of railway noise levels is performed using an indirect method (that is a method for measuring individual noise events) and calculations. Noise measures are implemented primarily for new and upgraded lines. The type of noise measures to be implemented is defined during the Environmental Impact Assessment.

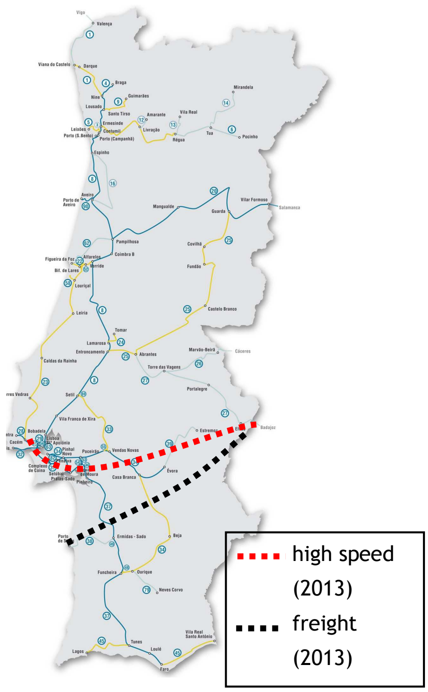
Noise abatement Noise abatement is carried out while upgrading the lines. On existing lines rail grinding is applied as a part of day-to-day maintenance.

Noise issues The noise limit are too stringent for railway lines. Also, new houses are built in close proximity to the railway line and will subsequently lead to noise claims against the infrastructure manager. Poland uses the EU interim calculation method (RMR2002), which leads to inflated results – this method should be adapted to Polish rolling stock.

Future PLK will consider introducing noise-differentiated track access charging.

G. FACTSHEET PORTUGAL

The infra manager of the Portuguese railway network (2 800 km) is REFER. High speed lines are planned between Lisbon and Madrid (2013), Porto-Vigo and Lisbon-Porto (later). A dedicated freight line will be constructed between Port of Sines and Badajoz (2013).



Passenger transport CP (=main), Fertagus
Freight transport CP Carga (=main), Cargorail Takargo, Iberian Link

The Portuguese network consists mainly of broad gauge tracks and has several connection with the Spanish (broad gauge) network. REFER is responsible to comply with the noise limits (noise studies and taking measures if needed for all projects that require an Environmental Impact Study) and to do the END noise mapping and action planning. Since 2001 municipalities have the responsibility to classify their land-use in sensitive zones and mixed zones. This classification is of great importance for the noise limits. The Ministry of Environment and agencies are responsible for noise regulations and inspection.
Almost all freight trains have K-blocks now. As noise measures, in practice only noise barriers are applied. Rail dampers may be considered in future. There is no façade insulation as noise limits are set for exterior noise.

Noise legislation The first law on noise dates back to 1987, later revisions were by Decree. The following reception limits apply to new and upgraded lines, but also to existing lines.

Land-use zones*	Lden	Lnight
Sensitive zone (residential, hospitals, schools)	55	45
Mixed zone	65	55
Sensitive zone close to existing major line	65	55
Not yet classified zones	63	53
Line projected when approving sensitive zone	60	50

The same limits apply to noise from depots and shunting yards, but these are mostly owned by the operators (REFER not responsible). Though the law makes no exception for existing lines, it is considered impossible to maintain these limits for all existing lines immediately. In practice, REFER prioritizes actions based on line modernization. The computation method is the EU interim method RMR2002, adapted to the Portuguese fleet.

Noise abatement First of all, the railway line has to be modernized. REFER thinks it has no sense to apply measures on a old track. First source measures are taken and if still needed a noise barrier is placed.

Noise issues The missing classification of zones by municipalities is causing REFER problems. Another issue is the permission granted by municipalities to build dwellings nearby noisy infrastructure, where it should not be. Most noise complaints have its origin in the densely-populated areas of Lisbon and Porto and are caused by passenger transport. In the cities most people ask for noise barriers, on the country-side people prefer not to have barriers. Freight train noise is, generally, no issue though it is a big issue in terms of annoyance.

Future The Environmental Department of REFER defends noise-differentiated track access charging.

Appendix 2 Noise emission ceilings in PwC study SEC(2008) 2203

4.2.3 Combined policy option C1 + D3: DEV **D**ifferentiated Track Access Charges + Noise **E**mission Ceiling + **V**oluntary Commitment

Differentiated access charges are currently applied in Switzerland and are about to be used in the Netherlands. In both countries they are combined with noise emission ceilings.

> The concept of emission ceilings is based on Dutch and Swiss examples.

The two countries use two different approaches for checking that ceilings are not surpassed. Switzerland relies on 6 measuring stations located so as to cover the major lines in terms of traffic. A noise emission indicator is calculated for each station on a yearly basis and compared with a ceiling established at a fixed date, so as to limit future emission increases.

In the Netherlands, a ceiling is fixed for several control points. Emissions in these points are verified using sound propagation software. In Europe thousand of points would result and calculations would be carried out by different persons with different software.

In Switzerland noisy wagons are not identified. This is probably due to the relatively small dimension of the country itself and consequently of the rail companies. Therefore the reduction of noise is the result of a process based on trust. Such a process is not believed to be feasible at the European level.

> PwC is looking for monitoring stations that are capable of identifying noisy wagons.

In the Netherlands the wagons are traceable with identification tags. The information of on how to attribute a level of noisiness to each wagon is available via data base.

An emission ceiling needs to be enforced either via measurements or calculations of noise emissions. In this study ceilings are assumed to be verified through measurements (Swiss solution). The number of stations was estimated for each country on the basis of network length and complexity – as a cross-check the network maps of some countries were analysed.
The possibility of calculating emission with sound propagation software (as in the Netherlands) was ruled out on account of the difficulty of unifying software or benchmarking different softwares at a European level (EU Rail Noise WG was of the same opinion).

> This paragraph implies that standardized measuring stations will become compulsory. Calculation of noise emission is rejected.

Emission may also be estimated as a function of the number of trains running and their composition in terms of LN wagons. This requires a perfect traceability of LN wagons. Two solutions are possible:

1. technological – LN wagons are equipped with transponders and ground stations detect number of trains, speed and number of wagons;
2. operational – railway personnel records the LN wagons in each train (burdens the operators and owners).

> Remark: both alternative solutions seem to rely on trust, while 'trust' was not a good basis for 'reduction of noise'. Note that tags can be installed on any wagon and personnel is not really independent.

An alternative to emission ceilings are operating restrictions limiting the daily/monthly/yearly amount of non-LN wagons that run on critical lines. The combination of these with DTAC was ruled out since a large part of the burden would lie with RUs, whilst funding would go to IMs. With emission ceilings, the consequent restrictions would derive from an agreement between IMs and RUs.

The DEV combined option considered in this study is thus characterised as follows:

- **Differentiated access charges** are put in place by IMs: a bonus is granted to RUs for each "wagon path" run by a LN wagon, identified with markings and declared by the RU, verified by IM personnel. Automatic legislation, declaration or verification, are required. The entity of the bonus is such as to make retrofitting convenient with mileages that are feasible by the RU and is differentiated between countries after agreements between MS on the harmonisation of charges. Transfer of funds from RUs to POs is to be ensured by making the discounts granted to RUs "transparent" to POs so that the latter feel entitled to claim a discount to the former.
- **Emission ceilings** are fixed at locations equipped with measurement stations ("noise traps"), on the basis of emissions measured before the date of ceiling-enforcement-start (end of retrofitting programme). Noisy wagons are identified with appropriate algorithms yet to be studied. Penalties are imposed by the IM on "noisy" RUs. Penalties are eventually transferred from RUs to POs.
- **Voluntary commitment** by the RUs to transfer funds to POs through discounts on demand and not to increase charges after the noise bonus ceases.

> Remark: it would be interesting to know how to calculate penalties in case the ceiling is exceeded on a line that is shared by different RUs.

The incentive mechanism consists of RUs retrofitting their own wagons and in turn incentivising POs due to the possibility to fund retrofitting through the decrease in the cost of access charges. Also the introduction of noise emission ceilings at a future date and the possibilities of consequent penalties imposed by the IM may play a role. The IM is incentivised to encourage retrofitting and to enforce ceilings due to the future benefit constituted by the long-term reduction of IRMs.

Drivers are the EU and the MS. An important role is played by the IMs.

Appendix 3 Analyzing the PwC concept of emission ceilings

Based on the text given in Appendix 2, the following features can be derived for the PwC noise emission ceilings[14]

- The Swiss and Dutch ceiling systems[15] served as a basis for the PwC concept of ceilings. Both systems share the following features:
    - At certain positions along the network the noise emission is monitored continuously. This means that the actual yearly emission level is compared with a ceiling level that should not be exceeded;
    - This noise emission ceiling is established at a fixed date, so as to limit future growth of emission;
    - If a ceiling is exceeded, the infrastructure manager should take appropriate measures to comply with the ceilings;
- The PwC study simply states that the Swiss ceilings are monitored by measurements while the Dutch ceilings are monitored by calculations. However, in reality both ceiling systems (will) mainly rely on calculations using operational data, partly supported by local noise measurements. (The main purpose of the six measuring stations in Switzerland is to monitor the progress of retrofitting; these six stations alone cannot prove that the ceilings are satisfied elsewhere on the network. An emission control tool for the whole network is being prepared in Switzerland and will be operational within a few years.) The main difference between the Swiss and Dutch ceilings is the reference position: 1 m from the track in Switzerland versus 50 m from the track in the Netherlands, in other words, whether or not to include noise barriers in the source definition.
- The PwC study rejects the Dutch concept because (1) too much reference points would be needed and (2) these would require software unifying and benchmarking when implemented on European scale. (Actually, the Swiss ceilings could have been rejected based on the same arguments, as their system consists of about 6 500 ceiling sections at which the emission should be checked annually[16].)
- The Swiss design of measuring stations is rejected because noisy wagons should be identified (the Swiss stations do not count noisy and non-noisy freight wagons separately);

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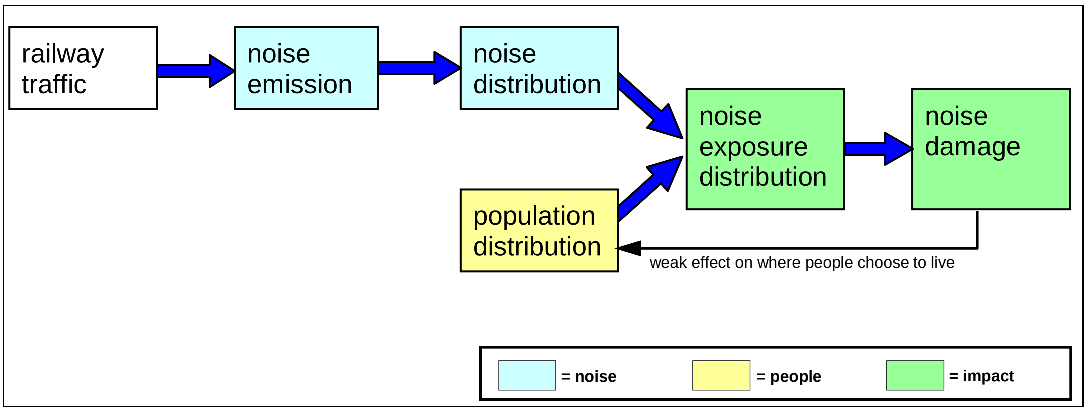
[14] *Impact assessment study on rail noise abatement measures addressing the existing fleet', PricewaterhouseCoopers, {SEC(2008) 2203}*

[15] *The Swiss and Dutch ceiling systems are described in detail in Chapter 2.*

[16] *This follows from http://www.bav.admin.ch/ls/01576/01580/index.html?lang=de*

- As an alternative to identifying noisy freight wagons based on acoustical features (using ‘algorithms yet to be studied’), counting may be applied (either electronically using RFID tags or manually by personnel).
- As appropriate measures, imposed by the infrastructure manager when a ceiling is exceeded, PwC only mentions penalties for the railway undertaking. How penalties shall be divided between railway undertakings that pass the same exceeded ceiling point is not described.

Appendix 4 Example calculation of benefits of noise reduction



This appendix demonstrates how to calculate the benefits of railway noise reduction in terms of money. Benefits can be though of as savings on health treatment, better recovery from stress and (as a result) a higher productivity, improved well-being. As long as these benefits in terms of money are greater than the costs of noise measures, it will be cost-efficient to further reduce the noise, until a break-even point is reached. The method estimates roughly the benefits of 5 dB noise reduction in terms of millions of euros for the agglomerations in 23 European countries. It is then shown that 10-20% of the network in some countries can be treated cost-efficiently by noise measures that render 5 dB reduction (e.g. 2m high barriers, but source measures will be even more effective). In those countries where this percentage is more than the part of the network that lies within the agglomerations, even higher noise reductions would be cost-efficient.

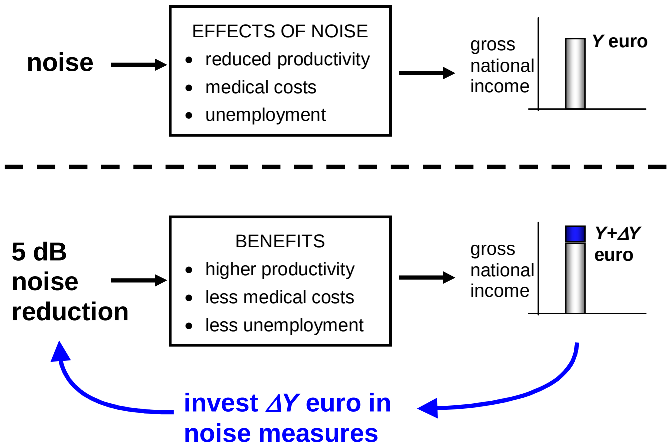


Figure 39: Effects of noise / benefits of noise reduction to be expressed in money terms.

However, as the available information is not complete or not necessarily valid for railway noise, the results of this appendix are not conclusive. In order to produce reliable estimates for such an equilibrium for railway noise, some assumptions and extrapolations need to be proved, adjusted or refined.

Main restrictions and assumptions

- The analysis in this example is restricted to the agglomerations of 250 000 or more inhabitants within 23 European countries. On average, 23% of all the people in these countries live within these agglomerations.
- Various estimates have been reported for "the price of a decibel". Result from economical valuation methods like **hedonic pricing** (HP) or **contingent valuation** (CV) are cited most, see e.g. [31,35,37,38]. However, these methods are criticized because they rely on how well-informed citizens are about effects of noise [31], for example when buying a house (HP) and when asked to state the price of a dB (CV). Therefore a slightly different approach is used here, based on **disability adjusted life years** (DALYs) as proposed by Hofstetter and Müller-Wenk [30]. They found that the monetary value of one person year of sleep disturbance is roughly 2 500 - 16 000 CHF (2000), and of one person year of interference with communication is 1 500 - 10 000 CHF (2000). Monetary values of other health effects, like cardiovascular illnesses, can safely be ignored in comparison to these values for sleep disturbance and annoyance.
- These monetary values have been derived for road traffic noise. As the character of railway noise (intermittent) is quite different from road noise (fairly constant level), it can be expected that railway noise would yield different price estimates. However, like in most economical valuation studies it will be assumed here without proof that price estimates for railway noise are also valid for railway noise, see e.g. [35,36]. It requires further investigation before this assumption can be accepted as reliable.
- No attempt is made to estimate price differences between countries, for example based on the **gross national income** per person. For all countries the same Swiss standard is applied. Converted to EUR (exchange rate in 2000 was 1.6), the above cited Swiss values corresponds to EUR 5 800 for sleep disturbance and EUR 3 600 for interference with communication, each with an accuracy bandwidth of ±73%. No correction for inflation since 2000 and the large drop in EUR-CHF exchange rate over the year 2010 is made. Hence, the results are expressed in EUR (2000).
- In order to minimize the influence of gross national income on the results of this exercise, the benefits of noise reduction are not only expressed in euros, but finally also in kilometers of railway track that can be fitted with noise barriers. As the price of noise barriers will depend on gross national income in almost the same way as the benefits do, the resulting number of kilometers with cost-efficient noise barriers is more or less independent of the gross national income.

- Due to lack of input data, our analysis assumes that the monetary value of railway noise will drop to zero below 50-55 dB. However, this is in line with common practice in economical valuation methods like hedonic pricing or contingent valuation, where a threshold of 50-55 dB is used for external effects of traffic noise [35–38]. Any economical benefits from railway noise reduction outside the group of annoyed and sleep disturbed inhabitants is neglected. Although the inhabitants who also live close to railways but are not annoyed or disturbed by railway noise will certainly benefit in terms of improved well-being, this improvement is neglected in terms of money.
- It is assumed that the self-reported severely annoyance on which Miedema's dose-response functions were based [20-21] is equivalent to the "interference with communication" as stated by Hofstetter and Müller-Wenk. Likewise it is assumed that Miedema's self-reported sleep disturbance is the same quantity as the sleep disturbance in the article by Hofstetter and Müller-Wenk.

Calculating the number of annoyed and sleep disturbed

The EEA website gives a summary of the results of the first round strategic noise mapping (2007). The percentage of exposed refers to the inhabitants of those agglomerations that are exposed to railway noise. Besides 21 EU member states, also results for Switzerland and Norway are listed, see Table 10.

Table 10 Information from first stage of END noise mapping.

Taken from file END_DF4_Results_101005_ETCLUSI_inclBG&SW.xls downloaded 7 February 2011 from http://eea.eionet.europa.eu/Public/irc/eionet-circle/etcte/library?l=/2009_subvention/113noise/data/etclusi_inclbgswxls/_EN_1.0_&a=i

	nr of agglos	mln inh. in agglos	% from total	Percentage exposed to Lnight [dB]					Percentage exposed to Lden [dB]				
				50-54	55-59	60-64	65-69	>70	55-59	60-64	65-69	70-74	>75
Austria	1	1.6	20	6	5	3	2	0	7	5	4	2	1
Bulgaria	3	2.1	27	1	0	0	0	0	1	0	0	0	0
Czech Republic	3	1.9	18	3	4	2	0	0	4	3	4	1	0
Denmark	1	1.1	20	1	0	0	0	0	2	1	0	0	0
Estonia	1	0.4	28	2	1	1	0	0	3	2	1	0	0
Finland	1	0.6	11	5	4	0	0	0	5	5	3	0	0
France	6	13.7	23	10	1	0	0	0	11	2	1	0	0
Germany	25	17.3	21	2	1	0	0	0	3	1	1	0	0
Hungary	1	2.1	20	5	2	1	0	0	6	2	1	0	0
Ireland	1	1.2	27	1	0	0	0	0	1	1	0	0	0
Italy	2	4.2	7	1	1	0	0	0	1	1	1	0	0
Latvia	1	0.8	34	3	1	1	0	0	4	2	1	0	0
Lithuania	2	0.9	26	1	0	0	0	0	1	1	0	0	0
Netherlands	6	5.0	31	2	1	0	0	0	2	1	0	0	0
Norway	1	0.8	18	2	2	1	0	0	2	2	2	1	0
Poland	12	7.4	19	3	1	1	0	0	4	3	1	1	0

	nr of agglos	mln inh. in agglos	% from total	Percentage exposed to Lnight [dB]					Percentage exposed to Lden [dB]				
				50-54	55-59	60-64	65-69	>70	55-59	60-64	65-69	70-74	>75
Romania	8	4.1	19	5	3	1	0	0	3	2	0	0	0
Slovakia	1	0.5	10	17	10	6	2	0	18	13	7	3	1
Slovenia	1	0.3	14	2	1	0	0	0	3	1	0	0	0
Spain	11	8.1	18	0	0	0	0	0	0	0	0	0	0
Sweden	3	1.5	17	4	1	0	0	0	5	2	1	0	0
Switzerland	N/A	5.3	71	3	2	2	1	0	3	2	2	1	0
United Kingdom	28	25.6	42	1	1	0	0	0	2	1	1	0	0
Total general	**119**	**106.4**	**23**	**3**	**1**	**1**	**0**	**0**	**4**	**2**	**1**	**0**	**0**

Using these figures, the benefits of railway noise reduction in the agglomerations of these 23 countries is calculated.

First the number of annoyed and number of sleep disturbed is calculated by multiplying the reported numbers per 5 dB band Table 10 and the percentages listed in Table 11. To make the calculation more accurate, the original reported numbers were used instead of the rounded percentages of Table 10.

Table 11 Percentage of severely annoyed and sleep disturbed. Source: Miedema [20-21].

L_{den} band [dB]	55-59	60-64	65-69	70-74	>75
% severely annoyed	11.4	18	26.7	38	46.7
L_{night} band	50-55	55-59	60-64	65-69	>70
% sleep disturbed	8.4	11.2	14.5	18.4	21.2

The second step is to repeat this calculation after applying an overall noise reduction of 5 dB in day and night time. This corresponds to shifting the data in Table 10 one band to the left.
Both calculations are demonstrated in Table 12 for Austria. In Austria, only Vienna was required as agglomeration to draw noise maps and action plans in 2007. The total number of sleep disturbed inhabitants of Vienna is originally about 29 thousand inhabitants. After reducing L_{night} by 5 dB, the number of sleep disturbed is about 16 thousand inhabitants. Likewise, the number of severely annoyed in daytime is reduced from 60 thousand to 33 thousand inhabitants.

Table 12 Number of severely annoyed and sleep disturbed. A=2007, B=after 5 dB reduction.

Austria (Vienna)		Lnight				Lden						
		50-54	55-59	60-64	65-69	>70	55-59	60-64	65-69	70-74	>75	totals
A	exposed (END)	101 900	76 700	41 900	28 800	4 100	107 000	81 100	57 900	35 500	9 500	
	sleep disturbed	8 560	8 590	6 076	5 299	869						29 394
	severly annoyed						12 198	14 598	15 459	13 490	4 437	60 182
B	exposed	76 700	41 900	28 800	4 100		81 100	57 900	35 500	9 500		
	sleep disturbed	6 443	4 693	4 176	754							16 066
	severly annoyed						9 245	10 422	9 479	3 610		32 756

Calculate yearly benefits

Using the monetary estimate for sleep disturbance, this L_{night} reduction of 5 dB corresponds to a yearly benefit of 77 mln euro (±73%) for Austria. Using the monetary estimate for interference with communication, this L_{den} reduction of 5 dB corresponds to a yearly benefit 99 mln euro (±73%).

Calculate total benefits

Next the investment costs are calculated, that would just compensate the yearly benefits over a lifetime of noise measures, the so-called **net present value** (NPV). This is necessary as the Austrian government will need to lend the money and pay interest. Therefore the size of an investment is calculated per person of *Y* euro that just equals the yearly benefits per person *B* over a time span of 30 years. This is including interest, which is taken here as the average lifetime of a noise measure. Figure 40 shows the cash flow in this simplified scheme.

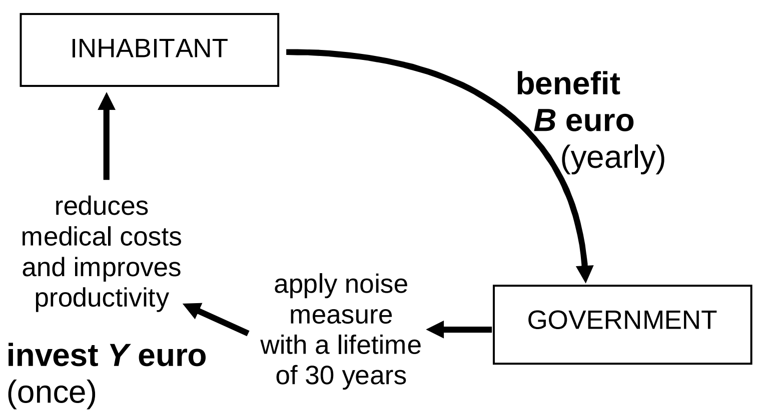


Figure 40: Simplified cash flow scheme for yearly benefits and one-off costs for investment.

The investment at an interest of 4% equals EUR 62 250 for interference with communication and EUR 100 300 for sleep disturbance. These NPV benefits lead to 1 707 mln euro for interference with communication and 1 337 mln euro for sleep disturbance, in Vienna. These potential revenues of noise reduction are sufficient to build 2 m high noise barriers along 850 km or 670 km of track (two-sided), respectively. This is more than the total network length inside the agglomeration of Vienna, estimated to be about 500 km at maximum. Barrier costs are used here as an example to compare benefits with costs[17]. Such a 2 meter high barrier will yield 5 to 10 dB noise reduction, depending on the distance, track lay-out and receiver height. Installing this many barriers is just a theoretical solution – of course source measures are preferable and in many cases barriers are rejected anyway inside cities (safety, aesthetics). But it demonstrates that noise measures can be very cost-efficient in principal.

This exercise can be carried out for all 23 countries, rendering the results in Table 13. This table shows the benefits of an reduction of noise annoyance and sleep disturbance, separately. These benefits are also expressed in the percentage of the total network per country that can be provided with 2 m high noise barriers (or any other noise measure that yields about 5 dB reduction and costs 2000 euro per meter of track).

Table 13 Benefits of 5 dB noise reduction (mln euros). Also expressed in terms of barriers (percentage of total network to be equipped double-sided with 2 m high barriers).

Country	network length[a]	# of agglos	mln inh. in agglos	**I. benefits annoy.[b]**		**II benefits sleep dist.[b]**	
				[mln €]	barriers[c]	**[mln €]**	barriers[c]
Austria	6256	1	1.6	**1 707**	14%	**1 337**	11%
Bulgaria	4150	3	2.1	**158**	2%	**155**	2%
Czech Republic	9578	3	1.9	**1 234**	6%	**837**	4%
Denmark	3181	1	1.1	**190**	3%	**126**	2%
Estonia	1196	1	0.4	**129**	5%	**101**	4%
Finland	5919	1	0.6	**391**	3%	**300**	3%
France	**29200**	6	13.7	**12 739**	22%	**12 818**	22%
Germany	**34000**	25	17.3	**5 323**	8%	**4 189**	6%
Hungary	7808	1	2.1	**1 316**	8%	**1 127**	7%
Ireland	1834	1	1.2	**122**	3%	**80**	2%
Italy	16529	2	4.2	**555**	2%	**485**	1%
Latvia	1884	1	0.8	**324**	9%	**258**	7%

[17] Barriers of 2 m high cost approximately 1000 euro per running meter (price in the Netherlands, inclusive of maintenance costs for 30 years). This price has to be doubled as both sides of the track should be shielded.

Country	network length[a]	# of agglos	mln inh. in agglos	**I. benefits annoy.**[b]		**II benefits sleep dist.**[b]	
				[mln €]	barriers[c]	**[mln €]**	barriers[c]
Lithuania	1768	2	0.9	**93**	3%	**84**	2%
Netherlands	**3000**	6	5.0	**1 294**	22%	**969**	16%
Norway	4114	1	0.8	**321**	4%	**233**	3%
Poland	**19600**	12	7.4	**3 949**	10%	**2 046**	5%
Romania	10784	8	4.1	**1 430**	7%	**2 032**	9%
Slovakia	3623	1	0.5	**1 298**	18%	**1 080**	15%
Slovenia	1228	1	0.3	**67**	3%	**58**	2%
Spain	13354	11	8.1	**156**	1%	**94**	0%
Sweden	**13000**	3	1.5	**876**	3%	**572**	2%
Switzerland	**3700**	N/A	5.3	**2 929**	40%	**2 109**	29%
United Kingdom	15754	28	25.6	**5 221**	17%	**3 540**	11%

[a] Network length according to Eurostat (2009), except for the bold face figures, that have been provided by the interviewed countries included in Appendix 1.

[b] Benefits calculated as described in the text.

[c] Percentage of the network that can be fitted cost-efficiently with noise barriers of 2 m height.

Appendix 5 Examples of trespassing and correction of the ceiling value

This appendix gives additional examples of trespassing and correction of the ceiling value and the choice 'who gets the benefit of the advantage'. These examples are additional to the examples described in Section 6.4.

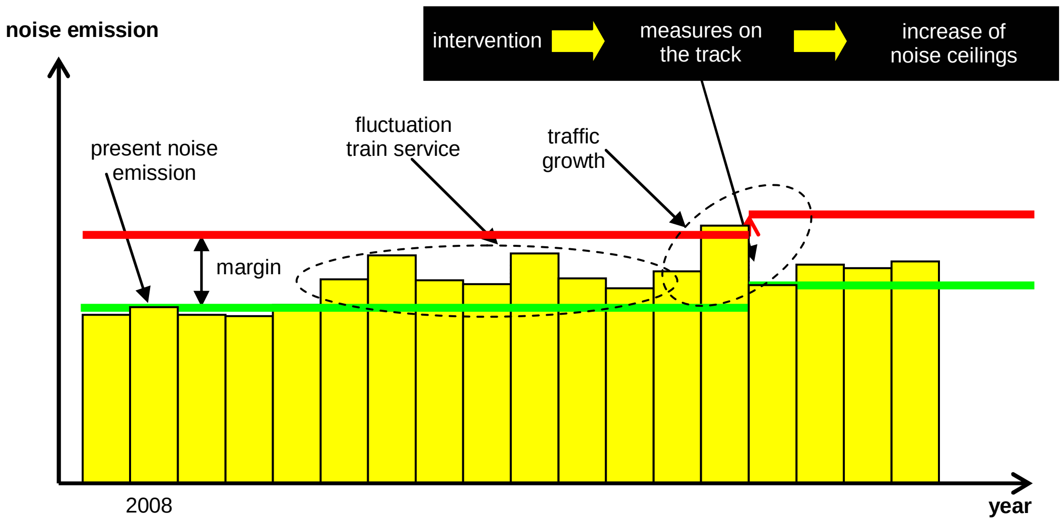


Figure 41: Graphical presentation of a situation where is decided to take noise measures after a trespassing the noise emission ceilings. Both the residents along the railway line and the railways profit. Extra capacity is created with a small increase of noise.

The first example above figures a situation where the noise measures do not fully compensate the growth of noise. A small increase (relative to the initial noise emission) is left. After the new situation is finished a small increase of the height of the emission ceiling is accepted. The advantage of the extra noise reduction is donated to the residents along the railway line. On the other hand the traffic increase that results in a small increase of the ceiling value is also accepted. This example prefers in situations were noise measures are available to compensate a part of the increase. To compensate the full increase 'unbearable' measures need to be installed. The increase that is left is therefore accepted. The increase is compensated as much as is reasonable possible.

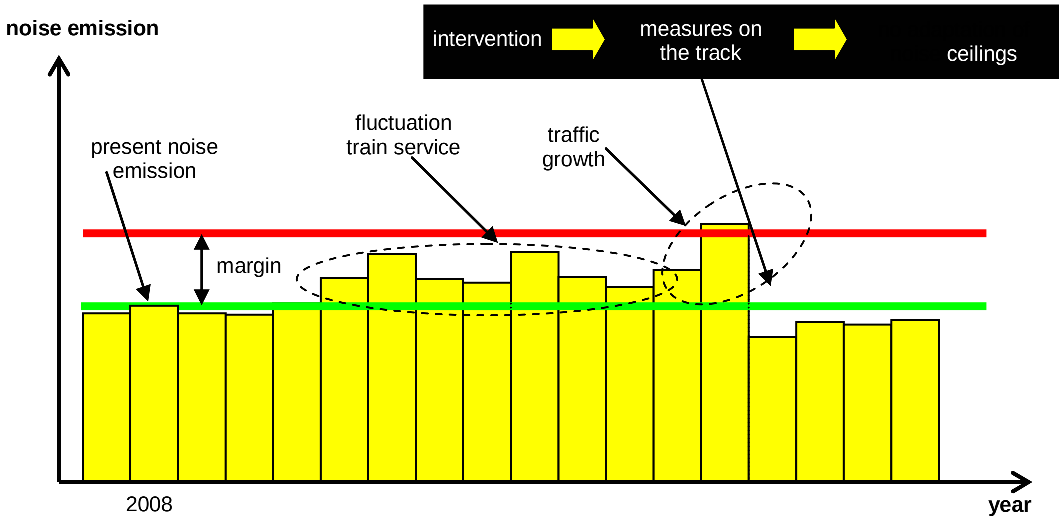


Figure 42: Graphical presentation of a situation where is decided to take noise measures after a trespassing the noise emission ceilings. Both the residents along the railway line and the railways profit. Extra capacity is created with a small increase of noise.

This example describes a situation where the noise measures also more than fully compensate the growth of noise. A small decrease (relative to the initial noise emission) is left. After the new situation is finished no adaptation of the height of the emission ceiling is accepted. The advantage of the extra noise reduction is donated to extra capacity on the railway line. This example prefers in situation with relative low noise levels around the railway line and a relative large interest in extra capacity on the railway line.

Retrofitting

This first retrofitting example describes a situation where noise reduction is created by retrofitting.

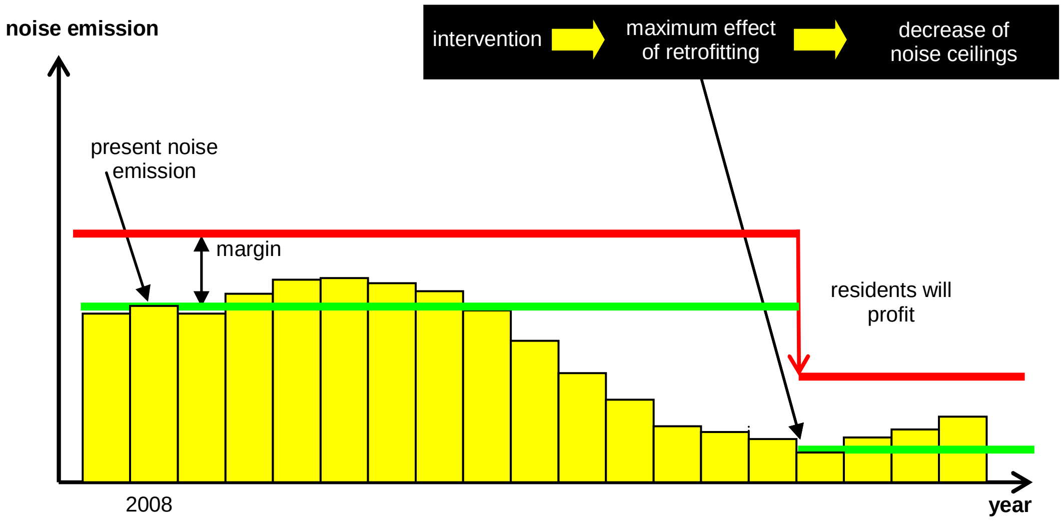


Figure 43: Graphical presentation of a situation where is decided to give all the benefits of noise reduction to the residents along the railway line. The railways will not profit.

This example describes a situation where retrofitting creates a decrease of the noise creation. After the maximum effect of the retrofitting is reached, the height of the emission ceiling is decreased. The advantage of the noise reduction by retrofitting is donated to the residents along the railway line. This example prefers in situation with very high noise levels around the railway line and a relative minor interest in extra capacity on the railway line.

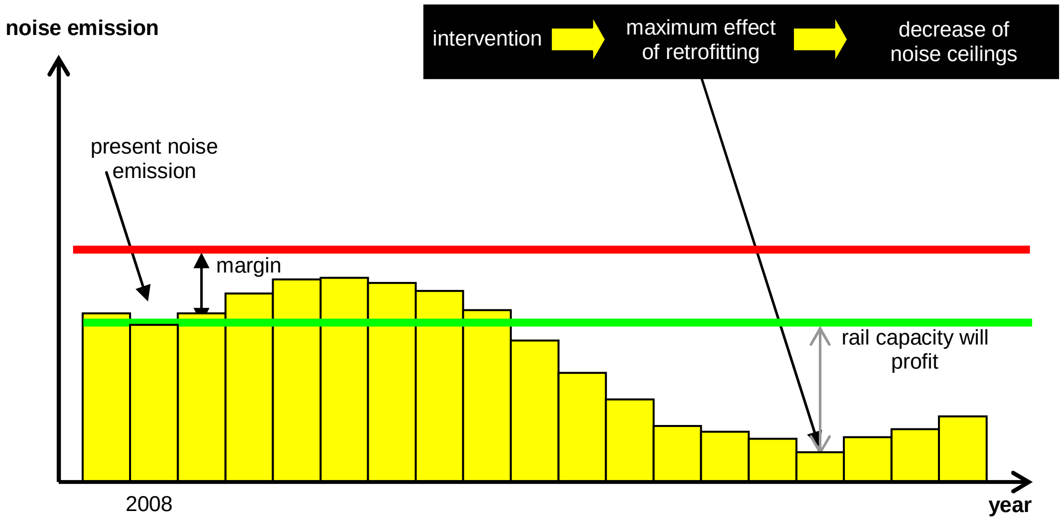


Figure 44: Graphical presentation of a situation where is decided to give all the benefits of noise reduction to the railways. The residents along the railway line will not profit.

This second retrofitting example describes a situation where retrofitting also creates a decrease of the noise creation. After the maximum effect of the retrofitting is reached, the height of the emission ceiling is not adapted. The advantage of the noise reduction is donated to extra capacity on the railway line. This example prefers in situation with relative low noise levels around the railway line and a relative large interest in extra capacity on the railway line.

One can imagine a combination of above described examples. For example the acceptance of a temporarily trespassing the ceiling, for situations where future retrofitting will result in a decrease of the initial noise levels and therefore a decrease of the noise ceiling.

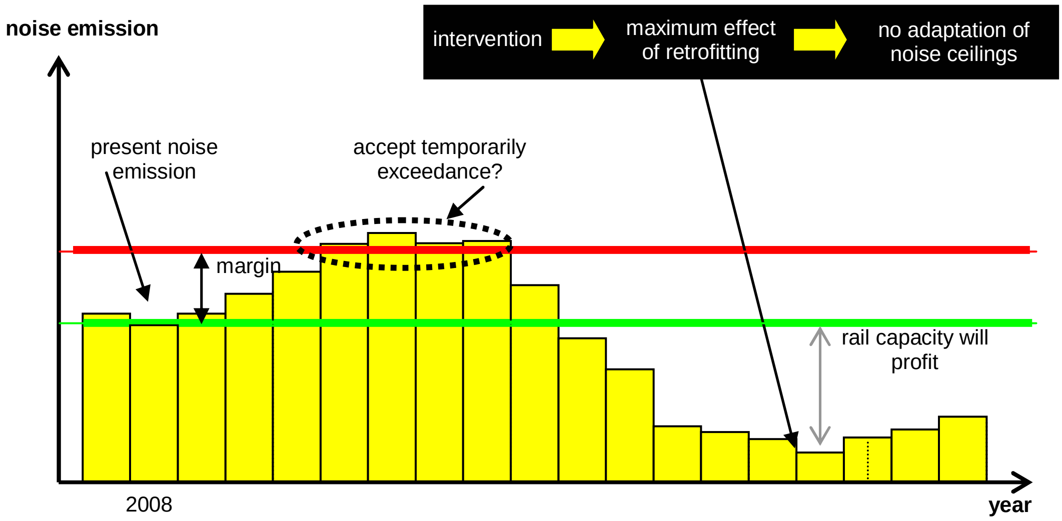


Figure 45: Graphical presentation of a situation to accept a temporarily trespassing of the ceiling, because of a future noise reduction due to retrofitting.

Noise barriers

This example for noise barriers shows a situation where an increase of noise emission is compensated with noise barriers. A simple example is the situation where the increase of noise emission is equally compensated with the effect of noise barriers. Although the ceiling value will increase, the noise effect on the dwellings is zero due to the noise barriers.

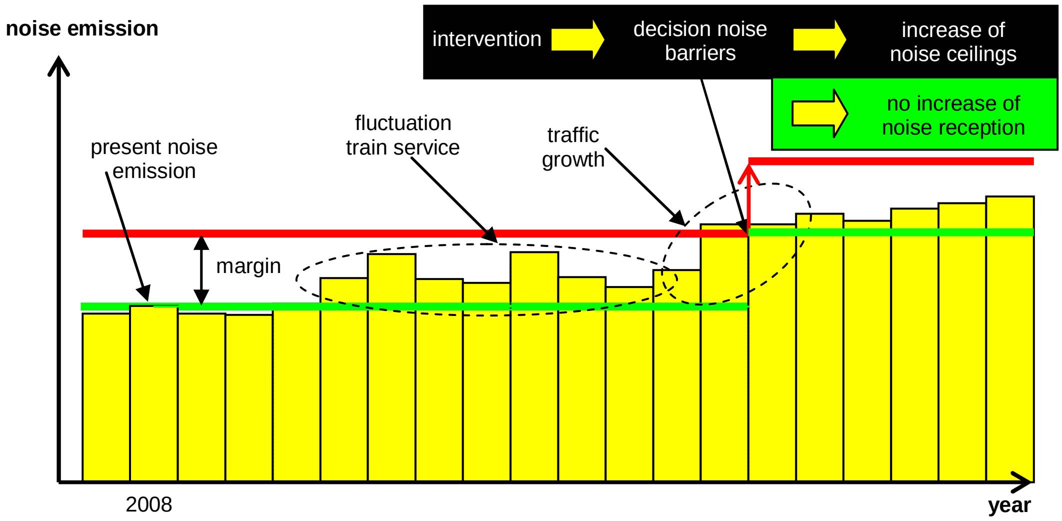


Figure 46: Graphical presentation of a situation to increase the noise ceiling (after trespassing) and to compensate the residents along the railway line with noise barriers.

In more complex situations the effect of the noise barriers is different for different dwellings. The effect of noise barriers is less for dwellings on a hill or apartments high above the ground. The effect is more for dwellings relative low (compared to the track height) like houses in a flat shapes land landscape. In that situation the effect of the noise barrier is positive for some dwellings and negative for others.

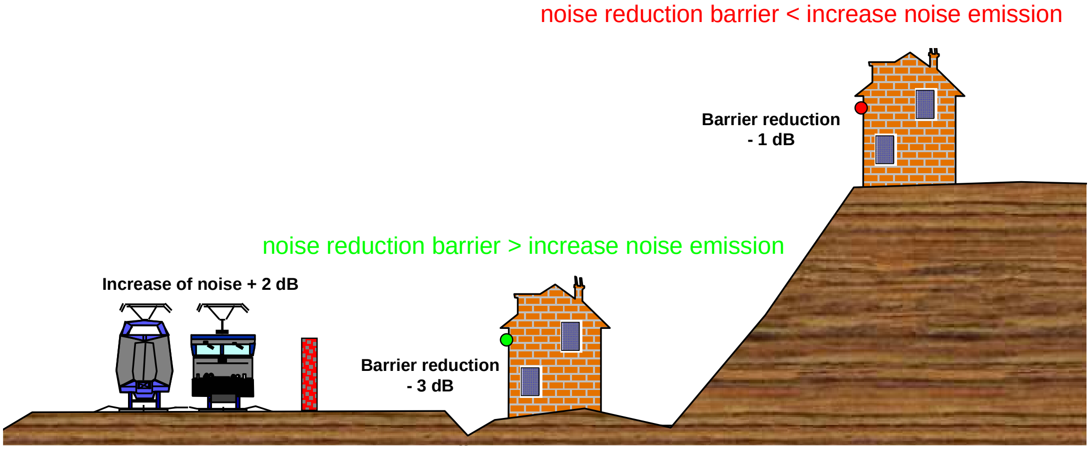


Figure 47: Graphical presentation of a situation with barriers. Dwellings that have a large noise reduction will profit and dwellings with a small noise reduction will not profit.

Operational measures like reduction of speed or trains

A special case is the operational measures like the speed reduction and the reduction of number of trains. These measures can prevent an trespassing of the ceiling and therefore prevent a intervention. It is likely that these two measures will not be translated to an adaptation of the noise ceiling, because of the large impact of the capacity of the rail system.

Appendix 6 List of key words

This appendix gives an explanation for the key words used in this report.

DG MOVE	Directorate-General for Mobility and Transport (European Commission).
DG ENV	Directorate-General for the Environment (European Commission).
EC	European Commission.
END	Environmental Noise Directive
IT	Interim target level as proposed by the World Health Organization
L_{den}	The average noise level during the day-evening-night. **L_{den}** is defined for the Environmental Noise Directive together with **L_{night}**. The noise levels during the evening and night count with a bonus op 5 and 10 dB.
L_{night}	The average noise level during the night.
NDTAC	Noise-differentiated track access charge
NNG	Night Noise Guideline as proposed by the World Health Organization
Noise emission	Noise production from the railway system.
Noise reception	Noise level at the façade of a building.
TSI	Technical Specification for Interoperability.
WHO	World Health Organization.

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Colophon

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Exploring bearable noise limits and emission ceilings for the railways
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Core group: Matthias Mather (DB), Martina Fleckenstein (DB), Bernhard Koch (DB) and Peter Hübner (UIC).

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