CEDR Transnational Road Research Programme

Call 2012: Noise: Integrating strategic noise management into the operation and maintenance of national road networks

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

funded by Belgium/Flanders, Germany, Ireland, Norway, Sweden, United Kingdom

DISTANCE

Developing Innovative Solutions for TrAffic Noise Control in Europe

Deliverable D7.1

Developing Innovative Solutions for TrAffic Noise Control in Europe

Partners:

BRRC (Belgian Road Research Laboratory) [Belgium]

TRL (Transport Research Laboratory) [UK]

SINTEF [Norway]

ANAS S.p.A. [Italy]

This page is intentionally left blank

CEDR Call 2012: Noise: Integrating strategic noise management into the operation and maintenance of national road networks

DISTANCE: Developing Innovative Solutions for TrAffic Noise Control in Europe

Policy brief

Due date of deliverable: 6/2015
Actual submission date:
Draft submission: 01-10-2015
Final submission: 24-11-2015

Start date of project: 01-09-2013 End date of project: 30-06-2015

Author(s) this deliverable:

Luc Goubert (BRRC)

Quality Review:

On behalf of the Lead Author's Institute				
Author:	Name	Luc Goubert	Signature	
Technical Reviewer:	Name		Signature	

Version: final, 11/2015

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

This page is intentionally left blank

Table of contents

This page is intentionally left blank

Executive summary

The DISTANCE project was initiated to provide NRAs with comprehensive information/guidance to assist with planning noise abatement in the future by addressing five standalone key questions, comprising the subjects of the DISTANCE project's five work packages as follows:

- What are the data requirements for future noise mapping and action planning?
- Which secondary functions exist for pavements and noise screens and are these functions feasible/interesting?
- What are the potential noise effects of future traffic scenarios?
- What alternative "smart" noise mitigation measures exist or are under development?
- What is the possible role of perception and awareness of noise mitigation measures?

The aim was to review and assess all knowledge available in literature and additional non-published sources, as opposed to carrying out new research, and to provide an expert vision; summarizing the information in practical guides, for use by road administrations.

After a thorough analysis of the available data, the findings of the consortium can be summarized as follows:

1. A survey was conducted by distributing a questionnaire to responsible authorities in fifteen member state countries; twelve replies were received. The survey focused on data collection in four subject fields: road surfaces, noise barriers, traffic volumes and geospatial data (terrain profile). Positively, all responding countries were already involved in collecting such data. However, a few gaps were identified, including failure to consider the impact of ageing on the acoustic quality of road surfaces. Furthermore, there was a lack of data on the sound absorption characteristics of roadside areas; recommendations were made to fill those gaps. It would be beneficial for road administrations to exchange information in this field.

2. The concept of "secondary" functions of noise barriers was taken in a relatively broad sense. In addition to apparent possibilities such as generating electricity with photovoltaic cells integrated in noise barriers or including safety rails in noise barriers, attention was paid to added architectural values and to "greening" the environment by using plant screens for noise control. Unfortunately, the potential in this area is rather limited, as demonstrated by a number of foreign pilot projects. Photovoltaic cells in noise screens, integrated noise screens and safety barriers and green barriers are the most interesting, yet of limited use.

3. Serious consideration was given to possible developments in road infrastructure and in vehicle and tyre technologies, and their foreseeable effects on traffic noise. From the available data, it appears that the following will occur over the next few years in Europe:

- the portion of motorways in the total road network will increase;
- the use of ITS to improve the fluidity of traffic flows will grow;
- the percentage of light lorries in the total vehicle fleet will increase;
- the use of durable noise-reducing road surfaces will grow;
- technological improvements to tyres and vehicles will have a marginal impact on overall traffic noise;

- hybrid and electric cars will be increasingly used.

None of these measures/developments will significantly reduce traffic noise. However, models have indicated that it is possible to achieve significant reductions in traffic noise if infrastructural changes are suited to developments in vehicle and tyre technologies.

4. In relation to new technologies/measures for mitigating traffic noise, all conceivable (conventional and innovative) possibilities were listed. They can all be categorised under one of the following four headings:

- traffic control and management measures;
- land use and road design;
- socio-economic actions;
- innovative solutions.

All the measures were briefly described and evaluated for effectiveness, technological development and cost-benefit ratio. A final selection of eight measures, suitable for implementation on major roads (the primary concern of national road administrations and, hence, in the DISTANCE project), was made. Significant noise reductions (exceeding 7dB(A)) are achievable in the future with poro-elastic road surfaces and “sonic crystals”. The latter comprise arrays of poles in repeated rows along the road which do not “stop” noise as a conventional barrier does but allows part of it to propagate, and eliminates part of it by destructive interference of the noise waves. The literature reports outstanding results in a number of pilot projects and it is worth investigating this further, e.g. with experimental setups. Another interesting development is the use of diffractors, i.e. a series of trenches, parallel to the road, deflecting the noise upwards so as to achieve a noise reduction of approximately 4dB(A) at roadside dwellings.

5. Finally, the project demonstrated the importance of the psychological aspects of annoyance from traffic noise. A substantial part of the annoyance perceived is “subjective” and can be significantly reduced by a correct “psychological” approach, with all the associated advantages. A number of adverse effects of noise, e.g. stress and related health problems, are due to annoyance and if this annoyance can be mitigated, the adverse effects can also be mitigated. For instance, a series of studies have shown that citizens’ participation in a new project can have a major impact. Lack of involvement can increase the nuisance. It is hence advised to involve people as early as possible when new road infrastructure is planned and public hearings, on which the project is presented from different perspectives can be a great tool to involve the public.

The findings from the project are described in five detailed, yet practical reports, which can be downloaded free of charge from the website of the DISTANCE project (www.distanceproject.eu).

1 Introduction

Traffic noise is one of the main environmental issues in Europe today; both in terms of human health and wellbeing, relating to economic damage. It is unlikely that the problem will disappear or even diminish by itself. On the contrary, traffic volumes continue to increase year by year. In the EU-27, freight traffic increased by on average 1.5% per annum in the period 2000–2010 and passenger traffic by 1.4% per annum in the period 1995–2009.

National Road Authorities (NRAs) are under increasing pressure to reduce noise exposure and nuisance but are facing restricted budgets due to the economic crisis. The challenge they face is to achieve a positive effect with an equal or even lower budget. This “effect” can be a reduction in the number of people exposed, a reduction in exposure or even a reduction in perceived exposure, leading to a reduction in noise nuisance.

A key initial requirement is that NRAs have accurate noise maps in which the effects of noise abatement measures are well integrated, in order to allow optimized action planning. To obtain an accurate noise map, it is not only important to have accurate input data but also appropriate input data. However, the use of noise maps for action planning is not obligatory; therefore, the costs associated with obtaining detailed noise maps on a small scale could alternatively be spent on noise measures.

Technological and scientific developments are ongoing, therefore, “smart” solutions are continually arising which could contribute to solving noise issues. Frequently, many of these technologies and ideas turn out to be impractical. A comprehensive, independent and critical review of existing and “arriving” technologies and ideas by a competent team is one of the key elements offered in the DISTANCE project.

In the current economic climate, budgetary restrictions mean that NRAs must strive to ensure that implemented measures are fit for purpose and durable whilst keeping costs as low as possible. Noise mitigation measures, providing additional benefits beyond simple noise reduction, may therefore be an attractive proposition to NRAs if they can be achieved with minimum expenditure or if whole-life costs are favorable. The objective of the DISTANCE project was to provide NRAs with comprehensive information/guidance on a wide range of topics, and to assist them in planning and implementing future noise mitigation measures on their road networks, by addressing the following key issues:

- Data requirements for future noise mapping and action planning,
- State-of-the-art secondary functions for pavements and noise screens,
- Future potential traffic scenarios,
- Critical guidelines to the effective implementation of alternative “smart” noise mitigation measures, and
- Perception and awareness of noise mitigation measures

These issues were the subject of five relatively independent DISTANCE work packages (WP2–WP6). The research findings and expert vision on these five issues are summarized in the subsequent chapters of this document.

2 Data requirements for future noise mapping and action planning (Work Package (WP)2)

The objective of WP2 was to list and assess data that should ideally be provided by the NRAs, outside of data already collected, in order to produce more robust strategic noise maps and action plans in the future, in accordance with requirements described by the Common NOise aSSessment methOdS (CNOSSOS-EU) project.

The focus was on selected data types, concerning road surfaces, noise barriers, traffic data and geospatial data. It was within the scope of the work to explore the implications of new requirements and recommendations, examine related problems and challenges in the NRAs, and provide recommendations for future data capture.

One assumed that general knowledge about noise mapping related to the new CNOSSOS-EU requirements is available at the NRA's. This knowledge should be combined with the additional information from the DISTANCE consortium. The extent of the study and its results were, however, limited to the data types focused on in the objectives, and the general limitations imposed by the WP budget.

The results of this WP are summarized in the following table, listing themes and data types considered, brief indications on the fulfilment of corresponding CNOSSOS-EU requirements, and future recommendations for the NRAs to close gaps. The DISTANCE also indicated where transnational collaboration of the NRAs could be useful.

Group of Data	Data Type	Are the NRAs prepared for new requirements?	Recommendation for the NRAs	Co-oper. across NRAs
Road Surfaces	Pavement Type	Yes. Categories are based on physical parameters. But some have low coverage	Adapt to the coming ROSANNE[1] unified method for classification	Yes
	Pavement Degeneration	No. Except for a few countries	Perform translations to spectral α- and β-coefficients. Carry out national investigations to establish average effects, or to underline other conclusions	Yes
Noise Barriers	Barrier Type	These data types are not investigated specifically in this study because of lack of support in the calculation methods, including CNOSSOS-EU		
	Barrier Transmission			
	Barrier Degeneration			
	Barrier Top			
	Barrier	Yes, for most countries.	For some countries:	No

[1] ROlling resistance, Skid resistANce and Noise Emission measurement standards, FP7 project, see http://rosanne-project.eu/

Group of Data	Data Type	Are the NRAs prepared for new requirements?	Recommendation for the NRAs	Co-oper. across NRAs
	Dimension		Improve precision. Invoke national Geographic Information System (GIS) mapping agencies	
	Barrier Position			
	Barrier Absorption	Yes, for most countries	For some countries: Start collecting absorption data	No
Traffic Data	Vehicle Category	Yes. Although some are still in the adaption process	Keep up the good work	No
	Speed	Yes for DEN-distribution. But most countries do not use actual speed	Estimate actual average speed for each vehicle category	Yes
	Quantity	This is implicitly covered by the previous "Vehicle Category".		
Geospatial Data	Topography	Yes. Although a few countries have low resolution	A few countries should increase the topography resolution	No
	Ground Surface	No. Most countries do not have easy access to graded surface data	Considerable efforts are needed to provide data by the 8 classes	Yes
	Road Information	Yes (probably)	Maintain current attention	No
	Building Geometry	Yes	Keep attention on building heights	No
	Population per Building	Yes, for most countries	For some countries: Work towards specific numbers or more diverse statistics	No
	Population Distribution over Façades	Yes, for some countries No, for others	Co-operate to find common approaches and practices	Yes
	Building Type	This is implicitly covered by data sets on buildings		

The overall conclusion of this WP is that the NRAs appear to be well prepared for the CNOSSOS-EU requirements (limited to the themes of the present study). However, further work on some issues is required by several NRAs in order to fulfil all requirements; specifically in relation to providing data for *pavement degradation*, *ground surfaces* and *population assignment to building façades*. In addition, separate issues need to be addressed by individual NRAs. Among these, we recommend that issues on *pavement type acoustics*, *speed distribution over vehicle categories*, *ground surface* and *population assignment to façades* should be addressed internationally across several NRAs; bearing in mind that some NRAs do not use noise maps directly for action planning.

We discovered no prominent regional differences in this study, such as systematic difference between northern and southern Europe. Nevertheless, many of the challenges relating to CNOSSOS-EU requirements are similar for several countries. There is an apparent advantage in discussing and resolving issues across the NRAs, even though the issue may be of local nature. Therefore, any NRA may benefit in co-operating with a neighbouring country that may have already solved the issue. This will also contribute to the underlying aim of European harmonisation.

3 State-of-the-art secondary functions for pavements and noise screens (WP3)

WP3 of the DISTANCE project investigated how primary NRA assets, such as road surfaces and noise barriers, could be enhanced to provide additional benefits (referred to here as “secondary functions”). Options have been identified and assessed in terms of their known or anticipated (whichever is applicable) advantages, disadvantages and likely costs (relative to conventional measures); the level of technical readiness, i.e. how ready they are for commercial application, has also been identified.

The studied secondary functions within WP3 were identified, from both a comprehensive literature review and an open exchange of novel concepts within the project team, as having secondary functions.

Comprehensive tables are presented in the WP report, where the secondary functions for noise barriers and pavements are assessed by different criteria.

The studied enhancements for noise barriers are as follows:

- Use of PVNB (photovoltaic noise barriers)
- Safety barriers
- Added devices
- Enhanced visual characteristics
- Transparency
- Use of recycled materials
- Green barriers
- TiO_2 capture
- Electrostatic capture
- Lighting
- Adverts/information
- Rainwater harvesting

The studied enhancements for pavements are as follows:

- Dynamic markings (lane delineation)
- Dynamic markings (lane control)
- Inductive charging
- Heat capture/storage
- Modular pavements
- Self-healing surfaces
- Air pollutant capture
- Energy generation
- Recycled materials (asphalt and concrete)
- Recycled materials (tyres, etc.)

These secondary functions are assessed by indicating the following:

- Technical feasibility (ranging from no (major) technical obstructions, or already available, to still only a concept in the early stages of investigation/development)
- Financial impact (supplementary cost compared to a conventional noise barrier or road surface by Indicative Cost Band)
- Sustainability impact (in terms of ecological, financial and/or social impact)
- Main pros and cons to implementation ("what is the stimulus in the decision making process")
- Potential for use by the NRA, according to the authors' expert judgment, ranging from "readily implemented and suitable for widespread use on an NRA road network" to "not ready for implementation" or "suitable for very restricted use on an NRA road network"

From the various options reviewed, the following are considered as being presently available and offering the most useful benefits to NRAs, with respect to secondary functions:

For noise barriers with secondary functions:

- Noise barriers with photovoltaics
- Integrated noise and safety barriers

Concerning architectural features (including the use of transparency):

- Green barriers

It must be noted that not all of the secondary functions identified will be suitable for widespread use on a given NRA road network. This will be particularly relevant in the use of photovoltaics, as the cost-benefit ratio may be negative in the case of high installation and/or maintenance costs and a low energy production.

For road surfaces with secondary functions:

- Use of recycled materials (recycled asphalts)

One can conclude that the possibilities for cost-efficient measures appear to be quite limited.

4 Future potential traffic scenarios (WP4)

The work in WP4 considered potential changes to road infrastructure and vehicle and tyre technology which may impact traffic noise levels at source. It found that in the coming years the following are likely to occur:

- An increase in motorways as a fraction of the road network
- An increase in the use of Intelligent Transport Systems (ITS), designed to smooth traffic flow
- An increase in light goods vehicles as a fraction of the fleet
- An increase in the use of durable low-noise road surfaces
- A minimal impact on overall traffic noise from improvements in vehicle and tyre technology
- A slight increase in the use of electric and hybrid electric cars

In this WP, the influence on the average road side noise level $L_{Aeq,1h}$. change in 14 scenarios has been calculated. Scenario 1 is the “baseline scenario” and the final scenario, Scenario 14, is the “future scenario”. Scenarios 2–13 reflect changes to a particular modelling parameter in isolation so that its impact can be assessed. The scenarios have been considered for five road/traffic situations: free-flow and congested motorway, trunk, principal and minor roads. The following table presents the expected impacts (dB(A)).

Scenario (description)	Motorway (free-flow)	Motorway (congested)	Trunk	Principal	Minor
1 (baseline: 2015 vehicle and infrastructure status of technology and 2015 vehicle volumes)	-	-	-	-	-
2 (+50% flow)	1.8	1.8	1.8	1.8	1.8
3 (+50% heavy good vehicles)	0.4	1.5	0.3	0.3	0.1
4 (-50% heavy good vehicles)	-0.4	-2.2	-0.3	-0.3	-0.1
5 (speed/ITS)	1.1	-3.1	-	-	-
6 (SMA 0/6)	-2.1	-0.1	-1.6	-1.0	-0.9
7 (porous asphalt)	-5.9	-4.6	-5.0	-4.3	-3.9
8 (exposed aggregate concrete)	1.2	0.1	1.1	1.0	1.2
9 (studded tyres)	1.2	0.4	1.7	2.5	3.0
10 (acceleration)	-0.2	-	-0.1	0.7	-0.4
11 (quiet tyres)	-1.5	-0.2	-1.5	-1.3	-1.4
12 (electric cars)	-0.3	-0.4	-0.4	-0.6	-0.8
13 (quieter cars)	-0.2	-1.6	-0.3	-0.3	-0.3
14 (future scenario)	-3.6	-4.6	-3.1	-2.4	-2.5

It is evident that the impact of measures/changes differs from scenario to scenario and is also dependent on the situation. The introduction of porous asphalt would have the largest

noise reduction, followed by the introduction of quiet tyres. The increase in traffic volume represents the highest noise increase.

5 Critical guidelines to the effective implementation of alternative "smart" noise mitigation measures (WP5)

Conventional traffic noise mitigation measures are based on insulation and absorption techniques. Sound insulation prevents the transmission of noise by the introduction of an acoustical shield whilst sound absorption reduces the amount of energy reflected into the environment, mainly through a dissipating mechanism. These systems are quite consolidated and widely used by NRAs, and include noise barriers, façade insulation, porous asphalt pavements, and other widely known techniques.

There are alternative methods of noise mitigation that are more oriented towards reducing noise at the source; this is the case with regulations on low noise vehicles, low noise tyres, urban planning, roadway design and speed control systems, which are measures that try to reduce noise in an unconventional way. Furthermore, there are some innovative solutions that have been developed recently or that are still at a prototype stage, whose aim is to achieve higher noise reductions compared to other conventional and proven techniques.

Among used and proposed alternative smart noise mitigation solutions, four well-defined categories emerge from the literature review. These categories are as follows:

a) Measures applied to traffic control and management
b) Urban planning and road design measures
c) Socio-economic actions
d) Innovative solutions

Based on the analysis carried out in this report, the following important conclusions can be drawn:

- In order to achieve higher levels of noise mitigation (IL>7dB(A)), two specific innovative technological solutions appear promising: Poroelastic Road Surfaces (PERS) and sonic crystals
- In order to achieve medium levels of noise mitigation (3<IL≤7dB(A)), various measures other than PERS and sonic crystals are available, such as diffractors; they can achieve noise reductions up to 4dB(A) but, for safety reasons, they can be installed along highways/motorways only
- Some other investigated measures, even if effective in noise reduction, actually need to be further developed in order to improve their technical feasibility level; for example:

  a) Replacing hard ground with soft ground is a measure that can lead to noise reductions ranging from 2dB(A) to 9dB(A), but with a low level of technical feasibility (2). Furthermore, the applicability of this measure is limited to rural areas, where the cost of the land is lower than in urban areas.

  b) Artificial surfaces can obtain noise reductions ranging from 2.5 to 4dB(A), but they show a low level of technical feasibility (2) and its application on a large scale seems unlikely.

For these measures (PERS, diffractors and ground absorption), NRAs could contribute towards improving technical and scientific knowledge by promoting transnational research projects to upgrade the technical feasibility at least to level 3.

When lower levels of noise mitigation (IL≤3dB(A)) are required, various traffic management measures can be applied, e.g. as part of future ITS applications.

Socio-economic actions, such as new EU tyre and vehicle noise limits, can be effective in obtaining noise reductions ranging from 2 to 4dB(A), and particularly in reducing noise mitigation costs for NRAs.

6 Perception and awareness of noise mitigation measures (WP6)

Regulations aim to limit noise emissions from vehicles and tyres to maximum A-weighted sound levels, measured according to standardized procedures. Furthermore, regulations dictate energy-based sound levels (L_{den}) and a maximum level during night time (L_{Anight}) to limit road traffic noise emission levels. However, the noise ***annoyance*** from traffic noise is based on a subjective experience by an individual.

An individual's experience can be influences by a range of non-acoustical factors such as:

- Awareness of the noise
- Influence on the noise situation
- Sensitivity to noise
- Activity during exposure
- Additional socio-psychological and socio-demographic variables

Several studies show that energy-based indices explain approximately 30% of experienced annoyance. It is therefore relevant to investigate how non-acoustical mitigation measures can contribute to a low-cost and easily implementable noise mitigation strategy for the NRAs.

The WP6 deliverable describes the relationship between road traffic noise annoyance and public awareness and participation in noise mitigation measures. The study is based on a literature review of the most relevant publications and projects on this subject.

The study has been divided into the following four main areas:

- Communication
- Compensation
- Participation
- Additional non-acoustical mitigation

The main findings within these three areas were as follows:

Communication and participation:

- Being informed and involved can enhance perceived control, and as such significantly reduce annoyance. The same applies for being treated fairly, even if people know their actual influence is limited
- Organized events such as workshops and public meetings can be a great tool for informing and involving the public
- The use of websites and social media can be positive tools for communication with people not able to attend public events
- Communication with noise experts at public events is strongly recommended
- The use of descriptors more easily interpreted than L_{den} and L_{night} can assist communication with the general public

Compensation:

- There are many examples of court rulings on the issue of economic compensation for people exposed to noise. However, it may be more advantageous to look at the opposite scenario: how much money are people willing to pay for reduced noise?
- Willingness to pay (WTP) may vary with income, but also with a number of cultural and social factors and their influence may be greater than that of income alone. Various studies indicate a WTP per year per person in the range of €4–10 for a noise reduction of 1dB

Additional non-acoustical mitigation:

- Several studies show that the noise annoyance reduces when there is access to quiet areas (parks, zones, etc.) and quiet façades/backyards

7 References

Olsen, H. “Data requirements for future noise mapping and action planning”, DISTANCE project deliverable DISTANCE-SINTEF-D21-V01-01102015-Data requirements for future noise mapping and action planning (2015), can be downloaded free of charge from the DISTANCE home page www.distanceproject.eu

Maeck, J.; Morgan, P.; Muirhead, M.; Bellucci, P.; Grecco, R. “State-of-the-art on secondary functions of noise barriers and pavements”, DISTANCE project deliverable DISTANCE-BRRC-D31-V01-010415-State-of-the-art on secondary functions of noise barriers and pavements, can be downloaded free of charge from the DISTANCE home page www.distanceproject.eu

Muirhead, M. “Future potential traffic scenarios”, DISTANCE project deliverable DISTANCE-TRL-D42-V01-15072015-Future potential traffic scenarios, can be downloaded free of charge from the DISTANCE home page www.distanceproject.eu

Losa, M.; Bellucci, P.; Grecco, R.; Pacciardi, S. “Critical guidelines to the effective implementation of alternative “smart” noise mitigation measures”, DISTANCE project deliverable, DISTANCE-ANAS-D51-V01-19052015-Critical guidelines to the effective implementation of alternative “smart” noise mitigation measures, can be downloaded free of charge from the DISTANCE home page www.distanceproject.eu

Gelderblom, F.; Gjestland, T.; Berge, T. “Perception and awareness of noise mitigation measures”, DISTANCE project deliverable, DISTANCE-SINTEF-D61-V01-15072015-Perception and awareness of noise mitigation measures, can be downloaded free of charge from the DISTANCE home page www.distanceproject.eu