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Road Traffic Noise Research Needs

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ROAD TRAFFIC NOISE RESEARCH NEEDS

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Executive summary

This report describes the results obtained from a survey on knowledge gaps in noise assessment and abatement techniques as seen by the National Road Administrations (NRAs). The survey was conducted in the winter of 2011-12. The status on the need for noise research within Europe was investigated by sending a questionnaire to 16 CEDR Road Noise members. The questionnaire aimed to elucidate priority noise research themes common to the European area, identify a shared approach to the noise problems and to promote national and joint future research projects. The questionnaire included 10 main thematic domains. Each thematic domain comprised of a group of issues. In order to identify the issues that need in-depth study, research and development, it was asked to indicate the priority to be assigned to domains and issues.

The following top five thematic domains were found to meet member states interests:

- rolling noise,
- improved or new socio-economic instruments to promote efficient noise abatement,
- advanced noise reduction technologies between source and receivers,
- advanced computation and measurement methods for more accurate assessment of noise exposure,
- active noise mitigation measures.

Themes related to systems and methods to abate noise are considered of primary importance. In particular, the priority list reasserts the common opinion that noise must be reduced first at the source and then using screens between source and receivers. The need for high quality input data and more accuracy on the results provided by calculation models has been also highlighted and reasserted in order to improve noise maps reliability.

In order to help identify the preferred approach to noise issues emerge from the survey, thematic domains were also clustered in three main categories:

A. noise assessment and indicators,
B. policy and socio-economic actions,
C. techniques and technologies for noise abatement.

The results achieved by grouping the thematic domains, show that the cluster 'noise assessment and indicators' has the highest score. The importance of improving the thematic domain related to computation and measurement methods has been reasserted to encourage the development of more reliable evaluations of noise perception. Less demanding are research themes on dose-effect relationships and specific indicators.

Domains in the cluster 'techniques and technologies for noise abatement' maintain their high ranking. As in the previous edition of the survey, the thematic domain related to rolling noise was judged to be of primary importance. Common opinion is that passive mitigation systems must be enhanced in order to abate noise effectively and efficiently, especially at the source.

Another filtering step was implemented to achieve a priority list of topics for future research. The algorithm adopted for data filtering used information related to the state of the art of different matters as input. Outcomes from this last step show that for the most interesting thematic domain on rolling noise, just one topic survived to data filtering. A similar result was also achieved for thematic domain on improved and socio-economic instrument to promote efficient noise abatement. The main priority has been given to themes related to noise abatement, in particular to the development of environmentally and economically sustainable mitigation measures.

Recommendations

The results of the questionnaire highlight the need for more research on road noise. High priority was assigned to research themes related to noise abatement, in particular to the development of environmentally and economically sustainable mitigation measures. Medium priority was given to research themes related to noise mapping and cost-benefits assessment of noise impact and noise abatement. So the CEDR Project Group Road Noise strongly recommends to focus attention on topics regarding the design and development of effective and efficient solutions to abate noise, including their environmental and economic assessment.

Based on this overall recommendation, CEDR Road Noise has two specific recommendations.

First, to use the information on noise research needs when defining, planning and prioritizing new research and development activities in relation to:

- national research programmes of individual National Road Administrations (NRAs),
- regional and bi-lateral cooperation by NRAs of several EU member states,
- CEDR transnational programme on research (ERA-NET Road and ERA-NET Transport),
- FEHRL programme Forever Open Road,
- EU research programmes such as FP8 and Horizon 2020.

This recommendation sounds simplistic, but in fact this will require a lot of effort and resources to get it involved on noise research at a transnational level. To cope with these preconditions, one has to focus on specific programmes. That's why the follow-up activities are concentrated on the recent CEDR Call 2012 on noise: integrating strategic noise management into the operation and maintenance of national road networks.

Second, to use the information on noise research needs in the scope of CEDR Road Noise 3, whose mission, in the period 2013-17, will be focused on the collation, dispersion, implementation and adoption of results from recent innovative noise research projects undertaken within CEDR member states.

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1 Introduction

In their CEDR Strategic Plan 2009-13 (SP2) [1] the Conference of European Directors of Roads (CEDR [2]) defined a Thematic Domain (TD) Construction, focused on environmental and road safety issues. Five main objectives were established for this thematic domain:

- contribute to the efforts deployed by standardization bodies to establish and update modern standards in line with the objectives of the NRAs;
- facilitate the individual use of new standards;
- monitor the European law-making;
- take appropriate action on EU directives;
- develop and share knowledge on a sustainable infrastructure.

To meet this goal a CEDR Project Group Road Noise was established. Four subgroups were composed to deal with as many topics:

- noise mapping
- EU action plans
- tyre and vehicle noise
- EU noise calculation model.

An additional survey was also added; to define the state of the art on road noise research and identify research themes to be used as background information for the development of joint future research projects supported by the national road administrations as well as other European frameworks (such as ERA-NET-ROAD, EU framework programmes etc.).

This report presents the results of the questionnaire on knowledge gaps that was conducted in 2011-12. The basic idea of this report is to share information among the national road administrations on knowledge gaps in noise abatement. It is hoped that this report will give inspiration for further research on noise abatement in Europe and benefit people living as neighbours to the national road networks in particular and to all roads in general.

The questionnaire on knowledge gaps was produced by Patrizia Bellucci from ANAS in Italy, who also drafted this report with input from many road administrations in Europe. The CEDR Project Group Road Noise would like to thank all the members from the national road administrations who carried out substantial work in answering the questionnaire. The work and this report have continuously been discussed at the meetings of CEDR Road Noise. Nico Faber, Vincent O'Malley and Wiebe Alberts edited the report. The editors would like to express their warm thanks especially to Mrs. Patrizia Bellucci and to the members of CEDR Road Noise for their dedicated work producing this report.

2 The survey questionnaire

The survey questionnaire on knowledge gaps was developed to establish a range of research themes on road noise that need further investigation. Research themes were identified based on the trend outlined by the most reliable research programmes and projects, as those reported in the bibliography (see paragraph 6). The survey questionnaire includes 10 main thematic domains that are listed in Table 1:

Table 1 List of the thematic domains proposed in the survey questionnaire

ID	Thematic domain
1	Advanced computation and measurement methods for more accurate assessment of noise exposure
2	Definition and identification of urban and rural high acoustic quality areas
3	Improvement in dose-effect relationships
4	Additional noise indicators considering specific effects
5	Advanced methods of cost-benefit assessment of noise impact and noise abatement
6	Information and public participation
7	Improved or new socio-economic instruments to promote efficient noise abatement
8	Rolling noise
9	Advanced noise reduction technologies between source and receivers
10	Active noise mitigation measures

Each thematic domain comprises a group of issues connected to the particular domain (for details on issues see Annex A). In order to identify the issues that need in-depth study, it was requested to mark the domains that are considered worthy of further research with a number from 0 to 4, indicating the priority to be assigned to domains and issues, as shown in Table 2.

Table 2 Scores to be assigned to thematic domains and issues

Score	Thematic Domain Priority	Items Interest Level
0	No priority	Not interesting
1	Low priority	Little interesting
2	Medium priority	Interesting
3	High priority	Rather interesting
4	Absolute priority	Very interesting

For each issue the questionnaire also asked participants to specify if:

- the research on that issue has already been developed;
- the research on that issue is still in progress;
- the research on that issue is going to be developed at a future time;
- the research on that issue has not been undertaken or planned.

The questionnaire also allowed participants to insert remarks and suggestion on each thematic domain and to add references on reports, proceedings, articles on topics already developed or in progress (see Annex B for the list of publications collected).

The survey questionnaire was sent to 16 CEDR member states and 14 of them responded to the survey questionnaire, as shown in Table 3:

Table 3 List of participating countries

Austria		The Netherlands	
Belgium (Flanders)		Ireland	
Denmark		Italy	
Estonia		Latvia	
Finland		Norway	
France		Poland	
Germany		Spain	
Greece		Sweden	

The complete survey questionnaire is available in Annex A.

3 Results

In this section the results of the survey are described. The results are analysed from two different perspectives:

- by theme, and
- by country.

The first approach focuses on the interest expressed by each member state on the thematic domains and issues. Aim of this analysis is to compare different views and provide results of the research needs in Europe in relation to the proposed themes.

The second approach is aimed at pointing out research priorities on a country basis and issues each member state is interested in progressing.

3.1 Results per thematic domain

The thematic domains proposed in the questionnaire were a collection of 10 subject matters based on recent publications on research visions and scientific articles on specific subjects related to road noise. The list of the thematic domains put in the questionnaire is shown in Table 1.

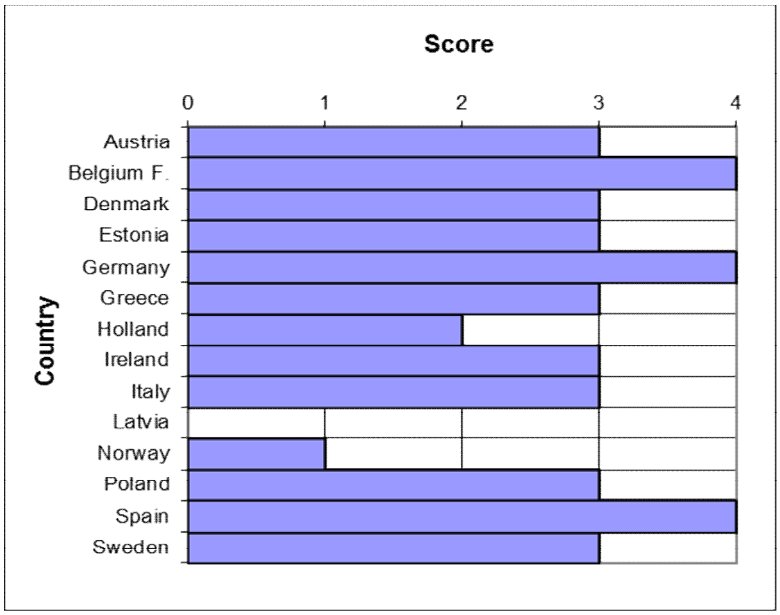
In the following figures a short description of each thematic domain is reported with the results of the survey by theme.

For details on the issues suggested in the thematic domains, please refer to Annex A.

THEMATIC DOMAIN 1

"ADVANCED COMPUTATION AND MEASUREMENT METHODS FOR MORE ACCURATE ASSESSMENT OF NOISE EXPOSURE"

This thematic domain includes research topics considered of interest for drawing up noise mapping, in particular for increasing the accuracy and completeness of results and speeding up the assessment process.



TOTAL SCORE	39

THEMATIC DOMAIN 2

"DEFINITION AND IDENTIFICATION OF URBAN AND RURAL HIGH ACOUSTIC QUALITY AREAS"

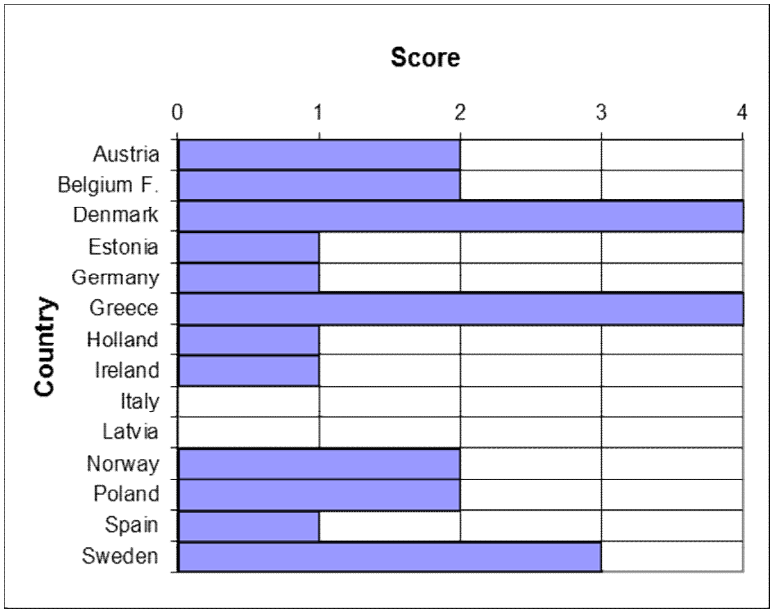
This thematic domain refers to the need of defining appropriate indicators and limit values to delimit urban and rural quiet areas and to determine the public response to noise exposure.

TOTAL SCORE	26

THEMATIC DOMAIN 3

"IMPROVEMENT IN DOSE-EFFECT RELATIONSHIPS"

The effects induced by noise on the population exposed to road traffic noise are important to establish the relationships between noise levels and annoyance. The items in this thematic domain tackle some aspects of the problems related to the development of dose-effects relationships that allow improvement in their confidence level.

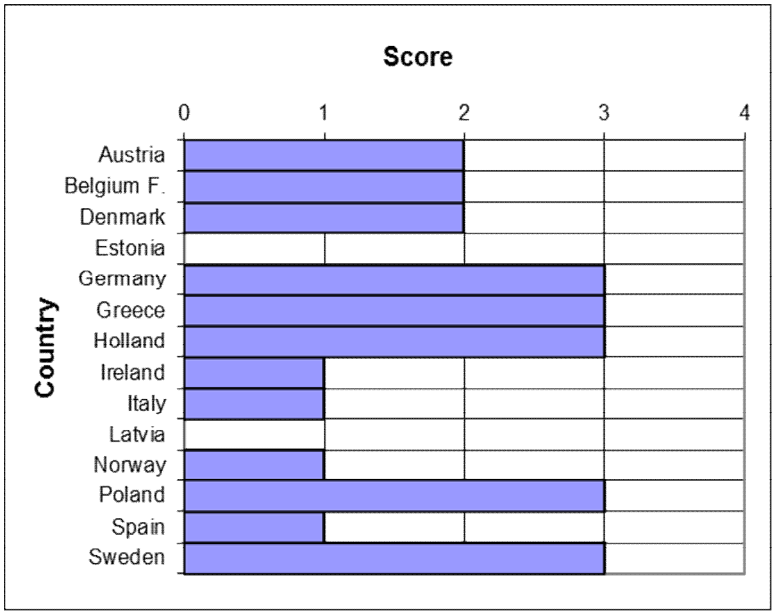


TOTAL SCORE	24

THEMATIC DOMAIN 4

"ADDITIONAL NOISE INDICATORS CONSIDERING SPECIFIC EFFECTS"

This thematic domain addresses specific properties that have significant influence on noise perception, but are not sufficiently described and represented by the common indicators L_{den} and L_{night}. Research in these fields should focus on dose-effect relationships due to low frequency components, impulsive noise, infrequent events and the occurrence of quiet periods.

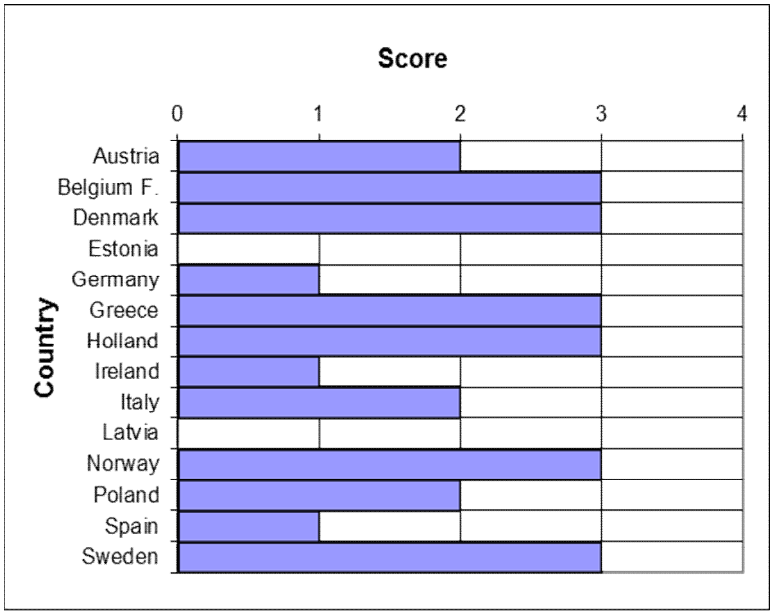


TOTAL SCORE 25

THEMATIC DOMAIN 5

"ADVANCED METHODS OF COST-BENEFIT ASSESSMENT OF NOISE IMPACT AND NOISE ABATEMENT"

Cost-benefit analysis is an important tool to value the efficiency and effectiveness of noise measures to be undertaken in action plans. Further development of the stated preference method and the house price method is required to reduce uncertainties and to provide more accurate estimates. A novel indicator considering the influence of the initial sound level, the health impacts and other factors related to noise reduction measures such as the effects on local air quality, the emission of greenhouse gases, traffic safety, etc. is also required to improve cost-benefit analysis.

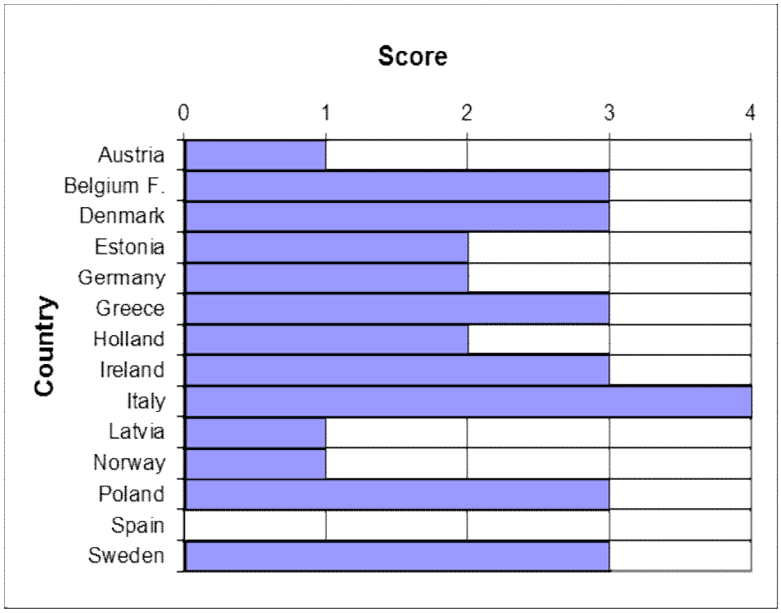


TOTAL SCORE 27

THEMATIC DOMAIN 6

"INFORMATION AND PARTICIPATION OF THE PUBLIC "

The Environmental Noise Directive states that member states should ensure that strategic noise maps and action plans are made available and disseminated to the public. The information should be clear, comprehensible and accessible. Member states should also ensure that the public is consulted about proposals for action plans, given early and effective opportunities to participate in the preparation and review of the action plans, that the results of that participation are taken into account and that the public is informed on the decisions taken. A reasonable time-frame should be provided to allow sufficient time for each stage of public participation. Results related to the first round of the END showed that poor participation of the public was achieved and that research on this field is necessary, in order to outline suitable communication languages and modes.

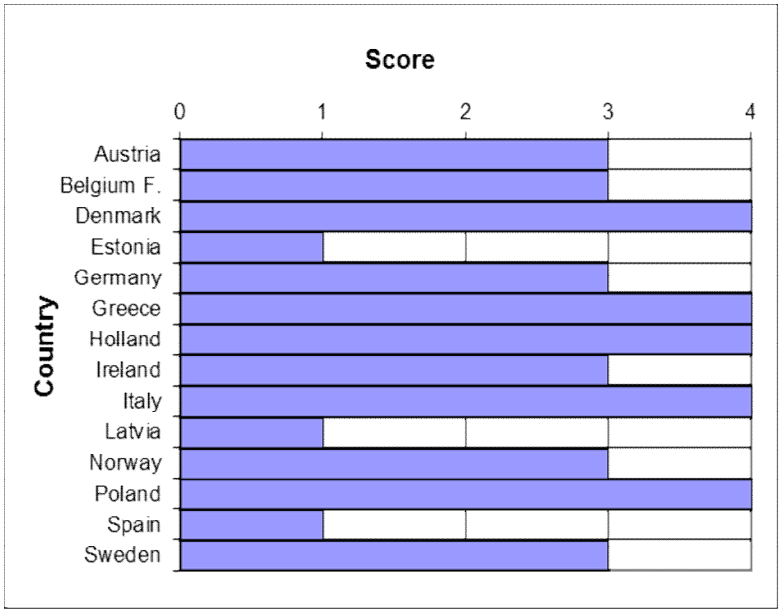


TOTAL SCORE	**31**

THEMATIC DOMAIN 7

"IMPROVED OR NEW SOCIO-ECONOMIC INSTRUMENTS TO PROMOTE EFFICIENT NOISE ABATEMENT"

Efficient instruments are required to direct consumers towards quieter products and quieter behaviour based on positive or negative incentives and regulations related to the use of noisy devices, to the extent of noise nuisance or to the cost caused by the noise impact to the society. At the same time, efforts should be focused on providing reliable vehicle noise assessment methods, representative of the typical conditions in real traffic situations, to make noise emission limitation a more effective and efficient noise reduction tool. Noise emission is also dependent on driving styles, therefore systems supporting and promoting low-noise driving styles by engine management, intelligent transmissions and electronic driver assistance are necessary. In the specific field of powered two-wheelers (PTWs), the driving style and the manipulation of the engine and exhaust system have a big impact on the noise emission so that investigations towards efficient training and control programmes for quieter driving of PTWs are needed.

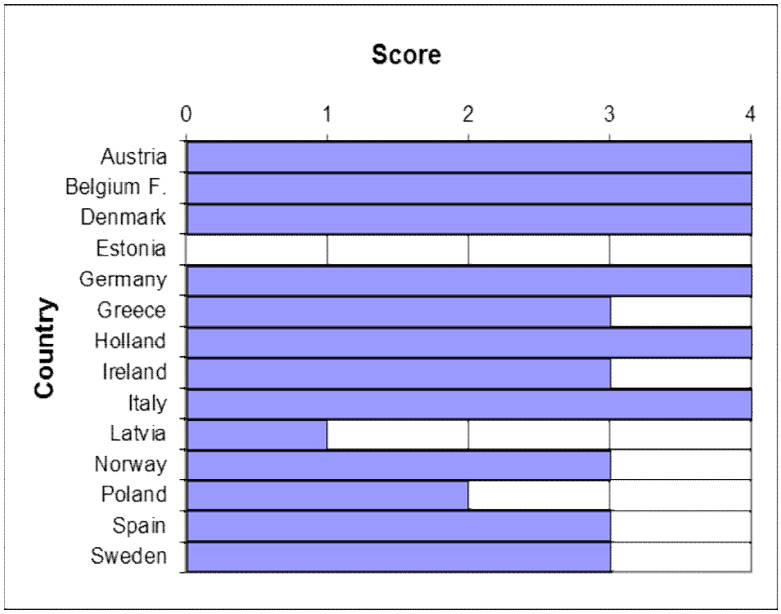


TOTAL SCORE	41

THEMATIC DOMAIN 8

"ROLLING NOISE"

Rolling noise is the main factor contributing to noise level in many traffic situations. Improvement in understanding the interaction between tyre and road surface is necessary to progress noise reduction techniques and modelling. New concepts for low noise tyres and road surfaces have to be developed and implemented on models with increased accuracy. For road surfaces, new production technologies, cleaning and maintenance techniques for porous asphalts are needed to achieve sustainable noise reduction.



TOTAL SCORE	42

THEMATIC DOMAIN 9

"ADVANCED NOISE REDUCTION TECHNOLOGIES BETWEEN SOURCE AND RECEIVERS"

Sound pressure levels in residential areas can also be reduced by hindering noise propagation from road to receivers with measures such as noise barriers around acoustic "hot" spots. The noise protection effect of barriers is considered to be not yet fully exploited so that further research on noise barriers is needed, especially for top end design optimization. Research is also required to develop new and sustainable types of panels to allow for active noise control, the production of renewable energy, etc.

TOTAL SCORE	35

THEMATIC DOMAIN 10

"ACTIVE NOISE MITIGATION MEASURES"

Noise in large residential areas provides a complex system that can be treated only with a holistic approach. Solutions limited to single sources could be insufficient to abate noise levels at receivers, so combined solutions should be investigated in order to guarantee the required noise reduction. Combined solutions include active mitigation measures, such as traffic management (speed and volume control) and city planning. Cities with short distances to be covered help to reduce traffic and noise. Thus, it is important to understand the forces that favour the long distance in a city and to develop instruments to counteract such forces. Further knowledge is needed about the best city layout for noise and about efficient integration of noise related city planning into mobility planning or planning of sustainable urban transport.

TOTAL SCORE	34

3.2 Global results

Table 4 shows the scores given to the priority level associated to the thematic domains proposed in the questionnaire.

Table 4 Thematic domains and priority level

Priority	TD	Thematic Domain	Score
1	**8**	Rolling noise	**42**
2	**7**	Improved or new socio-economic instruments to promote efficient noise abatement	**41**
3	**1**	Advanced computation and measurement methods for more accurate assessment of noise exposure	**39**
4	**9**	Advanced noise reduction technologies between source and receivers	**35**
5	**10**	Active noise mitigation measures	**34**
6	**6**	Information and public participation	**31**
7	**5**	Advanced methods of cost-benefit assessment of noise impact and noise abatement	**27**
8	**2**	Definition and identification of urban and rural high acoustic quality areas	**26**
9	**4**	Additional noise indicators considering specific effects	**25**
10	**3**	Improvement in dose-effect relationships	**24**

As it can be seen in Table 4, the themes considered of primary importance to be developed are those related to systems and methods to abate noise. In particular, the priority list reasserts the common opinion that noise must be reduced first at the source and then using screens between source and receivers.

The way noise can be reduced is another important matter to be investigated. The experience gained in the last decade shows that solutions limited to single noise sources could be insufficient to abate noise levels at receivers, so combined solutions should be investigated in order to guarantee the required noise abatement. Policies and strategies are necessary to ensure an efficient and effective solution to the problem.

The development of additional and innovative noise abatement techniques, such as traffic management, speed reduction, electric or non-motorized transport solutions, photovoltaics integration in noise barriers, as well as managerial and financial tools to reduce the cost of noise mitigation measures, are also required.

On completion of the first round of the END, the need for high quality input data and more accuracy on the results provided by calculation models was again highlighted in order to improve noise maps reliability. Methods to check the veracity of results are also required to guarantee noise maps outcomes.

In Tables 5 to 9, the first five thematic domains are expanded to show the most relevant issues to emerge from the survey.

Table 5 Scores related to issues proposed in the thematic domain 8

1	**Thematic Domain 8** **ROLLING NOISE**	
ID	Issue	Score
8.3	New concepts for low-noise road surfaces (design, material, production technologies)	41
8.6	Development of optimised noise reducing pavements	40
8.11	Procedures for the acoustic labelling and conformity checking of road surface products or techniques	38
8.2	New concept for low-noise tyres (geometry, design, material, matching to road surfaces)	37
8.7	Life cycle assessment of PERS	36
8.4	Cleaning and maintenance techniques for low-noise road surfaces (cleaning techniques, winter maintenance, renewal techniques)	35
8.10	Development of reliable methods for static and dynamic characterization of the acoustic performance of low noise pavements (emission and absorption).	35
8.1	Better understanding of road-tyre interaction for improved simulation tools with increased accuracy	34
8.12	Benefits and drawbacks from low rolling noise systems (tyres and pavement) such as reduced rolling resistance, fuel consumption, etc.	34
8.5	Testing of existing model for tyre/road noise with data from several countries and types of tyres and surfaces (testing models)	33
8.8	Investigations and improvement of acoustic and structural durability of noise reducing pavements	33
8.9	Durable silent expansion joints and their acoustic characterization	31

Table 6 Scores related to issues proposed in the thematic domain 7

2	**Thematic Domain 7** **IMPROVED OR NEW SOCIO-ECONOMIC INSTRUMENTS TO PROMOTE EFFICIENT NOISE ABATEMENT**	
ID	Issue	Score
7.4	Development of noise requirements and regulations for road surfaces based on reliable data	41
7.9	Development of national demonstrative programmes for testing novel noise abating measures and technologies.	36
7.3	New noise emission testing for road vehicles that better represent typical conditions in real traffic situations	35
7.6	Tax incentives for low noise vehicles and tyres (requires appropriate noise emission indicators and customer information)	35
7.10	Development of a classification system for road surfaces, including acceptance testing and ageing effect.	35
7.1	Incentives (positive or negative) related to the use of noise reducing devices (silent tires, mufflers, etc.)	34
7.2	Development of regulations and tools for sharing and contributing to noise abatement measures in complex environments where many noise sources are present.	29
7.5	Checks of powered two-wheelers to prevent the use of illegal exhaust systems and manipulations of engine	26
7.8	Improve knowledge of the relations between the road geometry and the driving behaviour	25
7.7	Efficient training programmes for quieter driving styles	20
7.11	Development of a classification system for barrier tops, including test and calculation rules in traffic noise models	3

Table 7 Scores related to issues proposed in the thematic domain 1

3	**Thematic Domain 1** **ADVANCED COMPUTATION AND MEASUREMENT METHODS FOR MORE ACCURATE ASSESSMENT OF NOISE EXPOSURE**	
ID	Issue	Score
1.2	Quality system for noise mapping input data	37
1.3	Methods using noise mapping data to estimate population exposure to environmental noise (linking noise mapping data with population location data i.e. number and location of exposed people).	32
1.7	Development of methods and indicators to check noise mapping results	32
1.8	Development of a shared noise mapping process for road networks	31
1.1	Fast and low cost solutions for updating noise maps, including web-based sensors networks.	30
1.5	Meteorological conditions influence on noise levels	29
1.6	Procedures and criteria for calculating uncertainty connected to noise mapping results	29
1.10	Development of tools for locating and characterizing noise sources in complex environments where many different sources are present (roads, railways, etc.)	25
1.9	Development of traffic congestion calculation models	19
1.11	Development of algorithms for assessing noise levels based on adaptive calculation grids as a function of population density and morphology of the area to be noise mapped for speeding up the calculation process	19
1.4	Temporal and spatial sampling techniques for long term noise level assessment	17
1.12	Development of procedures to integrate special noise barrier constructions (e.g. curved noise barriers) in noise mapping calculations	3

Table 8 Scores related to issues proposed in the thematic domain 9

4	**Thematic Domain 9** **ADVANCED NOISE REDUCTION TECHNOLOGIES BETWEEN SOURCE AND RECEIVERS**	
ID	Issue	Score
9.5	Further research on noise mitigation including road screening that is effective and cost-efficient, reflective buildings, new design concepts and noise absorbing materials.	42
9.3	Improved noise barriers (beautiful design, better absorption behaviour, combination with other benefits like photovoltaics, use of recycled materials, etc.)	41
9.1	Improve the reliability and flexibility of simulation software for the design of acoustic mitigation measures.	38
9.6	Improvement of in-situ acoustic characterization of noise barriers and development of correlation figures between laboratory tests results and in-situ values to be applied for quality check.	35
9.2	Development of calculation models and indicators for assessing the durability of noise barriers and other mitigation measures.	31
9.7	Overall sustainability of ground transport noise reducing devices (materials, construction technology, carbon footprint, maintenance and decommissioning). Development of criteria and tools for product sustainability assessment of noise mitigation technologies.	30
9.4	Active noise control (noise barriers panels, windows, virtual noise barriers, electroacoustic systems).	24
9.8	Development of a new barrier top (reflective type).	4

Table 9 Scores related to issues proposed in the thematic domain 10

5	**Thematic Domain 10** **ACTIVE NOISE MITIGATION MEASURES**	
ID	Item	Score
10.3	Explore telematics solutions for better traffic management and smoother traffic flow to reduce emissions and noise, and contribute to more efficient road use.	36
10.6	Action planning: development of tools for choosing the right strategy and planning the measures to be applied, based on an objective prioritization index.	35
10.1	Development of sophisticated models and network systems that enable the prediction and control of traffic flow to achieve environmental target.	32
10.2	Improvement of existing traffic management systems to smooth traffic and thus reduce noise and vibration.	32
10.5	Electronic support of the driver e.g. by intelligent transmission or engine management.	30
10.7	Development of economically sustainable tools to support noise mitigation measures (photovoltaic, project financing, integration with maintenance plans etc.).	29
10.4	Environmental and safety investigations on low speed and non-motorized transport solutions.	26
10.9	Techniques to assess and optimize the effectiveness of combinations of highway and land-use noise control measures (highway alignment, road surface design, land-use and topographical considerations, screening techniques, etc).	26
10.8	Advanced simulation tools for better understanding the benefits resulting from different urban and traffic planning strategies with all its elements considered in a holistic way.	21

To determine the preferred approach to the management of road traffic noise, thematic domains were gathered in groups corresponding to three main categories:

A. noise assessment and indicators,
B. policy and socio-economic actions,
C. techniques and technologies for noise abatement.

Table 10 shows the thematic domains that were included in each group and the colour code assigned to the clusters.

Table 10 Thematic domains clustering

TG	TD	Thematic domain
A. Noise Assessment and Indicators	1	Advanced computation and measurement methods for more accurate assessment of noise exposure
	2	Definition and identification of urban and rural high acoustic quality areas
	3	Improvement in dose-effect relationships
	4	Additional noise indicators considering specific effects
B. Policy and socio-economic actions	5	Advanced methods of cost-benefit assessment of noise impact and noise abatement
	6	Information and public participation
	7	Improved or new socio-economic instruments to promote efficient noise abatement
C. Techniques and technologies for noise abatement	8	Rolling noise
	9	Advanced noise reduction technologies between source and receivers
	10	Active noise mitigation measures

The preferred approach to the noise issue can be evaluated by adding the normalized scores related to the domains included in the clusters and then calculating their percentage with respect to the total score. The highest percentage should reveal the kind of action considered most convenient or worthy of further analysis to solve the noise problem.

Figure 1 shows the global result representing the European perspective on subjects to be developed to reach a better understanding of the noise problem and improve techniques to abate sound levels.

As it can be seen from Figure 1, the three clusters are quite balanced. The highest score has been reached by cluster A including thematic domains related to noise assessment and indicators. Within this group, great emphasis was placed on the thematic domain on computation and measurement methods revealing the need for more reliable noise exposure assessment techniques. Less demanding research theses were found to be those related to dose-effect relationships and specific indicators.

Themes included in cluster C, techniques and technologies for noise abatement, also got a high rank. As in the previous edition of the survey, the thematic domain related to rolling noise was judged to be of primary importance. Common opinion is that passive mitigation systems must be enhanced in order to abate noise effectively and efficiently, especially at the source.

Thematic domains of cluster B, policy and socio-economic action, are considered worthy to be developed as well, especially those related to regulations on noise emission, including test methods and socio-economic effects. Improvement of cost-benefit analysis and public information and participation is also considered of great interest.

EUROPE

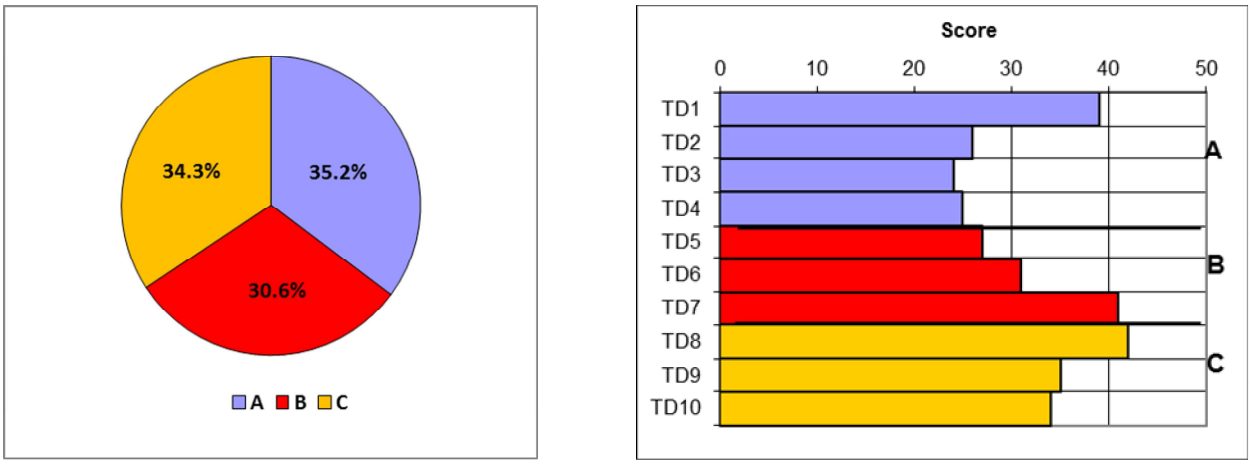
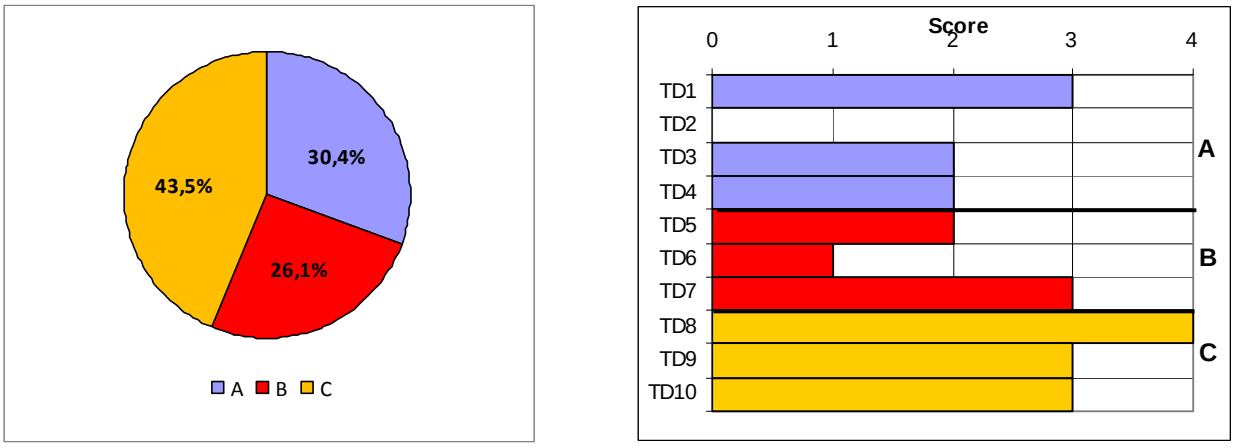


Figure 1 Clustered global results

3.3 Results on a country basis

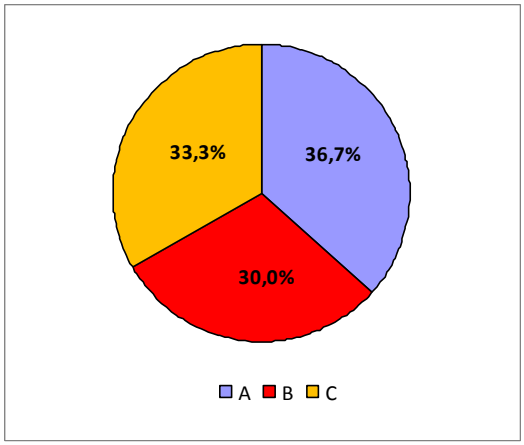
In this section the outcomes on a country basis are reported. For each country the scores given to the investigated domains are shown. The following graphs illustrate the results provided by processing individual data.

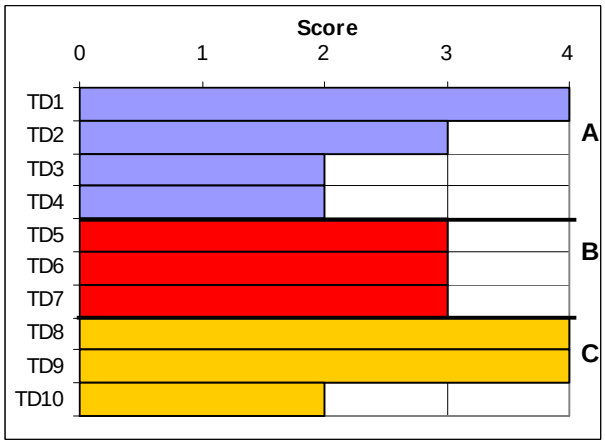
AUSTRIA



Austria seems mainly focused on themes related to techniques and technologies for noise abatement. The highest score was given to thematic domain 8 on rolling noise. High priority was also given to thematic domains 1 and 7 on computation and measurement methods and socio-economic instruments to abate noise.

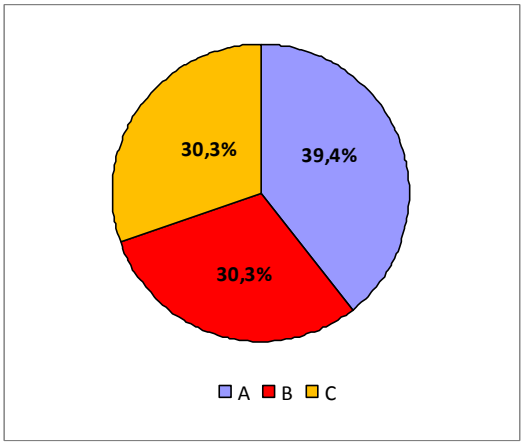
BELGIUM (Flanders)

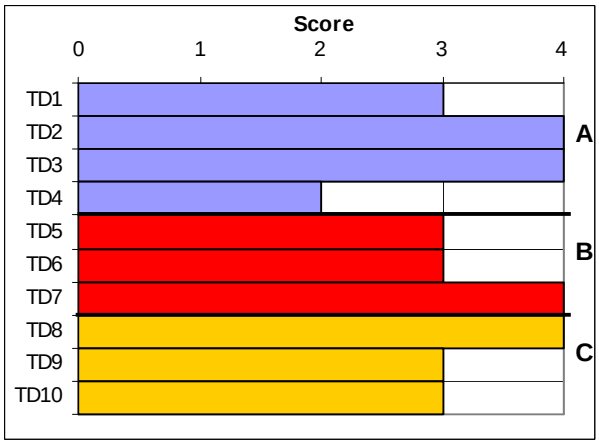




Interest in Belgium seems to be uniformly distributed. High priority is given to thematic domains 1, 8 and 9.
Belgium's preference is focused on abatement strategies, especially on passive systems, together with noise computation and measurement techniques. Themes of group B on policy and economic actions are also considered to be worthy of further development. Less weighty is the need for new noise indicators or sophisticated relationships, as well as for active noise mitigation measures.

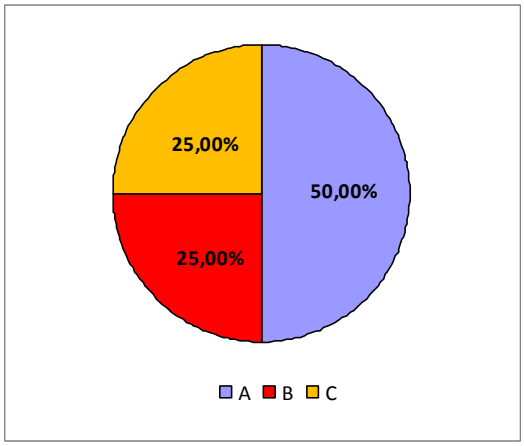
DENMARK

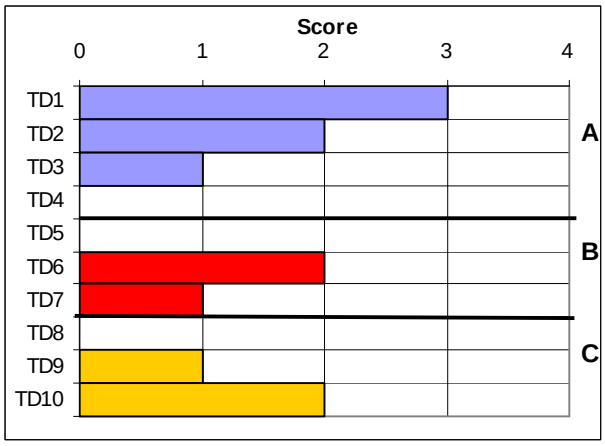




Denmark's approach seems to be quite comprehensive. For each group at least one thematic domain was recommended. In particular interest is focused in thematic domain 2, 3, 7, and 8. Improvement in dose-effect relationships is required, together with effective and efficient techniques to abate sound levels. Noise emission regulations, including test methods, are also very interesting matters. Research on rolling noise was judged of primary importance.

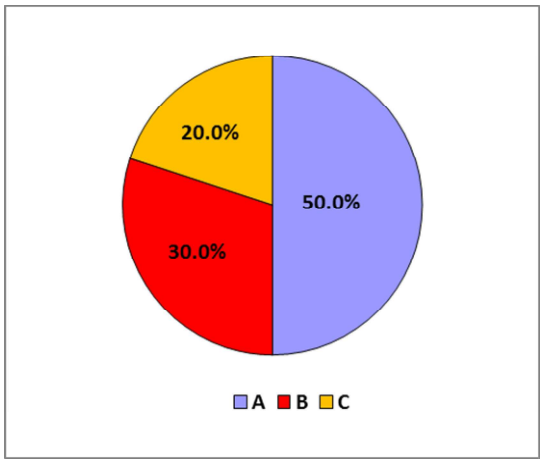
ESTONIA

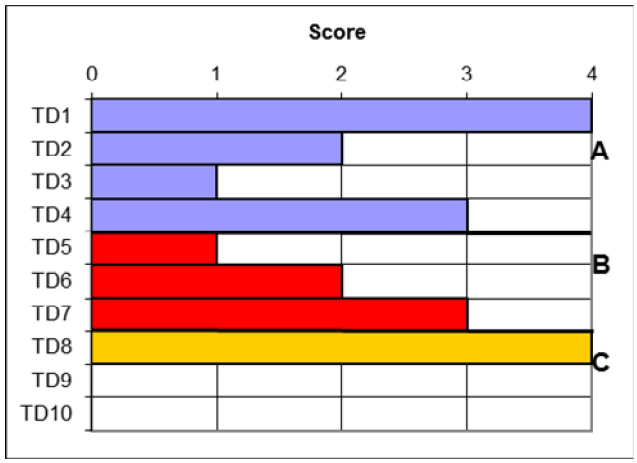




Estonia gives primary importance to thematic domains belonging to group A on noise assessment and indicators, especially on advanced computation and measurement methods. Information and public participation, as well as active noise mitigation measures are also considered worthy of further knowledge.

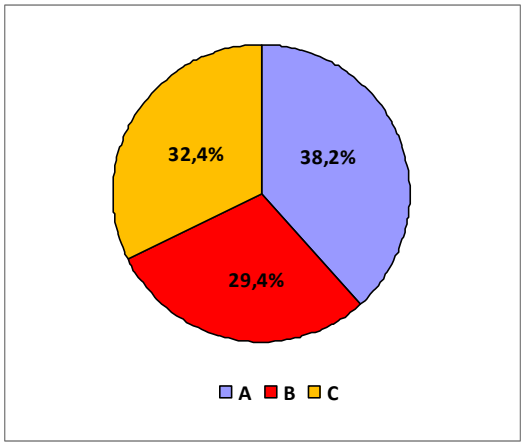
GERMANY

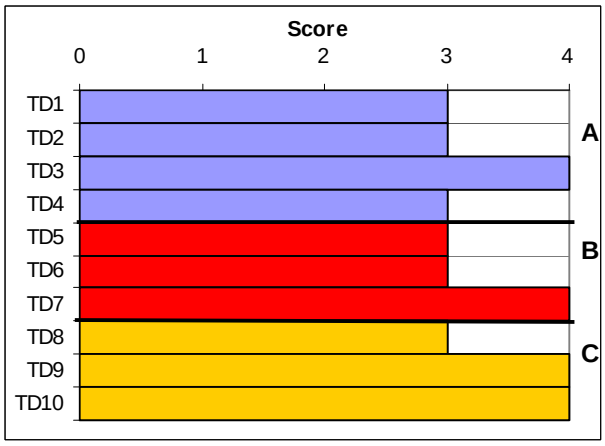




Germany shows a strong interest in thematic domains of group A on noise assessment and indicators, especially on advanced computation and measurement methods and additional noise indicators considering specific effects, revealing the need for improved accuracy in noise exposure assessment. Worthy of attention are also themes 7 and 8 on improved or new socio-economic instruments to promote efficient noise abatement and rolling noise, confirming the priority of reducing noise at the source. On the contrary, absence of interest is shown for thematic domains 9 and 10 on noise barriers and active noise mitigation measures.

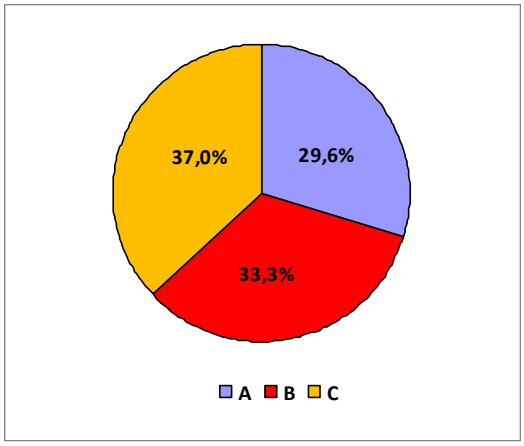
GREECE

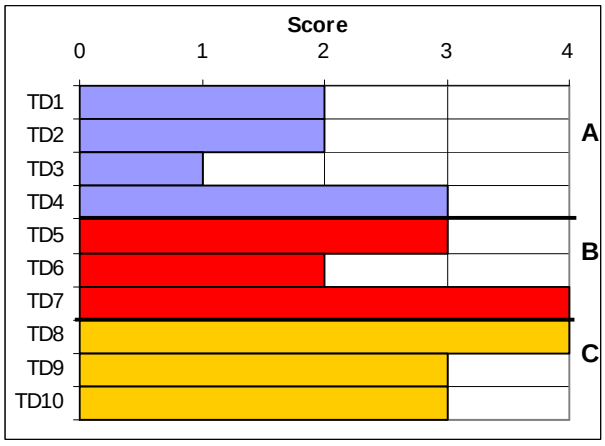




For Greece all thematic domains have more or less the same high priority. For each thematic domain at least one preferred theme was pointed out. In group A, the need for improvement in dose-effect relationships was highlighted, while in group B the preference to improved or new socio-economic instruments to promote efficient noise abatement was given. In group C attention was focused on advanced noise reduction technologies between source and receivers and active noise mitigation measures, revealing Greece interest in innovative approach to noise abatement.

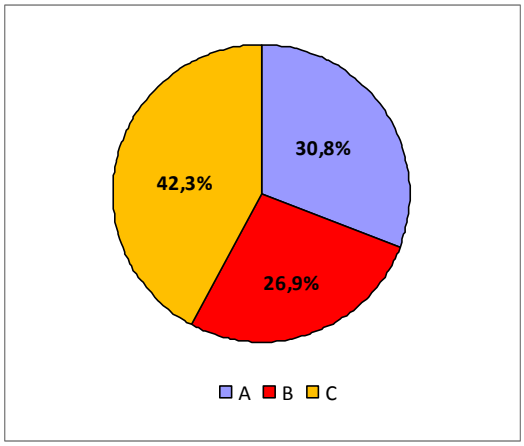
THE NETHERLANDS

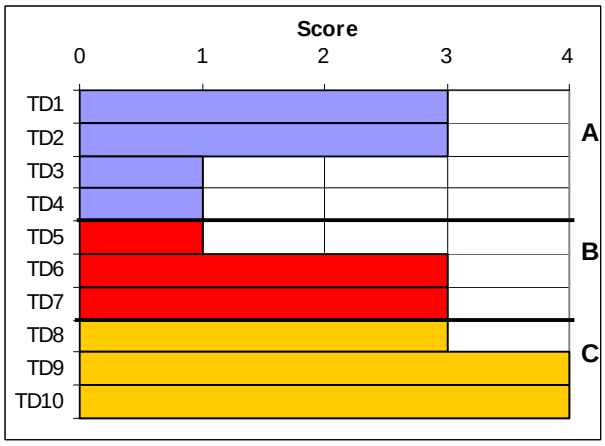




The Netherlands' interest is mainly focused on themes of group C, like many other countries. Absolute priority is given to all thematic domains concerning mitigation systems, both passive and active. Socio-economic instruments to promote efficient noise abatement are also of primary importance, as well as information and public participation. Less worthy of further research seems the thematic group A, especially the theme related to dose effect relationships.

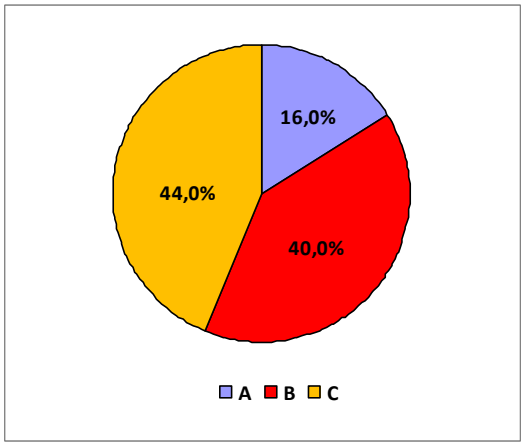
IRELAND

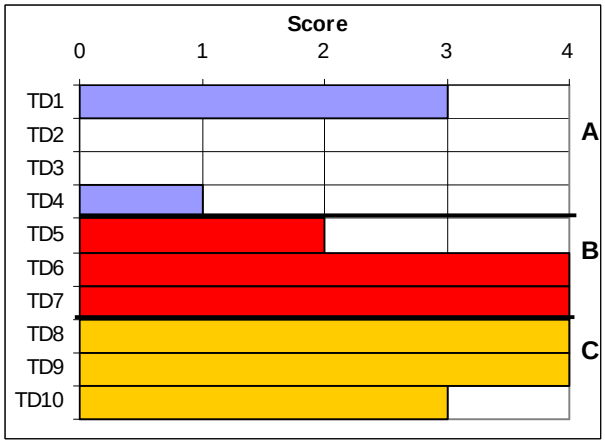




The graphs show that Ireland is mainly interested in developing efficient and effective mitigation systems (group C), both passive and active. Themes included in groups A and B are also worthy to be developed, especially those related to advanced computation and measurement methods for more accurate assessment of noise exposure and improved regulations on noise emission. Less interest is shown in dose-effect relationships, cost benefit analysis and additional noise indicators.

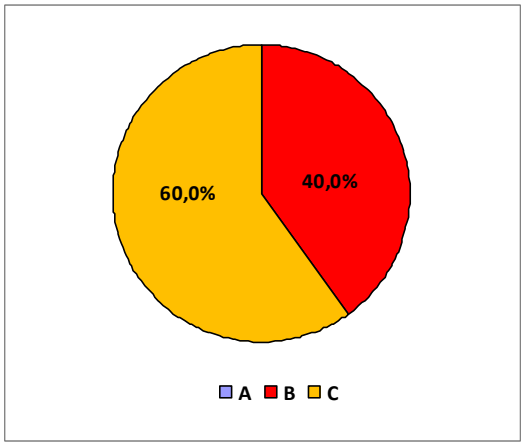
ITALY

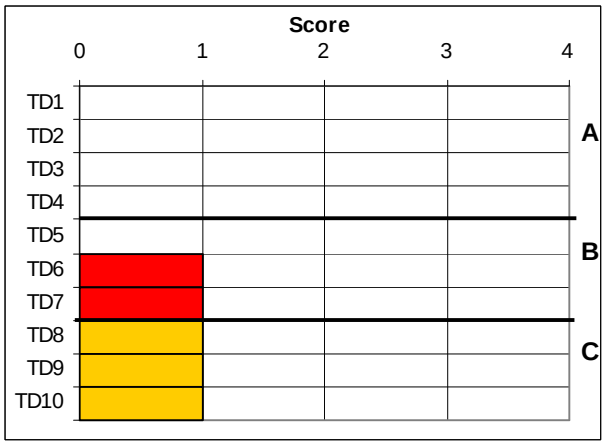




Italy's main interest is focused on thematic groups B and C, related to policy and technologies to abate noise. After the first round of the END and the large number of critical areas emerged from noise mapping the road network, Italy's concern is now addressed on sustainable methods to abate noise. Less required are themes of group A, with the only exception for theme 1 on advanced computation and measurement methods for more accurate assessment of noise exposure, still judged worthy of further research.

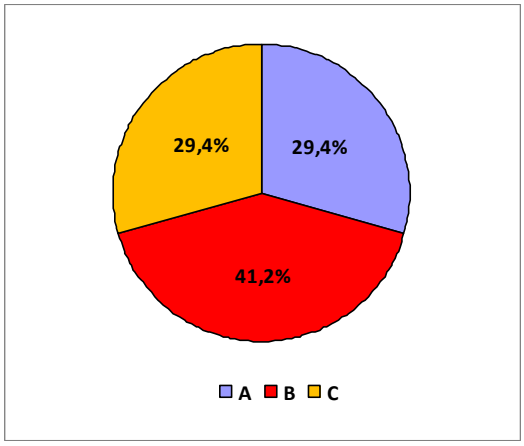
LATVIA

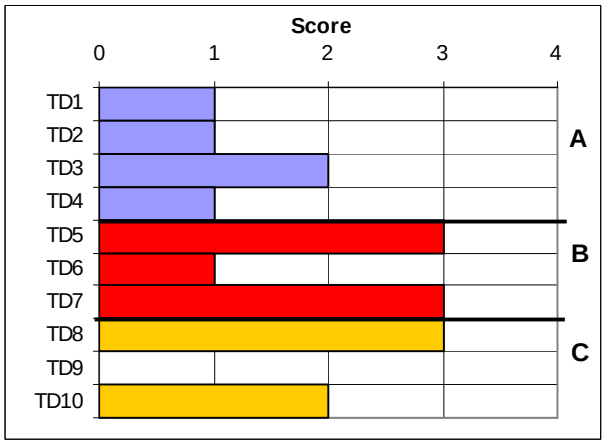




Latvian interest for research is limited to themes of group B and C on policy and economic actions, and techniques and technologies for noise abatement. Equal priority has been given to all themes, with the only exception of TD5 on cost-benefit assessment of noise impact and abatement.

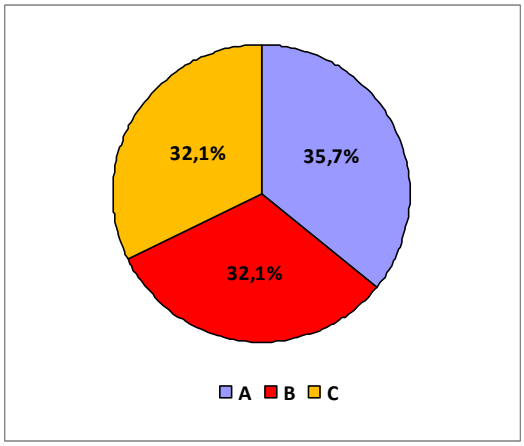
NORWAY

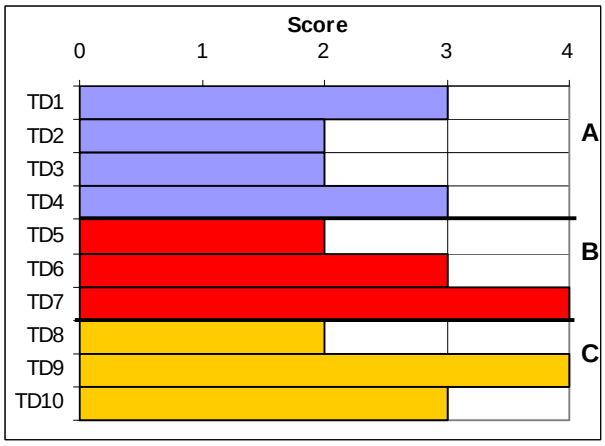




Norway seems particularly interested in the thematic group B related to policy and economic actions. High priority is given to methods for cost-benefit analysis and socio-economic instruments to promote efficient noise abatement, revealing a strong concern on themes focused on the sustainability of noise mitigation measures and the possibility of reducing their economic and financial burden, through actions directly affecting noise levels at the source. Also for Norway the thematic domain 8 on rolling noise still continue to be attractive as a valid measure to abate noise at the source.

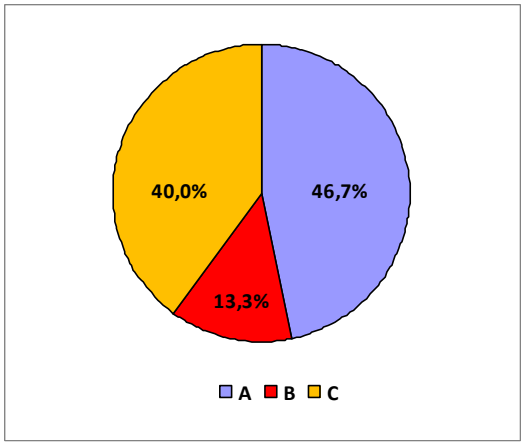
POLAND

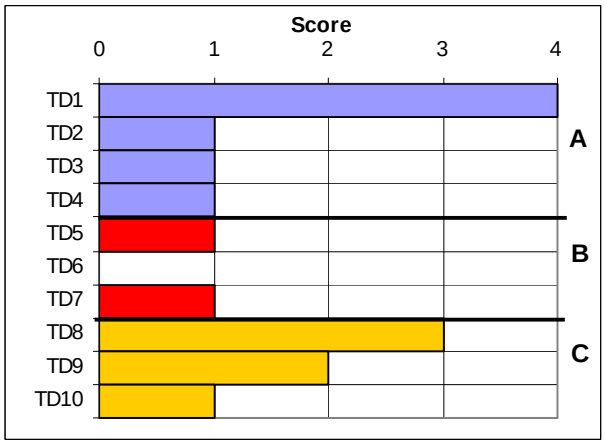




Poland's data reveal particular interest in groups B and C, especially in thematic domains 7 and 9 on socio-economic instruments and noise barriers, exhibiting their preference on measures acting at the source or based on screening between source and receivers, while low noise pavements and their associated research themes noise are judged of minor importance. More or less equal interest is turned to the remaining thematic domains, showing a comprehensive approach to the noise issue.

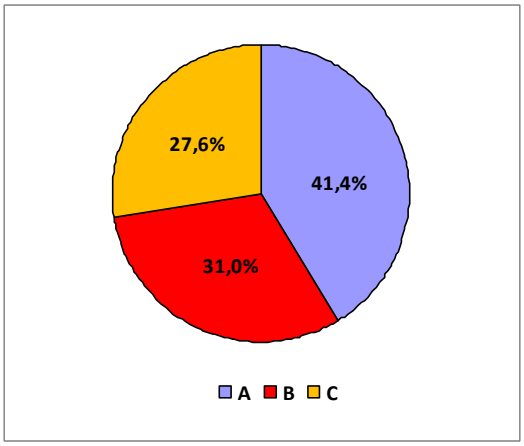
SPAIN

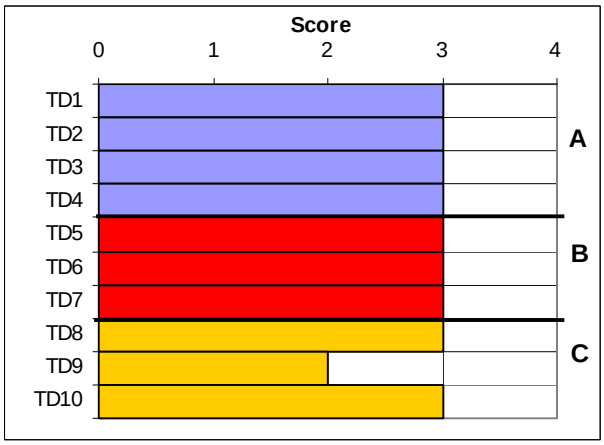




Spain exhibits a strong interest on thematic domain 1, on advanced computation and measurement methods for more accurate assessment of noise exposure, revealing the need for methods and standard improving the reliability of noise maps. As many other states, Spain also seems to prefer an approach based on low noise pavements to abate noise and consequently high priority is also given to thematic domain 8 on rolling noise.

SWEDEN





Sweden shows a comprehensive approach to the noise issue. All the thematic domains are judged of the same relevance, with the only exception for thematic domain 9 on advanced mitigation measures between source and receivers, revealing a preference towards different noise abatement interventions, such as low noise pavements and socio-economic instruments to reduce noise emissions directly at the source.

3.4 Research priorities

As highlighted at the beginning of this report, the questionnaire intended to collect information on research themes considered of interest for NRAs and to find the priority to be assigned to each matter in order to arrange a list of topics to be taken into account for future research. With this perspective in mind, each topic in the questionnaire also included further details to determine if:

- the research on that topic has already been developed (B);
- the research on that topic is still in progress (C);
- the research on that topic is going to be developed at a future time (D);
- the research on that topic has not done or planned (E).

To let research priorities emerge from the survey, another filtering step was added to the results.

3.4.1 Description of the algorithm used

The algorithm used to extrapolate research priorities takes into account information related to the state of the art on research. It is visually represented as a flow chart in Figure 2. Particular attention was paid to themes already developed (B) or in progress (C), in order to avoid subjects not worthy of further research. To that end, it seemed reasonable to exclude research themes financed by at least three countries, regardless of the interest level assigned by NRAs. In that case, no research on that topic should be done and information related to that subject should be retrieved from countries participating in the research.

Differently, if the number of countries that have already developed a particular theme or are still working on it is less than three, then the interest shown by NRAs is taken into account. To be put into the priority research list, the algorithm requires that an issue should be reported as planned at a future time by at least two countries, otherwise the priority is set to zero.

Finally, the ranking list of future noise research topics is achieved by multiplying the score assigned to the filtered topics by a weighting factor. The weighting factor positively depends on the percentage of countries willing to develop a topic at a future time and negatively depends on the countries that have already developed the same topic or that are still working on it. The weighting factor used to weight the resulting scores is:

$$F_w = 2 \cdot P_D - P_C - P_B$$

where:

P_D is the percentage of countries that have planned to develop the research topic at a future time;
P_C is the percentage of countries that are still working on the same research topic;
P_B is the percentage of countries that have already developed the same research topic.

The final score (priority) assigned to topics included in the ranking list comes from the following formula:

$$Priority = F_W \cdot Score$$

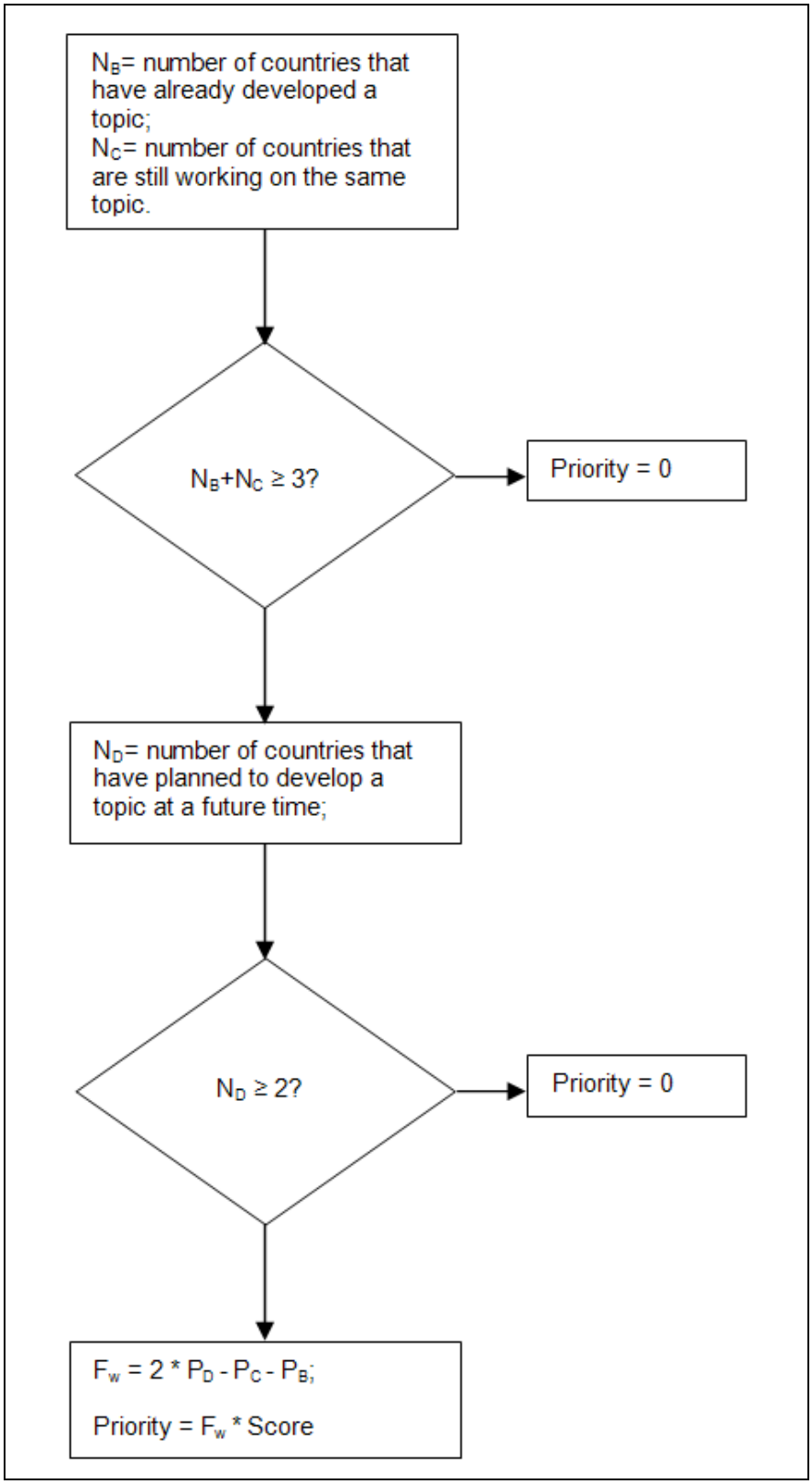


Figure 2 Flow chart of the algorithm used for data filtering and to extrapolate research priorities

3.4.2 Results achieved after the filtering step

Table 11 reports the priorities calculated for research themes after the last filtering step. The table excludes issues with zero priority (completed research or ongoing projects). As evident from this table, few topics included in the most interesting thematic domains, such as rolling noise (TD 8) and improved or new socio-economic instrument to promote efficient noise abatement (TD 7), survived the processing procedure. The main priority seems, instead, to converge on themes related to the thematic domain on advanced noise reduction between source and receivers. This last filtering step also shows that thematic domains and issues with high interest scores do not necessarily correspond to those suitable for future research, as reported in Table 11, where topics with lower ranks, previously discarded, are now present.

Table 11 Road Noise Research list after the last filtering step

ROAD NOISE RESEARCH LIST		
ID	Topic	Priority
9.5	Further research on noise mitigation including road screening that is effective and cost-efficient, reflective buildings, new design concepts and noise absorbing materials.	25.3
9.1	Improve the reliability and flexibility of simulation software for the design of acoustic mitigation measures.	14.6
7.3	New noise emission testing for road vehicles that better represent typical conditions in real traffic situations	12.0
1.8	Development of a common procedure to map traffic noise.	9.7
1.1	Fast and low cost solutions for updating noise maps, including web-based sensors networks.	9.5
1.10	Development of tools for locating and characterizing noise sources in complex environments where many different sources are present (roads, railways, etc.)	8.4
5.2	Improved benefit estimates based on HP method (hedonic price, i.e. house price method)	8.4
9.7	Overall sustainability of ground transport noise reducing devices (materials, construction technology, carbon footprint, maintenance and decommissioning). Development of criteria and tools for product sustainability assessment of noise mitigation technologies.	7.6
5.1	Improvement of benefit estimation based on SP (stated preference) method including valuation for quiet and undisturbed sleep	6.8
3.8	Development of dose-effect relationships for L_{day}, $L_{evening}$ and L_{night}.	6.6
5.6	Methods for the valuation of health impacts and other impacts of noise reduction	6.3
10.4	Environmental and safety investigations on low speed and non-motorized transport solutions.	6.3
3.7	Annoyance perception on private outdoor areas	6.0
10.6	Action planning: development of tools for choosing the right strategy and planning the measures to be applied, based on an objective prioritization index.	5.8
8.2	New concept for low-noise tyres (geometry, design, material, matching to road surfaces).	5.7
7.2	Development of regulations and tools for sharing and contributing to noise abatement measures in complex environments where many noise sources are present.	5.4
1.9	Development of traffic congestion calculation models	5.2
6.1	Development of advanced communication techniques, like virtual reality, to stimulate public awareness and participation in noise issues.	5.2
5.4	Influence on noise annoyance valuation of different noise levels during day, evening and night periods.	4.7
1.6	Procedures and criteria for calculating uncertainty associated with noise mapping results.	4.5

Results depicted in Table 11 show that high priority was given to research themes related to noise abatement, in particular to the development of environmentally and economically sustainable mitigation measures. To guarantee the result expected from their implementation, the improvement of reliable and flexible simulation software for the design of acoustic mitigation measures is also required. The interest toward noise reduction is also strengthened by the need of finding solutions to contain noise at the source. To that end, new noise emission testing for road vehicles and tyres that better represent typical conditions in real traffic situations, as well as new material and techniques to mitigate the noise produced by road joints and potholes were highlighted by the questionnaire respondents as important issues to improve the environmental performance of infrastructures.

Medium priority was reserved to research themes related to noise mapping and the thematic domain on advanced methods of cost-benefits assessment of noise impact and noise abatement. Research themes related to dose-effect relationships and noise perception, as well as themes on health impacts are included in this context.

Low priority was given to matters that can be considered as support tools for assessing noise pollution and preparing strategic action plans, as well as themes related to the reliability of calculation models.

3.4.3 Results on ongoing or finished projects

Themes related to ongoing or finished projects are also important for the scope of CEDR Road Noise 3, as in the period 2013-17 the attention will be focused on the collation, dispersion, implementation and use of results from recent innovative noise research projects undertaken within specific CEDR member states, including results and recommendations from CEDR Road Noise 1 and 2.

The five most interesting examples of recent finished or ongoing noise research deal with the following subjects:

- development of optimised noise reducing pavements,
- development of noise requirements and regulations for road surfaces based on reliable data,
- procedures for the acoustic labelling and conformity checking of road surface products or techniques,
- improved noise barriers (beautiful design, better absorption behaviour, combination with other benefits like photovoltaics, use of recycled materials, etc.),
- quality system for noise mapping input data.

4 Conclusions

A questionnaire on road noise research needs was developed with the aim to elucidate priority noise research themes common to the European area. The questionnaire was sent to all member states of CEDR Road Noise.
The questionnaire responses were analysed from two perspectives, by thematic domain and by country.

The top five thematic domains meeting CEDR member states interest are:

1. rolling noise,
2. improved or new socio-economic instruments to promote efficient noise abatement,
3. advanced computation and measurement methods for more accurate assessment of noise exposure,
4. advanced noise reduction technologies between source and receivers,
5. active noise mitigation measures.

Themes related to systems and methods to abate noise are considered of primary importance. In particular, the list of the thematic domains with the highest priority reasserts the common opinion that noise must be reduced first at the source and then using screens between source and receivers.

The way noise can be reduced is another important matter to be investigated. The experience gained in the last decade shows that solutions limited to single noise sources could be insufficient to abate noise levels at receivers, so combined solutions should be investigated in order to guarantee the required noise abatement. Policies and strategies are necessary to ensure an efficient and effective solution to the problem.

The development of additional and innovative noise abating techniques, such as traffic management, speed reduction, electric or non-motorized transport solutions, photovoltaics integration in noise barriers, as well as managerial and financial tools to reduce the cost of noise mitigation measures, are also required.

On completion of the first round of END, the need for high quality input data and more accuracy on the results provided by calculation models was also highlighted in order to improve noise maps reliability. Also methods to check the veracity of results are required to guarantee noise maps outcomes.

In order to help identify the preferred approach to the noise issue emerge from the survey, thematic domains were also clustered in three main categories:

A. noise assessment and indicators,
B. policy and socio-economic actions,
C. techniques and technologies for noise abatement.

The results achieved by grouping the thematic domains show that the cluster 'noise assessment and indicators' has the highest score. The importance of improving the thematic domain related to computation and measurement methods has been reasserted to encourage the development of more reliable evaluation of noise exposure. Less demanding are research themes on dose-effect relationships and specific indicators.

Domains in the cluster 'techniques and technologies for noise abatement' maintain their high ranking. As in the previous edition of the survey, the thematic domain related to rolling noise was judged to be of primary importance. Common opinion is that passive mitigation systems must be enhanced in order to abate noise effectively and efficiently, especially at the source.

Thematic domains in the cluster 'policy and socio-economic actions' are considered worthy to be developed as well, especially those related to regulations on noise emission and socio-economic effects. Improvement on cost-benefit analysis and public information and participation is also considered of great interest.

Another filtering step was used to achieve a priority list of topics for future research. The algorithm adopted used information related to the state of the art on different matters as input. Outcomes from this last step show that for the most interesting thematic domain on rolling noise, just one topic survived to data filtering. A similar result was also achieved for thematic domain on improved and socio-economic instrument to promote efficient noise abatement. The main priority has been given to themes related to noise abatement, in particular to the development of environmentally and economically sustainable mitigation measures.

These results prove that in general themes with high ranks do not necessarily correspond to those suitable for future research and that the interest shown in the questionnaire is often focused on topics under development.

5 Recommendations

The results of the questionnaire highlight the need for more research on road noise. High priority was assigned to research themes related to noise abatement, in particular to the development of environmentally and economically sustainable mitigation measures. Medium priority was given to research themes related to noise mapping and cost-benefits assessment of noise impact and noise abatement. So the CEDR Project Group Road Noise strongly recommends focusing attention on topics regarding the design and development of effective and efficient solutions to abate noise, including their environmental and economic assessment.

Based on this overall recommendation, CEDR Road Noise has two specific recommendations.

First, to use the information on noise research needs when defining, planning and prioritizing new research and development activities in relation to:

- national research programmes of individual National Road Administrations (NRAs),
- regional and bi-lateral cooperation by NRAs of several EU member states,
- CEDR transnational programme on research (ERA-NET Road [3] and ERA-NET Transport),
- FEHRL programme Forever Open Road [4] [5],
- EU research programmes like FP8 and Horizon 2020.

This recommendation sounds simplistic, but in fact this will require a lot of effort and resources to get it involved on noise research at a transnational level. To cope with these preconditions, one has to focus on specific programmes. That's why the follow-up activities are concentrated on the recent CEDR Call 2012 on noise: integrating strategic noise management into the operation and maintenance of national road networks.

Second, to use the information on noise research needs in the scope of CEDR Road Noise 3, whose mission, in the period 2013-17, will be focused on the collation, dispersion, implementation and adoption of results from recent innovative noise research projects undertaken within CEDR member states.

6 References

[1] CEDR Strategic Plan 2009-13
[2] CEDR homepage: http://www.cedr.fr/
[3] ERA-NET-ROAD homepage: http://www.road-era.net/
[4] FEHRL Strategic European Road Research programme V (2011-2016) – May 2011
[5] FEHRL Forever Open Road - 2011
[6] ERTRAC Strategic Research Agenda – Toward a 50% more efficient road transport system by 2030 – October 2010
[7] ERTRAC Road Transport Scenario 2030+ – October 2009
[8] ERF Position paper on Road Traffic Noise: the road sector's perspective – The European Road Federation, May 2004
[9] Research needs for a quieter Europe: silent road surfaces solutions – R. Cordero, STOA Workshop, November 2011
[10] Sustainable noise reducing devices: the Quiesst Project – G. Brero, STOA Workshop, November 2011
[11] QUIESST - **QUI**etening the **E**nvironment for a **S**ustainable **S**urface **T**ransport - http://www.quiesst.eu
[12] TYROSAFE Tyre and Road Surface Optimisation for Skid Resistance and Further Effects - http://tyrosafe.fehrl.org
[13] SILENT ROADS - http://www.silentroads.nl/
[14] PERSUADE - http://persuade.fehrl.org/
[15] INMAR - http://www.inmar.info/
[16] QCITY - http://www.qcity.org/
[17] ROTRANOMO – Road Traffic Noise Model - http://www.rotranomo.com/
[18] SILENCE - http://www.silence-ip.org
[19] ETSC ShLOW – Reducing excessive and inappropriate speed now – October 2008
[20] HUSH Project - http://www.hush-project.eu/it

Annex A The blank questionnaire

PROJECT GROUP ROAD NOISE

QUESTIONNAIRE ON ROAD NOISE REASERCH NEEDS

General Information:

Country:

Organisation:

Name: **Address:**

E-mail:

Introduction

Aim of the following questionnaire is to find research themes on road noise that need further knowledge. The questionnaire includes 10 main thematic domains. Each thematic domain comprises a group of items connected to the peculiar domain (see fig. 1).
In order to identify the items that need in-depth study, you are kindly requested to mark the domains you think worthy of further research with a number from 0 to 4, indicating the priority to be assigned to domains and items, as shown in the table below. If you can't assign a score please click the "N" button. (Null answer)

Score	Thematic Domain Priority	Items interest level
N	Null (not known)	Null (not known)
0	No priority	Not interesting
1	Low priority	Little interesting
2	Medium priority	Interesting
3	High priority	Rather interesting
4	Absolute priority	Very interesting

For each item it is also asked to specify if:

- the research on that item has already been developed in your country
- the research on that item is still in progress
- the research on that item is going to be developed at a future time
- the research on that item has not done or planned.

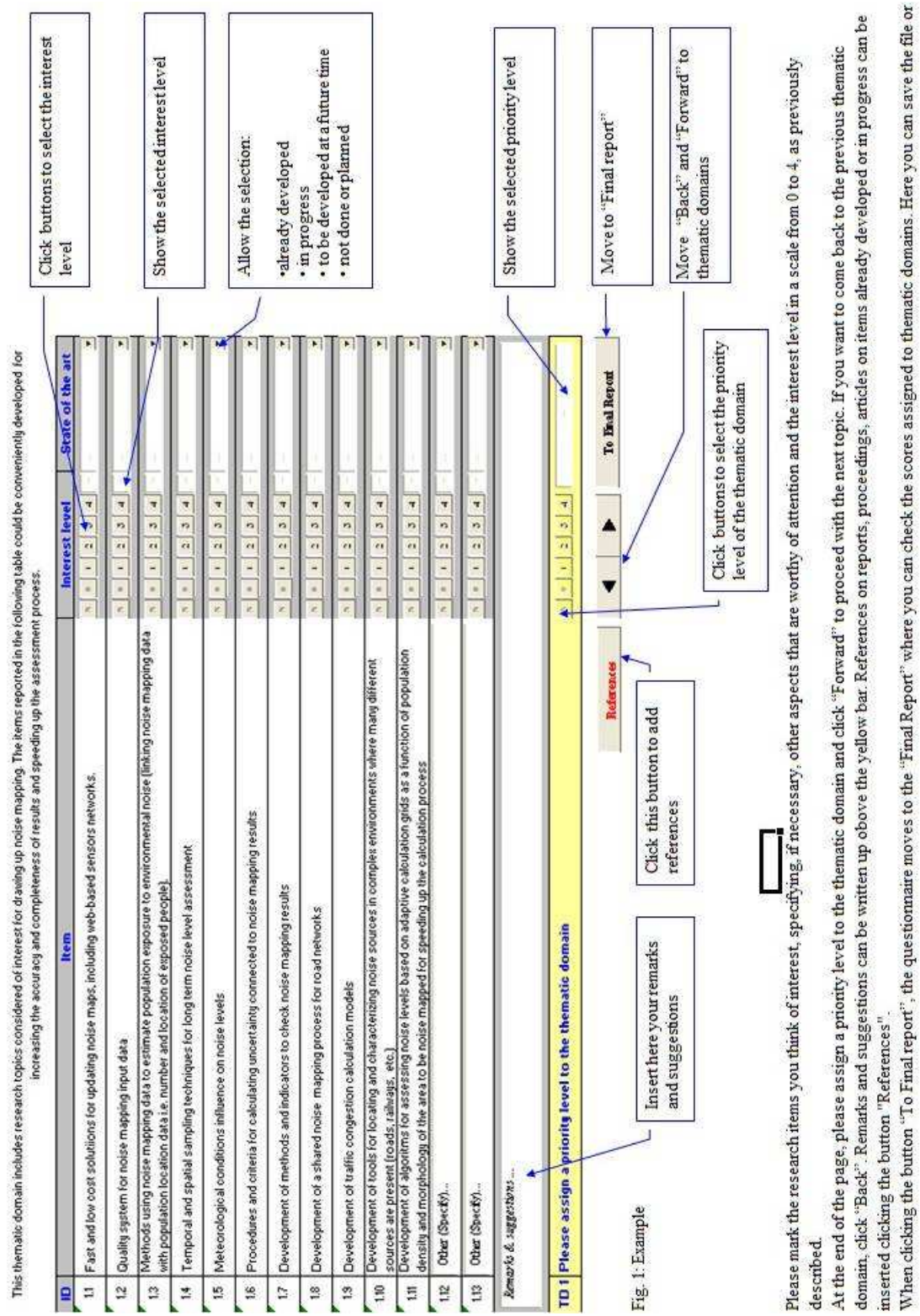


Fig. 1: Example

Please mark the research items you think of interest, specifying, if necessary, other aspects that are worthy of attention and the interest level in a scale from 0 to 4, as previously described.

At the end of the page, please assign a priority level to the thematic domain and click "Forward" to proceed with the next topic. If you want to come back to the previous thematic domain, click "Back". Remarks and suggestions can be written up above the yellow bar. References on reports, proceedings, articles on items already developed or in progress can be inserted clicking the button "References".

When clicking the button "To Final report", the questionnaire moves to the "Final Report" where you can check the scores assigned to thematic domains. Here you can save the file or

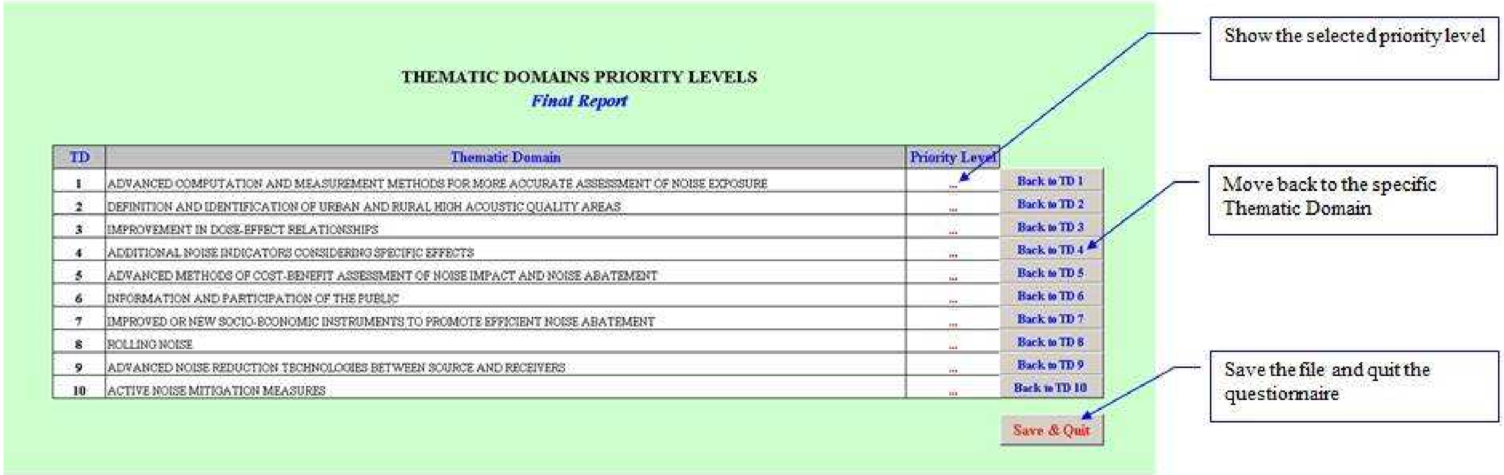


Fig.2: Final Report

Before starting the questionnaire, ***please make sure*** ***<u>the file is saved in a folder</u>*** ***on your computer and*** ***<u>macros are activated</u>***.
When finished, click on the button "Save and Quit" and send the file to Patrizia Bellucci [p.bellucci@stradeanas.it] and Michiel Roebben [Michiel.Roebben@Oranjewoud.nl].

Thanks for your precious cooperation. You will be informed on the results emerged from this survey as soon as they will be available.

Now click the button and start the questionnaire

START

THEMATIC DOMAIN 1

"ADVANCED COMPUTATION AND MEASUREMENT METHODS FOR MORE ACCURATE ASSESSMENT OF NOISE EXPOSURE"

This thematic domain includes research topics considered of most interest for drawing up strategic noise mapping. The items reported in the following table could be conveniently developed for increasing the accuracy and completeness of results and speeding up the assessment process.

ID	Item	Interest level	State of the art
1.1	Fast and low cost solutiions for updating noise maps, including web-based sensors networks.	N 0 1 2 3 4 ...	...
1.2	Quality system for noise mapping input data	N 0 1 2 3 4 ...	...
1.3	Methods using noise mapping data to estimate population exposure to environmental noise (linking noise mapping data with population location data i.e. number and location of exposed people).	N 0 1 2 3 4 ...	...
1.4	Temporal and spatial sampling techniques for long term noise level assessment	N 0 1 2 3 4 ...	...
1.5	Meteorological conditions influence on noise levels	N 0 1 2 3 4 ...	...
1.6	Procedures and criteria for calculating uncertainty associated with noise mapping results.	N 0 1 2 3 4 ...	...
1.7	Development of quality control methods and indicators to check the veracity of noise mapping results.	N 0 1 2 3 4 ...	...
1.8	Development of a common procedure to map traffic noise.	N 0 1 2 3 4 ...	...
1.9	Development of traffic congestion calculation models	N 0 1 2 3 4 ...	...
1.10	Development of tools for locating and characterizing noise sources in complex environments where many different sources are present (roads, railways, etc.)	N 0 1 2 3 4 ...	...
1.11	Development of algoritms for assessing noise levels based on adaptive calculation grids as a function of population density and morphology of the area to be noise mapped for speeding up the calculation process	N 0 1 2 3 4 ...	...
1.12	Other (Specify)...	N 0 1 2 3 4 ...	...
1.13	Other (Specify)...	N 0 1 2 3 4 ...	...

Remarks & suggestions ...

TD 1	**Please assign a priority level to the thematic domain**	N 0 1 2 3 4	...

References ◀ ▶ To Final Report

THEMATIC DOMAIN 2

"DEFINITION AND IDENTIFICATION OF URBAN AND RURAL HIGH ACOUSTIC QUALITY AREAS"

Appropriate indicators and limit values are needed to define and delimit urban and rural quiet areas and to determine the public response to noise exposure.

ID	Item	Interest level	State of the art
2.1	Methods for identifying rural and urban quiet areas	N 0 1 2 3 4 ...	...
2.2	Identification of the features providing the most appropriate indicators and limit values for rural and urban quiet areas	N 0 1 2 3 4 ...	...
2.3	Parameters influencing public's perception of quiet areas	N 0 1 2 3 4 ...	...
2.4	Environmental control procedures to maintain quiet areas	N 0 1 2 3 4 ...	...
2.5	Other (Specify)...	N 0 1 2 3 4 ...	...
2.6	Other (Specify)...	N 0 1 2 3 4 ...	...
2.7	Other (Specify)...	N 0 1 2 3 4 ...	...
2.8	Other (Specify)...	N 0 1 2 3 4 ...	...
2.9	Other (Specify)...	N 0 1 2 3 4 ...	...
2.10	Other (Specify)...	N 0 1 2 3 4 ...	...
2.11	Other (Specify)...	N 0 1 2 3 4 ...	...
2.12	Other (Specify)...	N 0 1 2 3 4 ...	...
2.13	Other (Specify)...	N 0 1 2 3 4 ...	...
Remarks & suggestions ...			
TD 2	**Please assign a priority level to the thematic domain**	N 0 1 2 3 4	...

References ◀ ▶ To Final Report

THEMATIC DOMAIN 3

"IMPROVEMENT IN DOSE-EFFECT RELATIONSHIPS"

TThe effects induced by noise on the population exposed to road traffic noise are of great importance to establish the relationships between noise levels and annoyance. The following items tackle some aspects of the problem related to the development of more accurate dose-effects relationship.

ID	Item	Interest level	State of the art
3.1	Health effects of sleep disturbance (awakening) due to road traffic - Relevant indicators and dose-effect relationship	N 0 1 2 3 4 --	...
3.2	Effects of the degree of façade insulation and of a quiet side of the building on noise perception	N 0 1 2 3 4 --	...
3.3	Effects of noise management measures on people's perception (reaction on changes of exposure situations)	N 0 1 2 3 4 --	...
3.4	Combined health effects due to noise and air pollution exposure.	N 0 1 2 3 4 --	...
3.5	Influence on noise annoyance on cultural differences among countries including the effects of different patterns of social behaviour.	N 0 1 2 3 4 --	...
3.6	Epidemiological studies	N 0 1 2 3 4 --	...
3.7	Annoyance perception on private outdoor areas	N 0 1 2 3 4 --	...
3.8	Development of dose-effect relationships for Lday, Levening and Lnight.	N 0 1 2 3 4 --	...
3.9	Dose-effect relationship for cardiovascular effects.	N 0 1 2 3 4 --	...
3.10	Other (Specify)...	N 0 1 2 3 4 --	...
3.11	Other (Specify)...	N 0 1 2 3 4 --	...
3.12	Other (Specify)...	N 0 1 2 3 4 --	...
3.13	Other (Specify)...	N 0 1 2 3 4 --	...

Remarks & suggestions ...

TD 3	**Please assign a priority level to the thematic domain**	N 0 1 2 3 4	...

References ◀ ▶ To Final Report

THEMATIC DOMAIN 4

"ADDITIONAL NOISE INDICATORS CONSIDERING SPECIFIC EFFECTS"

In this thematic domain, specific properties that have significant influence on noise perception are addressed, but not sufficiently described and represented by the common indicators Lden and Lnight. Research in these fields should focus on dose-effect relationships due to low frequency components, impulsive noise, infrequent events and the occurrence of quiet periods.

ID	Item	Interest level	State of the art
4.1	Effect of low frequency noise	N 0 1 2 3 4 ...	...
4.2	Effect of impulsive noise (for example noise produced by joints on a viaduct or a bridge, potholes, etc.)	N 0 1 2 3 4 ...	...
4.3	Influence of infrequent noise events on the overall sound preassure level	N 0 1 2 3 4 ...	...
4.4	Effect of vibrations	N 0 1 2 3 4 ...	...
4.5	Effect of quiet periods on long-term noise levels (source not working during specific time intervals, for example at night time)	N 0 1 2 3 4 ...	...
4.6	Effect of tunnel openings and avalanche protectors.	N 0 1 2 3 4 ...	...
4.7	Other (Specify)...	N 0 1 2 3 4 ...	...
4.8	Other (Specify)...	N 0 1 2 3 4 ...	...
4.9	Other (Specify)...	N 0 1 2 3 4 ...	...
4.10	Other (Specify)...	N 0 1 2 3 4 ...	...
4.11	Other (Specify)...	N 0 1 2 3 4 ...	...
4.12	Other (Specify)...	N 0 1 2 3 4 ...	...
4.13	Other (Specify)...	N 0 1 2 3 4 ...	...

Remarks & suggestions ...

TD 4	**Please assign a priority level to the thematic domain**	N 0 1 2 3 4	...

References ◀ ▶ To Final Report

THEMATIC DOMAIN 5

"ADVANCED METHODS FOR COST-BENEFIT ANALYSIS OF NOISE IMPACT AND NOISE ABATEMENT"

Cost-benefit analysis is an important tool to evaluate the efficiency and effectiveness of noise mitigating measures to be undertaken in action plans. Further development of the stated preference method and house price method is required to reduce uncertainties and to provide more accurate estimates. A novel indicator considering the influence of the initial sound level, health impacts and other factors related to noise reduction measures such as the effects on local air quality, emission of greenhouse gases, traffic safety, etc. is also required to improve cost-benefit analysis.

ID	Item	Interest level	State of the art
5.1	Improvement of benefit estimation based on SP (stated preference) method including valuation for quiet and undisturbed sleep	N 0 1 2 3 4 ...	...
5.2	Improved benefit estimates based on HP method (hedonic price, i.e. house price method)	N 0 1 2 3 4 ...	...
5.3	Improved benefit estimates due to changes in model-split (e.g. for car transport to cycling)	N 0 1 2 3 4 ...	...
5.4	Influence on noise annoyance valuation of different noise levels during day, evening and night periods.	N 0 1 2 3 4 ...	...
5.5	Influence of the initial sound level on the valuation of noise reduction	N 0 1 2 3 4 ...	...
5.6	Methods for the valuation of health impacts and other impacts of noise reduction	N 0 1 2 3 4 ...	...
5.7	Influence on noise annoyance valuation of peculiar receivers characteristics, such as façade insulation and living outdoor areas (garden, terrace, etc.)	N 0 1 2 3 4 ...	...
5.8	Other (Specify)...	N 0 1 2 3 4 ...	...
5.9	Other (Specify)...	N 0 1 2 3 4 ...	...
5.10	Other (Specify)...	N 0 1 2 3 4 ...	...
5.11	Other (Specify)...	N 0 1 2 3 4 ...	...
5.12	Other (Specify)...	N 0 1 2 3 4 ...	...
5.13	Other (Specify)...	N 0 1 2 3 4 ...	...

Remarks & suggestions ...

TD 5	Please assign a priority level to the thematic domain	N 0 1 2 3 4	...

References ◀ ▶ To Final Report

THEMATIC DOMAIN 6

"INFORMATION AND PUBLIC PARTICIPATION "

The Environmental Noise Directive states that Member States should ensure that strategic noise maps and action plans are made available and disseminated to the public. The information should be clear, comprehensible and accessible. Mamber States should also ensure that the public is consulted about proposals for action plans, given early and effective opportunities to participate in the preparation and review of the action plans, that the results of that participation are taken into account and that the public is informed on the decisions taken. Reasonable time frames should be provided allowing sufficient time for each stage of public participation. Results related to the first round of the END showed that there was poor participation by the public and that research on this field is necessary, in order to outline suitable communication languages and modes.

	Item	Interest level	State of the art
6.1	Development of advanced communication techniques, like virtual reality, to stimulate public awareness and participation in noise issues.	N 0 1 2 3 4 ...	...
6.2	Survey on novel communication languages of public interaction, based on social networks.	N 0 1 2 3 4 ...	...
6.3	Development of new communication languages to inform and enhance public participation.	N 0 1 2 3 4 ...	...
6.4	Development of "real time" noise measurements network to support public information.	N 0 1 2 3 4 ...	...
6.5	Other (Specify)...	N 0 1 2 3 4 ...	...
6.6	Other (Specify)...	N 0 1 2 3 4 ...	...
6.7	Other (Specify)...	N 0 1 2 3 4 ...	...
6.8	Other (Specify)...	N 0 1 2 3 4 ...	...
6.9	Other (Specify)...	N 0 1 2 3 4 ...	...
6.10	Other (Specify)...	N 0 1 2 3 4 ...	...
6.11	Other (Specify)...	N 0 1 2 3 4 ...	...
6.12	Other (Specify)...	N 0 1 2 3 4 ...	...
6.13	Other (Specify)...	N 0 1 2 3 4 ...	...

Remarks & suggestions ...

TD 6	**Please assign a priority level to the thematic domain**	N 0 1 2 3 4	...

References ◀ ▶ To Final Report

THEMATIC DOMAIN 7

"IMPROVED OR NEW SOCIO-ECONOMIC INSTRUMENTS TO PROMOTE EFFICIENT NOISE ABATEMENT"

High level information instruments are required to direct consumers towards quieter products and quieter behaviour based on positive or negative incentives and regulations related to the use of noisy devices, to the extent of noise nuisance or to the cost caused by the noise impact to society. At the same time, efforts should be focused on providing reliable vehicle noise assessment methods, representative for the typical conditions in real traffic situations, to make noise emission limitation a more effective and efficient noise reduction tool. Noise emission is also dependent on driving styles, therefore systems supporting and promoting low-noise driving styles by engine management, intelligent transmissions and electronic driver assistance are necessary. In the specific field of powered two-wheelers (PTWs), the driving style and the manipulation of the engine and exhaust system have a big impact on the noise emission so that investigations towards efficient training and control programmes for quieter driving of PTWs are needed.

ID	Item	Interest level	State of the art
7.1	Incentives (positive or negative) related to the use of noise reducing devices (silent tires, mufflers, etc.)	N 0 1 2 3 4 ...	...
7.2	Development of regulations and tools for sharing and contributing to noise abatement measures in complex environments where many noise sources are present.	N 0 1 2 3 4 ...	...
7.3	New noise emission testing for road vehicles that better represent typical conditions in real traffic situations	N 0 1 2 3 4 ...	...
7.4	Development of noise requirements and regulations for road surfaces based on reliable data	N 0 1 2 3 4 ...	...
7.5	Checks of powered two-wheelers to prevent the use of illegal exhaust systems and manipulations of engine	N 0 1 2 3 4 ...	...
7.6	Tax incentives for low noise vehicles and tyres (requires appropriate noise emission indicators and customer information)	N 0 1 2 3 4 ...	...
7.7	Efficient training programmes for quieter driving styles	N 0 1 2 3 4 ...	...
7.8	Improve knowledge of the relationship between the road geometry and the driving behaviour	N 0 1 2 3 4 ...	...
7.9	Development of national demonstrative programmes for testing novel noise abating measures and techonologies.	N 0 1 2 3 4 ...	...
7.10	Development of a classification system for road surfaces, including acceptance testing and ageing effect.	N 0 1 2 3 4 ...	...
7.11	Other (Specify)...	N 0 1 2 3 4 ...	...
7.12	Other (Specify)...	N 0 1 2 3 4 ...	...
7.13	Other (Specify)...	N 0 1 2 3 4 ...	...

Remarks & suggestions ...

TD 7	**Please assign a priority level to the thematic domain**	N 0 1 2 3 4	...

References ◀ ▶ To Final Report

THEMATIC DOMAIN 8

"ROLLING NOISE"

Rolling noise is the main factor contributing to noise level in many traffic situations. There is a need to enhance our understanding of the interaction between tyres and road surfaces in order to achieve greater reductions in noise levels from various mitigation measures and to lead to more enhanced modelling techniques. New concepts for low noise tyres and road surfaces have to be developed and implemented in models with increased accuracy. For road surfaces, new production technologies, cleaning and maintenance techniques for porous asphalts are needed to achieve sustainable noise reduction.

ID	Item	Interest level	State of the art
8.1	Better understanding of road-tyre interaction for improved simulation tools with increased accuracy.	N 0 1 2 3 4 ...	...
8.2	New concept for low-noise tyres (geometry, design, material, matching to road surfaces).	N 0 1 2 3 4 ...	...
8.3	New concepts for low-noise road surfaces (design, material, production technologies)	N 0 1 2 3 4 ...	...
8.4	Cleaning and maintenance techniques for low-noise road surfaces (cleaning techniques, winter maintenance, renewal techniques).	N 0 1 2 3 4 ...	...
8.5	Testing of existing models for tyre/road noise with data from several countries and types of tyres and surfaces (testing models).	N 0 1 2 3 4 ...	...
8.6	Development of optimised noise reducing pavements	N 0 1 2 3 4 ...	...
8.7	Life cycle assessment of Poro Elastic Road Surfaces (PERS)	N 0 1 2 3 4 ...	...
8.8	Investigations and improvement of acoustical and structural durability of noise reducing pavements	N 0 1 2 3 4 ...	...
8.9	Durable silent expansion joints and their acoustic characterization	N 0 1 2 3 4 ...	...
8.10	Development of reliable methods for static and dynamic characterization of the acoustic performance of low noise pavements (emission and absorption).	N 0 1 2 3 4 ...	...
8.11	Procedures for the acoustic labelling and conformity checking of road surface products or techniques	N 0 1 2 3 4 ...	...
8.12	Benefits and drawbacks from low rolling noise systems (tyres and pavement) such as reduced rolling resistance, fuel consumption, etc.	N 0 1 2 3 4 ...	...
8.13	Other (Specify)...	N 0 1 2 3 4 ...	...

Remarks & suggestions ...

TD 8	**Please assign a priority level to the thematic domain**	N 0 1 2 3 4	...

References ◀ ▶ To Final Report

THEMATIC DOMAIN 9

"ADVANCED NOISE REDUCTION TECHNOLOGIES BETWEEN SOURCE AND RECEIVERS"

Sound pressure levels in residential areas can also be reduced by hindering noise propagation from road to receivers with measures such as noise barriers around acoustical "hot" spots. The noise protection effect of barriers is considered to be not yet fully exploited so that further research on noise barriers is needed, especially for top-end design optimization. Research is also required to develop new and sustainable type of panels, for active noise control, production of renewable energy, etc.

ID	Item	Interest level	State of the art
9.1	Improve the reliability and flexibility of simulation softwares for the design of acoustic mitigation measures.	N 0 1 2 3 4 --	...
9.2	Development of calculation models and indicators for assessing the durability of noise barriers and other mitigation measures.	N 0 1 2 3 4 --	...
9.3	Improved noise barriers (beautiful design, better absorption behaviour, combination with other benefits like photovoltaics, use of recycled materials, etc.)	N 0 1 2 3 4 --	...
9.4	Active noise control (noise barriers panels, windows, virtual noise barriers, quiet bubbles).	N 0 1 2 3 4 --	...
9.5	Further research on noise mitigation including road screening that is effective and cost-efficient, reflective buildings, new design concepts and noise absorbing materials.	N 0 1 2 3 4 --	...
9.6	Improvement of in-situ acoustic characterization of noise barriers and development of correlation figures between laboratory tests results and in-situ values to be applied for quality check.	N 0 1 2 3 4 --	...
9.7	Overall sustainability of ground transport noise reducing devices (materials, construction technology, carbon footprint, maintenance and decomissioning). Development of criteria and tools for product sustainability assessment of noise mitigation technologies.	N 0 1 2 3 4 --	...
9.8	Other (Specify)...	N 0 1 2 3 4 --	...
9.9	Other (Specify)...	N 0 1 2 3 4 --	...
9.10	Other (Specify)...	N 0 1 2 3 4 --	...
9.11	Other (Specify)...	N 0 1 2 3 4 --	...
9.12	Other (Specify)...	N 0 1 2 3 4 --	...
9.13	Other (Specify)...	N 0 1 2 3 4 --	...

Remarks & suggestions ...

TD 12	Please assign a priority level to the thematic domain	N 0 1 2 3 4	...

References ◀ ▶ To Final Report

THEMATIC DOMAIN 10

"ACTIVE NOISE MITIGATION MEASURES"

Noise in large residential areas provides a complex system that can be treated only with an holistic approach. Solutions limited to single sources could be insufficient to abate noise levels at receivers, so combined solutions should be investigated in order to guarantee the required noise reduction. Combined solutions include active mitigation measures, such as traffic management (speed and volume control) and city planning. Cities with short distances to be covered help to reduce traffic and noise. Thus, it is important to understand the forces that favour the long distance in a city and to develop instruments to counteract such forces. Further knowledge is needed about the best city layout for noise and about efficient integration of noise related city planning into mobility planning or planning of sustainable urban transport.

ID	Item	Interest level	State of the art
10.1	Development of sophisticated models and network systems that enable the prediction and control of traffic flow to achieve environmental targets.	N 0 1 2 3 4 ...	...
10.2	Improvement of existing traffic management systems to smooth traffic and thus reduce noise and vibration	N 0 1 2 3 4 ...	...
10.3	Explore telematics solutions for better traffic management and smoother traffic flow to reduce emissions and noise, and contribute to more efficient road use.	N 0 1 2 3 4 ...	...
10.4	Environmental and safety investigations on low speed and non-motorised transport solutions.	N 0 1 2 3 4 ...	...
10.5	Electronic support of the driver e.g by intelligent transmission or engine management	N 0 1 2 3 4 ...	...
10.6	Action planning: development of tools for choosing the right strategy and planning the measures to be applied, based on an objective prioriziation index.	N 0 1 2 3 4 ...	...
10.7	Development of economically sustainalble tools to support noise mitigation measures (photovoltaic, project financing, integration with maintenance plans etc.)	N 0 1 2 3 4 ...	...
10.8	Advanced simulation tools for better understanding the benefits resulting from different urban traffic planning strategies with all its elements considered in a holistic way.	N 0 1 2 3 4 ...	...
10.9	Techniques to assess and optimise the effectiveness of combinations of motorway and land-use noise control measures (motorway alignment, road surface design, land-use and topographical considerations, screening techniques, etc.).	N 0 1 2 3 4 ...	...
10.10	Other (Specify)...	N 0 1 2 3 4 ...	...
10.11	Other (Specify)...	N 0 1 2 3 4 ...	...
10.12	Other (Specify)...	N 0 1 2 3 4 ...	...
10.13	Other (Specify)...	N 0 1 2 3 4 ...	...

Remarks & suggestions ...

TD 10	**Please assign a priority level to the thematic domain**	N 0 1 2 3 4	...

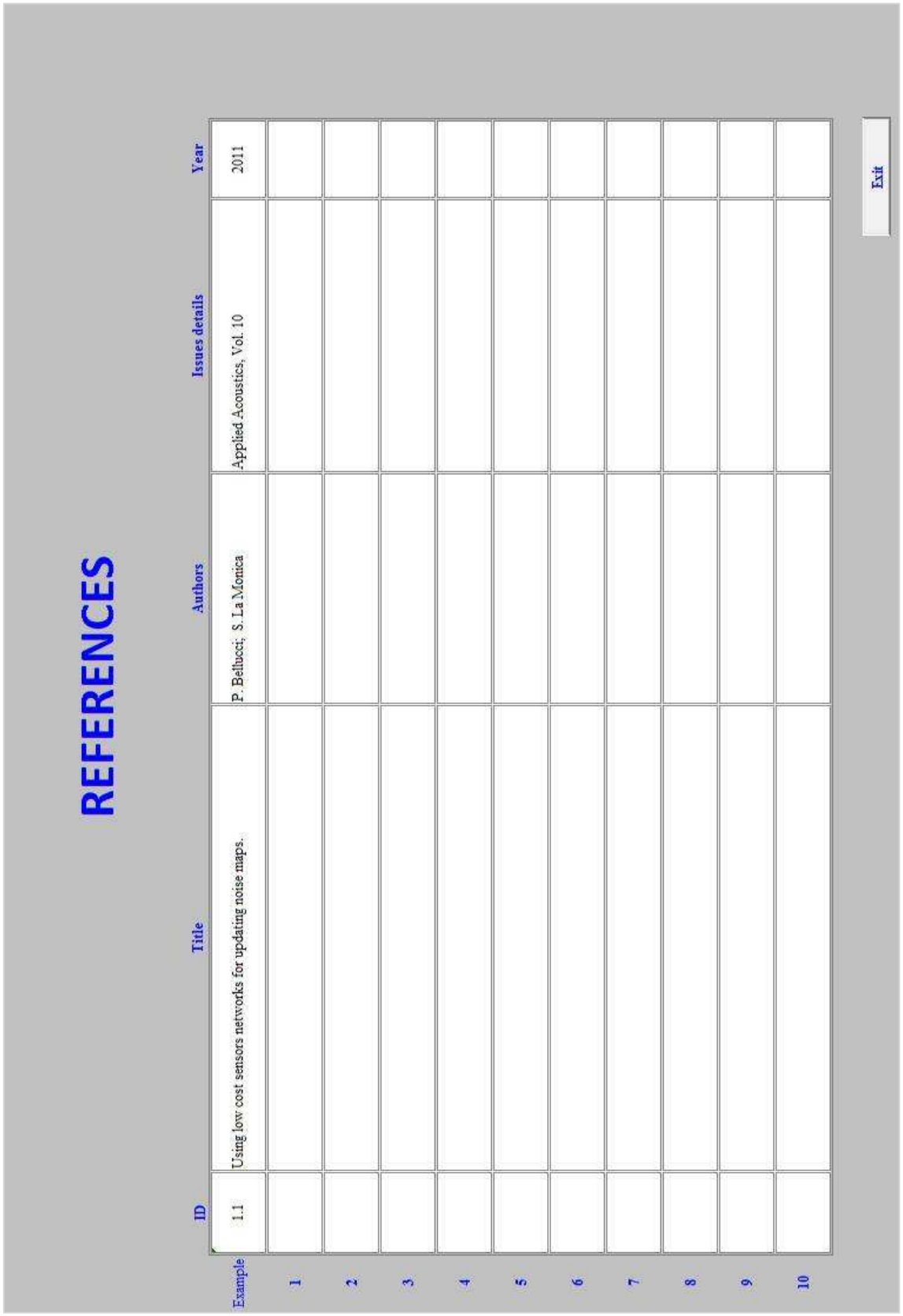
References ◀ To Final Report

THEMATIC DOMAINS PRIORITY LEVELS

Final Report

TD	Thematic Domain	Priority Level	
1	ADVANCED COMPUTATION AND MEASUREMENT METHODS FOR MORE ACCURATE ASSESSMENT OF NOISE EXPOSURE	...	Back to TD 1
2	DEFINITION AND IDENTIFICATION OF URBAN AND RURAL HIGH ACOUSTIC QUALITY AREAS	...	Back to TD 2
3	IMPROVEMENT IN DOSE-EFFECT RELATIONSHIPS	...	Back to TD 3
4	ADDITIONAL NOISE INDICATORS CONSIDERING SPECIFIC EFFECTS	...	Back to TD 4
5	ADVANCED METHODS OF COST-BENEFIT ASSESSMENT OF NOISE IMPACT AND NOISE ABATEMENT	...	Back to TD 5
6	INFORMATION AND PUBLIC PARTICIPATION	...	Back to TD 6
7	IMPROVED OR NEW SOCIO-ECONOMIC INSTRUMENTS TO PROMOTE EFFICIENT NOISE ABATEMENT	...	Back to TD 7
8	ROLLING NOISE	...	Back to TD 8
9	ADVANCED NOISE REDUCTION TECHNOLOGIES BETWEEN SOURCE AND RECEIVERS	...	Back to TD 9
10	ACTIVE NOISE MITIGATION MEASURES	...	Back to TD 10

Save & Quit


REFERENCES
ID
Title
Authors
Issues details
Year
Example
1.1
Using low cost sensors networks for updating noise maps.
P. Belluci; S. La Monica
Applied Acoustics, Vol. 10
2011
1
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Annex B List of publications

TD	ID	Title	Authors	Issues details	Year
1	1.4	Temporal sampling techniques of non urban road traffic noise	P. Bellucci, G. Brambila, A. Corvaja	5° European Conference on Noise Control	2003
	1.5	Influenza delle condizioni meteorologiche sul rumore da traffico stradale - Influence of meteorological conditions on road traffic noise	P. Bellucci	Convegno AIA - Proceedings	2007
	1.5	User's Guide Nord2000 Road.	Kragh, Jørgen et. al.	Delta, SINTEF, SP and VTT.	
	1.6	UNI/TR 11326:2009		Italian Standard	2009
	1.12	Road noise prediction: 1 – Calculating sound emissions from road traffic	Sétra	Sétra, reference 0957-1A. Bagneaux, France	2009
	1.12	Road noise prediction: 2 – Noise propagation computation method	Sétra	Sétra, reference 0957-2A. Bagneaux, France	2009
2	2.1	Stiltegebieden in Vlaanderen	Vlaamse Overheid, Departement LNE	http://www.lne.be/themas/hinder-en-risicos/stiltegebieden/meer-informatie/stiltegebieden_in_vlaanderen.pdf	2006
3	3.3	Noise Annoyance from Motorway 3. A pre and post-study	Emine Celik Christensen	Danish Road Directorate, Technical note 79	2010
	3.6	Road traffic noise and stroke: a prospective cohort study	Mette Sørensen et al.	European Heart Journal Advance Access, published 25 January 2011	2011
	3.X	Health effects of noise on children	Marie Louise Bistrup	Danish National Institute Public health	2001
	3.3/3.8	Befolkningsreaktioner på støjreducerende vejbelægninger / Public reaction on noise reducing pavements	Torben Holm Pedersen, Guillaume Le Ray	Danish Road Directorate, report 2012 to be published	2012
	3.8	Traffic noise annoyance. A survey in Aarhus, Odense and Randers	Larsen, L.E., Bendtsen, H. and Mikkelsen, B.	Danish Transport Research Institute	2002
	3.3	Beboernes opfattelse af støjen ved Ringmotorvejen. Undersøgelse før og efter udvidelsen af M3. Sammenfatningsrapport.	Bendtsen, H.; Christensen E. C	Danish Road Directorate, report 187	2010
4	4.1	Road traffic noise of expansion joints - assessment method and results	Willem Jan Van Vliet, Ronald Van Loon	Paper Internoise 2011	2011

TD	ID	Title	Authors	Issues details	Year
	4.2	Bouwdienstnorm NBD 00401 Geluideisen Voegovergangen	R.C.L. van Loon and W.J.A. van Vliet	http://www.pvo-nl.eu/main.asp?id=195	2010
	4.2	Railway crossings. Road traffic noise measurements	Sigurd N. Thomsen, Hans Bendtsen, Jørgen Kragh	Danish Road Directorate. Technical note 49	2007
	4.2	Traffic noise at rumble strips. Inter-noise paper 2007	Jørgen Kragh, Bent Andersen, Sigurd N. Thomsen	Danish Road Directorate, Report 156	2007
5	5.2	Værdisætning af transportens eksterne omkostninger. Pricing of the external costs of transport	COWI	Danish Ministry of transport, Report	2010
	5.2	The price of noise - evaluation of road noise using the house price method	Camilla Damgård	Danish Environmental Protection Agency, Environmental project 795	2003
7	7.9	Demonstration af støjreducerende SRS belægninger ved Igelsø/demonstration of noise reducing SRS pavements at Igelsoe	Hans Bendtsen and Jens Oddershede	Danish Road Directorate, Report to be published	2012
	7.11	Circulaire Bouwlawaai	Ministerie van Infrastructuur en Milieu	Circulaire Bouwlawaai. Den Haag, Nederland	2010
8	8.3	Optimized thin layers - urban roads. The Kastrupvej experiment.	Sigurd N. Thomsen, Hans Bendtsen,	Danish Road Directorate. Technical Note 66	2008
	8.3	Two-layer porous asphalt - lifecycle The Øster Søgade experiment	Lars Ellebjerg, Hans Bendtsen	Danish Road Directorate. Report 165	2008
	8.6	DRI-DWW Thin Layer Project. Final report.	Hans Bendtsen et. Al.	Danish Road Directorate. Report 159	2008
	8.6	Noise reducing thin pavements. Urban roads.	Hans Bendtsen et al.	Danish Road Directorate. Report 149	2006
	8.8	Støjreducerende tyndlagsbelægninger. Statusrapport 2010 (Noise reduction over a long time period. Noise reducing thin layers. Status report 2010	Bendtsen. H, Andersen. B, Oddershede, Jens	Danish Road Directorate. Report 2012. To be published	2012
	8.8	Acoustic Aging of pavements. A Californian Danish Comparison	Hans Bendtsen	Danish Road Directorate. Report 171	2009

TD	ID	Title	Authors	Issues details	Year
	8.12	Rolling resistance - Copenhagen 2009. Guide NordFoU project "Road surface texture- low noise and low rolling resistance"	Jørgen Kragh	Danish Road Directorate ,Technical note 77	2010
9	9.3	On photovoltaics tunnel shaped sound barriers	P. Bellucci, L. Schirone	28th IEEE Photovoltaic Specialists Conference - Proceedings	2000
	9.3	A structured approach to the development of photovoltaic-sound barriers	L. Schirone, P. Bellucci	Eurosun 2002 - Proceedings	2002
	9.3	A project to promote widespread diffusion of photovoltaic sound barriers in Italy	L. Schirone, P. Bellucci	PV in Europe (Conference) - Proceedings	2002
	9.3	Assessment of the potential of PV noise barriers technology along national roads in Italy	P. Bellucci, S. La Monica, L. Schirone	Euronoise - Proceedings	2003
	9.3	On the quality of photovoltaic sound barriers	L. Schirone, P. Bellucci	Euronoise - Proceedings	2003
	9.3	Assessment of the photovoltaic potential on noise barriers along national roads in Italy	P. Bellucci, S. La Monica, L. Schirone	30th IEEE PVSC Conference - Proceedings	2003
	9.3	Quality issues for photovoltaic sound barriers	L. Schirone, P. Bellucci, U. Grasselli	30th IEEE PVSC Conference - Proceedings	2003
	9.3	A test site for Photovoltaic Noise Barriers	P. Bellucci, F. Dardano, M. Gagliarducci, U. Grasselli, L. Mancini, L. Schirone	20th European Photovoltaic Solar Energy Conference - Proceedings	2005
	9.3	Infrastructures integration of photovoltaic power	U. Grasselli, L. Schirone, P. Bellucci	IEEE 2007	2007
10	10.4	Effect of electric cars on traffic noise and safety	Verheijen, E.N.G & J. Jabben	RIVM, letter report 680300009/2010. Bilthoven, the Netherlands	2010
	10.4	Elektrisch rijden in 2050: gevolgen voor de leefomgeving.	Nijland, H., Hoen, A., Snellen, D. & B. Zondag	Planbureau voor de Leefomgeving, nr. 500226002. Den Haag, Nederland.	2012
	10.10	dBvision (2011) - Handleiding spreadsheet doelmatigheidscriterium voor geluidsmaatregelen langs provinciale wegen	dBvision	PRV014-01-08ew. Utrecht, Nederland	2011