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ON-AIR
Investigation of noise planning procedures and tools

Danish Road Directorate – DRD

Institute of Transport Economics – TOI

LÄRMKONTOR – LK

CEDR Call 2012: Noise

ON-AIR
Optimised Noise Assessment and Management Guidance for National Roads

Investigation of noise planning procedures and tools

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Executive summary

The ON-AIR project “Optimised Noise Assessment and Management Guidance for National Roads” was launched in November 2013 and will have a duration of two years. The objective of the project is to develop tools and guidelines which can facilitate the integration of noise abatement into planning and management situations in national road administrations. This report comprises a review describing how noise is handled in the planning procedures of selected NRAs in Europe today. The purpose of this report is to conduct a European investigation into the various noise planning procedures and tools currently in use in different CEDR countries. The objective is to provide a series of good and interesting planning procedures, tools and practical implementation practices. This information will be the foundation for the development of a guidance book on integration of noise in road planning and management in the second part of the project.

Noise planning and management experts from selected European countries have been interviewed. The results of these interviews on how noise is integrated in the following areas are presented in the report:

1. Planning of new roads and Environmental Impact Assessment (of alternative solutions)
2. Road enlargement/redevelopment projects
3. Detailed planning of road construction
4. Day-to-day maintenance of road infrastructure
5. Planning and handling of noise in the construction phase
6. Cooperation and efficient handling of noise issues between national road administrations and regional as well as local authorities
7. Communication with the public and public participation in the planning and decision-making

In order to include more information relevant literature has been investigated as part of the development of this status report. On the basis of a literature survey a short analysis of noise action plans developed in relation to the European Noise Directive has been performed.

An short inventory of noise abatement measures and their estimated effect based on literature is included. Different methods for evaluating and quantifying noise and noise abatement are presented together with methods for including noise in cost-benefit and cost-effectiveness methods. Illustrative examples are also included.

1 Preface

The ON-AIR project "Optimised Noise Assessment and Management Guidance for National Roads" was launched in November 2013 and will have a duration of two years. The objective of the project is to develop tools and guidelines which can facilitate the integration of noise abatement into the three most common planning and management situations of national road administrations (hereafter NRAs):

1. Planning of new roads and motorways
2. Planning of reconstruction and enlargement of existing roads and motorways
3. Maintenance and management of existing roads and motorways

The guidelines will be presented in a guidance book that will be published at the end of the project.

The ON-AIR project is carried out for the Conference of European Directors of Roads (hereafter CEDR). The project was selected by the CEDR on the basis of the CEDR Call 2012: Noise. The title of the noise call was "Noise integration into the planning of new national road schemes and upgrade of existing roads". The ON-AIR project addresses Project 1 of this call titled "Optimisation of noise assessment and management strategies". Wolfram Bartolomaeus from the Federal Highway Research Institute (BASt) in Germany is the CEDR Project Manager of the ON-AIR project. More information about ON-AIR can be found on the home page: http://www.on-air.no/

The ON-AIR project is carried out by three partners:

- Danish Road Directorate (hereafter DRD)
- Institute of Transport Economics (hereafter TOI)
- LÄRMKONTOR (hereafter LK)

Hans Bendtsen from the DRD is the coordinator of the project. The following specialists have produced this report:

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This report comprises a review describing how noise is handled in the planning procedures of selected CEDR NRAs in Europe today. The report will function as background information and inspiration for the work on the ON-AIR guidance book. The report is Deliverable D2.1: Report on the result of WP2 titled: "Investigation of noise planning procedures and tools".

2 Introduction

Sustainable development and planning is important for the ongoing development of the European societies, including the transport infrastructure where the national road networks constitute an important component. Sustainable planning includes a holistic approach covering many social, economic and environmental factors. Noise from road transport is one of these many factors. In the ON-AIR project the focus is especially on noise.

The ON-AIR project stands on the shoulders of existing best planning practice and the important European research of the past decades on improved methods for noise abatement. The objective of this report is to conduct a European investigation into the various noise planning procedures and tools currently in use in selected CEDR countries. The report gives a state-of-the-art view focusing on good examples of the existing practices of selected European countries, in particular the six countries Norway, Sweden, Germany, Belgium/Flanders, United Kingdom and Ireland who funded the ON-AIR project. To give a broader representation Denmark, Hungary and Switzerland have also been included.

Noise planning and management experts from these countries were invited to an interview and workshop event at the offices of LÄRMKONTOR in Hamburg in April 2014.

An in-depth interview guide containing 34 questions and themes was developed and used for the expert interviews (see Annex A). The following issues were included:

1. Planning of new roads and Environmental Impact Assessment (hereafter EIA) of alternative solutions
2. Road enlargement/redevelopment projects
3. Detailed planning of road construction
4. Day-to-day maintenance of road infrastructure
5. Planning and handling of noise in the construction phase
6. Cooperation and efficient handling of noise issues between NRAs and regional as well as local authorities
7. Communication with the public and public participation in the planning and decision-making

The purpose of these interviews was not to get a total and comprehensive description of the noise planning system in each country. The objective was to get a review and to compile a series of good and interesting planning procedures, tools and practical implementation practices.

The experts that participated and were interviewed in the Hamburg event were the following:

- Ann Buytaert, NRA Flanders/Belgium
- Lars Dahlbom, NRA Sweden
- Vincent O'Malley, NRA Ireland
- Helena Axelsson, NRA Norway
- Christoph Schröder, Hamburg Länder/Germany
- Tina Wagner, Hamburg Länder/Germany
- Urs Walker, Environmental Protection Agency Switzerland

After the Hamburg event Jo Morphet from NRA United Kingdom and Jakob Fryd from the Danish NRA also filled in the questionnaire.

In order to develop new ideas for noise abatement and management a Future Workshop was arranged as part of the Hamburg event. The programme and minutes can be seen in Annex B. The international NRA experts as well as the ON-AIR project group participated in the workshop, which was conducted by Margit Bonacker from the konsalt company.

In order to include more information relevant literature has been investigated as part of the development of this status report. Among others, publications from the CEDR noise group have been included (Bendtsen et al., 2009).

Figure 2.1: Pictures from the Future Workshop in Hamburg.

This report provides a range of examples of actual measures, organisational structures and legislative framework. Some describe beneficial practices, while others illustrate practices hindering optimal handling of noise abatement. Throughout the report we have made a choice to mention the country name when a beneficial situation is described and to provide less concrete descriptions in opposite cases.

The role of the interviewees needs to be clarified. While the interviewees from Belgium, Norway, Sweden, Denmark, the United Kingdom and Ireland all represent NRAs, the Swiss interviewees work at the ministry level and the Hungarian interviewee is employed at a consulting company. In addition, the two German interviewees represent the Municipality of Hamburg. Our choice of interviewees is believed to provide us with complementary perspectives on noise abatement. However, it is worth noticing that the examples from Germany describe the specific context of Hamburg.

The structure of the report is the following:

Chapter 3 will present an inventory of how noise is handled in NRA planning today based on the results of the interviews.

On the basis of a literature survey Chapter 4 will present a short analysis of noise action plans developed in relation to the European Noise Directive (hereafter END).

Chapter 5 will include an inventory of measures of noise abatement and their estimated effect based on literature, CEDR reports and the professional knowledge and judgement of the ON-AIR consortium.

Based on the interviews and literature survey Chapter 6 will present different methods for evaluating noise and noise abatement.

Also based on the interviews and literature survey methods for assessing the burden of noise in monetary terms will be presented in Chapter 7.

All noise levels mentioned in this report are A-weighted; normally “dB” is used, but sometimes “dB(A)” is used as well.

3 How noise is handled in NRA planning today

A systematic overview of the questionnaire answers provided by the interviewees from the seven different countries/regions concerning how noise is handled by the respective NRAs can be seen in Tables 3.1 and 3.2 below. Switzerland has not been included in this overview as the replies from Switzerland covered the noise and planning situation as seen from the environmental protection administration and not the NRA. Hungary is also not included as these replies came from a consultant and not the NRA.

This review has been subdivided into the following 12 themes:

1. The main noise problems seen from the point of view of the NRA
2. NRA policy on how to handle noise problems
3. Noise in strategic planning
4. Noise in EIAs
5. Noise management of existing roads
6. Method used for prediction of noise
7. Measurement of noise
8. Guidelines for noise
9. Cost Benefit Analysis (hereafter CBA) and Cost Effectiveness Analysis (hereafter CEA)
10. Typical tools for noise abatement
11. Public participation in planning of road noise and noise abatement
12. Important factors or procedures to further improve noise management/abatement

The aspects covered by the different countries in the 12 themes are not always identical in all situations due to differences in the interview material. In Sections 3.1 to 3.6 some aspects of these themes are described in further detail and a series of good and illustrative examples from the countries are included. Activities in relation to the END are presented separately in Chapter 4.

Table 3.1: A systematic overview of the questionnaire answers provided by the interviewees from the seven different countries/regions concerning how noise is handled by the respective NRAs covering themes 1 to 6.

Country	1. The main noise problems seen from the point of view of the NRA	2. NRA policy on how to handle noise problems	3. Noise in strategic planning	4. Noise in EIAs	5. Noise management of existing roads	6. Method used for prediction of noise
Flanders/ Belgium	Noise has so far not been taken into account in spatial planning. Local roads with old surfaces - concrete slaps	When there are five or more houses in an area of 70 dB or 50 houses in areas with 60 dB a silent surface is considered	Normally not included	For new roads EIA is produced, and noise is covered in the report	Don't have much budget and have a road maintenance backlog	Dutch method, until now version 2002
Ireland	Public complaints about road tyre noise. Day-to-day maintenance of the national road network undertaken mainly by local authorities. Some undertaken by NRA	Polices exist on: - Operational noise for new roads - Construction noise - Maintaining roads and noise - Noise complaints - Noise barriers - Low noise pavements	A national development plan did exist, but now each local authority has its own County Development Plan, but noise impacts are not considered at this stage	Noise is considered early in the process and is part of the evaluation of different route corridors	NRA and local authorities look at need for new pavement and consider using less noisy pavement. Noise barriers are generally not considered on existing roads	The UK CRTN method. Produces L_{18} that is converted to L_{den} using regression analysis
United Kingdom	Existing noise, especially at night. Problems with some housing developments being built too close to roads creating noise problem, but not providing sufficient mitigation. Complaints. Health issues	Developed environmental assessment guidance for application on road projects. Noise hotspot programme for existing roads, identified through Noise Action Plans	Corporate performance reports/targets reviewed annually. Potential noise impacts considered at each stage of project development, level of assessment depends upon the likely noise problems	Guidance for assessment of noise is contained within Design Manual for Roads and Bridges	The END and Noise Action Plan process is the adopted position for tackling noise on existing roads	The UK CRTN method

Denmark	Existing traffic noise. Increasing traffic creates more noise. Lack of cheap noise mitigation measures. Lack of political will to reduce car noise. New housing too close to roads and not providing sufficient noise mitigation	On existing roads housing over 68 dB L_{den} has high priority for noise abatement. In road maintenance, noise-reducing pavements used when road passes housing above 58 dB. For new roads noise abatement over 58 dB	Normally not included	Guidance for assessment of noise in Design Manual for Roads and Bridges. Noise mapped along different lines. Number of exposed evaluated using "Noise Exposure Factor", an expression of accumulated noise load on all dwellings	From 1992 to 2008 40 mill. € to noise barriers and facade insulation, 5000 dwellings got less noise. From 2009 to 2014 53 mill. € spent. Use of noise-reducing pavements when relevant	Nord2000 Nordic prediction method. Free field calculation at facades and grid noise maps 25x25 metres
Norway	1.4 mill. inhabitants above 55 dB L_{den} dominating problem. Only low noise pavements on test sections	10% reduction noise annoyance within 2020 (1999 baseline) Number of persons above 38 dB indoors reduced by 30 % (2005 baseline)	At the highest planning level noise is usually not considered explicitly. However, noise considerations always included in plans under the municipal master plan	Noise is part of EIA. Noise considered when deciding where new roads should go and in the road layout	Noise barriers monitored to assess status, detect safety problems and to prioritise maintenance/ rehabilitation	Requirement Nord96 or equivalent. Consultants use Nord96 and NRA Nord-2000. Department of Environment considers Nord-2000 possible requirement
Sweden	Noise from existing roads due to continuous increase in traffic, which means that more people are becoming exposed	If noise exceeds 65 dB ($L_{Aeq,24h}$) at dwellings, administration is forced to carry out a noise action plan including barriers	Strategic plan 12 years ahead for all road investments	Ambition to comply with noise limits for new dwellings. Depends on technical/economic possibilities. Obliged to comply with indoor limits	Administration expects noise guidelines followed at existing road when a new urban area is planned, otherwise the plan will be appealed	Nord96: Nordic Calculation Method version 96
Hamburg Länder Germany	Noise protection still lower priority in environmental policy in Hamburg. Little action and money. Hard to establish clear ''polluter pays" principle	1. Noise Action Plan 2.Hamburg has informal working group, which handles complaints regarding road noise	Noise handled in EIA	Noise integrated in strategic road planning as a part of EIA from beginning of process. Gives strong possibility for identification and evaluation of alternative solutions	Noise management one criterion when reconstructing/ maintaining roads. Measures considered are speed reduction and traffic management	German method RLS-90

Table 3.2: A systematic overview of the questionnaire answers provided by the interviewees from the seven different countries/regions concerning how noise is handled by the respective NRAs covering themes 7 to 12.

Country	7. Measurements of noise	8. Guidelines for noise	9. CBA and CEA on noise	10. Typical tools for noise abatement	11. Public participation in planning of road noise and noise abatement	12. Important factors or procedures to further improve noise management/ abatement
Flanders/ Belgium	Used in relation to noise complaints and on new barriers and to check the reliability of the calculation model	Different limits are used like L_{den} 60 or 65 dB. Sometimes L_{Aeq} limits are used		Pavements. Noise barriers. Speed reduction. Localising of traces. Noise absorbing panels. Facade insulation	Website where people can place complaints, give advice and take possible action	For the planning phase, the EIA in our case, we really need a regulation. Measurements to control the real impact of a noise barrier
Ireland	Short- and long- time measurements are performed. Used as noise background for predictions. Before/after measurements to evaluate noise abatement	Noise design goal of 60dB L_{den} 15 years after scheme opening	Project Appraisal and CBA as part of the early strategic planning process	Distance to housing. Pavements. Barriers. Lower speeds. Steadying traffic flows	Public oral hearings on EIA. Noise is raised as an issue at these hearings	More could be done in the pavement noise issue. Measurements to test absorption and reduction of barriers. Built noise into PM-System
United Kingdom	Measurements not used		Transport Analysis Guidance software on transport modelling and appraisal methods, includes CBA. Monetary value of noise, based on house price	Pavements. Earth bunds. Barriers. Facade insulation only if criteria met under Noise Insulation Regulations	Noise page on NRA website. Website “Noise Mapping England”. For major projects always public consultation. Information events are held in local areas	Existing road network, funds for noise barriers would show NRA commitment. More stringent corporate targets in planning phase may encourage stakeholder engagement/increased customer service

Denmark	Measurements not used for planning and administrative purposes	For new roads 58 dB L_{den}. For road enlargements 63 dB L_{den} has been used. Politically defined in construction act of each project	CEA used to select most cost-effective use of noise abatement tools. Noise Exposure Factor basis of Danish CEA/ CBA of noise, price based on house and health impact	Distance to dwellings. Trenches. Barriers. Pavements. Facade insulation	Public consul-tation always used on major projects. Noise often main is-sue at public meetings. Brochures. Public hearings. Headphone listening examples. Noise website	Overall strategy and procedures for noise handling in planning, construction and operational situations im-plemented at all levels of NRA. Employees with noise knowledge
Norway	Control measurement in complex situations (tunnel openings). Measurements are used for quality assurance (intermittent sampling)	Indoor below 42 dB. 65 dB L_{den} not for sensitive constructions. 55 dB L_{den} requires noise assessment before new constructions	CBA is done according to procedures in handbook. Noise Cost 12400 NOK_{2005} per person fully annoyed per year derived by EPA based on previous expert judgement	Noise barriers. Facade and window insulation. Low noise pavements only on test sections	High public interest in noise. Public informed about plans, public meetings. Websites, leaflets. Personal handling of complaints	Research on affordable low noise pave-ments. Interdis-ciplinary co-operation in NRA. Knowled-ge dissemi-nation in NRA
Sweden	Measurements used in situations where the calculation model is insufficient, e.g. motor-bikes, bridge joints etc.	Guidance for new housing: - 30 dB indoor $L_{Aeq,24h}$) - 45 dB indoor L_{max} night - 55 dB outdoor $L_{Aeq,24h}$ - 70 dB L_{max} patio/terrace	Road analysis and noise impacts - an Excel-based tool calculating noise impact of measures due to investments or rebuilding on road network	Distance to dwellings. Noise barriers. Earth banks. Facade insulation. Tunnels in bigger cities	10 persons working with complaints. EIA includes public meetings also with noise. Not so much communication constructing noise barriers	Use of low noi-se pavement in a larger scale. Hope for better future soluti-ons. Better tools for asses-sing noise miti-gation e.g. si-lent tyres and silent cars
Hamburg Länder Germany	Measurements not used. Noise is calculated.	Guidelines for new housing and other developments. Guidelines for new and extended infrastructure. Noise Action Plan.	CBA not used on noise mitigation measures. Noise is one criterion of CBA of infrastructure projects	Pavements. Barriers. Facade insulation Local barriers near houses. Speed reduction. Steadying traffic flow	Brochures. Noise maps on website. Websites about noise	Introduce noise in all planning procedures from beginning. Consider noise protection during mainte-nance/ enlar-gement of roads. More budget. Cam-paigns on noise protect-tion importance

3.1 Planning of new roads and Environmental Impact Assessment

Strategic EIA can be performed in relation to the Directive 2001/42/EC (Directive 2001/42/EC). Concerning the assessment of the effect of certain environmental plans and programmes the Directive 2001/42/EC states that the “environmental assessment is an important tool for integrating environmental considerations into the preparation and adoption of certain plans and programmes which are likely to have significant effects on the environment [..], because it ensures that such effects [..] are taken into account during their preparation and before their adoption”. As a possible significant effect according to Annex I of the directive noise is not mentioned specifically, but issues such as the effect on population, human health and air are included. The environmental report shall contain an identification, description and evaluation not only of the plan or programmes, but also of reasonable alternatives. The report shall also take “into account current knowledge and methods of assessment”.

EIA is a tool for integrating environmental concerns into decision-making processes. It is legally based on an EU directive named the EIA Directive (85/337/EEC), the latter of which has been in force since 1985 and has been implemented in national legislation. Over the years this directive has been revised several times, with Directive 2014/52 being the current version. The EIA Directive contains a revision of Directive 2011/92, primarily stating the amendment of the latter. Important statements of the directive are the precautionary principle, the polluter pays principle and the emphasis on taking effects on the environment into account as early as possible in all technical planning and decision-making processes (EIA Directive, 2014). The EIA Directive involves public and private projects likely to have significant effects on the environment and on human beings.

Of relevance to this status report is that the construction of motorways and express roads requires EIAs. A similar requirement is set for the construction of new roads of four or more lanes to a continuous length of 10 km or more (EIA Directive, 2014). These types of projects have been made subject to assessment procedures due to their potential effect on the environment, human health and well-being.

Transport, and especially road transport, is a major contributor to human exposure to noise. High noise levels are seen by the EU as a major environment-related health concern in Europe. While the overall burden is difficult to quantify, concern is raised over the ways in which noise annoyance interferes with basic activities such as resting, studying and communicating (European Environmental Agency, 2007). In this context annoyance can be defined as a feeling of displeasure evoked by noise (WHO, 1980; Klaeboe, 2011). As such, noise is seen as a serious health hazard with a potentially negative influence on quality of life. Therefore, noise is treated as a side effect of road projects together with air, water and soil pollution, vibration, light and so on.

The interviews forming the basis of this status report reveal different procedures for integrating environmental assessment in the planning of new roads. Table 3.3 summarises some planning and working procedures in the selected CEDR countries. The aspects covered by the different countries are not always identical in all situations due to differences in the interview material.

Table 3.3: Overview of noise planning and working procedures (based on the interviews).

	Planning and working practice
Belgium	• NRA responsible for carrying out measurements and for advising local governments and inhabitants • For new roads EIAs are made, with noise covered in the report. There is no uniform regulation, meaning that the limited values used differ from EIA to EIA. Neither is the difference between old and new condition taken into account • For existing roads there is a classification system of 27 zones. The higher on the list, the higher the priority (classification based on exposure score)
Ireland	• NRA responsible for strategic noise mapping on the national road network. Local authorities responsible for action planning • Guideline on how to handle noise in different situations (e.g. EIA for construction of new roads, maintenance and handling of complaints) • For new roads the first stage is to assess and quantify existing noise environment, typically in the proximity of the proposed road
United Kingdom	• Environmental assessment guidance developed for road projects (on the strategic road network) in a design manual • For handling of noise on existing roads, there is a noise hotspot programme identified through the noise action plans. Through these a priority list of locations for noise barriers has been made • At the strategic planning level corporate performance reports and targets are reviewed annually • Potential noise impacts considered at each stage of project development, and the level of assessment depends upon the likely noise problems
Denmark	• A core function for the NRA is analysis and EIAs for new roads and enlarging of existing roads • Guidance for the assessment of noise in relation to new roads is contained within a design manual • Noise impacts are considered at all stages in road projects. Level of assessment depends on likely noise problems
Norway	• Noise is part of EIAs and is assessed relative to land-use guidelines in force. Influences decisions over where to locate new roads • Guidelines regulate the planning of new road construction projects • The Norwegian Planning and Building Act regulates land-use planning and zoning. There is a red zone (not suitable for noise sensitive constructions) and a yellow zone (requiring mitigation efforts to satisfy requirements and noise assessment for new constructions)
Sweden	• Analysis and EIAs conducted for new roads and enlarging of existing roads • Equal practice and criteria for noise abatement for road and rail • Noise calculations carried out by the Swedish Transport Administration based on a central database with values concerning the existing road net • In relation to a new roads, enlargement or redevelopment analysis is conducted of noise exposure at dwellings with and without the new road, and with and without mitigation measures
Germany (Hamburg)	• Noise included in detailed planning of new roads and road enlargements/redevelopments • Noise management does not have priority when it comes to maintenance of existing roads • Noise integrated in the strategic planning of road infrastructure as EIA studies • In the EIAs noise is considered from the beginning of the planning process
Hungary (private consultant's view)	• Before construction work can start an EIA is required • Regulations require appropriate mitigation measures to be launched when the limit value is exceeded with more than 10 dB • Noise plays an important role in cases of particularly sensitive environments (e.g. health resort, concert hall etc.)

A shared characteristic for the selected countries is that the EIAs in general are anchored in formal procedures and strategic documents in the different countries. However, this does not secure implementation. This was also noted by our interviewees, with one noting that other objectives tend to take precedence over noise considerations, and another noting that the ability to comply with defined noise limits depends on the economic possibilities. Still, the use of EIAs seems to benefit the structuring of noise considerations. Furthermore, a result hereof seems to be that noise considerations are included in the early stages of the planning process. As noted by an interviewee from Germany, the consideration of noise throughout the planning process enhances the possibility for the identification and the evaluation of alternative solutions. In contrast, an interviewee representing a country where noise was only taken into account in the final project approval processes emphasised the challenge of such a practice.

3.1.1 Extended examples, Ireland and Denmark

Road traffic noise, as well as a range of other environmental factors, is considered during the early planning phase of new national road schemes. In the route corridor selection stage a potential impact rating (PIR) is established for each proposed route. The larger the PIR, the greater the potential noise impacts. During preparation of the EIA, all impacts at noise sensitive receptors are assessed in accordance with a design noise goal. The traffic noise design goal for new roads in Ireland is 60 dB L_{den}. This goal, along with a set of other road building requirements, can be found in Guidelines for the Treatment of Noise and Vibration in National Road Schemes (2004). The design goals determine whether or not mitigation measures are required. When the following three conditions are satisfied, noise mitigation is to be implemented: 1) combined expected maximum traffic noise level (from the new road and other traffic) in the vicinity is greater than the design goal; 2) noise level is at least 1dB above the expected level without the planned road in place; 3) the increase in noise level from the new road is at least 1dB. Ireland operates with a prediction horizon of 15 years. This means that for a road opening in 2020 the design goal applies for this year and for 2035 (referred to as the design year).

As part of EIA processes in Denmark different routes for new roads are elaborated in relation to noise and other factors such as pollution, impact on green corridors, wildlife etc. In addition, a scenario termed the “reference situation” is sketched. Here future traffic increase is taken into account. Thereafter the different solutions are compared before one is recommended. The EIA includes calculations of the types of measures which are needed to reach the defined limit values. In addition to noise barriers, noise-reducing pavements and wide greenbelts, more drastic measures are discussed in some cases, e.g. the making of deep trenches and tunnels.

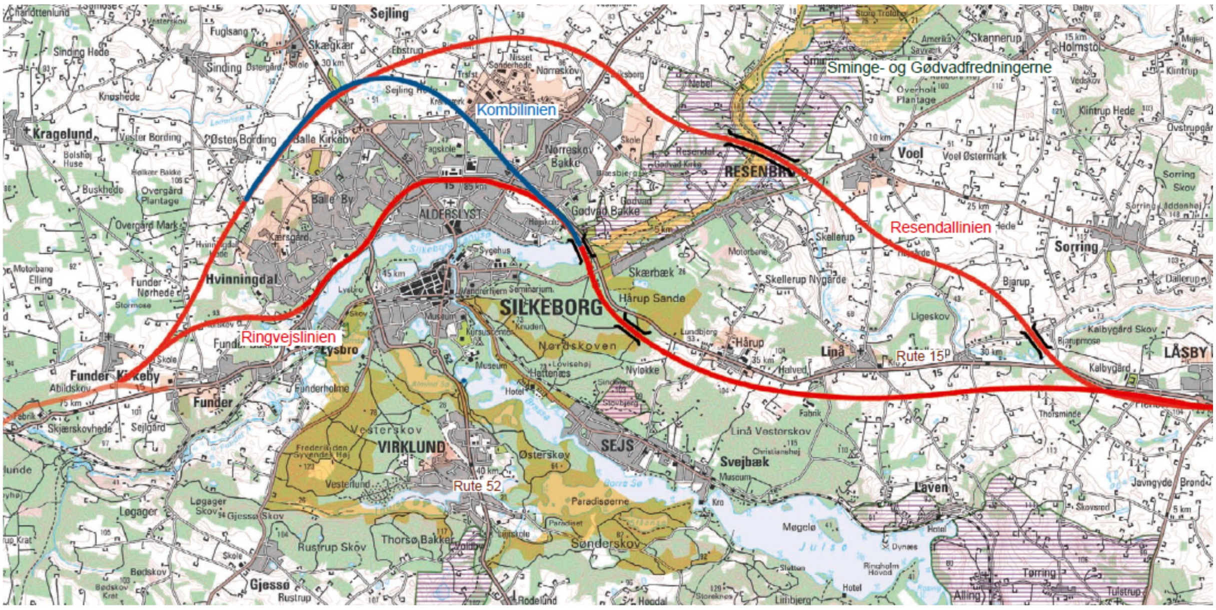

Figure 3.1: Map of the two alternatives for a new motorway near Silkeborg in Denmark chosen for full EIA. Source: DRD.

Figure 3.2: A trench under construction at the Silkeborg motorway.

In the Silkeborg area the needs of protecting the natural environment (protection of EU Habitat Areas) had to be balanced with the needs of the urban population, when a new motorway was to be built. Through the EIA process different alternatives were elaborated (see Figure 3.1). After several rounds, a route passing through urban areas was chosen. The choice of leading the motorway through populated areas required drastic noise abatement measures. A decision was thus made to make a trench where the road passes through the urban areas (see Figure 3.2). After the completion of the road, new buildings are planned in the adjacent areas. This illustrates the close relationship between quality of noise abatement and opportunities in urban development.

The following is another example of how noise was handled in the EIA conducted as part of the planning of a new motorway in Denmark between Ølholm and Vejle (Bendtsen, 2009). For the existing road network with no new motorway, the noise was mapped for 2015 taking into consideration an increase in traffic – this is called the reference situation. The existing road network includes the existing highway carrying the main traffic as well as the other roads in the district which will experience a change (primarily reduction) in traffic of 15 % or more if the new motorway is constructed. Three different routes for the new motorway have been evaluated:

- Main Solution
- Alternative 1
- Alternative 2

Noise mapping has been conducted for these situations. The number of dwellings exposed to different noise levels has been counted on the basis of the noise mapping and the Noise Exposure Factor (hereafter NEF) (for more information on NEF see Section 6.3.1, Annex C and (Bendtsen, 2009)) which has been predicted (see Table 3.4).

Table 3.4: Summary of noise mapping. Number of dwellings exposed to noise, the NEF (see Chapter 7) and the change in NEF compared to the reference situation.

Scenario	**Total of noise exposed dwellings**					**NEF**	**Change in NEF**
	55-60 dB	**60-65 dB**	**65-70 dB**	**>70 dB**	**Total**		
Reference	272	153	197	38	660	153.8	-
Main Solution	189	159	214	0	562	122.3	-31.5
Alternative 1	201	132	222	0	555	116.2	-37.6
Alternative 2	222	133	221	0	576	119.2	-34.6

In the reference situation 660 dwellings along the road network are exposed to more than 55 dB. The NEF is predicted by multiplying the number of noise exposed dwellings with a weighing factor that increases exponentially with noise. This represents an NEF value of 153.8. In the main solution this is reduced by 98 to 562 dwellings, reducing the NEF by 31.5. Alternatives 1 and 2 represent slightly higher NEF reductions of respectively 37.6 and 34.6. The EIA discusses noise barriers, noise-reducing pavements and wide greenbelts as possible measures of noise abatement, but at this stage in the planning process no decisions were made as to which measures of noise abatement should be implemented.

3.2 Road enlargement and redevelopment projects

Similar to the construction of motorways, express roads and new roads with more than four lanes, EIAs are also required for some changes to existing roads. This is the case when roads are realigned and/or widened to provide four or more lanes to a continuous length of 10 km or more (EIA Directive, 2014). There are also similarities between the practical handling of new roads and road enlargement/redevelopment projects. With or without an EIA noise is often taken into consideration in enlargement and redevelopment projects.

While some noise mitigation measures are applied in large scale, others are more often used in specific research and pilot projects. One of the most used measures is noise barriers.

Ireland is among the countries that extensively apply noise barriers in mitigation work; the country even has a specific policy on barriers and where to place them.

When a road is to be enlarged or redeveloped noise calculations are often carried out with and without barriers. This is the established procedure in Sweden where the enlargement or redevelopment of roads implies analysis of noise exposure at dwellings with and without the changed road, and with and without the presence of mitigation measures. In Denmark noise barriers are typically established when noise exceeds the before-mentioned limit of 58 dB and the distance from the road to the receiver is no more than 150 m. At longer distances the barriers are considered to have no significant impact. The distance to the noise source, however, is in itself an important measure for reducing noise and this illustrates the need for integrating noise considerations into land-use planning. Again this calls for noise to be included in the early stages of planning and decision-making processes.

In Norway a wide range of noise barriers are applied. When the specific type is chosen, a wide range of factors are taken into consideration. Among these are noise-reducing effects, adaptation to cultural heritage and natural environment and effects on the road users. In an area just south of the capital Oslo, emphasis has been put on adapting the barrier to the countryside and natural characteristics of the area (see Figure 3.3). This had consequences for the choice of material used and the alignment of the barrier. The NRA concludes that the barrier has resulted in good noise-reducing effects and low maintenance costs. In addition, they find that the planting of trees close to the barrier has reinforced the desired visual effect of the construction fitting into its surroundings (Norwegian Public Road Administration, 2008).

Figure 3.3: Noise barrier in Asker, Norway. Source: Norwegian Public Road Administration, 2008.

Another type of measure in use in the selected countries is noise-reducing pavements. However, the degree to which these are applied varies considerably. In the United Kingdom the policy position is to use noise-reducing pavements before noise barriers. In Ireland porous asphalt was used in some instances; but problems were in encountered with it ravelling too quickly. Currently, a modified SMA11 is used as a “low noise pavement”.

Other measures mentioned by some of the interviewees include reduced speed, earth banks and measures at dwellings (e.g. facade insulation and window isolation).

3.2.1 Extended example, Denmark

The M3 is a motorway which functions as a ring road around Copenhagen, as well as being part of the E47/E55 European corridor that connects Sweden and Germany. In order to improve the traffic situation, it has been decided to widen the M3 from four to six lanes (Bendtsen, 2009).

The M3 motorway passes through densely populated residential districts. As part of the planning of the extension, an EIA has been carried out, including noise mappings and planning of noise abatement measures. The NRA, which is responsible for the extension, has made a great effort to inform and reach out to the neighbours of the motorway. Noise mapping has been performed for the existing situation, including the noise from other main roads in the area. On the basis of the noise mapping, the consequences of using noise barriers of different heights have been analysed. Table 3.5 gives a summary of the results. In the current situation 10,305 dwellings were exposed to more than 55 dB, equivalent to an NEF value of 1,717. By using noise barriers of respectively 3, 4 and 5 meters, the NEF value can be reduced by 149, 630 or 769.

Table 3.5: Evaluation of the effect on noise exposed dwellings and the NEF value of noise barriers of 3, 4 and 5 metres along M3.

Scenario	Number of noise exposed dwellings				Total noise exposed dwellings	Total NEF	ΔNEF
	55-60 dB	60-64 dB	65-69 dB	≥70 dB			
Existing	6,503	3,244	482	76	10,305	1,717	-
3-m barrier	5,472	2,985	526	78	9,061	1,568	149
4-m barrier	4,766	1,890	253	36	6,945	1,087	630
5-m barrier	4,027	1,663	238	35	5,963	948	769

Table 3.6: Evaluation of the price and cost-effectiveness of the different barrier solutions.

Scenario	Price per m^2 in DKK	Total price in mill. DKK	Total price in mill. €	Total price in mill. USD	ΔNEF	ΔNEF per 1 mill. DKK
3-m barrier	2,600	138	19	25	149	1.1
4-m barrier	2,380	169	23	31	630	3.7
5-m barrier	2,400	212	28	39	769	3.6

In order to evaluate the cost-effectiveness of noise barriers with different heights, the ΔNEF per mill. DKK invested has been predicted (see Table 3.6). The predictions show that a 1 mill. DKK investment in a three-metre-high noise barrier gives an NEF reduction of 1.1 and for a four-metre-high barrier the NEF reduction is 3.7 per 1 mill. DKK invested. The four-metre-high noise barrier is in this prediction slightly more cost-effective than the five-metre-high barrier and the total investment needed for four-metre barriers is 169 mill. DKK (€ 23 mill.), whereas the total investment for five-metre barriers will be 212 mill. DKK (€ 28 mill.).

The cost-effectiveness study supported a decision to use a combination of three- and four-metre-high noise barriers. The consequence of this solution was a reduction of the total NEF value by 677 at a total noise barrier cost of 162 mill. DKK (€ 22 mill.) and with an NEF reduction of 4.2 per 1 mill. DKK invested in noise barriers.

On the basis of the EIA and an evaluation of the cost-effectiveness it was decided in this specific project to use 60 dB as the noise guideline for noise exposure from the M3 motorway. 60 dB represents a significant reduction in noise for many of the dwellings situated along the M3 motorway. In order to achieve 60 dB, the following measures must be implemented:

- 17,900 metres of noise barriers have been constructed
- Noise-reducing pavements have been used
- Facade insulation at some houses close to the motorway

Figure 3.4: Noise barriers along the enlarged ring motorway around Copenhagen.

3.3 Planning and handling of noise in the construction phase

Noise is not only a source of annoyance when the roads are operating, but can in some cases also be a source of annoyance during the period of construction. Depending on the type of project the noise exposure may vary in strength and duration. When a road has to pass through rocky areas, extremely noisy spike hammers and dynamite blasting are likely to be applied, while these techniques are less required when building on sand banks and agricultural land. When constructing roads in urban areas, noise from the construction machinery and the construction process can also cause annoyance. Projects also differ with regard to time of day and week, as some work is conducted during the day and sometimes during the weekend. If a project causes strain on other types of transport, such as railroads, work can be intensified, in turn causing disturbance outside regular working hours. In situations where settlements are located close to the road being constructed and where the project period is of some duration noise handling is important to reduce the implications for the affected dwellers.

The interviews illustrate that emphasis is put on handling noise during the construction phase. This implies that the construction work is regulated by limit values which the contractors have to follow. Typically a noise plan has to be developed by the contractor, and the performance is evaluated with the use of monitoring systems. Most of the countries that participated in the interviews have noise limits for construction noise, with stricter demands during the evening, night and weekends. For example in Norway the limit is 65 dB between 07-19 on weekdays ($L_{Aeq,12h}$) and during daytime in weekends. Between 23-07 the limit value is 45 dB. These criteria become stricter for longer term activities. Switzerland is one of the countries that have no limit values. They do however have a construction noise directive stipulating that the contractor must develop a noise handling plan and apply less noisy construction methods. An example of the latter is the replacement of old vehicles and equipment with newer ones. Another interesting practice for reducing noise during the construction period is found in Ireland, where fast built barriers are used where noisy activities take place. In the United Kingdom the responsible construction firm establishes a set of noise control methods in consultation with the local authorities. This is presented in a so-called Construction Environment Management Plan (CEMP). Table 3.7 summarises procedures in relation to the construction phase. The aspects covered by the different countries are not always identical in all situations due to differences in the interview material.

Figure 3.5: Temporary wooden noise barriers built around a new road construction site.

CEDR
Conférence Européenne des Directeurs des Routes
Conference of European Directors of Roads

Table 3.7: Overview of procedures in relation to the construction phase (based on the interviews).

	Practice	Limit value in use
Belgium	• The NRA does not have a procedure for handling construction noise in detailed planning. This is handled by other authorities	
Ireland	• Fast built barriers are used in cases of high noise levels • Limit for noise from construction. Different limit levels for different times of day and weekdays • Monitoring systems often used • An environmental operating plan must be developed by the contractor, and these are also obliged to have an environmental manager monitoring the noise • In relation to particularly noisy activities information is given to the public	Maximum noise levels: • Monday-Friday 07-19: 70 L_{Aeq} (1 hour), $L_{pA(max)}$ slow 80 dB. • Monday-Friday 19-22: 60 L_{Aeq} (1 hour), $L_{pA(max)}$ slow 65 dB. • Saturday 08-16:30: 65 dB L_{Aeq} (1 hour), $L_{pA(max)}$ slow 75 dB • Sundays and bank holidays 08-16:30: 60 L_{Aeq} (1 hour), $L_{pA(max)}$ slow 65 dB
United Kingdom	• An indicative construction noise assessment is undertaken at the time of the EIA • At the construction phase the contractor decides methods for noise control in consultation with the local authority • For major projects a public consultation is undertaken, hereunder public information events. Often a website is used to inform about progress and publish reports • All affected within a set radius are sent details of the scheme and procedures to mitigate noise	
Denmark	• Construction noise limits are set by the municipality	Typical limits at dwellings are: • Daytime 07-18: 70 dB (L_{Aeq},8h) • Saturday 08-17: 70 dB (L_{Aeq},8h) • Otherwise: 40 dB (L_{Aeq},1h) (evening) and L_{Aeq},½h (night)
Norway	• Construction noise regulated during construction, with the criteria becoming stricter for longer term activities • Environmental authority has set limits that entrepreneurs have to adhere to • Alternative sleeping arrangements are offered	Limits: • Daytime 07-19: 65 dB (L_{Aeq},12h) • Evening 19-23: 60 dB. This limit also applies to daytime on Saturdays and Sundays. • Night time 23-07: 45 dB (L_{Aeq},12h)
Sweden	• Contractors have to follow noise limit values for construction work	

Germany (Hamburg)	• In Hamburg construction work is not allowed at night (22–06) • There are regulations for use of quieter equipment • No specific procedures for information to neighbours in relation to construction work, just recommendations for citizen-friendly planning	
Hungary (private con-sultant's view)	• Limit values for construction work are in place (not specifically for road construction) • Requirements for information to the public when noise limits are exceeded	• Noise limits depend on duration of work

3.4 Day-to-day maintenance of road infrastructure

Wear and tear from traffic and exposure to all types of weather, make road maintenance a continuous task. Since the materials used in the top layer pavement influence on the noise level, maintenance provides a window of opportunity for the integration of noise consideration. This means that through road maintenance a noisy top layer can be replaced with less noisy surfaces. An example of this is the use of thin layers or a two-layer porous pavement when maintaining an existing road. There are both advantages and disadvantages to such pavements. In addition to the noise-reducing effects, the two-layer porous pavement increases the road capacity during rainfall by reducing splash and spray. A disadvantage is that the pavement implies higher costs and a shorter life-cycle (Bendtsen et al., 2009).

The selected countries have different practices in relation to noise and day-to-day maintenance of road infrastructure. Similar to the redevelopment and construction of new roads, noise considerations seem to be taken into account, even if this is neither the driving force of existing projects nor the sole objective under consideration. While some of the countries do not have a specific routine, criteria for action are in other cases based on strategic documents or, as in one country, the level of public complaints.

3.4.1 Extended example, Norway

The need for maintenance does not only concern the roads themselves, but also the noise barriers. In Norway there has been an extensive programme for evaluating the status of existing noise barriers. The first mapping was conducted in the mid-2000s and the arrangement has since been adopted in other Norwegian regions. The working procedure is that students equipped with a standardised scheme have made the classifications, which have later formed the basis for updating the noise screen database and maintenance prioritising. Maintenance frequency and cost will, among other things, depend on the type of material used for the barrier. This is exemplified in a noise barrier project along a motorway outside Oslo. Here, both dwelling areas and a small boat harbour were exposed to high noise values. To maintain the view from the road towards the coastal environment a glass barrier was set up (see Figure 3.6). While serving its purpose in terms of noise reduction and aesthetics, the Norwegian NRA notes that vandalism, including breaking of glass, has resulted in high maintenance costs (Norwegian Public Road Administration, 2008).

Figure 3.6: Glass noise barrier outside Oslo, Norway. Source: Norwegian Public Road Administration, 2008.

3.5 Cooperation between NRAs and levels of government

The ways in which noise is handled are regulated by the legislative framework and distribution of power between levels of government in each country. This entails that procedures for cooperation on the handling of noise issues are likely to reflect more general organisational principles in the country in question. The interviews therefore reflect different forms of cooperation between the NRAs and the local and regional authorities.

The interviews reveal no severe or systematic cooperation problems between the NRAs and the local/regional levels of government. However, the degree of cooperation in relation to noise issues varies. In Denmark the NRA decides where to finance noise reduction measures along the existing state road network based on a set of objective criteria. While the local authorities are involved in the planning of new major roads, they have no direct influence on the extent of noise mitigation measures integrated in the NRA road projects. From the NRA perspective it is emphasised that the level of noise protection is similar from project to project, and from municipality to municipality.

An important aspect regulating the procedures for cooperation is the legal status of the established noise limits. A survey from 2010 has revealed that in most CEDR member states the noise limits have a legal status. In most Scandinavian countries the guidelines are more or less similar to the legislation (Bendtsen et al., 2009). For Norway this implies that noise is regulated based on the Norwegian Planning and Building Act (2008). Through this act a wide set of procedures is defined for how to balance different needs in planning and the distribution of power between local, regional and national authorities. This implies that while local and regional authorities may plan for a new road or settlement, such plans may be appealed by the county governor or the NRA if they are in violation with guidelines regulating noise in land-use planning. If a disagreement persists, a solution is reached by involving the ministry level. An example of such disagreements is municipalities seeking to build new settlements in areas already exposed to road noise. In relation to this, an interesting legislative proposal is found in Sweden. In situations where a municipality wants to build close to national roads, and the planned settlement is unable to comply with established noise limits, it is suggested that the municipality pays for future noise mitigation measures. If passed, this will apply to building plans started after 1 January 2015.

3.5.1 Extended examples, Belgium and Switzerland

Belgium (similar to the United Kingdom) has established a priority list of locations where noise abatement action is considered needed. In Belgium it is the five provincial departments in Flanders that produce regulations and receive complaints from citizens. As such they have a coordinating function towards the NRA. Based on shared efforts, a list consisting of 27 residential zones has been made, where inclusion is based on the individual residential zones' exposure score (L_{den}). The higher the score, the higher the ranking on the list. This procedure not only regulates the prioritising between projects, but also the financing of them. If included in the list, the national government will pay for the measures used to reduce noise. If not, there is a financial distribution between national and local authorities. The system seems beneficial with regard to rendering visible zones exposed to noise. Of vital importance in this regard is the increased budget for handling noise issues in Belgium these years. Good cooperation between NRAs and the different levels of government is of little use if there is no money for taking action.

In Switzerland the national level does the planning of new roads, with comments provided by the cantons during the process. For existing roads four-year plans are produced, establishing where to place noise abatement measures. 25 % of the costs of these projects are paid by the national authorities and the cantons pay the remaining 75 % from their share of a petrol tax and a licence plate car tax. Hence, and in accordance to the polluter pays principle, petroleum taxes are used to finance noise abatement. The income from this tax goes to both the federal and cantonal governments. Some cantons in turn distribute a portion of this money to the municipal level, the latter being responsible for roads in urban areas. The importance of access to economic resources is reflected in the great effort made to reduce noise problems outside urban areas in Switzerland. In urban areas where municipal budgets for noise abatement are limited, progress seems to be slower. Outside urban areas noise is regulated via the Swiss constitution, which means that since 1985 there has been a national obligation to reduce noise along existing roads. Action at different locations is based on trigger values. 2015 has been set as the goal achievement deadline for national roads and 2018 for county roads. While full goal achievement may be difficult within these deadlines, the funding system and the legal status of noise abatement bring the work forward. Another driving force in Switzerland is the role of the court system, as issues of noise are often brought to court by communities, inhabitants, organised groups of people and NGOs.

3.6 Communication and public participation

Involvement of the public in road projects is relevant both in relation to construction noise and road traffic noise. It is also relevant both during maintenance and construction/redevelopment. Public involvement and participation in relation to questions of noise is anchored in the EIA Directive of the EU (EIA Directive, 2014). The directive states that when a decision to grant or refuse development consent has been made, the public must be informed in accordance with national procedures and information must be made available (among other things, on the consequences of the decision). Public participation is also an integrated part of the noise action plans (described in more detail in Chapter 4).

Involvement of the public in road planning can be justified on different bases. In a normative view, their involvement can be based on a stated need for involving people affected by decisions made (see e.g. Sørensen and Torfing, 2005). In accordance with this argument, people living in settlements where noise increases temporarily or permanently in the wake of road projects should be involved. Their arguments should be heard and their opinions should be taken into account before a final decision is made. Involvement of the public can also be based on the belief that it will increase effectiveness in decision-making processes. In this view, which is often linked to concepts such as collaborative or communicative planning, involvement of the public and stakeholders is believed to make it easier to reach viable compromises (Innes and Booher, 2010). With this follows lower tension between the parties, eventually facilitating implementation (Goldsmith and Eggers, 2004). Hence, public involvement can both be related to a normative perspective (that affected parties should be included) and to an effectiveness perspective (that it eventually enhances decision-making processes). In practice there is a clear overlap between the two perspectives, as many spokespersons base their arguments for involvement on both perspectives. It is important to note, though, that involvement of the public does not necessarily entail that action is taken in relation to noise. This was evident in an example from Belgium, where the result of involving the local government and inhabitants was that the concerned noise barrier was not built. After investigating the different effects of the barrier on noise and sunlight, among other things, the participants decided not to have a barrier built. This illustrates the balancing of different needs in noise mitigation work.

NRAs often present noise impacts in noise maps based on model calculations. This can be referred to as the ‘acoustic landscape’. Here compliance in light of defined noise limits is central. There is however a ‘perceived soundscape’ represented by people who are affected by the noise. This may be different from the acoustic landscape, as it describes sound experienced for example by people living in the adjacent areas. Good planning processes need to take both into account. A given road project may, for example, be within the given noise limits, but the change in noise before and after could be significant. This change can cause negative reactions towards the project among the affected groups of people.

With the exception of one country, all the participating countries actively communicate with the public in connection with the planning of road projects. This shows how the EU requirements presented in the EIA Directive (EIA Directive 2011) impact on national legislation and central policy documents. Examples of this is the emphasis put on public participation in the Norwegian Planning and Building Act (Norwegian Planning and Building Act, 2008) as well as in more concrete guidelines regulating noise in land-use planning in Norway (Norwegian Ministry of Environment, 2012). Table 3.8 summarises procedures for communication and public participation. The aspects covered by the different countries are not always identical in all situations due to differences in the interview material.

Among the activities described by the NRA representatives interviewed are public meetings. Here the road project is typically presented via pamphlets, maps, brochures and through an oral introduction, and the participants are given the opportunity to ask questions and discuss the planned construction work. Denmark has good experiences with occasionally supplementing noise maps with listening examples at public meetings. Through a set of headphones the participants can for example hear differences in noise levels in situations with and without noise barriers or with and without noise-reducing pavements. For instance, a series of public meetings was organised in different urban areas along the ring road around Copenhagen and here the results of the EIA were presented. As this existing motorway runs through densely populated urban areas the issue of noise and noise abatement turned out to be the most important environmental subject to the hundreds of citizens who participated in these meetings.

Table 3.8: Overview of procedures for communication and public participation *(based on the interviews).*

	Practice
Belgium	• Results of noise mapping placed on the Internet, with explaining text and an option for downloading maps
Ireland	• Hearings in relation to EIA and the public is invited to meetings. Noise is among the issues discussed at these hearings • Noise maps available at home page (PDF and interactive)
United Kingdom	• Through the results in the published noise action plans and on a website (see Figure 3.7). Department for Environment, Food and Rural Affairs responsible for communicating anything to do with the END, noise mapping etc. Uses a dedicated website "Noise Mapping England"
Denmark	• Uses website containing noise maps, noise action plans, pamphlets about noise etc. • In the planning of major projects a public consultation exercise is always undertaken. Noise often the main issue at public meetings • At the public meetings an expert explains noise consequences. There are also here exhibitions with noise maps and, at times, listening examples • All affected properties within a set radius are sent details of the road scheme and proposed temporary mitigation/working practices concerning construction noise
Norway	• Procedures for public participation regulated through the Norwegian Planning and Building Act, among others the right to appeal decisions • The public is informed about plans, public meetings, NRA contact persons for the public in specific projects • Interaction with the public through websites, leaflets, brochures and personal handling of noise complaints
Sweden	• In the EIA process there are public meetings where noise issues are explained • In special cases public meetings are arranged in connection with new noise barriers
Germany (Hamburg)	• Interacts with the public through brochures, noise maps on website and websites about noise
Hungary (private con-sultant's view)	• Noise maps usually displayed on website • Public has to be informed about the planning of road construction work

Important functions of such public meetings are to reduce anxiety related to lack of knowledge and to create a shared understanding of realistic options to mitigate noise. Hence, public meetings serve both as an arena for dialogue and to prepare the public for what is to be expected from the planned road project.

Figure 3.7: Interactive noise level map that can be used by the citizens. Source: Department for Environment, Food and Rural Affairs, United Kingdom.

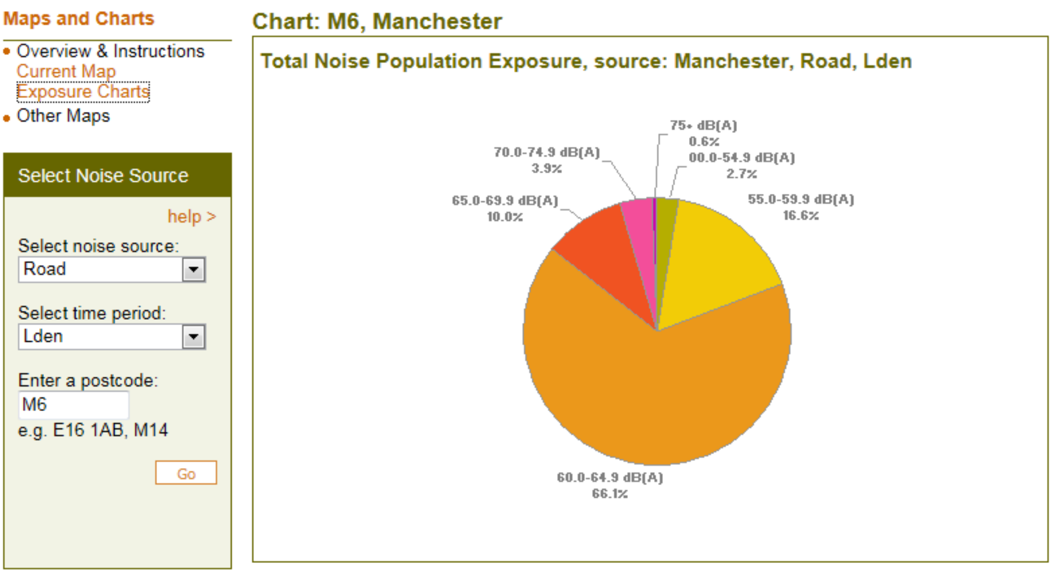

Figure 3.8: Population exposure statistics: Source: Department for Environment, Food and Rural Affairs, United Kingdom.

While the mass media is only partly engaged in noise issues, and often only when hotspot single cases arise, the Internet provides an opportunity to reach the broader population with information. This method is widely used in the countries focussed on here. Typically the Internet is used to inform the public, either through text or maps. In some cases the maps are interactive, allowing the reader to search for exposure levels in specific areas. For example, the United Kingdom has used interactive maps to show noise levels (see Figure 3.7) and figures to show noise exposure (see Figure 3.8) in specific geographical areas. In some of the countries these websites are also used for two-way dialogue, allowing people to post their opinions and complaints related to existing or planned road structures.

4 Noise action plans developed in relation to the END

Following a proposal by the Commission from 2000, the European Parliament and Council adopted Directive 2002/49/EC relating to the assessment and management of environmental noise on 25 June 2002, also known as the "END" (Directive2002/49/EC, 2002)

The Directive 2002/49/EC aims to "define a common approach intended to avoid, prevent or reduce on a prioritised basis the harmful effects, including annoyance, due to the exposure to environmental noise". For that purpose several actions are to be implemented progressively. Among these is the "adoption of action plans by the Member States, based upon noise-mapping results, with a view to preventing and reducing environmental noise where necessary and particularly where exposure levels can induce harmful effects on human health and to preserving environmental noise quality where it is good".

The most significant activities of NRAs in drawing up noise action plans can be divided into three main groups:

1. Development of noise action plans
2. Revision of noise action plans, prepared e.g. by the local/regional authorities
3. Assistance and consultation of local/regional authorities during the development of the action plan

In most European countries the NRAs have the leading role in the development and implementation of noise action plans concerning national roads. Among the interviewed countries in scope of the ON-AIR project, three NRAs are responsible for the development of noise action plans, three give assistance and consultation, and one is only responsible for the revision of noise action plans.

A systematic overview of the NRA answers to the questionnaire in relation to the END noise directive can be seen in Tables 4.1 and 4.2. Switzerland and Hungary are not included as these interviewees did not represent NRAs.

This review has been subdivided into the following eight themes:

1. Responsibilities for noise mapping and action planning performed along NRA roads
2. Cooperation with local/regional authorities
3. Information on noise mapping results
4. Effect of the noise mapping
5. Strategies and content of noise action plans
6. Common measures of noise abatement in action plans
7. Public participation in the noise action planning process
8. General experiences from the noise mapping and action planning

In Sections 4.1 to 4.5 some of these issues are described in more detail.

Table 4.1: A systematic overview of the questionnaire answers provided by the interviewees from the seven countries/regions concerning the END noise directive covering themes 1 to 4.

Country	1. Responsibilities for noise mapping and action planning performed along NRA roads	2. Cooperation with local/regional authorities	3. Information on noise mapping results	4. Effect of the noise mapping
Flanders **Belgium**	The agency of environment has the responsibility. The NRA has cooperation with this agency in relation to noise mapping	Local/regional authorities have not been involved in the preparation of noise action plans	Results on webpage with explaining text, the maps can be down-loaded. Results also published in the annual report of the agency	NRA created a priority list for noise problems. Local questions and problems addressed by local authorities and inhabitants
Ireland	National, secondary and regional roads were included. NRA designated responsi-bility for mapping national roads. Local authorities designated responsibility for all other roads. Within the larger agglomerations the municipalities mapped all the roads	Local authorities were not so happy about undertaking the noise mapping. NRA took over noise mapping technically, but local counties kept the legal responsibility. Local authorities have responsibility for actions plans on roads. NRA got the 26 plans for review	Maps available on NRA website as PDF and interactive mapping. As the maps are strategic the individual house owner cannot see the exact level. No meetings or information about the mappings in the media	Has raised the profile of noise in the engineering community of the NRA; more are aware of the situation regarding noise. Very little public reaction; the mass media picked up on initial round of mapping
United Kingdom	Department for Envi-ronment the lead de-partment for implemen-tation of the END. NRA quite involved in deve-lopment of noise maps. NRA participated in consultation about the framework process and the definition of Important Areas	Local/regional authori-ties were concerned that mapping was carried out centrally (but a secure way of obtaining robust results and meeting timetable). Involved more or less detailed action planning	Through the results in the published noise action plans and on a website	Helped identify the most affected locations. Visible demonstration for the public that authorities recognise that road traffic causes noise that should be managed
Denmark	According to Danish legislation the NRA is obliged to carry out noise maps along national roads. All NRA roads mapped	NRA carries out noise action plan for the entire national road network	Mapping is available on webpage. No reaction from the public	Some municipalities have become aware of the local noise problems and have called for reduced noise
Norway	NRA makes noise maps and action plans. Working group between road and rail authorities established by municipalities to coordinate efforts and take care of areas with overlap	The END provides information and a process that increases noise awareness. Generates dialogue between authorities. Increases aware-ness of areas that should be prioritised	Municipality uses news-paper ads. Results on NRA and municipality website. News bulle-tins. Very little feedback from the public. Some real-estate brokers have shown interest	Isolated no effect. Budget for noise abatement is connected to Norwegian legislation. The END is not harmonised with the Norwegian national transport plan process

Sweden	Swedish Transport Administration used consultants for noise mapping along major roads. Responsible for action plans for roads, railways and three airports. 13 munici-palities have carried out noise maps for agglo-merations, including national roads	No cooperation with local authorities in preparation of noise action plan as one-year deadline was too short. Noise action plan sent to municipalities for comments. 70 municipalities of 190 answered	Noise mapping been at homepage of Swedish Transport Administra-tion. Mapping has not received any public attention	END noise mapping not used for planning because noise indicator (L_{den}) is different from Swedish indicator ($L_{Aeq,24h}$). Used for scoping of schools affected by noise
Hamburg Länder Germany	NRA providing infor-mation on road infra-structure and traffic loads for noise mapping. Assistance during the development of the action plan, de-cision on which measu-res will be implemented according to action plan	Noise action plan is an official programme of the Federal State of Hamburg; the involvement of relevant authorities is obligatory	Several workshops with the citizens and Internet publication of the mapping results. Strong reactions from citizens who are using the noise maps when they want to complain about traffic noise	Noise problem has be-come visible. Most of the local authorities' noise mitigation planning is based on the mapping. But it is a problem that the END noise mapping is per-formed using another method than the normal German prediction method

Table 4.2: A systematic overview of the questionnaire answers provided by the interviewees from the seven different countries/regions concerning the END noise directive covering themes 5 to 8.

Country	5. Strategies and content of noise action plans	6. Common measures of noise abatement in action plans	7. Public participation in noise action planning process	8. General experiences from noise mapping and action planning
Flanders **Belgium**	Priority list of noise problems is used. If there are five or more houses in an area with 70 dB or higher a silent surface shall be chosen. Using barriers the goal is to get below 60 dB. A fixed budget for noise abatement	Noise barriers. Silent roads. Silent tyres. Test sections with silent surfaces. Spatial planning, but that has not started yet	Sometimes good experiences from the involvement of the public, sometimes bad experiences. 90 % of the people are positive	The good thing is that there is much more attention to noise problems. But it is not really clear what should be included in an action plan. One year to develop the action plan is too little time
Ireland	60 dB L_{DEN} is the design goal for new roads. When upgrading existing roads the goal is to try to at least keep similar noise levels. No budget for noise control has been allocated	Spatial planning. Traffic regulations. Speed regulations. Heavy traffic regulations	On website, local library and notices sent out in local papers. No public meetings	Had very little impact on how noise is addressed as NRA was doing quite fine technically already. Not expensive as a lot was done in-house. From management it is more felt as fulfilling a legislation requirement

United Kingdom	Definition of an Important Area has been based on the value $L_{A10.18h}$. No limit values. Measures must assist context of Government Policy on Sustainable Development. No central budget	By-pass Low-noise pavements. Barriers. Earth bunds	Plans and on a website. Participated in consultation about framework process and definition of Important Areas. Very limited response to consultation in second round. Maps in public domain raise public demand. Managing expectations against restricted re-sources is a difficult task	The action planning approach has provided a framework for the systematic management of noise from roads. Helped NRA identify and prioritise action. Developed new practices and business procedures
Denmark	“Hotspots” are residential areas with over 68 dB. “Hotspots” identify areas which are included in future planning of noise barriers. Budget for noise mitigation measures from political agreements in parliament	Noise barriers. Facade insulation for dwellings exposed to more than 68 dB (L_{den}). Low-noise pavements used around urban areas with dwellings with over 58 dB in connection with the regular pavement maintenance programme	Noise action plan was sent to eight week public hearings. The NRA received 32 responses. Focussed on local noise problems and demands of reduction	Having a systematic noise management framework has been positive, as well as having the data available to enable any measures to be prioritised
Norway	Action plans are based on Norwegian regulation and limit values. No specific budgets to satisfy the END	Strategy to reduce noise closest to the source. Most important measures not under NRA control (silent cars/tyres). Low-noise pavements considered but not ready for use	Municipalities inform about activities, also when action plan work started. Action plans have been in public hearings, but received little response from the public	Increased awareness of quiet areas. Positive effect in providing traf-fic data and better in-put for planning. Has increased competence on exposure from different sources. Oslo has defined quiet areas
Sweden	The main criteria for selecting noise mitigation measures are based on cost-effectiveness tech-nique and economy. 100 mill. Swedish kroner for road and rail noise abatement per year	Barriers where it is possible, otherwise facade insulation or alternatively noise-reducing asphalt	No public involvement in developing noise action plans	Noise mapping with L_{den} not interesting for Swedish Action Plan. To make an action plan for 12,000 inhabitants makes a good goal for us. Now it is publicly known
Hamburg Länder Germany	Indicators used are L_{den} and L_{night}. Mea-sures with most influ-ence on noise reduc-tion to be implemented first. Criteria for mitigation measures are noise potential, costs and timing with other issues, e.g. main-tenance programme. No specific budget for implementing action plan	Speed limit. Low-noise pavement. Replacement of cobblestone. Traffic management. Bus line management; promotion of public transport Establishment of urban mobility plan and a transport model	Public discussion and forums. Public participation was constructive and useful with good suggestions for practical solutions. However, the amount of specific proposals from the public was very difficult to handle for the authorities	Positive: The first and second rounds of noise action planning made the noise problem visible. Negative: Most measures introduced in the noise action plan have not been implemented yet

4.1 Noise mapping in relation to the European noise directive

In most of the interviewed countries the main criteria for including roads in the noise mapping was the END definition of major roads in the second round of noise mapping: “a regional, national or international road, designated by the Member State, which has more than three million vehicle passages a year”.

A derived criterion was the number of vehicles (more than three million vehicles, evenly distributed over the 365 days of the year). However, there were cases where local roads were not selected even though they had more than three million vehicles per year. Some countries decided to carry out noise mapping for the entire national road network in order to get a complete overview of the noise situation. This was the case in Denmark and Switzerland. Switzerland is not an EU Member State and is thus not required to implement the END, but the country nevertheless has cutting-edge solutions to noise management. One of these solutions is a database-driven system SonBase (Swiss Noise Database) which carries out noise calculations for all major road and rail noise sources in the entire country. SonBase is an example of a valuable noise abatement tool which has many potential applications, such as monitoring noise, establishing acoustical principals for future projects and plans, conducting analyses based on different criteria and thresholds and undertaking CBAs of existing or planed noise abatement measures (Ingold, Köpfli, 2009).

Noise maps have a significant influence on the practice of handling noise in the NRAs. Making noise problems visible they facilitate NRAs identify the most affected areas. In addition, the action planning approach has provided a framework for systematic management of road noise.

However, some countries have experienced difficulties implementing the END noise maps into further planning processes, as national noise indicators are not identical with the indicators provided by the END. For instance, in Sweden the END noise maps are not used for planning purposes, because the noise indicator (L_{den}) is different from the Swedish indicator ($L_{Aeq,24h}$). Another example is Germany, where no noise indicator for the 24-hour day is used. The German “day” (6-22 hours) also differs from the END day (6-18 hours). In addition, the calculation methods differ in numerous ways. On the other hand, some countries have implemented L_{den} as the national noise indicator, including Denmark.

4.2 Public participation process of noise mapping

Article 9 of the Environmental Noise Directive stipulates that strategic noise maps and action plans must be made available to the public, and that they must be clear, comprehensible and accessible.

Many of the interviewed countries have chosen to publish the strategic noise maps online on the website of the mainly responsible administration or on specialised noise mapping portals. Furthermore, they have used newspapers, public meetings and workshops as a basis for public participation.

Most of the interviewed countries stated that the results of the noise mapping generated none or very little response from the public, with the exception of Germany where noise mapping triggered strong reactions from the public. As a result, German citizens often use noise maps as an argument when they complain about traffic noise.

4.3 Noise action planning in relation to the European noise directive

Article 5 of the Environmental Noise Directive introduced the noise indicators L_{den} and L_{night}, which should be used as the main noise indicators in processes of noise mapping and action planning. Furthermore, some supplementary noise indicators (such as $L_{Aeq, 24h}$, $L_{A10.18h}$, L_{max}, L_{day} and $L_{evening}$) have also been used.

The END does not define any legally binding noise limit values or target levels. Thereafter, EU Member States were required to report the national limit values in force or under preparation. Generally, the Member States have taken a range of approaches. Most have set legally binding noise limit values or are currently revising them. Others have guideline values in place (Jan Vernon et al., 2010).

Some countries like Denmark have limit values that are usually followed when new urban or road development projects are developed and constructed, whereas guidelines are used in relation to existing housing and roads/motorways.

An overview of 26 countries is given in Figure 4.1, which shows the number of countries with noise limit values under revision and the number of countries with existing guideline values and legally binding noise limit values.

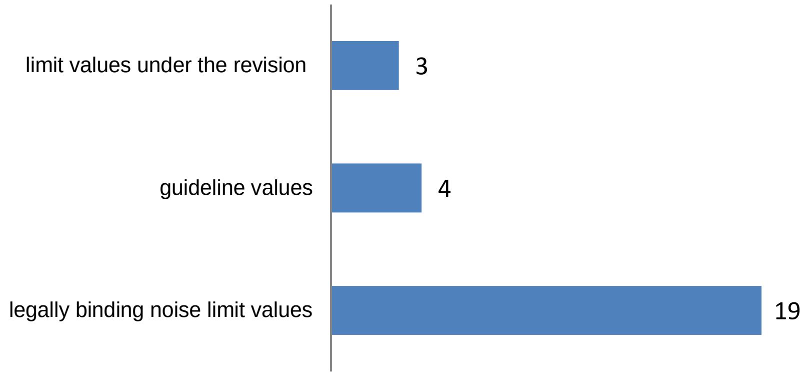

Figure 4.1: Noise limit values among European countries.

When it comes to the main criteria for selecting noise mitigation measures, the interviewed countries used several approaches. Priority was given to measures with the greatest noise reduction potential which give the best value for the money. Low cost measures together with reduction measures at the source have often been suggested. The most common measures in noise action plans are noise barriers and noise-reducing road surfaces.

The used measures are listed in Figure 4.2*Figure 4.2:* . It is important to clarify that these numbers just show measures mentioned in the ON-AIR interviews. Some of the measures that were mentioned by only a few countries surely are also applied in other countries. However, the focus with regard to noise mitigation is clearly not on traffic regulating measures such as speed reductions, vehicle ban and traffic management.

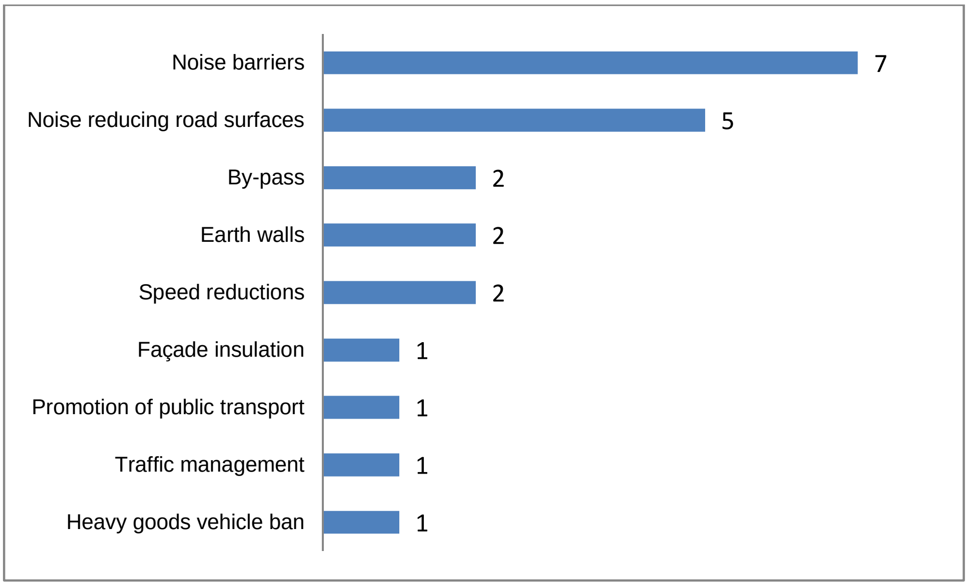

Figure 4.2: Noise mitigation measures included in noise action plans – results of ON-AIR interviews.

In practice, CBAs are rarely used for the evaluation of different noise reduction measures in the process of noise action planning. For more details on this subject see Chapter 7.

Financing of noise mitigation measures defined by noise action plans has been a problem in the majority of the interviewed countries. Belgium is the only country that has a fixed budget for noise control in relation to noise action plans. Other countries allocate means for this purpose from NRAs or local and regional authorities budgets.

Furthermore, it was pointed out that it is difficult to apply the “polluter pays principle”, with the exception of Switzerland, where petroleum taxes are used to finance noise protection measures.

The role of the local and regional authorities in the process of noise action planning is determined by the national legislation, which determines which authority is responsible for noise action planning. Therefore, the involvement of these authorities differs significantly from country to country.

In cases where the local and regional authorities are not responsible for the development of noise action plans, these have nevertheless been consulted and invited to give comments on the measures proposed in the noise action plan. It was stated that one of the main obstacles to cooperation with local authorities is that the one-year deadline between finishing the noise mapping and producing the action plan is too short.

In Germany, Ireland and Norway local and regional authorities are responsible for the preparation of action plans also covering the national highway network.

4.4 Public participation in the process of noise action planning

According to Article 8 of the END on action planning “Member States shall ensure that public is consulted about proposals for action plans, given early and effective opportunities to participate in the preparation and review of action plans; that the results of that participation are taken into account and that the public is informed on the decisions taken” (Jan Vernon et al., 2010).

Consultation of the public was mostly conducted through the official web presentations of the local authorities and NRAs responsible for noise mapping and action planning. Still, public meetings and discussions have been the exception rather than the rule. Noise action plans generated little response, indicating poor public involvement. Most of the received responses and comments focussed on local noise problems and demands for noise reduction. However, the United Kingdom, Germany and Belgium reported positive experiences with public participation in the noise action planning process.

E.g. the German Federal State of Hamburg conducted an extensive and effective public participation process in the first round of “strategic” noise action planning. From 2009 to 2010 17 public meetings – so-called “noise forums” – were organised in cooperation with the Ministry of Urban Development and Environment and the city boroughs.

In this first round of noise action planning, 10 forums were established. For this purpose, a broad information campaign on noise distributed through the local media, the Internet and billboards promoted citizens’ participation in the development of the noise action plan. In these forums participants received information on acoustic basics, the END, noise mapping and noise action planning. Furthermore, they identified individual and general noise problems and gave suggestions for possible solutions. In total, more than 1,000 citizens took part in the public participation process identifying nearly 800 specific noise problems and possible solutions, more than half of which concerned road traffic noise. All recommendations and suggestions have been documented in a booklet for each borough (konsalt GmbH, LÄRMKONTOR GmbH, 2011).

Nevertheless, the highly effective public participation process resulted in very few implementable suggestions for the noise action planning of the Federal State of Hamburg. On the one hand, the experience of the Federal State of Hamburg shows that providing clear and accessible information on the noise problem is fundamental to ensuring effective participation. On the other hand, it also shows that the final effectiveness of this process is highly dependent on the responsible authority and its will and budget to implement the suggested solutions.

4.5 General experiences

In conclusion, the analysis of the interviews with noise experts and available literature (Fryd et al., 2013, Jan Vernon et al., 2010, Guarinoni et al., 2012, Ingold, Köpfli, 2009) shows that noise mapping and action planning in relation to the END resulted in many positive experiences. First of all, they made the noise problem visible, not only to the public, but also in the engineering community of NRAs and other authorities. Furthermore, it was possible to identify and prioritise noise hotspots across the national road network. Thanks to the first and second rounds of noise mapping and action planning, new practices and working procedures were developed. These procedures provided focus and direction for handling the noise problem. The END triggered dialogue between different authorities.

Nevertheless, the END created good experiences as well as less good experience. It was stated by most of the interviewed countries that noise action plans seem to have no real influence on the noise situation, and that most of the foreseen measures have so far not been implemented. Furthermore, many countries experienced difficulties in preparing action plans. First, it was difficult to define the content and aim of an action plan. Second, the time span between noise mapping and action planning was too short. Finally, a lack of binding limit values impeded the definition of hotspots, most affected areas and quiet areas.

When comparing the advantages and disadvantages of noise management in countries where the NRA is the authority responsible for noise mapping and action planning along the state highway network, the following conclusions can be drawn:

In cases where NRAs are in charge of noise action planning and mapping it is possible to:

- Implement a more centralised approach to noise mapping and action planning.
- Establish nationwide priorities.
- More easily coordinate the entire process from noise mapping to action planning.

Still, there are some disadvantages, including:

- Lack of more detailed insight into special local problems.
- Some of the noise reduction measures prescribed in noise action plans are not within the jurisdiction of NRAs.

The noise action planning of regional and local authorities provides a more decentralised approach which allows them to better handle local problems. Nevertheless, it has been reported that an overview of the total noise situation, e.g. along a motorway, is missing, as the different authorities merely plan for their part of the road in question. Priorities for e.g. noise barriers and new road surfaces are hard to find.

In cases where local and regional authorities have jurisdiction over noise problems on the national highways the situation is even more disadvantageous than in cases when the NRAs handle noise action. Local and regional authorities have little or no jurisdiction over measures proposed through noise action plans. This creates a large gap between proscribed measures and measures implemented. This problem presents one of the biggest obstacles to more efficient noise abatement along the national highways in Germany.

“It seems to be most appropriate that it is the same authority, which both manages and maintains the road, which should also prepare the noise action plan for the road. For example, it makes no sense that a local authority in its noise action planning lays down noise mitigation measures for roads which the local authority does not manage/own and vice versa” (Fryd et al., 2013).

A possible solution to these problems could be the process already in force in Austria, which has a long-established advisory group on noise at the national level, the Working Group for Controlling Noise (Österreichische Arbeitsring für Lärmbekämpfung, OAL), although their mandate seems to be more technical and related to the provision of technical guidance (Jan Vernon et. al., 2010).

5 Noise abatement measures

The state road network is the backbone of the major national and transnational transport corridors through Europe and it helps to ensure an efficient flow of traffic between countries, regions and cities throughout Europe.

The mission of the NRAs is to improve mobility on the roads and to help ensure that the existing infrastructure can be used effectively. This implies that the NRAs conduct work to relieve the smaller roads and direct traffic to the state's major roads, which are adapted to ensure a faster and more efficient to handle the traffic.

It also means, however, that NRAs are usually prohibited from using any of the conventional methods for reducing road traffic noise. This applies to lower speed, diversion of traffic to other roads and limitation of heavy traffic. These methods will in fact push traffic back on the smaller roads.

For example, it may cause significant economic costs to reduce speed on motorways. In Denmark calculations have been made of the impact by reducing the speed on one of the major approach roads to Copenhagen. Analyses of the impact of reducing the speed from 110 km/h to 80 km/h in the evening and night time periods on weekdays and all day on weekends, on a motorway section of 8 km, showed that the socio economic costs over a 10-year period is approximately 80 million Euro - or about 1 million Euro per kilometre per year. Society's costs, particularly due to increased travel time in this case was about 7 times higher than the gains achieved, such as reduced noise and fewer accidents.

The methods commonly used by NRAs to reduce road noise are noise-reducing asphalt, noise barriers, noise insulation of homes and good planning of new roads.

The following noise measures are briefly included in this chapter:

1. Noise barriers
2. Facade insulation of dwellings
3. Noise-reducing asphalt

Table 5.1: Example of how and how much the noise can be lowered by various means, compared to how the changes in noise level are experienced.

Noise Reduction	Can be achieved by:	Changes are experienced as:
1 dB	Remove 25 % of traffic, or reduce traffic speed by 5-10 km/h	Very small change
2 dB	Use noise-reducing asphalt or reduce traffic speed by 10-20 km/h	A barely audible change
3 dB	Remove 50 % of traffic or increase distance to the road by 100 %, or reduce speed by 15-20 km/h	An audible, but small change
5 dB	Remove 65% of the traffic or use noise berm, noise barrier or noise insulation	A considerable and clear change
10 dB	Remove 90 % of the traffic or use high noise berm, noise barrier or noise insulation	A halving of noise
20 dB	Remove 99 % of traffic or build block of flats with closed courtyard areas	A very big change

5.1 Noise barriers

Noise barriers are solid obstructions built between the motorway and the receivers along the motorway. Effective noise barriers can reduce noise levels by up to 10 dB, cutting the experienced traffic noise in half.

Barriers come in the form of noise barriers, earth berms or a combination of earth berms and noise barriers. In some cases, buildings along the road can function as a noise barrier.

Noise barriers have limitations. For a noise barrier to function, it must be high enough and long enough to block the view to the road. Noise barriers do very little good for homes situated on a hill overlooking the road or for buildings that rise above the barrier. A noise barrier can reduce the noise level by approximately 5 dB when it is tall enough to break the line of sight between the motorway and the receiver, and it can further reduce the noise level by approximately 1 dB for each 1 metre of height after breaking the line of sight (with a maximum theoretical total reduction of 20 dB).

To avoid undesirable end effects, a good general rule is that the barrier should extend two to four times as far in each direction as the distance from the receiver to the barrier. Openings in noise barriers for driveway connections or intersecting streets reduce the effectiveness of barriers. In some areas, homes are scattered too far apart to permit construction of noise barriers at a reasonable cost.

Figure 5.1: Long wooden noise barriers along both sides of a motorway protecting nearby residential areas.

Noise barriers can be quite effective in reducing motorway traffic noise for receivers within approximately 50-100 metres of a motorway. At longer distances from the road noise barriers have only a minor effect.

The effect of a noise barrier is greater on high tones than on low frequencies. Lorries give off more low-frequency noise than passenger cars. Therefore, lorries are more clearly represented in the noise picture, even though the noise level has been reduced following the construction of a noise barrier.

Noise barriers are commonly used in road construction to reduce exposure to road traffic noise. They are rarely suited in city centre locations due to the lack of space between the road and the receiver. Noise barriers are costly and are mainly used as a local abatement measure at agglomerations, when many homes can benefit from the noise barrier.

Earth berms have a natural appearance and are therefore often attractive. However, due to their large footprint, tall berms require large amounts of land. Noise barriers require less space, but may involve height restrictions due to structural requirements and aesthetic considerations. Noise barriers can be made of wood, stucco, concrete, masonry, metal and other materials. Transparent barriers can be used for aesthetic reasons and to avoid blocking the view either from the residents and/or the drivers on the road. In some countries noise barriers also have to observe aesthetic requirements for colour and texture.

Figure 5.2: Transparent noise barrier along motorway.

The surface of many noise barriers is porous, which means that it can absorb sound. This means that noise barriers do not reflect all the sounds to the other side of the road.

The illustration in Figure 5.3 gives an example of the effect of a noise barrier. On the right side of the road a three-metre-high noise barrier has been constructed. On the left side of the road there is no noise barrier. The important issue concerning the effect of the barrier is that the barrier stops the direct propagation of sound from various noise sources to the receiver. If noise levels are compared on the left and right sides of the road, one can clearly see the effect of the barrier on the block of flats.

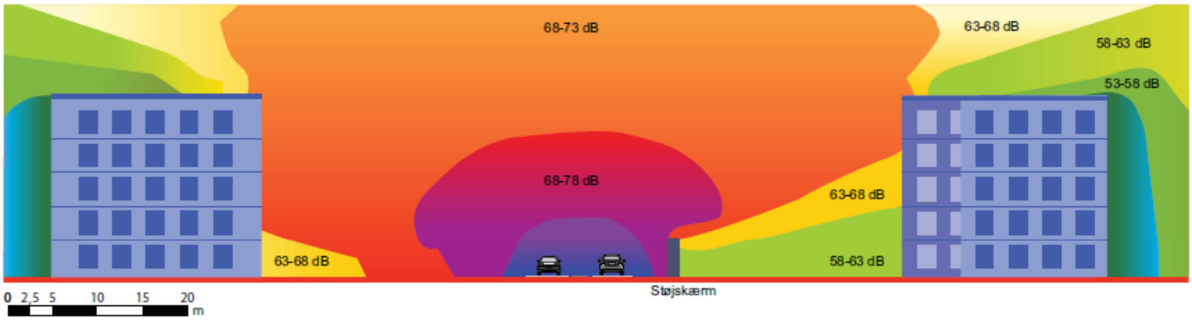

Figure 5.3: The figure shows the propagation of noise with a three-metre-high barrier and buildings which are 20 metres high. 10,000 vehicles pass by on the road every day at a speed of 50 km/h.

Figure 5.4: Motorway in a trench with high noise barriers on each side to provide noise protection to nearby blocks of flats.

5.2 Facade insulation

Facade insulation can include new windows, doors, walls, ventilation etc., and it differs from country to country how comprehensive this measure is. Facade insulation does not improve the quality of outdoor recreational areas as well as e.g. roadside noise barriers. Facade insulation is a measure used mainly for the highest noise levels, when other measures, like noise barriers, are not an option.

Figure 5.5: Extra movable noise protection placed in front of existing living room window. No noise protection has been applied to the kitchen window.

Noise is primarily transmitted through the weakest points of the building. The weakest points of a home are almost always the windows. Depending upon the isolation quality of the existing windows, upgrading the window assemblies could provide at least some relief. Replacing the windows will not help dramatically if you already have decent windows.

Window isolation quality is expressed as the Weighted Sound Reduction Index (Rw), which is a number used to rate the effectiveness of a soundproofing system or material. The higher the rating, the better the isolation quality of the window. A typical dual-pane window has an Rw value of 27-32 dB, while special soundproof windows can achieve an Rw of 37-40 dB.

In existing residences it can be very costly to replace the majority of the windows. A less expensive option, which may also produce better results, is to add a window insert to the existing windows. The window insert is placed inside the existing window sill.

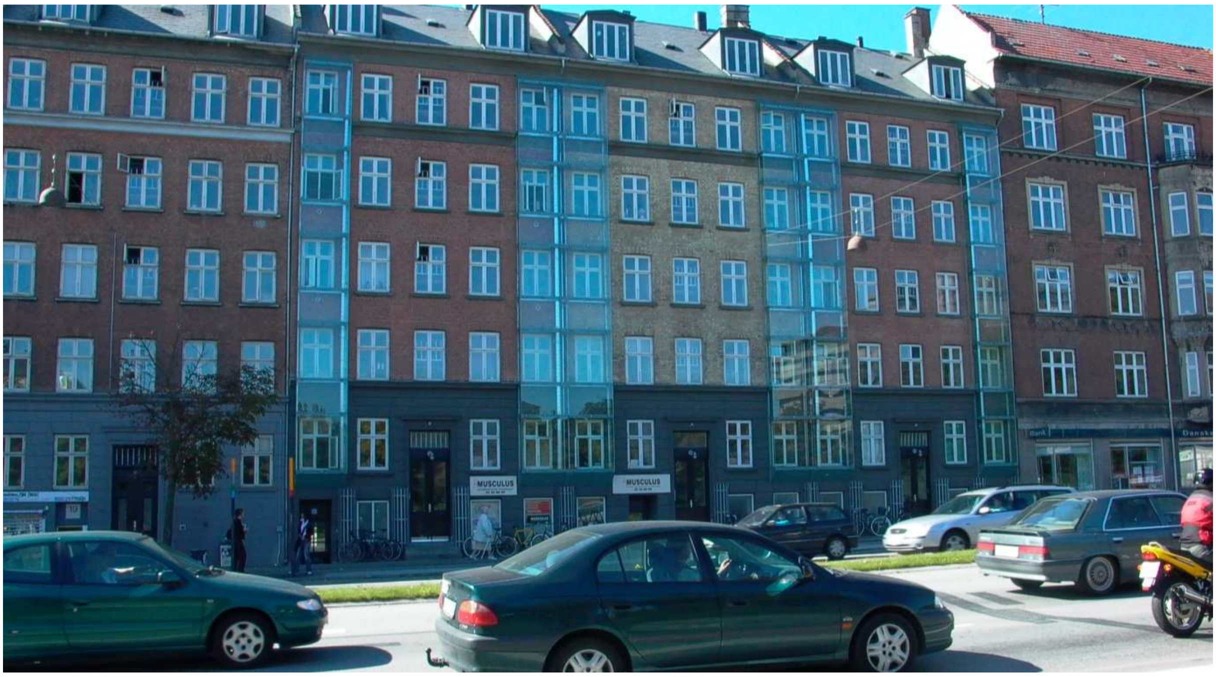

Figure 5.6: A noise insulation glass enclosure has been placed in front of the living room windows in this block of flats along a main urban road where there is no space for constructing noise barriers.

5.3 Noise-reducing asphalt

The road pavement has an influence on the amount of noise emitted from the road. Noise-reducing pavements can normally reduce the noise by 2-4 dB compared to traditional asphalt pavement, depending on the type used. This does not remove the noise, but seeing as this especially reduces the high- and medium-frequency buzzing noise caused by contact of the tyres on the road surface it does reduce the nuisance.

When a worn road pavement is replaced by a new pavement, one can easily hear the difference. The noise will then gradually increase as the pavement is worn again. This also happens with noise-reducing pavements, but the noise level remains somewhat lower all the time compared to regular pavements.

The most commonly used noise-reducing pavements are called thin-layer pavements or one- or two-layer porous asphalt. Here smaller aggregate is used than normally. This gives the pavement a more even surface and a more open structure, which means that the tyre/road surface noise is reduced. Noise-reducing pavements are expected to have a shorter lifetime than normal pavements, which have a lifetime of approximately 15 years depending on pavement type wear and tear and the use of studded tyres.

The Netherlands use both one- and two-layer porous asphalt. One-layer asphalt is less expensive, but also gives less noise reduction compared to two-layer porous asphalt. The ability of porous asphalt to reduce noise changes considerably during its lifetime, and a representative value for the average noise reduction is therefore chosen. The average noise reduction produced by porous asphalt during its lifetime is typically 2 dB and 4 dB or more, respectively, for single and double layers, compared to dense asphalt concrete, DAC11, as a reference pavement.

The noise-reducing effect of thin-layer surfaces is caused by smaller aggregate sizes, sometimes with optimised mixes to make it semi-dense or have an open-graded surface. Thin-layer surfaces are used as noise-reducing surfaces, but very few countries use these pavements to a large extent. In Denmark, a dense asphalt concrete with 11 mm aggregate (DAC11) is normally used as a reference pavement. Compared to this reference pavement, the noise reduction caused by using thin-layer surfaces is around 2 dB.

6 Methods to evaluate noise exposure and noise abatement

6.1 Noise limit values

As stated above in Chapter 4.3, no legally binding noise limit values apply for the END. Therefore, each country uses its own national guidelines and limit values, which are usually defined as a dB level expressed in the noise indicator used by the individual country.

The indicators used amongst the L_{den}, the noise indicator defined in END, include L_{Aeq24}, an “average” noise level for all 24 hours of the day, noise indicators for different parts of the day, such as L_{day}, $L_{evening}$ and L_{night}, both similar to and different from the END.

For planning purposes it can be an advantage to define methods and indicators that can sum up the “load” of noise exposure along a given road or motorway or for a given urban residential area. Based on different approaches, these can take noise annoyance or costs of noise into account, and some methods use freely selectable limits to allow for different “steps” of assessment.

6.2 Analysis of people affected

The easiest way to analyse the noise exposure or the effects of noise abatement is by using the number of people exposed to the noise. According to Annex VI, Item 1.5 of the END “the estimated number of people” affected must be established for bands of values ranging from 55 to 75 dB or more in classes of 5 dB.

It can be difficult to compare different noise abatement scenarios, as there are no “hard” limits for noise exposure which must be met. Choosing between reducing a noise of over 75 dB that affects five people or noise of 70-75 dB that affects 20 people is a subjective choice.

6.3 Analysis of noise impact and noise annoyance

Different methods exist and are used throughout Europe to more easily compare different scenarios or local situations. . However, they differ widely with regard to whether or not they take the annoyance of people into account.

The interviews touched upon the “DALY” (e.g. WHO, 2011), the Danish “Noise Exposure Factor” (e.g. Bendtsen, 2009b), the UK “WebTAG” method (WebTAG, 2013), the Norwegian “Noise Annoyance Index” (e.g. Gjestland, 2007) and methods for determining “(highly) annoyed” according to e.g. Miedema in general. Additional methods will be included in this overview.

6.3.1 Methods mentioned in the interviews

A main distinction between different methods is the requirement for a “limit value”. Some methods, such as the German LKZ (“LärmKennZiffer”, “noise index”) (Bönnighausen, Popp, 1988), are based on the exceedance of a freely selectable limit value. The LKZ for instance is the exceedance multiplied by the number of people affected without taking the annoyance itself into account. It provides a simple and explainable approach.

Other methods which focus on noise annoyance as “highly annoyed” allow no choice in limit values itself. As noise annoyance occurs even for comparably low noise levels, hotspot identification requires comparison of noise loads for given areas. An absolute identifier is not feasible.

Some methods are widely based on different aspects of noise exposure, such as the DALY method provided by the WHO. This method shall “calculate the burden of disease in terms of disability-adjusted life-years (DALYs)”, “based on exposure–response relationship, exposure distribution, background prevalence of disease and disability weights of the outcome”.

The DALY gives a single indicator of noise exposure: “DALYs are the sum of the potential years of life lost due to premature death and the equivalent years of ‘healthy’ life lost by virtue of being in states of poor health or disability”.

In Denmark, a “Noise Exposure Factor” is the basis of all CBSs of noise from road and rail traffic. “It is an expression of the accumulated noise load on all the dwellings in an area. It is calculated as the sum of the weighted noise loads on the individual dwellings in the area, so that dwellings with high noise levels weigh more than dwellings with less noise”.

Most methods that take noise annoyance into account, such as the German VDI 3722-2 (VDI, 2013), are mostly based on several earlier reports regarding noise annoyance (e.g. by Miedema, Vos, Guski and others). In general, two indicators are frequently used to describe noise annoyance: “highly annoyed” (%HA) and “sleep disturbance” (%SD). The percentage of people affected is calculated on the basis of the noise levels.

Various documents provide methods for calculating these indicators, e.g. the “Good practice guide on noise exposure and potential health effects” published by the EEA in 2010 or the “Night noise guidelines for Europe” published by the WHO in 2009.

E.g. the percentage of “highly annoyed” people according to the VDI 3722-2 is calculated using this formula, where $L_{r,TAN}$ is equal to L_{den}:

Road traffic ($42\ dB \leq L_{r,TAN} \leq 75\ dB$)	$\%\ HA = 9.868 * 10^{-4} (L_{r,TAN} - 42)^3 - 1.436 * 10^{-2} (L_{r,TAN} - 42)^2 + 0.5118 (L_{r,TAN} - 42)$

The Norwegian “Noise Annoyance Index” uses a simple linear approximation to the dose-response developed by Miedema. A method for the addition of different noise sources, such as railway and roads, is proposed, using a source-dependent constant correction factor.

The VDI 3722-2 “proposes procedures to determine characteristics for evaluating in case of impact of different types of noise sources with regard to annoyance and self-reported sleep disturbance”. The procedures comprise “a method to estimate the total annoyance based on effect equivalent continuous sound pressure levels from different types of sources”. The road traffic is “selected basically as the reference quantity for effects”. Chapter 6 of the VDI provides a procedure for investigating the effect of noise abatement measures and planning alternatives.

Other methods, such as the British WebTAG, also seem to be based on the basic principles of noise annoyance. However, the results of methods establishing the number of “annoyed” people differ and cannot be easily compared.

6.3.2 Additional methods used

The NoiseScore (NS) (Probst, 2006) is based on a function that linearly depends on the noise level L_{den}. It increases less when under 65 dB than when above 65 dB. The value derived from the function is multiplied by the number of affected parties. Since the function does not have a lower limit within its range of validity, the calculations are conducted for all level areas. Therefore, affected individuals with noise loads up to 65 dB have less bearing on the results than those who experience levels that are higher than 65 dB.

The noise inhabitants level UCE_{DEN} (Le Gouvernement du Grand-Duché de Luxembourg, 2010) is based on the logarithmic product of the de-logarithmided L_{den} and the number of affected parties. Therefore, this process differs from the other methods that link L_{den} and the number of affected parties. In contrast to the results generated by other methods, it takes some effort to sum up the UCE_{DEN} values determined in this way (e.g. hectare or building values).

The Bavarian noise evaluation measure (P-Score) (Federal Ministry of Transport, 1997) is derived from the noise level, a threshold value and the number of affected parties. The evaluation method and the threshold value can be applied in different ways depending on the task. With this function, values are determined only above a threshold that can be selected randomly.

6.3.3 Comparison

With these different methods different scenarios can be compared using just a single (or a few) indicator values. An example is given below. Here three alternatives lead to different numbers of people affected. In one case the total number of people affected by a noise of 65 dB is higher than in the other cases where the noise levels in general are lower for most inhabitants, while a few people are affected more intensively by levels of 70 dB. To make it easier to compare the scenarios, single values from the bands of the END are used.

Table 6.1: Number of people/dwellings at certain noise levels (no intervals).

Scenario	**60 dB**	**65 dB**	**70 dB**
1	50	120	0
2	100	50	20
3	110	30	30

These scenarios produce the following results using the different methods. As the DALY method is based on extensive data of the population, it has not been included in this simple comparison.

Table 6.2: Comparison of different methods for noise exposure evaluation (the scenario with the lowest rating is highlighted in green for each method, then follows orange, whereas the worst are red).

Method		Scenario 1	Scenario 2	Scenario 3
Number of people affected	> 60 dB	170	170	170
	> 65 dB	120	70	60
	> 70 dB	0	20	30
LKZ	Limit: 60 dB	600	450	450
	Limit: 65 dB	0	100	150
P-Score	Limit: 60 dB	3,181	2,605	2,715
	Limit: 65 dB	0	750	1,125
Noise Annoyance Index		64.8	62.4	62.4
Noise Exposure Factor		31.9	31.0	32.2
VDI 3722-2 (% HA)		24.6	23.4	23.6
WebTAG / Noise Annoyance		41.1	41.2	42.1
UCE_{DEN}		86.3	86.6	87.0
NoiseScore		22,920	124,522	177,516

Note: Decimals only used where necessary for distinction.

The result clearly shows that all methods prefer different scenarios. The only similarity is that the second scenario is never the “worst” scenario of the three alternatives given.

For the pure “number of people affected”, the LKZ and the P-Score results depend on the limit chosen. With a lower limit, the LKZ and P-Score also prefer the second or third scenario; with a limit of 65 dB the first scenario has a lower index. This result can easily be explained by the relevance of the limit value; that is, if a limit of 65 dB is chosen, noise levels of up to 65 dB are “accepted”. Therefore, in the first scenario no people are affected at this limit.

The “Noise Annoyance Index”, the “Noise Exposure Factor” and the VDI 3722-2 all prefer the second scenario, although the “Noise Annoyance Index” also prefers the third scenario.

WebTAG, UCE_{DEN} and NoiseScore focus on the first scenario. It is especially true for NoiseScore that the people affected by noise levels of 70 dB have a much higher significance for the overall rating than in most other methods.

6.4 Hotspot identification

Although noise maps point out areas with high noise levels, this criterion is not sufficient for determining in which areas measures are necessary, e.g. in the context of noise action planning. Therefore, in order to identify these so-called noise “hotspots”, it is helpful to combine the number of people with the extent of the noise load. This can be done individually for the facade levels calculated according to the END. However, the very large number of calculated spots makes the identification of hotspots more difficult. Hence, it is advisable to summarise the found results for the individual facade dots and to depict them as lines or in a laminar fashion.

Several of the before-mentioned methods can also be used for hotspot identification. For this purpose, the indicator values are calculated for each facade receiver point and then aggregated using different methods. The easiest method is aggregation by area. This could also be a region, a neighbourhood, a building block consisting of several homes or, generally, an evenly distributed area ("grid"), e.g. of 100 metres.

As a fact, this randomly selected grid may cause highly different results depending on the "origin" of the grid (see Figure 6.1). As discrete borders may cause single houses to belong to different grid areas depending on the origin, a more robust approach could be a "floating" summation, e.g. in a circle area for a higher resolution grid (see Figure 6.2). As this report is aimed at the networks of NRAs, some of these effects can be neglected at present, but should generally always be considered.

Figure 6.1: Shift of raster origin by 50 metres in x and y directions.

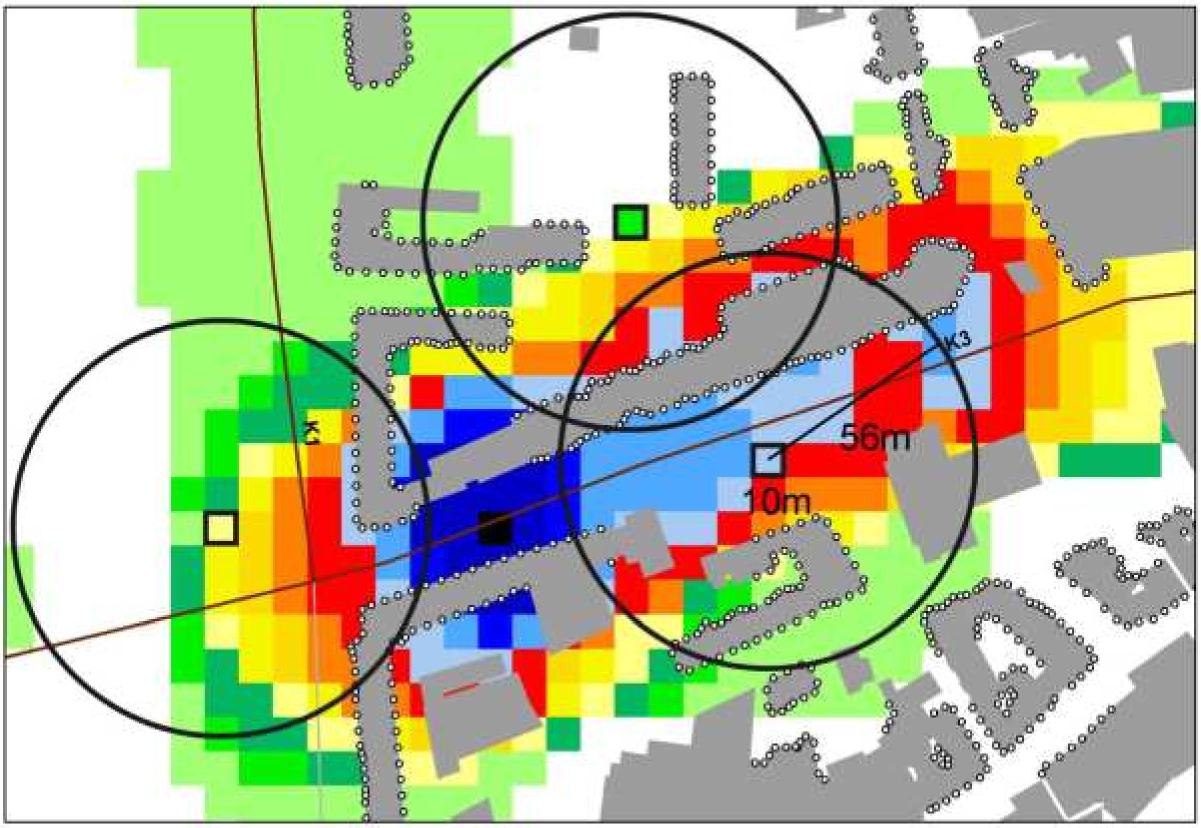

Figure 6.2: Gliding observation area – facade values are allocated to several evaluation areas.

Another summation approach could be the aggregation of calculated index values to the line-shaped noise sources. In cases where more than one source is present, e.g. in dense city areas or at railway or road intersections, a simple assignment of the values to the "nearest" source can lead to incorrect results. However, as long as a single source is present and this fact is taken into account near crossings etc. the method can be useful.

The methods LKZ, "highly annoyed", "NoiseScore", the Bavarian "P-Score" and the Luxembourg's "UCE_{DEN}" were analysed in a research project for the German Environmental Agency (UBA) on the optimisation of noise action planning ("OptiLAP"). All methods were evaluated using a town of about 100,000 inhabitants, providing several areas with a specific noise exposure.

The evaluation focussed on the 30-hectare areas with the highest indicator values. The result was that several groups of methods arrived at comparable results, although the mathematical approaches differed. Linear or mostly linear approaches such as the LKZ, the P-Score and UCE gave comparable results focussing on the number of people affected. The method "highly annoyed" gave results that focussed on the most exposed areas, whereas the result of NoiseScore was a mix of hotspots between "linear" and the "highly annoyed" approach.

7 Economic assessment of noise

7.1 Introduction

Investments in European road infrastructure demand about 50‰ and road maintenance another 25‰ of the Gross Domestic Product (GDP). Proper management of road surfaces is not only economically important, but also essential for preserving desirable properties of road surfaces such as maintenance of friction, drivers comfort, reduced road-tyre noise emissions, reduced emissions, and releases of air and waterway pollutants. Good performance on some parameters may reduce road surface performance on others; therefore, the investment, resurfacing and maintenance efforts need to balance different needs according to traffic, road type, built and natural environment as well as the use of studded tyres.

This report focusses on economic analyses of road investments, maintenance efforts and roadside measures (traditional and green noise barriers and road surface to reduce noise). The types of questions we seek to answer on the economic aspects of investing and maintaining a stretch of road are:

- How do we choose between a more durable and, at the same time, more expensive surface, on the one side, and a less expensive and less durable one, on the other?
- When does the additional cost of adding extra noise abatement elements, using higher quality components with better noise reduction or increasing the size of a noise-reducing structure exceed the additional acoustic benefits?

The types of questions we seek to answer on the subject of road pavement production are:

- Which combination and quality of materials and/or surface treatments are optimal with respect to satisfying the various and partial conflicting requirements for road surface properties (rolling resistance, road friction, low-noise durability, price, ease of deployment)?
- Which types of road surfaces are best suited to different contexts (traffic volume, vehicular fleet, neighbourhood, environment, type of road stretch)?

The types of questions we seek to answer concerning road pavement deployment are:

- What are the savings of motorists and equipment costs per kilometre by reducing the deployment time? Are these higher than the added cost of e.g. paying for more shift work?
- Is it feasible to fine-tune the laying process and pavement properties according to the local situation (e.g. thicker surfaces, surface texturing)?

The types of questions we seek to answer concerning road system asset maintenance are:

- What procedures and/or tools should be used to monitor the status of road surfaces and to generate the required statistics?
- What are the best overall maintenance strategies for road surfaces with different maintenance histories, requiring different repair, resurfacing and other efforts? What are the competing worthwhile maintenance activities for road stretches with different importance and priority, and in which stages of disrepair should they be funded and which not?

- What information is needed for providing decision support and making sound decisions?

Ideally, road surface pavements should be installed using production techniques and machinery/procedures that allow for the properties to be fine-tuned according to the traffic and environmental situation. Important aspects include traffic flow parameters (volume of passenger cars and heavy vehicles, lane usage, driver behaviour and speed of traffic) and the environment (road side environment, vegetation, distance to residential areas, layout of building blocks/structure, including the vertical dimension – number of floors), vertical distance to affected blocks/dwellings, number of people affected now and in the future.

The type of road surface, resurfacing activities and maintenance should strive for a property mix suited for the particular traffic and environmental contexts of the given stretch of road being treated. This could – at least in theory – support the seamless application of more expensive solutions resulting in greater noise reduction close to residential areas, increased friction in acceleration/deceleration areas and – whilst adhering to safety standards – prioritise lower rolling resistance on stretches where other concerns are of lesser importance.

The next best solution is to select a road surface that matches the main features of the local situation. Since each stretch of road is part of a road network expected to satisfy minimum standards and to have uniform and predictable properties, there are limits to how far local optimisation can be pushed.

Road surface replacement and/or maintenance strategies may be part of overall transportation and/or environmental packages to achieve transportation and/or environmental goals modifying some of the requirements. Changing speed limits, vehicle mix, enforcing noise emission regulation and/or using noise barriers may thus supplement road surface investment and maintenance strategies. Increases in traffic, more evening and night-time traffic may, on the other hand, increase the environmental load over time and the pressure on road managers to optimise their efforts.

7.2 Cost-effectiveness and cost-benefit analyses

The principles of cost-effectiveness (CEA) and cost-benefit analyses (CBA) are (TAG 2014):

- The impact of a scheme should be based on the difference between forecasts of the without-scheme and with-scheme cases.
- The impact should be assessed over a defined appraisal period, capturing the planned period of scheme development and implementation and typically ending 60 years after introducing the scheme.
- The magnitude of the impact should be interpolated and extrapolated over the appraisal period drawing on forecasts for at least two future years.
- Values placed on impacts should be based on the perceived costs, factor costs and market prices unit of account, converted as appropriate from factor costs using the indirect tax correction factor.
- Values should be in real prices, in the department’s base year, accounting for the effects of inflation.
- Streams of costs and benefits should be in present values, discounted to the department’s base year.
- Results should be presented in the appropriate CBA metrics, normally a Benefit-Cost Ratio (hereafter BCR).

- Sensitivity testing should be undertaken to reflect uncertainty

Economic analyses thus take into account that projects have different time profiles, and that costs and benefits that appear late in the planning period are discounted. Therefore, increasing the durability and thus the lifetime of a road surface has two beneficial effects:

- The production and road surface laying costs per year are reduced.
- Each resurfacing investment is discounted more heavily since it is pushed further into the future.

Typically, investments are done up front, and there is a period of maintenance and resurfacing at the end of the lifetime. The major expenditures are undertaken up front before the road is opened. Yearly benefits are usually much smaller than the investments, but they are delivered year after year. Their accumulated worth thus needs to be calculated.

Different European countries apply slightly different accounting principles. They differ with respect to the number of years over which a project is evaluated, the rate of discounting, whether use of public funding should be associated with taxation costs (that depriving citizens of funds also deprives them of other goods/opportunities), how to deal with VAT, fuel tariffs, costs before or after taxation etc. Projects may also differ with regard to the planning horizon and how residual values (value of investments at the end of a project period, where the infrastructure elements may still be considered to be of value) are dealt with.

For projects in a single country the national calculation regime should be applied. For EC-wide analyses and comparisons between countries it is necessary to select a common calculation framework.

In a project on green noise abatement measures (Klæboe and Veisten, 2014) valuations from a project encompassing several European countries were employed (Bickel et al., 2006). In addition, the aesthetic/amenity values of tree belts and parks that may be important for the assessment of green noise abatement measures were derived from international studies.

Note that socioeconomic analyses differ from simple calculations of costs in that it is the societal cost that is important. If a country imposes a fuel tax simply to generate income, the taxation part of the fuel price is not considered a societal cost; it is merely a change in ownership of the money, and society as a whole is believed to be just as well off after the transaction as it was before. In some situations land may be transferred from local authorities to public road authorities or vice versa. The societal costs do not include the transaction price, since the ownership of the land is irrelevant for the societal value of the property. But the opportunity cost does matter since the land is claimed for road purposes; it may thus no longer be employed otherwise.

7.3 Cost-effectiveness analyses

CEAs favour the least costly measure or group of measures achieving a predefined acoustic goal, e.g. a 3-dB noise reduction. Measures that have a more efficient design, employ fewer or cheaper materials, or cost less per dB noise reduction achieved for the affected population come out on top. A disadvantage of CEAs is that they disregard other potentially important positive or negative effects of the measures.

An advantage of CEAs is that there is no need to put a monetary value on the acoustic target; hence, CEAs can be used in situations where the monetary value of the benefits has not yet been assessed through valuation studies. This is currently the case for acoustic improvements in most non-residential settings, such as bicycle and pedestrian paths, city centres, cultural heritage and recreational areas. We lack knowledge of how often such areas are used, the duration of each visit/activity and the relationship between noise exposure and effects on human perception, well-being and health.

CEAs are often sufficient in situations where a predefined environmental limit needs to be reached or where a political decision has been made that a given acoustical improvement should be attained.

CEAs may also be used for selecting from a portfolio of potential measures and contexts. With a fixed budget earmarked for noise control purposes it is possible to use CEAs to identify contexts/measure combinations that provide the greatest acoustic benefit per unit cost. One starts by employing those measures and contexts that produce the highest noise reductions per €. After exhausting the opportunities for using the best measure/context combination, one proceeds with the second best measure/context combination etc. until the funds are used up.

Where different projects provide accumulative benefits, such as the number of people highly annoyed or a National Noise Annoyance Index, CEAs can be used to identify the policies/strategies or projects that reduce this number the most per € spent. An example would be to achieve the highest reduction of the number of highly annoyed persons for a given budget of say € 100 million.

This noise reduction policy differs from a regulative approach in that it selects areas and locations that fit the available measures and ignores areas where the context is unfavourable. The policy is more efficient than a regulative approach. The fact that it treats people exposed to the same environmental externalities differently may seem unfair, though.

One could perhaps argue that a regulative approach is best when dealing with unacceptable situations below minimum standards, whereas an economic approach might be better when dealing with improvements above minimum standards. However, in order to balance economic rationality and environmental justice it may be necessary to consider different facets, and this is a political matter.

7.4 Cost-benefit analysis

CBAs take a more holistic approach than does CEA, by expanding the scope of analysis to all impacts on those affected by the measure. Road surfaces have many properties, each of which can be assigned a value. The objective of CBAs is to achieve the best overall performance in money terms versus the cost. The CBA approach is more demanding than a CEA, because all relevant effects need to be assigned a monetary value. When such assignments are available, the cost-efficiency of a noise reduction method can be calculated. Note that *efficiency* is different from *effectiveness*.

Figure 7.1: The results of a CBA are often given in the form of a Benefit-Cost-Ratio (CBR). Values above one (BCR > 1) are cost-efficient. However, to be competitive projects should be robustly efficient (BCR > 2).

A measure should have a high socioeconomic efficiency (large benefits versus costs), whereas the cost-effectiveness of a measure should ideally be low (cost per achieved unit improvement).

When considering the cost-efficiency of a project we are interested in the full set of effects. We want to maximise the sum benefits relative to the sum costs. In some cases a noise reduction measure can create multiple benefits, and their accumulated worth will improve the social efficiency of the project. In other cases, e.g. when a noise screen ruins the visual aesthetics of a landscape, separates one part of a community from another or acts as a noise reflector (if an absorbing barrier is not used) so that other groups of people are adversely affected, the overall benefits are reduced.

7.5 Revealed and stated preference studies

Revealed preference studies, such as the hedonic pricing method, are often used to assess the monetary value of local public goods, like noise. In the hedonic pricing approach, the price differential when purchasing or renting houses or apartments with different properties, including acoustic environment, urban greenery, access to public transport etc., is analysed.

Hedonic pricing studies need to take into account all housing characteristics that are likely to affect the selling price (size, building quality, number of bathrooms etc.). Based on hedonic pricing methodology statistical techniques are used to extract the relative importance of e.g. the acoustical quality, vibrations and aesthetics for the valuations. However, the value of such regression analyses depend on the availability of suitable indicators, a sufficient number of dwellings (respondents) and sites. Whilst several studies provide unit values for reducing noise by 1 dB, the valuation of other factors may be scarce or lacking.

An alternative economic assessment to hedonic pricing is the stated preference approach. In this approach people are asked how much they value different aspects of their environment. One popular method for eliciting such valuations is choice experiments. Here people are presented with choice alternatives, systematically choosing between the attributes of different alternatives and thus facilitating statistical analyses of which factors are the most important. Using the stated choice methodology has the advantage that it is easier to extract

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valuations of particular aspects of an environment – such as its perceived restorative properties – e.g. by incorporating one or two relevant “willingness to pay” questions in socio-acoustic or soundscape research efforts already employing questionnaires.

In most cases the aim of the stated preference methodology is to determine individuals’ willingness to pay from their own funds for an improvement in some public good quality. One type of question could elicit the respondents’ use of municipal or state funds for increased/decreased availability of restorative areas, changes in how much time is spent or the size of the entrance fee deemed acceptable. The extracted values are often given as population averages. When applying the values it may be useful to consider subpopulations and contextual factors. Noise sensitive persons may perceive noisy areas to be considerably more annoying than non-sensitive persons.

For noise control measures, the economic values of noise reductions are available by applying unit prices, e.g. for the value of a given dB reduction, multiplied by the number of affected persons/dwellings. When noise control measures also have non-acoustic effects, these should also be assessed in economic terms. The expanded scope of CBAs may favour more expensive noise reduction methods or methods that are allowed in a CEA. If measures are aesthetically pleasing, the cost of green barriers or vegetation for noise protection can be subsidised by the contribution from the value of aesthetic improvements or other additional benefits bestowed on the recipients (Veisten et al., 2012).

If benefits exceed the costs, the BCR exceeds one (BCR > 1). To be competitive relative to other projects that apply for public funding, a noise reduction project should be highly efficient; that is, the benefits should outweigh the costs by a factor of two or more (BCR > 2).

Uncertainties are usually associated with both the cost and benefit estimates. Factors and aspects that have not been assigned a monetary value, or for which the monetary value is deemed uncertain, should be reported separately. We should also keep in mind that the costs of the measures are often dependent on the local availability of materials, scarcity of labour and strength of the competition. Sometimes there are larger uncertainties associated with “hard” cost estimates than with “soft” benefit estimates.

7.6 Noise control and soundscape approaches

The traditional noise control approach focusses on areas exceeding certain noise levels using regulation (noise zones, limits and guidelines) and financial disincentives (polluter pays) to limit adverse effects on life quality and health. However, one should be aware of the emergence of an additional socio-political and economic rationale in urban areas. Promoters of the soundscape approach focus on the value of positive urban environments in attracting people, businesses and economic activity. The idea is that it is not enough to establish a maximum noise limit for a certain area. Politicians and city and road planners need to create positive urban qualities of areas to attract skilled labour, high-income businesses, tourists etc.

When cities are successful in creating a positive urban environment, they will attract a higher number of businesses that generate tax income and general prosperity. If neighbouring cities do not want to lose their businesses to such cities, they must take measures to match this high-quality environment. These aspects are relevant for roads passing through or bordering on urban areas that have a high value due to their economic, cultural or recreational attributes. One challenge is that valuations of the soundscape quality of public areas with cultural heritage values, valuable business environments and businesses whose customers are the pedestrians who make use of the public areas have received little attention, and the valuations are thus not clear. Furthermore, there is no accepted indicator for the health-promoting restorative properties of relatively quiet areas, and therefore it is difficult to assess the potential benefits of having access to such areas. The value of quieter areas is probably highly dependent on the context, as it depends on the relative scarcity or abundance of areas with similar attributes and/or whether there are suitable indoor quiet areas for recreation.

7.7 Valuations of noise benefits

In practice, noise reduction benefits are assigned a unit value, the size of which depends on the effects that are being assessed, the methodology that is being used and the state of knowledge. When using a unit value an average value is assigned to the noise reduction of 1 dB for each person. In some approaches the value of the noise reduction is assessed through the impact reduction in the form of a reduced number of people who are highly annoyed, annoyed or affected. In other approaches the underlying rationale of the valuation are life quality aspects (noise annoyance) and health effects.

Traditionally noise annoyance has been determined as the number of people who are highly annoyed (Schultz, 1979). Socio-environmental studies typically show that the number of people who are highly annoyed increases more rapidly when the noise levels increase. See Figure 7.2.

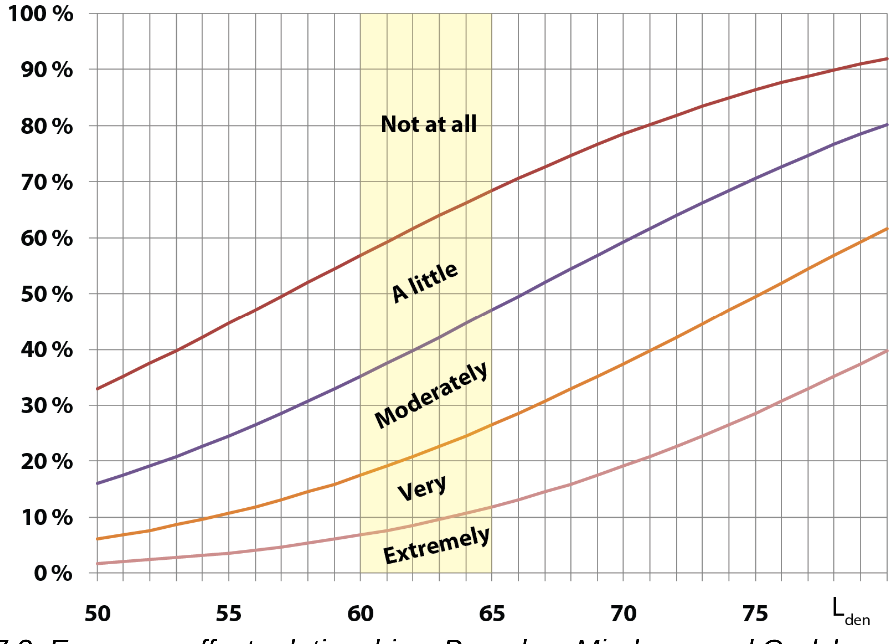

Figure 7.2: Exposure-effect relationships. Based on Miedema and Oudshoorn, 2001.

This means that a noise reduction from 70 to 69 dB should be valued higher than a reduction from 55 to 54 dB, because the reduction of the number of highly annoyed people is greater at higher noise levels (steeper slope). Norwegian authorities spend 1,548 € per highly annoyed person per year (2011 values). The number of highly annoyed persons is calculated with the programme VSTØY. When using other calculation tools the valuation is based on dB, and a value of 34.30 € per person per dB per year is used (2011 values).

It is not only the steepness of the slope that matters, though, but also the number of people who benefit. Most people live in dwellings with low noise levels. This means that noise reductions at lower noise levels often benefit more people (see Figure 7.3).

The annoyance score for each degree of annoyance can be determined based on the number of scale points. The scale points are translated into a number between 0 and 100. One can then use linear regression to estimate the average annoyance score for a given noise level (see Figure 7.4).

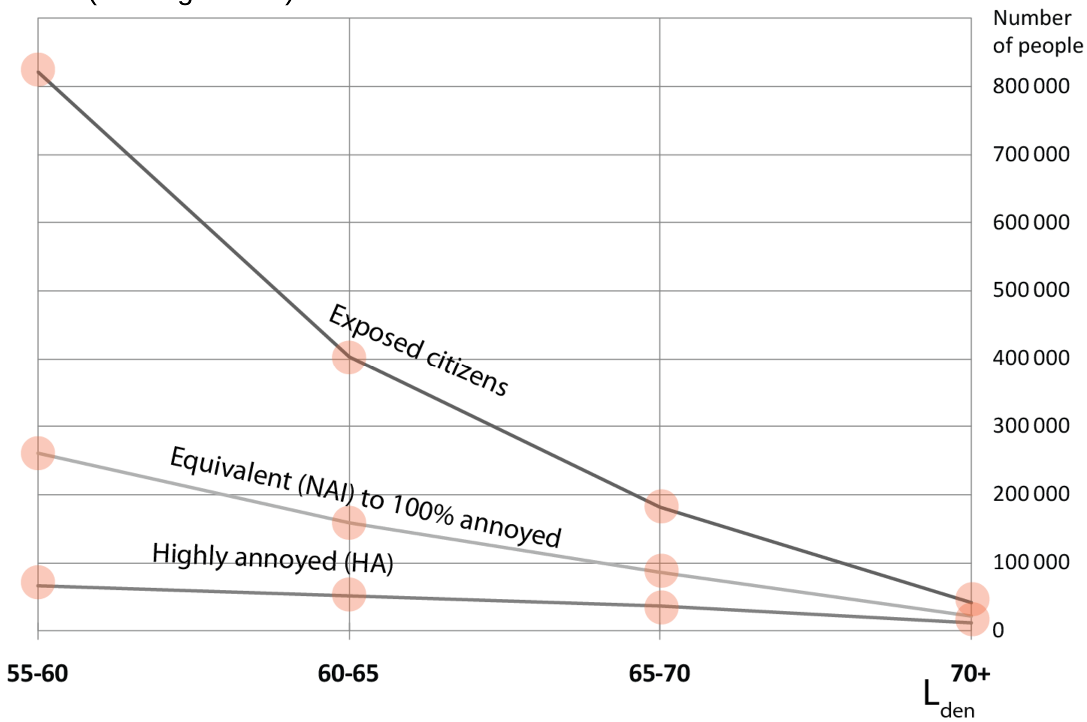

Figure 7.3: Number of people affected, "annoyed" (as indicated by the NAI) and highly annoyed by equivalent road traffic noise exposure (L_{den}), Norway (Klaeboe, 2011).

The equivalent number of highly annoyed persons (NAI) is derived from exposure-effect relationships. Each annoyance category is assigned a score, and the average annoyance at a given noise level is calculated. For road traffic noise the relationship is:

Average annoyance score = 1.55 %*(L_{den}-37). See Figure 7.4.

To calculate the total annoyance in a country the number of people exposed in each noise interval is multiplied with the annoyance score for the interval. Here is an example: 20 persons are exposed to 50 dB, and 10 persons are exposed to 69 dB.

At an equivalent noise level (L_{den}) of 50 dB the average annoyance is 20 %, and if 10 persons are exposed to this noise level the NAI is calculated as 20*20 % = 4. If in addition 10 persons are exposed to 69 dB with an annoyance score of approximately 50 %, then the NAI increases with five and we get the result NAI = 4+5 = 9.

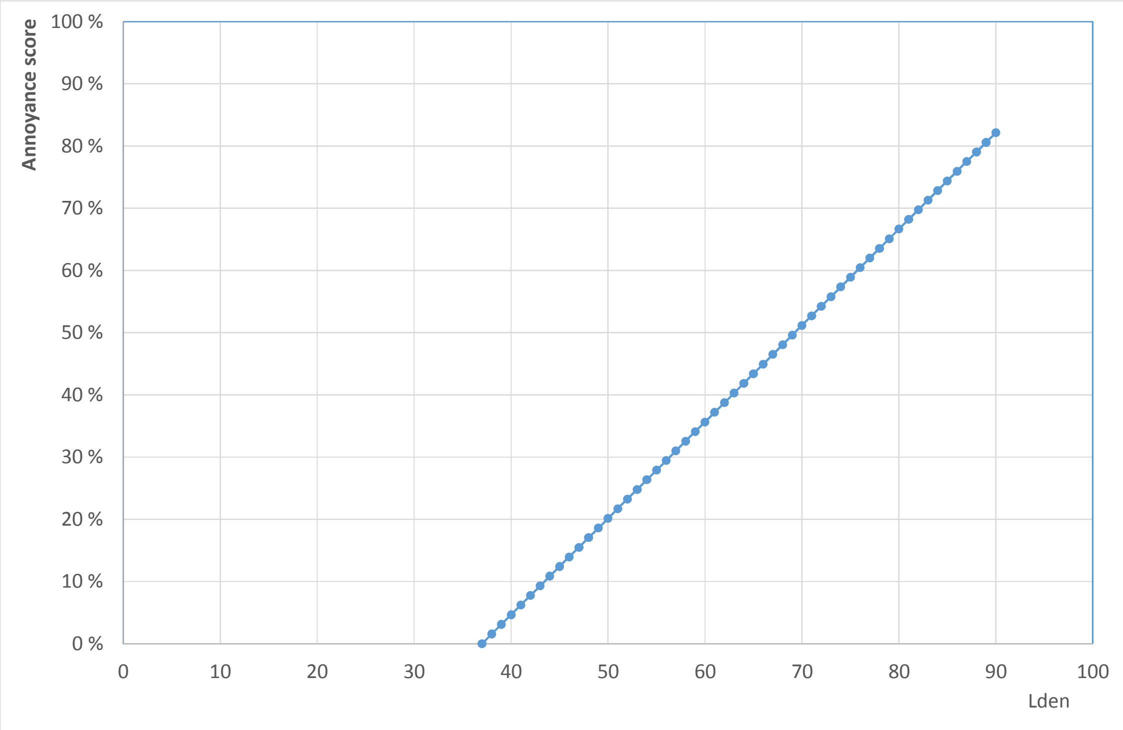

Figure 7.4: Average annoyance score as a function of noise exposure (L_{den}) in dB.

Not only amenity effects, but also the health effects of noise are believed to change more at high noise levels (typically above 60-65). In the HEATCO project (Bickel et al., 2006) noise costs were derived from country-specific valuations.

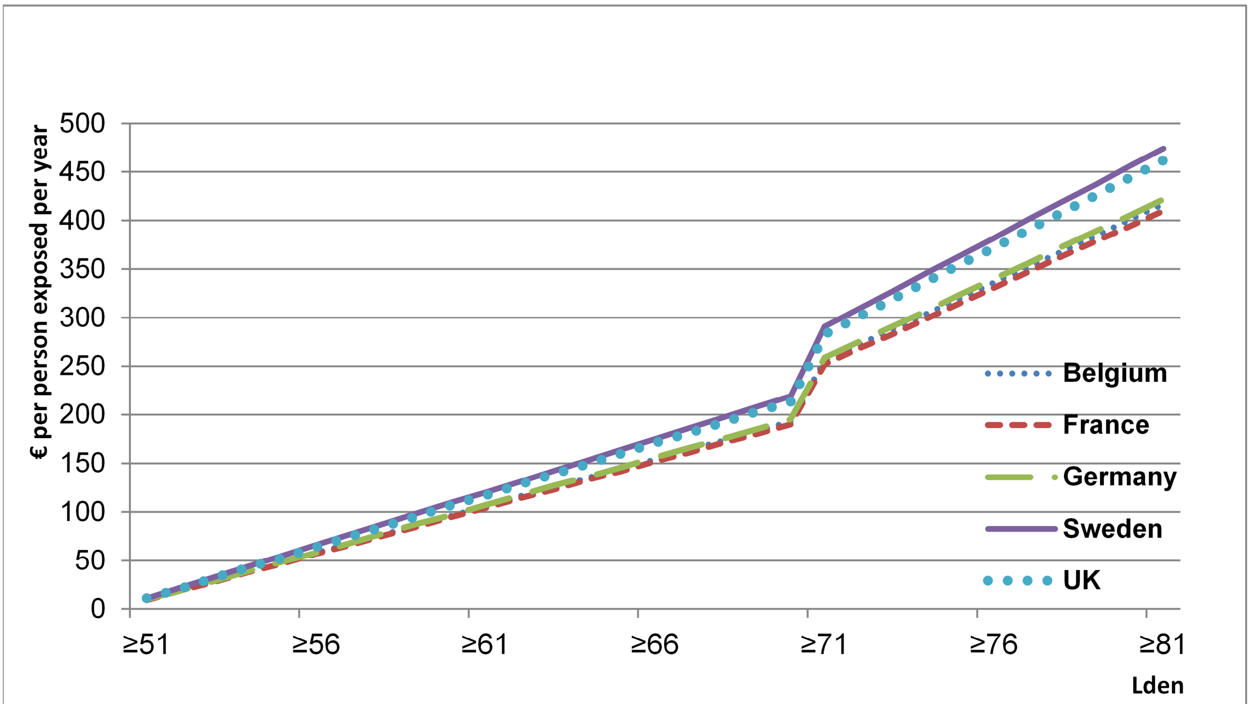

Figure 7.5: Noise cost per dB above a cut-off value of 50 dB (Bickel et al., 2006).

Two ranges were defined: 50-70 dB (annoyance) and 71 dB or more (annoyance + health – myocardial infarction). The effect of a measure is calculated as the noise after – noise before the measure. E.g. if the noise (in a Swedish case) is reduced from 71 to 66 dB for 100 people, the benefit can be calculated as (250-160)*€ 100 = 9000 €. The second range which takes health effects into account has a steeper slope.

However, the reporting of these results is less than clear, and the discussion on how the new results compare to the results of hedonic pricing methods could be improved (Navrud, 2003). Figure 7.5 could be considered misleading in that it is not obvious that it is meant to be used with a weighting factor, namely the proportion of people who are annoyed. See Bickel, 2006.

Current valuations of road traffic noise in Sweden take both life quality (annoyance) and health considerations into account. The new values are based on a hedonic pricing study (Andersson et al., 2008), where the benefit of a noise reduction is believed to be higher than in Bickel, 2006. Separate values are given for the reduction of outdoor and indoor noise, respectively. Since source measures such as low-noise surfaces provide both outdoor and indoor benefits, the total (outdoor + indoor) benefits can be calculated. For these calculations an average noise insulation of 25 dB is used. For windows/facade insulation it is the indoor benefits of a noise reduction that are taken into account. Note that the valuation is per person and not per household. The average number of persons in a household varies. (The Hosanna project used a European average of 2.4 persons per household). The benefit of a noise reduction per person per year increases depending on the baseline noise level. See Annex C.

In the United Kingdom (TAG, 2014) approach amenity and noise annoyance values are added to the independently derived health values of an increase or decrease of 1 dB. These vary depending on the noise level. See Annex C.

When health effects are taken into account, as is done in the United Kingdom, the value of reducing noise at a high level with 1 dB increases. This means that economic calculations will indicate that projects focussing on reducing noise in high-noise situations, ceteris paribus, will “pay more” than projects focussing on reducing noise levels in medium- and low-level situations. See Annex C.

In the Danish approach the value of noise reduction increases exponentially with the noise level (Jensen and Pigasse, 2013). See Annex C for details.

The Norwegian noise annoyance index is an alternative approach using the mean annoyance score. It includes not only the number of persons who are highly annoyed, but also those who are annoyed or a bit annoyed. The annoyance score of “highly annoyed” is greater than the annoyance score of “annoyed”. The method has the advantage that it takes into account the benefits of noise reductions for those who are exposed to “normal” noise levels. Another advantage is that the mean annoyance score is almost linear.

The linearity simplifies the calculation of noise benefits, since all noise reductions (above the cut-off) are treated as equal, irrespective of the baseline level. A counterargument is that long-term damages are believed to be greater at higher noise levels.

8 Acknowledgements

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Annex A: Questionnaire used for national experts

Function and role of expert

1. In which section/division of the NRA are you working?

2. What is your function?

3. If you are working with noise, please describe in what way!

General description

4. Please describe the main noise problems seen from the point of view of the NRA.

5. How would you describe the organizing of noise activities in your NRA?
    - Does your NRA have a special way of organizing noise activities, like for example a specific noise unit? If so, please describe.

6. Does your NRA have a policy on how to handle noise problems? If so, please describe the content of the policy.

7. Have there occurred any changes in the recent years in the policies on how noise is being handled? If so, please describe.

8. How could “noise management” of existing roads be defined? Any examples from your country?

9. How is the cooperation with local or regional institutions/administrations in the handling, planning and decision process in relation to noise along the NRA road network?

Activities in relation to the EU Noise Directive (END)

10. How have the development of noise mapping in relation to END been performed:
    - Which criteria have been used for selection the roads to be included in the mapping?
    - How have the public been informed about the results of the noise mapping?

11. Have the noise mapping had any effect:
    - Have the noise maps had any influence on the practice of handling noise in the NRA?
    - Have the noise mapping generated any reaction from the public?
    - Have the noise mapping generated any reaction from the local/regional authorities?

12. What were the NRA`s responsibilities for drawing up noise action plans in relation to END?

13. How has the noise action planning in relation to the EU noise directive been performed:
    - Which noise indicators and noise limit values have been used in the noise actions plans?
    - Which criteria and strategies for noise abatement have been used?
    - What are the main criteria for selecting noise mitigation measures?
    - What types of measures have been included in the noise action plan?
    - Have cost-benefit analysis been used to evaluate different measures?
    - Have budgets for noise control been allocated?

14. Have the public been involved in the preparation of noise action plans:
    - Which means including of consultation have been used?
    - What are the experiences from the involvement of the public?

15. Have local/regional authorities been involved in the preparation of noise action plans? Is this involvement voluntary or obligatory?
16. Are the noise action plans of municipalities and/or regions binding for the NRA?

17. What are the general experiences from the first and second round of noise action planning, including good and not so good experiences?

Planning and methods applied in the planning phase

18. Which methods are used for noise predictions and noise mapping?

19. Are noise measurements used at any phase in noise planning and administration? If so please describe.
20. Is noise annoyance an issue? If yes, which methods are used to predict/evaluate the annoyance from road traffic?

21. Is noise included in cost benefit analysis?
    - If so how is this done?
    - What unit cost on noise if any is used?
    - How has this unit cost on noise been calculated or defined?

22. Is noise integrated in strategic planning of road infrastructure? If so, please describe how.
    - To which extent does the noise planning at a strategic level provide a basis for good handling of noise problems?

23. How is noise handled when planning of new roads and in Environmental Impact Assessment (EIA) of evaluating alternative solutions?

24. How is noise handled and integrated when performing the detailed planning of a new road project or in road enlargement/redevelopment projects?
    - Which measures are used for noise reduction (like distance to housing, digging down the road (trenches), pavements, barriers, façade insulation, local barriers near houses, speed reduction, steadying traffic flow, etc.)?
    - Are there any criteria's for (when to) use of noise reducing measures?
    - Are there pavements distinguished after speed (e.g. inside and outside urbanized areas)?

Practice

25. How is noise from the road construction work handled in detailed planning of the road construction?

26. How is noise handled in day to day maintenance of road infrastructure?
    - Which measures are used for noise reduction (like barriers, pavements, etc.)?
    - Are there any criteria's for (when to) use of noise reducing measures?

27. Are special pavements used on bridges in your country? If so, please describe whether this gives any challenges regarding noise? Or controversy if noise reducing pavements are used on bridges does that gives any challenges regarding durability?

28. Are noisy expansion joints on bridges an issue? If so, please describe this issue.

29. Are noisy road markings an issue? If so, please describe this issue.

Communication

30. How is the communication on noise issues organized and performed with the public in relation to general information for citizens about the noise situation (existing roads) (eg noise maps on website, pamphlets about noise, websites about noise, etc.).?

31. How is public participation in the planning and decision making process regarding noise?) How to communicate the noise problems in road planning projects (EIA reports and at public meetings etc.)

32. Are there any procedures for information to the neighbors about the project, and when construction noise will occur:
    - During the planning of the construction?
    - During the construction phase?

33. How are the press/mass media handling road noise issues?

Concluding remarks

34. What are the most important factors or procedures to further improve noise management and abatement, if any:
    - Noise management along existing road
    - Planning phase
    - Construction phase

Annex B: ON-AIR Future Workshop

ON-AIR Future Workshop Friday, 25 April 2014, 8.30 a.m.-13 p.m.
Location: LÄRMKONTOR GmbH, Altonaer Poststraße 13b, 22767 Hamburg
Moderation: Margit Bonacker, konsalt GmbH
Minutes: Hans Bendtsen, Margit Bonacker

Programme

8.30 h **Arrival and registration**
9.00 h **Welcome**
Christian Popp, LÄRMKONTOR GmbH | Hans Bendtsen, Danish Road Directorate
9.15 h **Agenda of the day – Explaining method and rules**
Margit Bonacker | konsalt GmbH
Short introduction of participants – "Flash light"
9.30 h **About ON-AIR**
Hans Bendtsen, Danish Road Directorate
Examples from Switzerland
Urs Walker, Swiss Federal Office for Environment
10.00 h **I. Critique phase**:
Drawing out specific issues and problems
Producing a critical understanding of the problem
11.00 h **II. Fantasy phase**
Producing imaginations and fantasies
Constructing a "idea store"
12.00 h **III. Implementation phase**
Evaluating the concepts of the "idea store" with regard to realistic conditions
Finding the best solutions
13.00 h **Conclusions and end of workshop**

Welcome
Hans Bendtsen and Christian Popp welcomed the participants to the workshop.

Agenda of the day – Explaining method and rules
Margit Bonacker pointed to the aims of the workshop:

- Indicating international experts' experience
- Supporting adjustment to change
- Finding solutions

The concept of the "Future Workshop" goes back to Robert Jungk (1913-1994). In three phases of discussion – critique phase, fantasy phase and implementation phase – the participants will try to find new solutions and ideas.

Short introduction of participants – "Flash light"
In a short round of introductions the participants gave a "flash light" to the question: What is the most important factor for change? The answers are listed below:

Acceptance | Teamwork | Interdisciplinary work | Will | Simplicity | Integrated use of policy measures | Road engineers' thoughts on noise | Uniform regulations | Harmonisation of regulations | Noise source | Money | Monetary value | Speed limit for German "Autobahnen" | Slow driving is sexy, not driving is sexier |

About ON-AIR
Hans Bendtsen gave a brief introduction to the aims of On-Air, which is part of the CEDR Transnational

Road Research Programme. Out of the 40 million people living in European cities of more than 250,000 inhabitants are exposed to daily road traffic noise levels exceeding 50 dB L_{den}. The problems caused by road traffic noise exposure continue to grow. A unified and consistent approach is needed for the management and control of the problem (see http://on-air.no/site/background).

Examples from Switzerland
Urs Walker, Swiss Federal Office for Environment (EPA), presented experiences and examples from Switzerland.

Out of Switzerland's eight million inhabitants approximately 1.3 million people are exposed to high noise levels. Road noise is the source associated with the highest rate of effected people. There is a ban on lorries from 22 p.m. to 5 a.m. and a complete ban on Sundays. This is an old regulation from the 1960s, which may be the reason why it is generally accepted. There are parking areas where trucks can wait at night, including at the border stations. (Note: Parts of Stockholm also have night-time truck bans, and in Germany trucks are not allowed to use the motorways on Sundays).

Speed limits in Switzerland are generally 50/80/120 km/h.

Estimated costs of noise abatement along existing roads until 2018 are 3.5 bill. SF:

1. 48 % noise barriers
2. 38 % covering roads
3. 18 % windows (not considered as an optimal solution for reducing environmental noise, because people should be able to open the windows)
4. 3 % other (low-noise surface, speed reduction)

In Switzerland the “polluter pays principle” is generally valid. Federal roads are paid through petroleum taxes, and the cantons receive extra funds from vehicle taxes. This instrument has been used since 2008.
Federal funds cover more for pavements than for barriers and windows. Reimbursement at a higher percentage to the cantons.

Noise data for the entire country has been made available online, including a calculation function, which can estimate the effect of general tyre noise reductions etc. See http://www.bafu.admin.ch/laerm/index.html?lang=de.
$L_{Aeq\ 6\text{-}22}$ is used for noise mapping. The limit values for living areas are 60 dB (day) and 50 dB (night).

Measures for noise reduction in Switzerland:

- Low-noise surfaces are important, especially in urban areas. There is research on noise-reducing pavements. Problem: Noise increases over the years. In urban areas there are 155 sections with 8-mm surfaces and 99 sections with 4-mm surfaces. Research on the subject has been done by Erik Bühlmann (ETH Zürich, see http://www.isi.ee.ethz.ch/teaching/courses/ak1/buehlmann-2013.pdf). Expectations are -2 dB over long time for 8-mm pavements and -5 dB for 4-mm pavements. But pavements do not last long enough. More research is needed. Proposal: Buy the products and add noise reductions of e.g. -3 dB to the contract.
- Promotion of silent tyres; use the new EU labelling. Every autumn and spring when people typically change tyres, the EPA runs TV commercials on the labelling system to encourage people to buy the most silent tyres. If everyone uses the best tyres on the marked today, the EPA predicts a general reduction of -2 dB. Generally, silent tyres are in the same price range as noisy tyres.
- Speed limits for noise. It is difficult to get road administrations and people to accept and observe speed limits. If a 20-km/h reduction is introduced everywhere a reduction of 2 dB could be

achieved. At present, only speed limits where motorways pass by urban areas. CBAs are done on the subject.

- The behaviour of the drivers – driving patterns and thinking of noise – must change.

Summary: People must accept that noise abatement and noise-reducing pavements cost money.

Critique phase
The moderator asked the participants to identify specific issues and problems for noise reduction on roads (See Table B.1). A summary of the discussion is given below.

Even though noise is an increasing problem, noise is not a very important topic for people and politicians. A national policy is missing. In addition, there is no political acceptance that noise abatement costs money (contrary to the problem of climate change for instance. Noise experts are too modest. Focus should shift from abating noise to protecting quiet areas.

Noise is a product of wrong traffic planning, wrong urban planning and wrong behaviour. Noise and other negative effects of road traffic (safety, climate, flooding, air pollution etc.) are not seen together and are not treated in an integrated approach. Noise calculations should include all facades, not only the most exposed ones, as noise comes from all directions.

One big problem is the communication of noise and noise problems. If the public was more aware of noise and noise problems, more money would be allocated for noise abatement. Few politicians understand dB and annoyance curves and noise maps. Other ways of communicating noise and noise problems should be developed.

Very little is done on the existing road network. With regard to noise-reducing pavements, the municipalities do not know which forms of pavements they have and which to use to integrate noise reduction. So far, road people do not accept low-noise pavements because they are more expensive than traditional ones and because they are believed to wear more quickly.

Fantasy phase
In this phase the participants had to create an “idea shop”, which did not have to take into consideration the chances of realising the given items. A summary of the discussion is given below (also see Table B.2).

Again, focus was on communication and illustration of noise and the problems it causes. Pictures and acoustic examples should be used to “visualise” noise. One person suggested showing people a picture of a nice house surrounded by nature/fields and then ask them to set a price on the house. Then the fields should be replaced by a motorway and again the participants should be asked to set a price on the house. Finally, the motorway should be replaced by a noise barrier, and once again the participants should be asked to set a price on the house. Another idea was to replace the dB colours on noise maps with green areas indicating places where it is possible to sleep with the windows open and yellow areas indicating places where the windows need to be closed at night. Finally, red areas should be used to indicate places where people wake up at least once every night because of noise. Another idea was to relate housing prices with the colours on noise maps: Green areas full price, yellow areas house price 5 % reduced and red areas 10 % reduction because of noise.

It was also discussed how noise can be handled more emotionally and how it can be made attractive to integrate noise/silence into one’s “lifestyle”.

Noise considerations should be integrated into maintaining and rebuilding activities like fences, windows, guardrails and plantations in the very first stages of a project. Noise issues should be integrated into urban planning and transport planning in general. In addition, noise should be a part of the education of planners, architects and engineers.

Another idea was that the CEDR should found a school for teaching noise to professionals in Europe to help them understand the need for integrating noise in road planning and management.

Other ideas and questions were the following:

- Stronger regulation on noise from tyres and cars/engines.
- Public research on low-noise surfaces is needed.
- Widespread use of noise-reducing pavements when relevant.
- Noise issue needs big players and supporters. Whis it that German car manufacturers are unhappy with external noise reduction?
- Use health and sleep effects more actively.
- Affordable and durable noise-reducing pavements.
- Better exchange and cooperation on research in pavements in Europe.
- It is necessary to find “front-runners” in the vehicle manufacturing community.
- Public fleet owners could buy “silent” vehicles and “silent” tyres, perform “silent” driving, and communicate to the public that they do so.
- Politically defined noise limit values for the existing road network.
- Pizza delivery by electric cars and electric bikes.
- Reserve a lane on the motorway for car-pooling and buses.
- Congestion charging, as in London.
- Integrate noise in house taxes; people living in houses with high noise levels pay reduced taxes. This would give municipalities incentives to work with noise abatement.
- Integrate noise into road pricing and use the revenue for noise abatement. This is the polluter pays principle.
- Real-estate owners are often good at identifying and expressing problems concerning noise.

Implementation phase
In the last phase the items compiled in the “idea store” had to be evaluated with regard to realistic conditions and with a view to finding the best solutions. A summary of the discussion is given below (also see Table B.3).

First, there is a need for placing noise at the top of the agenda of road administrations. In addition, road administrations need to talk to environmental administrations.

In Europe stronger EU regulations on noise from vehicles are needed. The CEDR should have a voice in the EU on noise issues. There should be an EU whitepaper on costs and benefits of traffic, and this should presumably include noise costs.

Coordination of research is needed; the CEDR noise group is working on this already.

The strategic impact assessment directive is central, and noise should be included here. However, in some countries such strategic road and transport planning is not performed.

Conclusions
Hans Bendtsen thanked everyone for their participation and the interesting discussion. A vast range of interesting topics were discussed at the workshop. the following topics should be included in the handbook:

1. Integrate noise in the planning.
2. Use noise-reducing pavements.
3. Better communication of noise in projects.

Figure B.1: Discussions during the Future Workshop in Hamburg in April 2014.

Participants:

- Helena Axelsson, Norway
- Hans Bendtsen, Denmark
- Wolfram Bartholomaeus, Germany
- Ann Buytaert, Belgium
- Lars Dahlbohm, Sweden
- Jovana Dilas, Serbia
- Sebastian Eggers, Germany
- Vincent O'Malley, Ireland
- Jacob Fryd, Denmark
- Ronny Klaeboe, Norway
- Christian Popp, Germany
- Christoph Schröder, Germany
- Anders Tønnesen, Norway
- Urs Walker, Switzerland

Table B.1: Critique phase (original remarks by participants).

				Communication	
Policy - National - Local	Politically no support for extra for pavements	Not really regulations on noise emission at EU level	Health protection	Priorities!	Money!
	Lack of national policy/ambitions	Treated as an individual issue	NGOs?	Road noise -> main problems	Understanding of the problems
Organisation and cooperation	Road people do not accept that low-noise pavements have a cost/ reduced lifetime	Annoyance/nuisance		Social problem	dB is log, that means hard to explain
				Theoretical modelling of noise	Reality of noise perception
	No acceptance for “polluter pays principle“	Is noise part of urbanisation/modern living?		Conflict interest	Preserve not-noisy areas for the future
Planning and methods applied in the planning phase	Noise is a result of wrong traffic and man planning (architecture) and behaviour	Who is really responsible for noise reduction?	Main objective as road admin is much mobility – noise is only a product, which has to be handled to some extent	Noise awareness	Money ↑ ↓ Limit values ↑ ↓ Noise reduction
	Method of noise mapping is different	Joined-up thinking	Noise is a product of poor planning	Noise protectors: “Excuse me, but we need money for noise reduction …”	
Practice	Very little done on the existing roads				

Table B.2: Fantasy phase – "Idea shop" (original remarks by participants).

				Communication	
Policy	No taxes for noisy areas	Noise limits for cars and tyres		Give noise a face	Experience noise
Organisation and cooperation	Interdisciplinary work	Multimodal planning (transportation)		To use the health impact + sleep impact; very activate	Mainstream lifestyle
Planning and methods applied in the planning phase	Create parking area at the edge of the city and use public transport	Noise considered from projects Idea: the project should have a noise certificate		"Use" front-runners as good examples	mainstreaming
Practice	City noise planning	Integration of land management	Public fleet owners buy: - "silent" vehicles - "silent" tyres And perform "silent" driving		
	e-mobility for local urban transport	Car manufacturers have to talk to the tyre and road surface guys in an open manner	Widespread use of noise-reducing pavements when relevant		
	When you maintain modified things: fences, windows, plants, garden rails				

Table B.3: Implementation phase (original remarks by participants).

	Goal Measure/project			Responsibility/actors "who"	Time/ money
Policy	Stronger regulation from EU on noise emissions	Incentives for calm	Congestion charge (urban)	"Everybody" informing European politicians	White book traffic message "saving money"?
				Road directory CEDR Group	Strategy for approaching politicians/ decision-makers
	Noise taxes?	"Voice" noise -> EU -> NGOs ->mass media	Noise-integrated road pricing. Use revenue for noise abatement		GPS-oriented pricing (noise, air pollution, safety, barrier insecurity)
Organisation and cooperation	Noise issue needs supporters; "big players"			Letter to Deutscher Städtetag	
	Coordinate research →			Road administration + Inv. Adv.	
Planning and methods applied in the planning phase	Noise as a permanent "partner" in all planning processes →			Key aspect for ON-AIR	
	Integration of noise in policy packages for land use and transport system development →			Planning administration/ road administration	
Practice	Affordable, durable low-noise pavement Research = low-noise pavements Pavement standardisation			EU level (and higher)	
Communication	Use emoticons →			Noise mapping PR/magazines	Holistic approach
	Institute of CEDR on noise in planning →			Later	
	Education Schools/ universities				

Annex C: Economic assessment in the United Kingdom, Sweden, and Denmark

Table C.1: Values of changes in noise exposure used in the United Kingdom, Source: (https://www.gov.uk/noise-pollution-economic-analysis)

Volume (L_{Aeq}, 18hr dB)		**£ per household per dB change (per year, 2010 prices)**		
Low [dB]	High [dB]	Amenity	Health)	Total
55	56	£34.80	£0.00	£34.80
56	57	£37.40	£0.48	£37.88
57	58	£40.00	£2.70	£42.70
58	59	£42.70	£4.16	£46.86
59	60	£45.30	£5.67	£50.97
60	61	£48.00	£7.22	£55.22
61	62	£50.60	£8.82	£59.42
62	63	£53.20	£10.47	£63.67
63	64	£55.90	£12.17	£68.07
64	65	£58.50	£13.92	£72.42
65	66	£61.10	£15.71	£76.81
66	67	£63.80	£17.56	£81.36
67	68	£66.40	£19.45	£85.85
68	69	£69.00	£21.39	£90.39
69	70	£71.70	£23.37	£95.07
70	71	£74.30	£25.41	£99.71
71	72	£76.90	£27.49	£104.39
72	73	£79.60	£29.62	£109.22
73	74	£82.20	£31.81	£114.01
74	75	£84.90	£34.03	£118.93
75	76	£87.50	£36.31	£123.81
76	77	£90.10	£38.64	£128.74
77	78	£92.80	£41.01	£133.81
78	79	£95.40	£43.43	£138.83
79	80	£98.00	£45.90	£143.90
80	81	£98.00	£48.42	£146.42

Table C.2: Values of changes in noise exposure per exposed person per year used in Sweden, Source: http://www.trafikverket.se/Foretag/Planera-och-utreda/Planerings--och-analysmetoder/Samhallsekonomisk-analys-och-trafikanalys/

LAEq 24h ***outdoor*** (dB)	*Value SEK/year* indoor and outdoor	outdoor only
45	0	0
46	369	369
47	751	751
48	1144	1144
49	1550	1550
50	1969	1969
51	2409	2409
52	2868	2868
53	3523	3351
54	4216	3865
55	4950	4416
56	5732	5009
57	6553	5635
58	7520	6322
59	8570	7081
60	9659	7889
61	10807	8745
62	12001	9694
63	13343	10833
64	14816	12101
65	16323	13462
66	17943	14972
67	19631	16645
68	21531	18560
69	23625	20614
70	25890	22813
71	28383	25163
72	31309	27670
73	34431	30344
74	37755	33187
75	41328	36211

Average noise insulation 25 dB
Outdoor vs indoor weight 60/40

LAEq 24h ***indoors*** (dB)	*Value SEK/year* indoor only
25	0
26	246
27	501
28	763
29	1033
30	1312
31	1600
32	1916
33	2225
34	2569
35	2958
36	3339
37	3757
38	4215
39	4721
40	5259
41	5830
42	6463
43	7223
44	8068
45	8975
46	9982
47	11097
48	12374
49	13743
50	15209

Average noise insulation 25 dB
Outdoor vs indoor weight 60/40

The Danish values are expressed as DKK per NEF. NEF is short for Noise Exposure Factor and is a unit used in Danish social cost calculations in relation to noise. NEF expresses the total nuisances in a defined geographical area and is calculated as a sum by weighing of households exposed to different noise levels. The weighing factor follows an exponential curve and is calculated using the formula below. Weighing factor = $0.01*4.22^{(0.1(Lden-44))}$. The exponential curve used can be seen in the figure below.

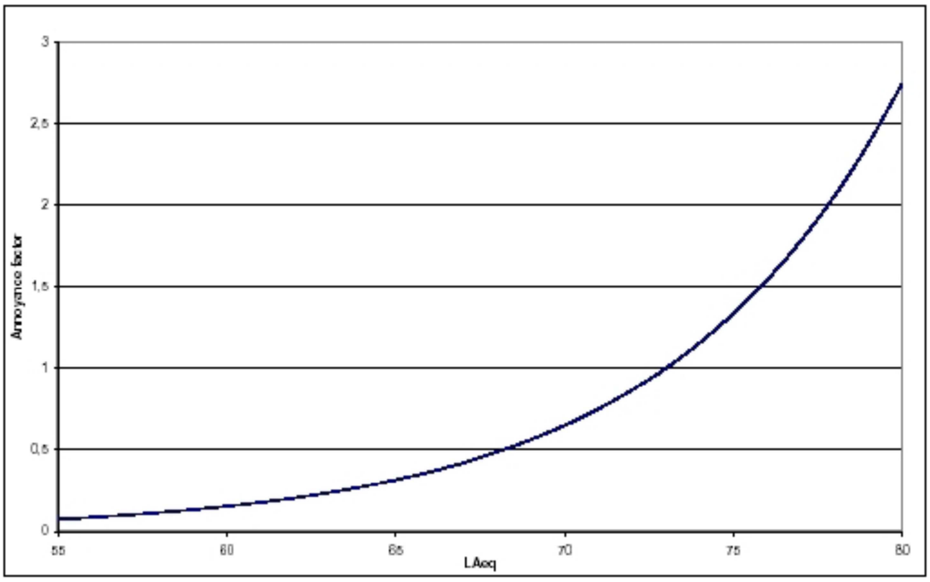

Figure C.1: The exponential curve used for weighing factors in the Danish system, here expressed in relation to L_{Aeq}.

After converting to euros, the Danish value corresponds to 32 € per person per 1 dB per year, which is considerably higher than the unit value suggested by the EU working group.