silence

Practitioner Handbook for

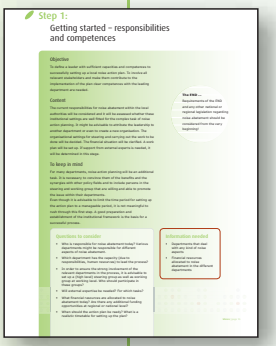
Local Noise Action Plans

Recommendations from the SILENCE project

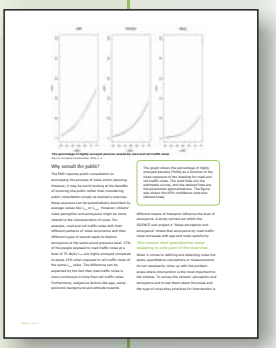
SILENCE is an Integrated Project co-funded by the European Commission under the Sixth Framework Programme for R&D, Priority 6 Sustainable Development, Global Change and Ecosystems

SIXTH FRAMEWORK PROGRAMME

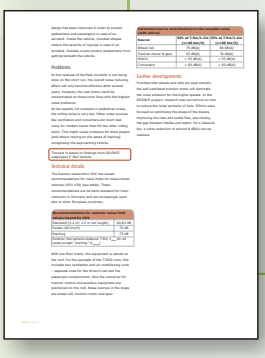
Guidance for readers



- These pages give an overview on the steps of action planning and the noise abatement measures and are especially interesting for DECISION MAKERS and TRANSPORT PLANNERS.



- These parts give detailed explanation concerning the action planning process and the noise abatement measures for those being in charge of noise action planning, mainly TRANSPORT PLANNERS.



- These sections contain more detailed technical information and are particularly addressed to TRANSPORT ENGINEERS.

The SILENCE project

This practitioner handbook was written in the framework of the SILENCE project on Quieter Surface Transport in Urban Areas. SILENCE is an integrated research project, co-funded for 3 years by the Sixth Framework Programme of the European Commission. The SILENCE project provides relevant and world leading methodologies and technologies for the efficient control of noise caused by urban road and rail transport, innovative strategies for actions plans on urban transport noise abatement and practical tools for their implementation. SILENCE includes research in the fields of road surfaces, tyres, and road vehicles, rail infrastructure and rail vehicles, as well as road traffic flow.

SILENCE involved the right mix of European expertise to develop appropriate solutions. The project gathered city authorities, public transport operators, research and engineering institutes, European associations, vehicle manufacturers, equipment, systems and technology suppliers, and specialised SME's. It was co-ordinated by AVL List GmbH (Austria).

Foreword

Urban life generates sound, often perceived as unwanted sound – as noise. Noise conflicts have always been part of urban life. They arise from the population density and the close vicinity of housing, industrial sites, traffic routes, etc. that form our cities. Today, much is known about the negative impacts of noise, in particular the related health problems have been widely discussed. This has led to the European Directive on Environmental Noise (END) that obliges Member States to develop noise maps and noise action plans for agglomerations with more than 250,000 inhabitants. The directive focuses on noise exposure of citizens, thus supplementing the European policy related to the control of noise emissions.

The European Directive on Environmental Noise is referred to as END in this handbook. The Directive can be found on the CD-Rom attached.

This handbook focuses on the second step of the END, i.e. the noise action plans. Only a short overview is given on noise mapping, for which other relevant literature is available. In most EU Member States, local authorities are responsible for drawing up the noise action plans. Many cities already have experience in this field, as even prior to the END, national legislation in many countries obliged them to take action. However, requirements might have changed due to the European directive and local authorities need to learn about their changed obligations. For other cities, noise action planning might be a completely new task.

This handbook aims to support local authorities in the process of setting up action plans. It is divided into 6 parts.

- Part 1 presents the noise problem and the obligations related to noise action planning.
- Part 2 introduces the main objectives, benefits and characteristics of noise action planning.
- Part 3 suggests a step-by-step approach to the process of action planning. Such an approach however, does not imply that one step is to be taken strictly after the other. Several steps are closely interlinked and might need to be addressed in parallel. However, with respect to local experience and local particularities, cities will find their own way to successfully development of a local noise action plan.
- Part 4 presents long-term strategies to avoid and abate noise.
- Part 5 presents a range of concrete noise abatement measures.
- Part 6 is the annex with the list of sources and examples for the soundscape approach.

The handbook is targeted to the three main groups concerned with noise issues at local level:

- Local decision makers
- Transport planners and urban planners
- Transport Engineers

Decision makers will find basic information about the requirements of noise action plans, the approach towards the action planning process and possible noise abatement measures. For planners, more detailed information is provided on how to organise the planning process, on advantages and problems of abatement measures and their links to other policy fields, as well as on long-term strategies to mitigate noise. Finally, engineers will find comprehensive technical information about the presented measures, and references to relevant technical SILENCE reports containing in-depth information. The reports are compiled on the CD-Rom attached to this handbook.

Table of content

Part 1:
Introduction

Why noise matters is the main question in the introduction. It refers to health effects and costs of noise and explains the obligations deriving from the European Directive on Environmental Noise. Noise action planning is presented as an essential piece in the puzzle of the various planning processes at urban level and a rough overview on noise mapping is given.

Why noise matters – The noise problem in European cities

All citizens are at some point affected by noise, which can have a considerable impact on people's quality of life. As stated in WHO's Guidelines for Community Noise (Berglund et al 1999, p. iii), about half of the EU citizens (EU 15) are estimated to live in areas which do not ensure acoustical comfort for residents: 40% of the population is exposed to road traffic noise with an equivalent sound pressure level exceeding 55 dB(A) during daytime, and 20% to levels exceeding 65 dB(A). At night, more than 30% are exposed to sound levels that disturb sleep (exceeding 55 dB(A)). Even though the question of causality between exposure to noise and health risks has not yet been answered, existing studies show that noise exposure increases the risk for high blood pressure and heart attacks. There is evidence that noise pressure levels exceeding 50 db(A) during night time are related to the development of high blood pressure. Road traffic noise exceeding 65 db(A) during day time increases the risk for heart attacks in men with 20% (Babisch, 2004: p. 51). It has been calculated for Germany that approximately 3% of myocardial infarctions are due to road traffic noise. This accounts for around 4,300 cases a year, of which about 2,800 end fatally (Babisch, 2006: p. 59f.).

Summarising these findings: noise kills - not directly, but causes premature death.

Photo: PORTAL project

Furthermore, noise diminishes the quality of life in a more general perspective. It interferes with communication, on the road, in the garden and even inside the dwelling. Many people react and leave cities as a result. Surveys show that (environmental) noise is a relevant reason for people moving out of the cities into the suburban area (e.g. for every third household moving out of Cologne, noise and air pollution in the city was a crucial reason; Stadt Köln, 2003, p. 28). Besides creating even more (road) traffic and noise, shrinking is also a risk for the city's revenues as in many countries the tax share is directly or indirectly linked to the number of inhabitants. More and more cities across Europe are aware that noise requires a dedicated and long-term abatement strategy of its own, and cannot just be tackled indirectly through other policies. Noise abatement requires a local and tailor-made approach to reduce noise along existing roads and for existing dwellings. However, there are many synergies between measures abating noise and other sustainable urban transport and development measures. Furthermore, many measures to abate noise also improve air quality; synergies with the clean air programme are considerable.

Over recent years, acoustic pollution has become a common problem for urban centres and its treatment one of the new challenges in environmental policy. As Ken Livingstone, the Mayor of London, puts it in his Ambient Noise Strategy (Greater London Authority 2004, p. 1):

"Our 'soundscape' needs as much care as the townscape or landscape".

When discussing costs of the development and particularly the implementation of noise action plans, it should be considered that noise itself generates costs. Those costs are for example related to health (medical treatments) and to decreasing house prices and rental income. The social costs of road traffic noise in the EU22 is estimated to be in the range of 30 to 46 billion euro per year, which is approximately 0.4% of the GDP in the EU22 (CE Delft, 2007, p. 21). With this

in mind, it is clear that noise abatement will not only result in social and health benefits, but in economic benefits as well. A Dutch study calculated the benefits of noise abatement measures for the Netherlands, using the reduction in market value of dwellings and building land in urban areas as a result of noise from road and rail traffic noise, to be nearly 10.8 billion EUR (Jabben, Potma, Lutter, 2007, p. 14). Other studies conducted in different European countries suggest a reduction of 20 EUR per person and year based on a monthly average rent of 350 EUR for each db(A) that exceeds the level of 50 db(A). Depending on the tax system, this might result in a decrease of tax revenues for the local authorities as well (Bund/Länderarbeits-gemeinschaft für Immissionsschutz, 2007, p. 12). These numbers clearly show that even high costs for noise abatement measures are often justified by high benefits through noise mitigation. This is especially true for noise abatement at the source. The Dutch government's Noise Innovation Programme (IPG) has for example calculated that for every decibel of noise reduction at-source, 100 million EUR for end-of-pipe measures (such as noise barriers and building insulation) will be saved (CE Delft, 2007, p. 23f., based on IPG 2007).

Obligation to act – European Directive on Environmental Noise

In 2002, Directive 2002/49 relating to the assessment and management of environmental noise was adopted by the European Parliament and Council. This Directive will guide and steer activities on noise in Member States and large conurbations in the coming years.
The directive describes environmental noise as "unwanted or harmful outdoor sound created by human activities, including noise emitted by means of transport, road traffic, rail traffic, air traffic, and from sites of industrial activity" (Directive 2002/49/EC, article 3). Ambient or environmental noise covers long-term noise, from transport and industry sources, as distinct from noise caused by neighbours, construction sites, pubs, etc.
Main aim of the Directive is to provide a common basis for tackling the noise problem across the EU, focusing on four underlying principles (cp. http://ec.europa.eu/environment/noise/directive.htm):

- Monitoring the environmental problem: competent authorities in Member States are required to make 'strategic noise maps' for major roads, railways, airports and agglomerations, using harmonised noise indicators Lden (day-evening-night equivalent level) and Lnight (night equivalent level). These maps will be used to assess the number of people throughout Europe that suffer from annoyance and sleep disturbance caused by noise.
- Informing and consulting the public: the public needs to be informed and consulted on exposure to noise and its effects, as well as the measures considered to address noise, in line with the principles of the Aarhus Convention.

- Addressing local noise issues: based on the noise mapping results, competent authorities are required to develop action plans to reduce noise where necessary and maintain environmental noise quality where it is good. The directive does not set any limit values, nor does it prescribe the measures to be used in the action plans.
- Developing a long-term EU strategy: including objectives to reduce the number of people affected by noise on the longer term and providing a framework for developing existing Community policy on noise reduction from source.

By June 2007 Member States were to ensure that strategic noise maps had been made for

- "all agglomerations with more than 250 000 inhabitants and for all
- major roads which have more than six million vehicle passages a year,
- major railways which have more than 60 000 train passages per year and
- major airports within their territories." (Directive 2002/49/EC, article 7)

By July 2008 competent authorities should draw up actions plans designed to manage, within their territories, noise issues and effects, including noise reduction if necessary for agglomerations and places near major roads, railways and airports as described above.

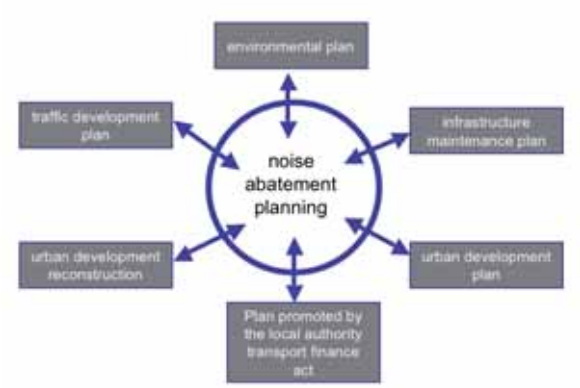
These plans shall also aim at protecting quiet areas against an increase in noise. The measures within the plans are at the discretion of the competent authorities. They should particularly address the priorities identified in the strategic noise maps. As a second step, noise maps and action plans are also to be drawn up for smaller agglomerations with more than 100,000 inhabitants. Maps have to be ready by 2012, action plans by 2013.

The END ...

indicates the minimum requirements that the action plans should fulfil:

"An action plan must at least include the following elements:

- a description of the agglomeration, the major roads, the major railways or major airports and other noise sources taken into account,
- the authority responsible,
- the legal context,
- any limit values in place in accordance with Article 5,
- a summary of the results of the noise mapping,
- an evaluation of the estimated number of people exposed to noise, identification of problems and situations that need to be improved,
- a record of the public consultations organised in accordance with Article 8(7),
- any noise-reduction measures already in force and any projects in preparation,
- actions which the competent authorities intend to take in the next five years, including any measures to preserve quiet areas,
- long-term strategy,
- financial information (if available): budgets, cost-effectiveness assessment, cost-benefit-assessment,
- provisions envisaged for evaluating the implementation and the results of the action plan."
(Directive 2002/49/EC, Annex V)



Noise abatement planning as part of urban planning processes (SMILE, n.d., p. 14)

SMILE, n.d., p. 14

Integrating noise abatement planning into urban planning processes

Noise - as unwanted sound - arises from the close vicinity of different land uses, housing, market places, industrial sites, traffic routes, etc. Urban development and the development of noise levels are closely linked. Thus, land use planning and urban development planning can significantly contribute to increasing or decreasing the noise exposure of residents.

However, today noise abatement planning is very often down on the planning hierarchy and is only done when general decisions on the future development have already been taken. Thus, noise abatement planning is degenerated to the 'management of deficits' (Lärmkontor, BPW, konsalt, 2004, p. 14).

Avoiding the generation of noise as the most effective way of noise abatement means influencing urban development in an early stage.

Considering the noise issue and avoiding noise conflicts should therefore be an integral part of land use planning, development plans, traffic or mobility plans, etc.

Integrating different planning processes and different objectives for urban development is a complex task, and conflicts between those cannot always be solved. Objectives such as the revitalisation of inner city brownfield development sites close to main roads for housing, or focusing growth on the city centre are likely to generate new noise conflicts. Considering the noise issue at an early stage however, gives the opportunity to find better solutions to reduce the noise level than simply adding a noise screen at the last minute. Making noise an important aspect of urban development and balancing the different objectives of urban development remains a challenge. Local noise action plans can be a support tool to stipulate the noise reduction targets and to feed them into local planning processes.

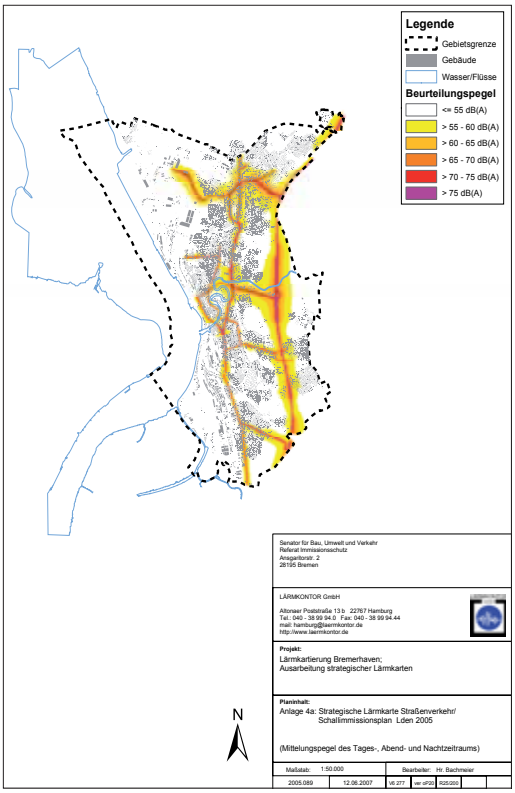
Noise mapping

The strategy put forward by the European Directive on Environmental noise is that the first step towards controlling ambient noise, consists of collecting detailed information on the number of residents exposed to various noise levels and providing these data in the form of noise maps. The Noise Directive describes noise mapping as "the presentation of data on an existing or predicted noise situation in terms of a noise indicator, indicating breaches of any relevant limit value in force, the number of people affected in a certain area, or the number of dwellings exposed to certain values of a noise indicator in a certain area" (Directive 2002/49/CE, p.3).

A noise map allows to visually present data related to the following aspects:

- the noise environment according to certain noise indicators;
- the exceeding of limit values;
- the estimation of the number of dwellings, schools and hospitals in certain areas that are exposed to certain noise levels;
- the estimated number of people exposed to certain noise levels in an area.

Noise maps thus identify and certify the scale of noise problems on a local level and inform planners where limits are exceeded and people affected. This is the basis for the development of local noise action plans. Evaluating the areas where noise limits are exceeded taking into account the number of people affected, allows for setting priorities and developing a hierarchy of noise abatement measures. Noise maps are a tool to set realistic targets for noise reduction and for a more effective use of planning controls to reduce noise from new noise sources, to protect new noise sensitive developments from existing noise sources and to identify, protect and create quiet areas. The maps can also be used as a tool to provide information to the public, politicians and noise professionals on noise problems in a city and the location of these problems.
The timeframe foreseen by the Directive is 2007 for the production of the noise maps and 2008 for the first noise action plans.



Noise map for the City of Bremerhaven, Germany (Noise exposure from road traffic in L_{den})
Source: Senator für Bau, Umwelt und Verkehr, 2007.

Noise mapping ...

is not in the focus of this report. A helpful guidebook on how to develop noise maps has been provided by the European Commission and can be found on the EC-website: Good Practice Guide for Strategic Noise Mapping and the Production of Associated Data on Noise Exposure (WG-AEN, 2006; http://ec.europa.eu/environment/noise/pdf/wg_aen.pdf).

Part 2:
Overview of noise action planning

Local noise action plans include the process of action planning as well as the plan itself as a (legal) instrument. This part gives an overview of the objectives and benefits, as well as the basic characteristics of both the plan and the planning process followed by a rough presentation of the main steps of action planning and a short summary of the general means of noise abatement.

Main objectives and benefits

Local noise action plans aim to avoid and abate noise, thus improving the noise situation in areas where the noise exposure of residents is considered too high and protecting relatively quite areas as recreational zones in urban or rural environments. As such, noise action plans aim to:

- protect the health and well-being of city-dwellers;
- improve quality of life and in particular quality of housing in urban areas, thereby supporting objectives to avoid further migration to the suburbs with all negative consequences for the centres of agglomerations, and along with this;
- increase the attractiveness of the area also for businesses and tourists.

Noise action plans help to structure and prioritise noise abatement measures through clear stocktaking and assessment of the noise situation and resulting conflicts, transparent prioritising of measures, as well as involving stakeholders and the public.

To formalise noise abatement measures in an action plan facilitates the coordination with other objectives, strategies, and instruments of urban development such as land use planning, protection of air quality, promotion of eco-friendly modes of transport, revitalisation of city centres, etc.

Ideally, setting up a local action plan is a well-structured and open process that aims to:

- subject the results of noise mapping to a quantitative and qualitative assessment which results in the detection of noise hot spots and the setting of priorities for intervention;
- involve all relevant departments of local authorities, other relevant stakeholders and the local public in this assessment process;
- link the action planning process to other local strategies and plans;
- develop solutions for the noise problems in cooperation with local authorities, stakeholders, and the public;
- implement the chosen measures with support of all the actors involved.

Basic characteristics

The action plan sets noise reduction targets and describes the measures to achieve these; it sets priorities and schedules the implementation of measures over a short, medium and long term period. The plan names the responsible agencies, the expected costs of the measures and financial means to be used for implementation. It specifies the expected noise reduction potential of all measures and determines responsibilities and timeframes for monitoring and evaluating the results.

The action plan includes maps and descriptions of the noise problems, as well as detailed descriptions of the chosen measures visualised with maps or sketches where useful. In order to produce documents that are also easily accessible to non-experts, it might be advisable to produce maps on two levels: one overview map showing the noise hot spots and the noise reduction targets for the whole area and more detailed maps showing the abatement measures for the individual noise hot spots.

The noise action planning process ideally follows some basic principles. It is a:

- *participatory approach*: it involves the public in the (qualitative) assessment of the noise situation, the discussion and selection of adequate abatement measures as well as the evaluation of their results and readjustment if necessary;

- *cooperative approach*: it involves all relevant stakeholders in assessing the situation, drawing up solutions and implementing measures;
- *open approach*: it actively links noise abatement to other objectives and instruments like clean air programmes, land use planning or mobility plans;
- *measurable approach*: it sets quantified noise reduction targets, specifies the expected reduction to be achieved by the implemented measures, and monitors the results.

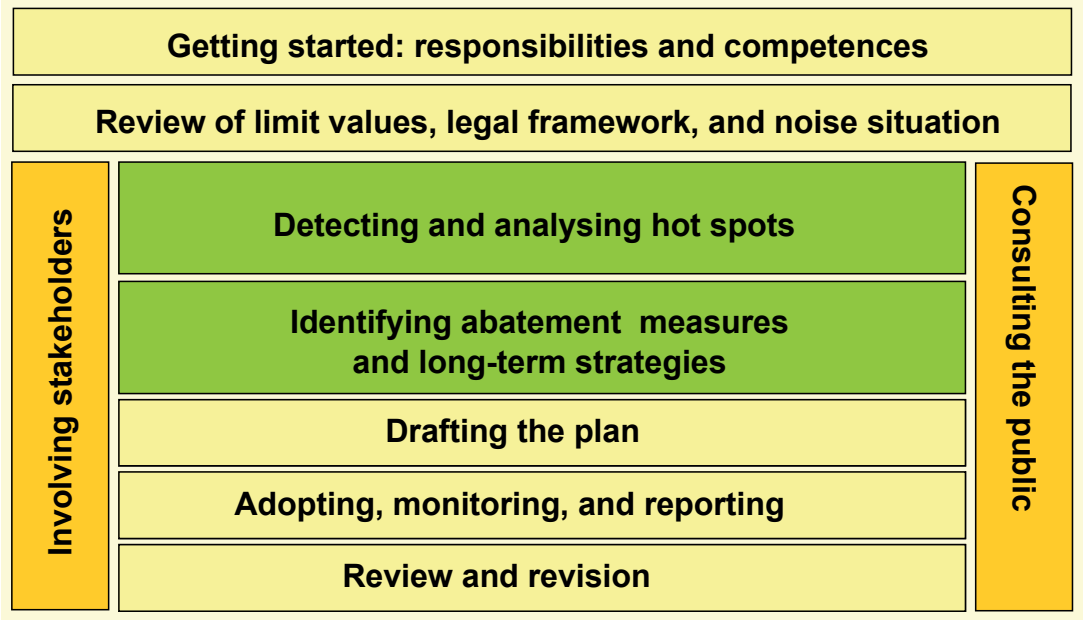
Even though the END stipulates some common requirements for noise action plans, there is no common standard for action planning which fits all the cities. The concrete noise problems, local possibilities and necessities, as well as existing institutional settings will guide the development of the action plan. Furthermore, cities usually have experience in involving stakeholders and the public in other policy fields (e.g. urban renewal, urban development plans). Participation and cooperation within the action planning process will make use of these practiced procedures – or will consciously develop a new approach.

Another basic characteristic of local noise action plans are its limits.

Local noise action plans can only abate noise in the legal and organisational framework set by European, national and regional regulations. Financial resources are needed for the implementation of most measures, which makes that necessary measures usually only can be implemented over a longer period. Thus, improvement of the noise situation will only appear gradually. Other limits are the limited competences of local authorities. For example, railway tracks and highways normally are not within their field of competence. Therefore, noise mitigation measures will also have to be taken by the railway and highway authorities. To get them involved in local noise action planning often is a challenge.

Action planning step by step

The following figure gives a rough overview of the typical steps of local noise action planning. It does not imply that all steps need to be taken one after the other. In fact, the process is much more complex. It can be necessary to do several steps in parallel or to go back to a step that was assumed to be finished.



Action planning step by step

Noise abatement measures – short overview

Different categories of measures with a clear hierarchy can be distinguished for the management and reduction of noise emission and exposure (CALM Network 2002, p. 17):

Measures to avoid and reduce noise at its source: noise which is not generated does not lead to noise exposure, e.g.

- low-noise road surfaces
- road traffic management
- traffic calming
- low-noise tyres
- low-noise vehicles
- driver behaviour

Measures to reduce the propagation of noise: as close to the source as possible to protect the highest number of people, e.g.

- land use planning and management
- noise screening
- buildings as noise barriers
- tunnels
- vegetation as noise shield (mainly impacting on annoyance levels, rather than having a physical noise reduction effect)

Measures to reduce noise at the receiver: only to be used if the other measures are ineffective, e.g.

- sound insulation
- building design

The first category of measures, reduction at the source, clearly is the most effective and also the most cost effective one.
Next to 'technical' measures, more socio-economically oriented measures can be introduced as well, e.g. noise taxes and charges, economic incentives for quiet vehicles, reducing the need for transport, awareness raising, etc. However, not all of these measures are within the competence of local authorities.

Part 3:
Action planning step by step

This part suggests a step-by-step approach to setting up local noise action plans. The description of each step starts with an overview page informing about the objective and content of the step and presenting a number of questions to consider in the process. Requirements of the END are mentioned where necessary. This is followed by more comprehensive information.

The presentation of a "step by step" approach does indeed not mean that one step is to be taken after the other. Several steps are closely connected and might need to be addressed at the same time.

This is a suggestion for a typical planning process and will not necessarily fit all the cities. With respect to local experience and local particularities the cities will find their own way how to successfully develop a local noise action plan.

Step 1:
Getting started – responsibilities and competences

Objective

To define a leader with sufficient capacities and competences to successfully setting up a local noise action plan. To involve all relevant stakeholders and make them contribute to the implementation of the plan clear competences with the leading department are needed.

Content

The current responsibilities for noise abatement within the local authorities will be considered and it will be assessed whether these institutional settings are well fitted for the complex task of noise action planning. It might be advisable to attribute the leadership to another department or even to create a new organisation. The organisational settings for steering and carrying out the work to be done will be decided. The financial situation will be clarified. A work plan will be set up. If support from external experts is needed, it will be determined in this stage.

The END ...

Requirements of the END and any other national or regional legislation regarding noise abatement should be considered from the very beginning!

To keep in mind

For many departments, noise action planning will be an additional task. It is necessary to convince them of the benefits and the synergies with other policy fields and to include persons in the steering and working group that are willing and able to promote the issue within their departments.

Even though it is advisable to limit the time period for setting up the action plan to a manageable period, it is not meaningful to rush through this first step. A good preparation and establishment of the institutional framework is the basis for a successful process.

Questions to consider

- Who is responsible for noise abatement today? Various departments might be responsible for different aspects of noise abatement.
- Which department has the capacity (due to responsibilities, human resources) to lead the process?
- In order to ensure the strong involvement of the relevant departments in the process, it is advisable to set up a (high level) steering group as well as working group at working level. Who should participate in these groups?
- Will external expertise be needed? For which tasks?
- What financial resources are allocated to noise abatement today? Are there any additional funding opportunities at regional or national level?
- When should the action plan be ready? What is a realistic timetable for setting up the plan?

Information needed

- Departments that deal with any kind of noise aspects
- Financial resources allocated to noise abatement in the different departments

Who takes the lead?

Today, abatement of (road) traffic noise and other environmental noise at municipal level is often spread among town and traffic planners, road administrations, environmental authorities, building authorities, and perhaps several other authorities. This is often a barrier to an effective effort and might even result in a lack of appropriate action because no one really feels responsible. For an effective development of noise action plans at local level, it has to be clarified which department of the city's administration shall take the lead.

Which department offers the best conditions for setting up the plan as well as for implementing it?

Usually, the environmental department is in charge of noise issues. So it would seem logical to make them responsible for the noise action plan as well. Many noise abatement measures however are closely linked to traffic management or traffic calming. Giving the transport department the leading role for the process could therefore facilitate the implementation of the action plan. Sometimes even a shared leadership between two departments could be the best solution to ensure adequate engagement.

Commitment to noise abatement through local government decision

It is obvious that besides the leading department other departments could and should contribute to developing the plan, such as the land use department or the health department. As cooperation might be difficult, with all departments having full agendas and noise having a different level of priority, it is advisable to have a formal decision from the local government on the development process and the contribution of the different departments. In the same way, it is essential to approve the developed action plan on the political level to raise the noise problem on the political agenda and to enforce the implementation of the chosen measures.

Example: Bruitparif – Ile-de-France

Bruitparif is the noise observatory for Ile-de-France, the Paris region. It was created in October 2004 at the initiative of the Regional Council, in order to gather the numerous noise actors in Ile-de-France, to centralise all the data available and to inform the public. It became fully operational in 2005.

In France, the transposition of the European Noise Directive is very complex. The State is in charge of the infrastructure maps, while the local authorities are responsible for the agglomeration maps. The Paris agglomeration represents 396 towns. Since some of them are grouped into cooperation structures 238 entities are in charge of the map. The role of Bruitparif is to help the various entities by giving them information on the Directive, providing technical assistance on map specifications and conducting noise measurements to validate the maps. In the future, Bruitparif will help to consolidate a global map for the Paris agglomeration and prepare guidelines for the action plans.

Bruitparif has also started to implement a long-term monitoring network, RUMEUR, in order to provide noise data in real time. The main objectives are to better understand noise influence factors, to provide indicators to local authorities for decision support and to give people easy-to-understand information.

Bruitparif has 7 employees. Its budget for 2008 is 800,000 EUR.

Responsible agencies and cooperation partners
Bruitparif is a non-profit association whose board is made up of representatives from the various entities involved in noise management: the State, the Regional Council, the 8 departments of Ile-de-France, the economic activities that generate noise (mainly means of transportation), acousticians and environmental protection associations.

Why is it regarded as good example?
The French transposition of the Directive made it necessary to have an entity in charge of co-ordinating all the actors involved in the noise maps. Bruitparif is also useful to provide objective noise measurements and to contribute to the improvement of noise indicators, mainly regarding multi-exposure contexts. Consumer groups, environmental protection associations and the general public appreciate being able to access free independent noise data.

Tips for copying
It is important that all the noise actors are involved in the structure so that effective actions can be taken.

For more details contact...
Mélaine Bossat at contact@bruitparif.fr; http://www.bruitparif.fr (website in French)

Could a new organisation support the process?

In urban agglomerations where several municipalities are in charge of developing action plans for their area, it might be wise to set up a special body to coordinate the process as competences may be split over different levels of authorities and institutions with different targets. Bruitparif for the Paris agglomeration is a good example for this.

Managing the project

Within the responsible authority, one person (or small team) should manage the action planning process. The project management task includes setting up a work plan and coordinating its implementation. The work plan should indicate:

- the main steps of the process;
- which stakeholders to involve and at which stage of the process;
- the organisational structure (e.g. working groups on distinct topics, steering group);
- the structure of public consultation;
- the schedule for the action planning process.

Furthermore, identifying the potential need for external consultancy (e.g. on technical issues, moderation of public consultation events) is also part of the project management task.

Financial resources

Developing a local noise action plan, and in particular implementing the chosen measures, requires funding. On all levels, national, regional and local, there will probably be (political) barriers to the allocation of additional funding for noise abatement. However, in most cities financial resources are already allocated to noise abatement measures or to other measures in transport planning that reduce noise or can be (re)designed to do so as well. Not all measures necessarily involve extra costs (e.g. choosing low-noise solutions when traffic calming devices like humps and cushions are to be implemented).

The key idea – with regard to small budgets everywhere – is to optimise the use of existing resources by using synergies between different measures and strategies (such as noise abatement and clean air programmes).

Of course, additional funding will still be necessary. Setting up a solid local action plan might need specialised staff either within the local authorities or subcontracted, as well as appropriate technical tools (e.g. for modelling of noise reduction potential of selected measures). With respect to funding, the responsible authority should consider the following when preparing for the development of the noise abatement plan:

- the budget currently (directly or indirectly) allocated to noise abatement policies;
- other departments concerned and their possibilities to contribute to funding;
- potential funding schemes to apply for at regional or national level (e.g. funding for measures of transport planning, funding for purchase of new public transport vehicles, funding for urban renewal);
- the polluter pays principle; possibilities to charge (motorised) road users for the generated noise should be investigated; the revenues can be used to finance noise abatement measures (cp. WG 5, 2002, p. 34);
- noise abatement measures are often also in the economic interest of people as reduced noise exposure may lead to increased property values; joint public-private financial schemes for noise abatement could be constructed, e.g. the additional costs for low noise pavements compared to traditional road surfaces could be passed to the building owners (Ellebjerg Larsen, Bendtsen, 2006, p. 4ff.);
- scheduled maintenance or renewal measures for streets which can be combined with noise abatement measures.

When discussing costs of the development and particularly the implementation of noise action plans,

it should be considered that noise itself generates costs.

Those costs are for example related to health (medical treatments) and to decreasing house prices, respectively rent levels. Studies conducted in different European countries suggest a reduction of 20 EUR per person and year based on a monthly average rent of 350 EUR for each db(A) that exceeds the level of 50 db(A). Depending on the tax system this might result in a decrease of tax revenues for the local authorities as well (Bund/Länderarbeitsgemeinschaft für Immissionsschutz, 2007, p. 12). To turn it around, abating noise results in financial benefits which need to be taken into account when discussing the costs of noise abatement measures. Calculating these benefits however is a complex task.

Step 2:

Review of current limit values, competences, (legal) measures, and existing conflicts

Objective

To take stock of the current context of the noise issue as a basis for any further action planning.

Content

The stocktaking refers to existing noise limit values at regional or national level and noise indicators in use that might be relevant in addition to those stipulated in the END. The availability of relevant data in addition to the noise maps will be reviewed, for example additional noise measurements in certain areas. Noise abatement measures currently in place will be mapped as well as already identified and so far unsolved noise conflicts (including those aspects that hindered solving the problems so far) and conflicts between different target groups about the preferred abatement solution.

Besides these direct noise related issues, it will be considered which other instruments and policies at the local level could have a positive or negative impact on the noise situation and it will be considered how noise action planning can be linked to other plans and planning processes.

The END ...

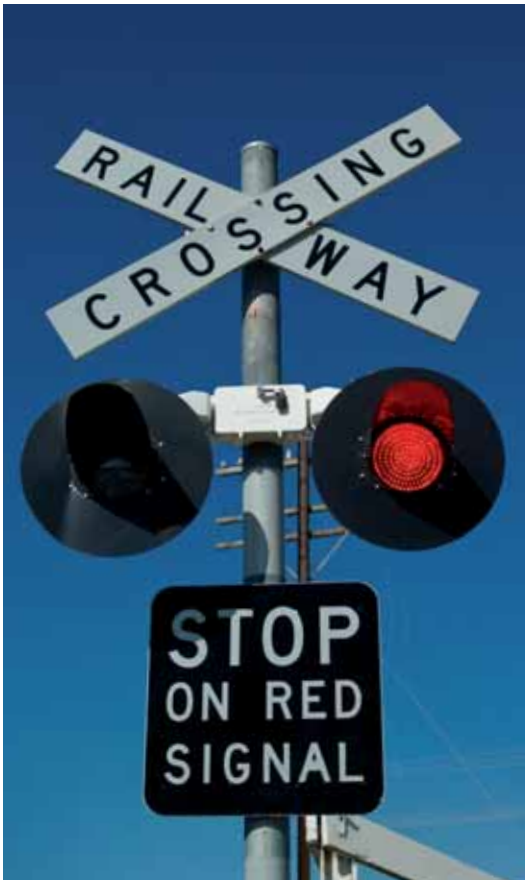
requires that the action plans include information on any noise reduction measures already in force and any projects in preparation.

Questions to consider

- Which limit values are set by the regional or national level? If no values are fixed legally, is it recommended to refer to other values (like those suggested by the WHO)?
- In addition to the noise map as required by the END, are there any other data available on the current noise situation?
- Which noise abatement measures are currently used?
- Are there certain areas in the city where noise conflicts are known but unsolved (e.g. along urban motorways)? Conflicts between different target groups like residents and shop owners that argue about the delivery with HGV? Which stakeholders are relevant?
- Which other plans or policies in place, under preparation or planned, impact on the noise situation? How can these be linked?

Information needed

- Limit values in place
- Noise data in addition to noise map
- Noise conflicts



Local authorities do not start from scratch

EU Member States are obliged to transpose the END into national legislation. Thus, before developing any new policy or action plan on noise to comply with the END, it is important to identify the (national) legal framework regarding local and regional competences, limit values and consequences when these are exceeded. Local authorities do not start from scratch when responding to the END requirements. A range of noise abatement measures already in place and often a long history of discussing noise problems at local or neighbourhood level should be taken into account when preparing a local noise action plan.

Noise indicators and limit values

The END does not set any limit values, but leaves it to the Member States to define criteria for the identification of priorities to be addressed by noise action plans. The END describes limit values as "a value of L_{den} or L_{night}, and where appropriate L_{day} and $L_{evening}$ as determined by the Member State, the exceeding of which causes competent authorities to consider or enforce mitigation measures. Limit values may be different for different types of noise (road, rail, air traffic noise, industrial noise, etc.), different surroundings and different noise sensitiveness of the populations; they may also be different for existing situations and for new situations (where there is a change in the situation regarding the noise source or the use of the surrounding)" (Directive 2002/49/CE, Article 3 (s)). This means that authorities responsible for noise action planning have to identify any limit values set by national regulation, in complying with the END or having been in place already before.

Available information on noise situation

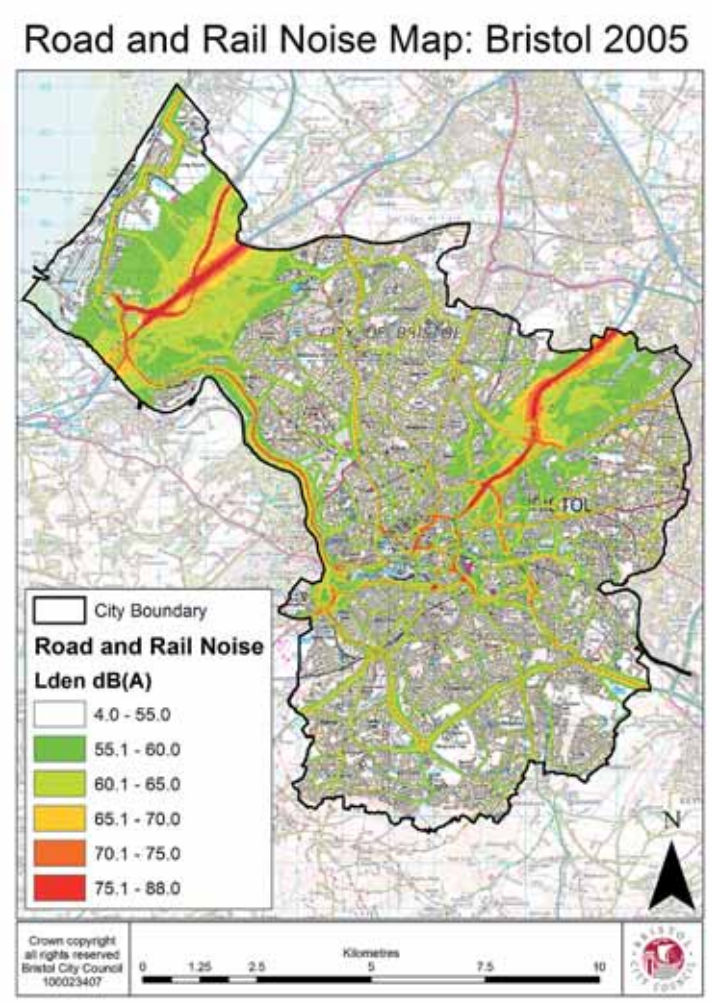
The noise maps as required by the END are supposed to be the basis for the local noise action plans. However, in many cities additional data on the local noise situation will be available. This might include noise measurements from certain areas (in addition to calculations of noise for noise mapping), information on noise perception collected through surveys or processing of citizens' complaints, etc. When preparing for noise action planning, all these data sources should be compiled and checked for relevant information. Thus, it might also become clear that relevant information is missing.

Surface Transport Noise Strategy for Bristol

This report prepared in the framework of SILENCE by Tim Clarke from Bristol City Council is a good example for stocktaking the legal framework for noise action planning, existing information on the noise situation, (legal) noise abatement measures in place, etc. The paper can be found on the enclosed CD-Rom.

The END ...

stipulates two different noise indicators to be used for the statutory noise maps, L_{den} ($L_{day\text{-}evening\text{-}night}$) and L_{night}. L_{den} is the long-term average sound level during the day, evening and night periods of a year, whereas L_{night} covers only the night periods. The END indicates that the day is 12 hours, the evening is 4 hours and the night is 8 hours. The start of the day, evening and night period is to be determined by the Member States. However, the default values chosen by the European Commission are 07.00 to 19.00 for the day, 19.00 to 23.00 for the evening and 23.00 to 07.00 for the night. The values for L_{den} and $_{Lnight}$ can be determined either by computation or by measurement. In some cases, supplementary noise indicators can be used, such as L_{day} or $L_{evening}$. Among commonly used noise indicators, the END mentions that L_{Amax} (maximum sound level) or SEL (sound exposure level) can also be used for night period protection in case of noise peaks. For further details regarding the noise indicators, see annex I of the directive (Directive 2002/49/EC).



Noise map of Bristol
Source: Bristol City Council

Existing abatement measures

In most cities, noise abatement measures have been put in place already before the END. Taking stock of these existing measures is an integral part of noise action planning. Relevant measures include those particularly designed for noise abatement, but also measures with positive effects on noise mitigation implemented in the frame of other policies (such as traffic calming, abating air pollution). However, this exercise will only focus on the priority areas identified for interventions and not on the complete area to be covered by the action plan.

Known conflicts

Noise problems and potential solutions often have a long history in cities. In many cases these include established conflicts in certain areas (like residential areas close to major roads), between different policies or plans (like focussing urban growth on the inner city to avoid additional traffic, as opposed to noise abatement in that area) or between different stakeholders (for example local businesses with delivery demands versus residents complaining about delivery noise during the night). These conflicts will influence further action planning and should therefore be mapped in the preparatory phase.

Step 3:
Involving stakeholders

Objective

To select the relevant stakeholders, make them aware of the noise issue, give real participation opportunities and convince them of participating in the process.

Content

Potential stakeholders will be listed, together with contribution they could/should make towards the noise action planning. A strategy on who will be invited to participate at which stage of the process will be set up. It will be decided which instruments will be used for participation, for example:

- steering or working group;
- general meetings to discuss the noise conflicts and potential abatement measures;
- small working group meetings to draft concrete measures;
- written input for the analysis of noise hot spots, etc.

The END ...

requires that the public – defined as natural or legal persons and in accordance with national legislation their association, organisations or groups – are consulted about proposals for action plans, giving them early and effective opportunities to participate. Results of the participation need to be taken into account. The action plans shall give a record of the public consultation organised.

Questions to consider

- Which stakeholders within the local authorities are concerned with the noise issue and need to be involved? Which other plans and instruments of urban development, transport, air quality etc. are in place, under preparation or planned, that impact on the noise situation and who is responsible for their development?
- Do any stakeholders on the regional level need to be involved?
- At local level, which stakeholders can contribute to the development of the plan on the level of the entire territory, which for certain areas / neighbourhoods, and which for certain thematic fields (e.g. railway noise)?
- Is the range of stakeholders balanced or are there gaps to be filled? You always have stakeholders that are well aware of opportunities to bring in their interests and others that need to be convinced because they do not see the advantage of participating (e.g. schools might not be aware of being a relevant stakeholder unless you explain them that the noise level could be significantly reduced by children walking to school instead of being taken by car).
- Do some stakeholders want to be involved from the very beginning to be able to influence the entire process, while others want to focus only on concrete noise hot spots and/ or measures? Allow for tailor-made participation.
- How could actions taken to involve stakeholders be recorded in an easy way as the action plan should summarise the consultation process?

Information needed

- Overview of potential stakeholders and earlier experiences with involving them

Local authorities need partners

Whilst the public authorities – preferably at local level – are responsible for developing and implementing the noise action plan, it is obvious that they do not have the competences to implement all necessary measures. Cities can only influence part of the noise sources; other sources are for example within the responsibility of public/ collective transport operators or local companies (deliveries). As local authorities are often not in the position to enforce third parties to introduce necessary measures, they need to invite these stakeholders to cooperate.

Anyway, cooperation proves often to be more efficient than forcing the private sector through regulations.

Cooperation is also needed within the public administration. Several departments at local, regional or even national level are concerned with noise issues or are working on closely related issues and can contribute to noise abatement. Noise action plans are associated with other plans and tools like local transport plans or urban development plans. Particularly close links exist between the issues of noise and air quality management. Monitoring and modelling both can be done in one integrated process. Munich's approach gives a good example.
Cooperation even within the city's administration is not always easy. All departments have their own, full agenda. Even for the most concerned departments, i.e. transport and environment, noise does not have the same priority, which influences their willingness to allocate resources to the development and implementation of noise action plans. As mentioned earlier, a formal

Environmental Module – calculation of air pollution and noise exposure in Munich

The Environmental Module is a programme, which is used to calculate the current air pollution and the current noise exposure caused by road traffic. Purpose of this system is to determine the current status of pollution (online) and to evaluate the output of traffic scenarios (offline). It contains various models for calculating the air pollution and the noise exposure:

- a model for calculating traffic-related pollutant emissions within the main road network;
- a model for determining the initial pollution in the streets, caused by surrounding emission sources and estimation of the regional background pollution;
- a model for determining pollution within the area of streets;
- a model for determining the noise-rating level within the area of streets.

The calculation of air pollution and noise exposure is carried out online and automatically every hour, when current traffic data are available. These data are delivered by the Traffic Centre as part of the city's administration. Data from every quarter of an hour are collected in a database and aggregated to hourly values. The traffic forecast information is extrapolated to full-hour values.

The installation of the Environmental Module in Munich started four years ago and it has not yet completely finished. At the beginning of the project, no other cities had experience with the implementation of such systems. Thus, a lot of development work and coordination was needed to set up the system in the Traffic Centre.

The most expensive part of the application of the module is the preparation of the input data. If the data are available in a compatible format, costs will be significantly lower. The costs for purchasing the module itself depend on which parts are included: noise and/or air pollution, only calculation of traffic emissions or taking into account the background immission as well. The minimum price for the Environmental Module will be about 20,000 Euro.

Responsible agencies and cooperation partners

- City of Munich – Department for Health and Environment
- City of Munich – Municipal Services Department – Traffic Centre
- Consulting engineer, specialised in air pollution and noise exposure (IVU-Umwelt GmbH)

Why is it regarded as good example?
The results of the noise and pollution modelling can be visualised immediately. On this basis, the Traffic Centre is able to react in time to increased pollution in the street by traffic management measures. Furthermore, the results of the calculation tool can be used to inform the public via online information on the current air pollution and noise exposure.

Tips for copying
Thorough preparation of the traffic data is crucial. The compatibility between the systems used for collecting and calculating traffic data and for the calculation of the noise exposure has to be ensured in the early beginning of the project.

For more details contact…
City of Munich: uw11.rgu@muenchen.de; http://www.muenchen.de/umweltatlas

IVU-Umwelt GmbH: info@ivu-umwelt.de; http://www.ivu-umwelt.de

decision taken by the local government on the contribution required from different departments to the plan can facilitate the cooperation.
For the leading department, the involvement of this range of internal (within the local authorities) and external stakeholders is challenging and the process needs to be planned carefully. In some countries, national regulations on the selection of stakeholders and the formal procedures of involvement are in force and need to be taken into account when preparing the noise action planning process.
The tables below list which stakeholders typically would need to be involved in the process of setting up and implementing local noise action plans. Information is given on how these stakeholders are concerned with noise issues and in which way they could contribute towards successful noise abatement. One table lists internal, the other external stakeholders (from the local authorities' perspective).

Which stakeholders should be involved and at which stage of the process depends on the local situation and has to be decided when preparing the action planning process.

However, it is advisable to involve stakeholders
at least in the defining and detecting of hot spots, defining of noise abatement measures and monitoring and reporting the mitigation measures.

Internal Stakeholders		
Stakeholder responsible for	**Why is cooperation with these stakeholders necessary?**	**What is expected from these stakeholders for the development and implementation of a noise action plan?**
Transport planning / Road maintenance (civil engineering) / Urban planning	- transport planning measures can a have positive or negative impact on noise (e.g. road safety measures like humps) - many measures to abate traffic noise at the source have an impact on traffic flows - these stakeholders are responsible for the implementation of many measures to abate traffic noise (e.g. redesign of residential roads, road surface replacement, speed limits)	- to revise transport planning strategies and measures regarding their noise impact - to assess potential noise abatement measures regarding their impact on traffic volumes, traffic flow etc. - to implement noise abatement measures
Air quality	- synergies between air quality and noise modelling are manifold: the same software can be used, the same traffic data are needed, etc. - skills like GIS analysis and traffic data processing are likely to be present already in teams dealing with air quality - measures taken to abate noise or to improve air quality often have a positive or negative impact on the other aspect as well	- to share software and data - to provide support in the modelling process - to provide information on the potential impacts of noise abatement measures on air quality
Health	- noise has adverse effects on health (e.g. annoyance, sleep disturbance, increase of cardiovascular diseases) - health departments are often assigned to protect residents from harmful environmental emissions - sirens from ambulance vehicles are an important noise source in particular in hospital areas	- to support public awareness raising regarding harmful effects of noise - standards for using sirens
Land use planning	- allocation of land use has an impact on traffic volumes and therefore on noise - avoiding and abating noise should be considered when setting up development plans	- to provide information on future development areas and their impact on traffic volumes and composition - to consider noise abatement targets in land use planning
Urban renewal	- renewal of neighbourhoods often includes the redesign of residential roads, which can be used as an opportunity for noise abatement as well	- to provide information on urban areas scheduled to be redesigned - to include the noise issue in public consultations on renewal activities - to consider the noise issue when redesigning (residential) roads
Municipal waste management	- waste collection is a noisy activity with much potential for noise reduction - waste collection often disrupts traffic which generates additional noise	- to make the collection fleet less noisy (through change of vehicles, staff behaviour) - to develop time frames for collection that interfere less with traffic
Communication	- raising public awareness on noise requires an efficient communication strategy - the END stipulates that the public is to be informed and consulted	- to support the development of a consistent public consultation scheme - to develop information material (e.g. websites, brochures, posters) targeted at stakeholders, the public and local decision makers/ local government
Local police (in some countries not part of the local authority, but external stakeholder)	- the police are responsible for enforcing speed limits and traffic restrictions (e.g. for HGVs), being often used measures for abating noise - in some cities an approval from the police is required for the implementation of traffic flow regulation measures - police sirens are a noise source	- to enforce speed limits and traffic restrictions - to check on noisy vehicles that do not comply with limit values (e.g. two wheelers) - to revise standards for the use of sirens and staff behaviour

External Stakeholders		
Stakeholder	**Why is cooperation with these stakeholders necessary?**	**What is expected from these stakeholders for the development and implementation of a noise action plan?**
Public transport operator	- public transport can be a major source of noise in urban areas; it might be the dominant noise source in hot spots (e.g. curve squeal from tramway tracks) - public transport offers a quieter alternative to private car use	- public transport operators should address the noise issue by making their own fleet and infrastructure (tracks, depots, etc.) as quiet as possible through the use of available technologies and training their staff - public transport operators can be asked to adjust and extend their services to support the reduction of private car use and if applicable to compensate for restrictions for individual motor car traffic (e.g. restrictions in the inner city)
Operator of regional / national roads and highways (that are not within the responsibility of the local authorities)	- because of the traffic volumes, the high share of HGVs and the higher speed, urban main roads and urban highways are a relevant source for traffic noise; local authorities are often not competent for these roads (e.g. in relation to speed limits)	- to provide data on road surface for analysing hot spots - to implement measures such as quieter road surfaces, speed limits, noise screens etc.
Railway operator (infrastructure, rolling stock)	- railway operation in urban areas is an important source of noise (tracks, stations, depots)	- to provide data on noise emissions - good maintenance of tracks and use of less noisy vehicles can help to avoid noise - to set up noise screens to reduce the propagation of noise - to review the operation of depots and to train staff for less noisy operation
Private transport operator (local companies, suppliers, etc.)	- heavy duty and even light duty vehicles are generally up to 6 dB noisier compared to a car; therefore; fleet owners are key stakeholders in reducing noise	- to use less noisy vehicles - to respect temporary restrictions (night-time restrictions) and restricted zones (e.g. residential roads) - to invest in less noisy trucks and delivery equipment (e.g. plastified roll-containers) and to train staff in quiet deliveries (in particular for deliveries in residential areas) - to develop delivery schemes that reduce the number of deliveries and that help to reduce congestion
Citizens (individuals, associations, groups)	- for the assessment of noise problems and the analysis of hot spots the perception and annoyance of citizens have to be taken into account - citizens generate noise themselves; it is necessary to make them aware	- to provide information on noise perception and annoyance - to bring in ideas for noise abatement measures (in particular at hot spots) - to change travel habits / driving behaviour to less noisy modes - to respect speed limits and restrictions
Shop owners, bars, etc.	- neighbourhood noise is not addressed in the END, but can be a major factor of noise annoyance and will certainly be an important issue in consulting the public	- to bring in ideas for noise abatement measures and to implement them
Noise abatement planning in neighbouring cities / counties	- noise (and traffic) does not end at a city or county border; noise abatement measures might be more effective when coordinated for the whole area - measures taken to abate noise in one city may have negative impacts on neighbouring cities	- to share data on noise exposure - to cooperate on noise abatement measures
National or regional government	- competences concerning noise are often shared between local, regional and national authorities; their involvement can be crucial for the implementation of certain measures - the involvement of higher levels of government can facilitate the cooperation with highway operators, national railways, etc.	- to provide available data as needed - to take necessary noise abatement measures - to support cooperation with other parties

Step 4:
Consulting the public

Objective

To consult the public on their noise perception, priorities for noise abatement and suggestions for abatement measures and thus, improve the selection and design of abatement measures, while increasing public acceptance for necessary measures.

Content

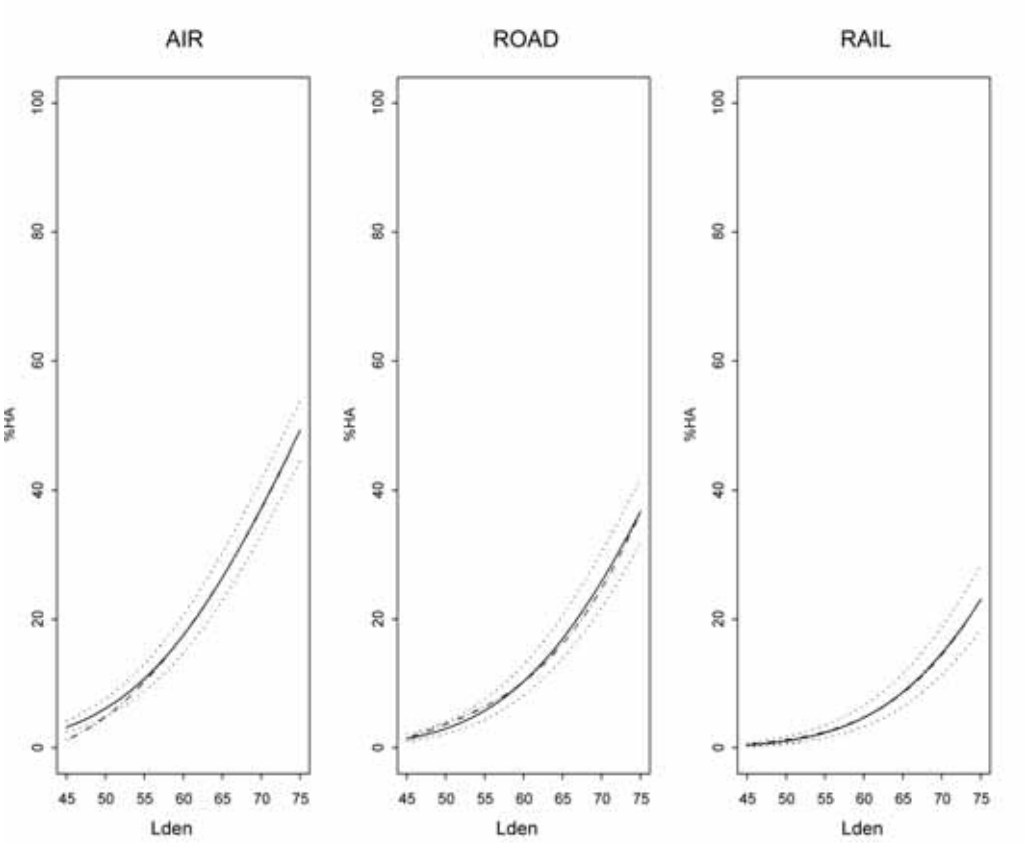
The various target groups and adequate consultation methods and tools are developed. Participation approaches differ between the city level and the level of hot spots. On the city level, consultation relates to the general targets and strategies for noise abatement. On the level of hot spots consultation involves the concrete analysis of the noise problem and suggested noise abatement measures in a certain area.

The END ...

requires that the public – defined as natural or legal persons and in accordance with national legislation their association, organisations or groups – is consulted about proposals for action plans, giving early and effective opportunities to participate. Results of the participation need to be taken into account and the public shall be informed on the decisions. The action plans shall give a record of the public consultation organised.

Questions to consider

- Which target groups can be differentiated?
- How are they concerned with noise? What are they interested in and how could they be addressed?
- How to make sure that results of consultation are taken into account when finally determining the noise abatement measures?
- How could actions taken to consult the public be recorded in an easy way? (The action plan shall record the consultation process.)



The percentage of highly annoyed persons caused by road and rail traffic noise

Source: European Communities, 2002, p. 6

The graph shows the percentage of highly annoyed persons (%HA) as a function of the noise exposure of the dwelling for road and rail traffic noise. The solid lines are the estimated curves, and the dashed lines are the polynomial approximations. The figure also shows the 95% confidence intervals (dotted lines).

Why consult the public?

The END requires public consultation to accompany the process of noise action planning. However, it may be worth looking at the benefits of involving the public rather than considering public consultation simply as statutory exercise. Noise exposure can be quantitatively described by average values like L_{den} or L_{night}. However, citizens' noise perception and annoyance might be more related to the characteristics of noise. For example, road and rail traffic noise with their different patterns of noise occurrence and their different types of sounds leads to distinct annoyance at the same sound pressure level. 37% of the people exposed to road traffic noise at a level of 75 db(A) L_{den} are highly annoyed compared to about 23% when exposed to rail traffic noise of the same L_{den} value. The difference can be explained by the fact that road traffic noise is more continuous in time than rail traffic noise. Furthermore, subjective factors like age, social-economic background and attitude towards different means of transport influence the level of annoyance. A study carried out within the SILENCE sub-project A "Noise perception and annoyance" shows that annoyance by road traffic noise increases with age and noise sensitivity.

This means that quantitative noise mapping is only part of the exercise.

When it comes to defining and detecting noise hot spots, quantitative calculations or measurements do not necessarily come up with the problem areas where intervention is the most important to the citizens. To survey the citizens' perception and annoyance and to ask them about the areas and the type of noise they prioritise for intervention is

therefore an essential part of analysing the noise situation in a city.
When assessing the initial noise situation, it should be borne in mind that citizens' perception might significantly differ from the suggestions of the quantitative analysis. Also when monitoring interventions in noise hot spots, citizens might come up with different evaluations than the quantitative measurements. Research in Berlin Germany, shows that citizens might perceive an improvement of the noise situation when the number of very loud incidents (such as passing by of a HGV in a residential area) is reduced even when the average sound level is almost the same as before (SMILE, n.d., p. 10). This highlights the need for discussing the priorities for intervention in a hot spot and potential measures for noise abatement with the residents when setting up an action plan, before implementing any measures.

Besides the perception issue, it is also worth addressing the public as generator of noise.

People make ambient noise.

Driver behaviour for example, can make an essential difference in generating or avoiding noise. Active noise abatement therefore requires an active contribution from the public. Involving the public in developing solutions to noise problems can help to find innovative solutions or better compromises as well as increase the acceptance of measures (e.g. speed limits in residential areas).
In this regard it is crucial to raise public awareness of the negative impacts of noise, e.g. the adverse health effects and the dampening effects on house prices. While air quality today ranks high on the political agenda and people are aware of the issue, ambient noise is not.
Informing the general public might also help to raise noise on the political agenda, which in turn might support the long-term implementation of noise abatement strategies.

Who is the "public"?

"'The public' shall mean one or more natural or legal persons and, in accordance with national legislation or practice, their associations, organisations or groups." (Directive 2002/49/EC, Article 3). National legislation might give further explanations on target groups that have to be involved.
In addition to legal regulations, the local specific context should guide the selection of target groups which are to be addressed by information and participation measures.

Here, a distinction should be made between the more general approach of action planning at the city level and the area based work when dealing with certain noise hot spots.

In the first case, the general approach towards the noise problem, the criteria for defining hot spots, and overarching noise reduction strategies are to be discussed. In the second case, the focus lies on the perception of the noise problem in a certain area as well as concrete abatement measures and their implementation. Depending on the level addressed, different kind of representatives of the public should be targeted.

- On the city level: Besides the stakeholders mentioned in step 3, all kind of civil society associations like chambers of commerce, home owners and landlord associations as well as tenants associations, and local groups dealing with transport, environmental or health issues can contribute to the development of local noise action plans.
- On the area level, the priority lies with informing and involving the people directly affected by noise and the potential abatement measures. This includes residents, shop owners, other businesses, schools, hospitals, and similar institutions.

On both levels, it needs to be ensured that the people involved properly represent the public, including groups which are often underrepresented in consulting processes such as the elderly, children and minority groups.

Actions to inform and involve the public

It goes without saying that actions to inform and involve the public will differ according to the level of action planning and the target group. For all measures it is to be kept in mind that people normally are no noise experts. All information given should be easily accessible and avoid technical terms and details.
To raise awareness, real time noise maps or the latest available version could be published on the web and via the newspapers. Recommendations on how to present noise maps to the public can be obtained from WG-AEN, 2008. Additionally, booklets, poster campaigns, special event days and many other tools can be used. Besides the general public, it is advisable to address certain target groups like schools with tailor-made information material. More information on public awareness raising can be found in part 4.

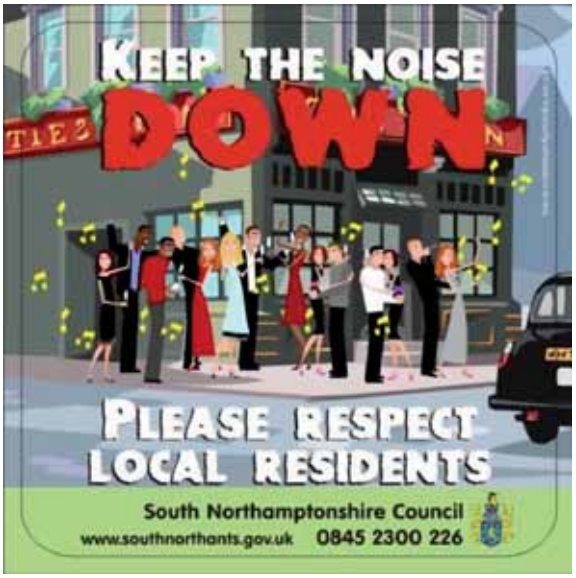
The END ...
stipulates in this regard, that for a wide spread of information the most appropriate information channels should be used (Directive 2002/49/EC, preamble).

Make consultation part of the process

To make public consultation an integral part of the noise action planning process, it is advisable to set up a schedule for information and participation together with the overall working plan. This schedule should contain measures

- to raise public awareness for the noise problem;
- and in particular to inform local politicians to raise the issue on the political agenda;
- to gather qualitative data on noise perception and annoyance to complement the quantitative noise mapping;
- to involve civil society representatives and institutional stakeholders in the process at city level;
- to inform the people affected by noise hot spots, to collect their viewpoints on the issue and to involve them in developing solutions.

When addressing local politicians, their limited time resources need to be taken into account. Therefore, the focus should rather be on concise information focusing on key messages, while the number of meetings should be restricted.
Often citizens complain about noisy situations towards the local authorities and thereby provide useful information even without being asked for it. Additionally, and to gather a more representative view, surveys on citizens' noise perception and annoyance could be conducted whether on the city level or targeted to hot spots. For the analysis of hot spots the soundscape approach can be used. This approach combines quantitative data on physical sound measurements with the scientific analysis of users' sound perception and takes into account the interaction between the acoustical, esthetical and social perception of a certain site. The soundscape of the studied area is recorded during so called "soundwalks". The recorded sound can be analysed in detail (characteristics of the single sources) and used to inform the public ("Here the sound level is made up of tram traffic and chatting on a cafe's terrace and here you can hear examples of the single noise sources …"). More details on the soundscape approach are provided in step 5.



Raising awareness
Picture: Environmental Protection UK

To involve people affected in hot spot areas in the development of solutions it is advisable to organise targeted meetings with concrete objectives.

These meetings should have the form of discussion forums with many possibilities for residents (and others interested) to bring in their opinion, rather than concentrate on speeches by experts. Additionally, advisory boards including representatives of residents and shop owners – maybe supported by experts – could be created that accompany the whole process. In particular, the practice of neighbourhood-based urban renewal has produced a lot of information and participation tools that can be used for noise action planning as well.

Finally, it should be mentioned that involving the public does not necessarily mean that all suggestions made have to be implemented, but they have to be considered and decisions have to be made transparent.

Step 5:
Detecting and analysing hot spots

Objective

To define what should be considered as a noise hot spot, to locate hot spots and to make a thorough analysis of the situation, the noise reduction potential and maybe upcoming conflicts.

Content

The definition of noise hot spots will be discussed. On that basis, hot spots will be identified and analysed. Priorities for tackling noise at the hot spots will be set following a discussion on criteria to be used for priority setting. Quiet areas and measures to protect them from an increase of noise will be defined.

The aim of analysing the noise situation is to detect areas, so called hot spots, where intervention is needed to decrease the noise level as well as quiet areas that need to be protected. Once defined, a thorough analysis of the hot spots will then be the basis for further discussion and action planning.

The END ...
does not define criteria for hot spots. It is in the hands of the Member States or the responsible authorities for local action plans to establish thresholds for intervention and criteria for setting priorities.

Questions to consider

- Which criteria shall be used to define hot spots?
- What are suitable criteria to set priorities for intervention considering the local context?
- For the analysis of hot spots: When does the noise mainly occur (time of the day)? Which are the relevant noise sources (rail, road traffic, HGV, etc.)? Which factors influence the noise generation (e.g. road surface, an intersection with starts and stops, congestion, etc.)? Which factors influence the propagation of noise (e.g. shape of the street, reflection at buildings, etc.)? How do the residents perceive the noise problem?
- How shall quiet areas be defined?
- Are there certain aspects that due to the local situation need to receive special attention in the analysis of the noise hot spots? Is there a (strategic) need to discuss this issue with certain stakeholders (e.g. to gain their acceptance for the results of the analysis)?

What are hot spots?

European cities use various approaches to define hot spots whereas it is most likely that most cities do not use a binding definition at all in this exercise. The cities involved in the SILENCE project, for example, use quite weak definitions like "areas where a high density of the population is exposed to noise levels exceeding the limits" or "areas where noise levels are very high". Their approach to detect noise hot spots is often based on data indicating areas with high levels of sound exposure combined with knowledge of the cities' structures (areas of high population density, major roads, etc.). The number of citizens' complaints concerning a particular area is also used for indicating hot spots.

To comply with the END, a more systematic approach of hot spot detection is needed.

This will also help to gain more transparency in the assessment of a city's noise situation, the priority setting and action planning, which is particularly valuable with respect to public consultation.

The END ...

stipulates that local noise action plans should address "priorities which may be identified by the exceeding of any relevant limit value or by other criteria chosen by the Member States and apply in particular to the most important areas as established by strategic noise mapping" (Directive 49/2002/EC, Article 8,1).

How to detect hot spots?

The END stipulates that noise maps shall put emphasis on the noise emitted by road traffic, rail traffic, airports and industrial activity sites, including ports. For the detection of hot spots, all these noise sources have to be taken into account. If the sound level for the different sources is calculated by using modelling tools, software can help to integrate them into one noise map showing the overall sound level exposure. Another possibility of course is to base the noise map on noise measurements. However, this is comparatively costly and does not allow for predicting changes in the noise exposure due to changes in traffic. It is therefore not advisable.

The noise maps, as required by the END, show noise exposure for different bands of noise levels in L_{den} (e.g. 55-59, 60-64 dB, etc.).

The next step is to compare the sound pressure level with any targets set for the noise exposure of citizens.

These targets can be any limit values defined by the national or regional authorities. The comparison between real noise levels and limit values will result in noise conflicts, which can be shown in conflict maps. Such maps present the areas where limit values are exceeded but they do not refer to whether the area is densely populated or used as industrial site. To detect noise hot spots and to set priorities for intervention, it is therefore also necessary to relate the exceeding of limits to the number of people affected. Also, the END demands that the noise action plans inform about the number of people affected in the initial situation and after the abatement measures will have been implemented.

Noise limit values

When no limit values are set or when the local authorities choose to define own quantified targets for the maximum noise exposure of the population, the WHO recommendations regarding day and night noise limits can be used as guidance: 65 dB daytime, 55 dB night time.

To show the noise level combined with the number of people affected on a map, it is helpful to create single scores representing these information.

Various methods have been suggested to calculate those scores. Two different approaches are shortly described here:

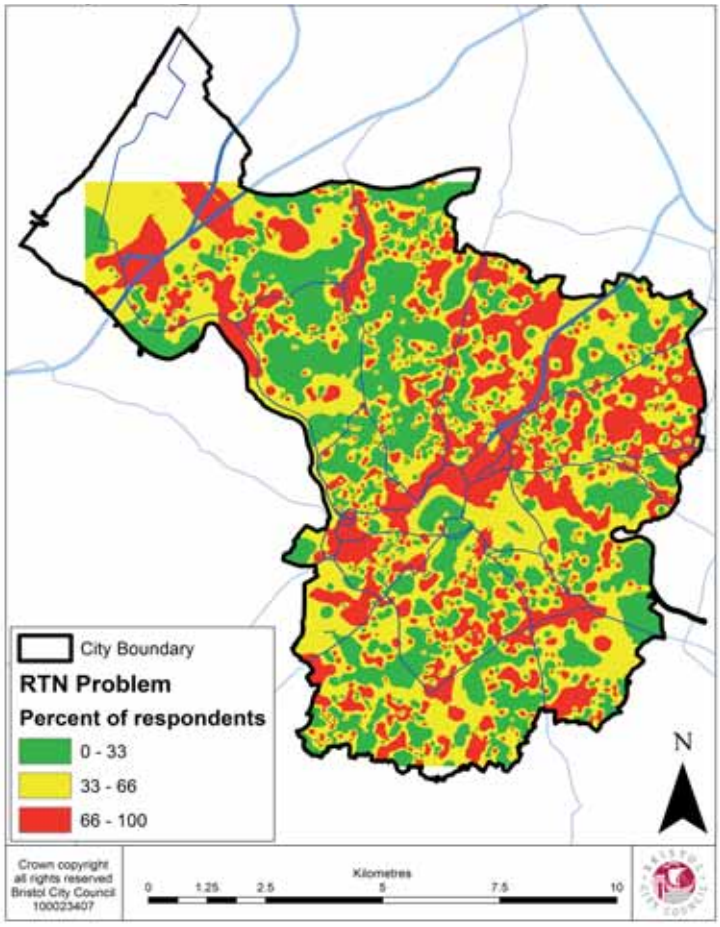
- Counting the number of highly annoyed people

This concept is based on the number of people that are 'highly annoyed' by a given noise level. A lot of surveys have been carried out to investigate the percentage of people highly annoyed by a certain noise level with regard to three different transport modes (road traffic, rail traffic, and aircraft noise). Based on the analysis of a range of surveys, Miedema and Vos suggest a method to calculate the number of highly annoyed people in relation to different noise levels and noise sources (Miedema, Vos, 1998). They estimate for example that for road traffic noise with a level of 65 dB, 18% of the population is highly annoyed whereas for rail traffic noise only 11% is highly annoyed with the same noise level.
The problem with this approach is that only highly annoyed people are taken into account. This results in noise scenarios with more highly annoyed people being ranked higher than scenarios where the number of highly annoyed people is lower but the number of annoyed people is significantly higher.

- Taking into account the total number of residents affected with the related level of annoyance

This method is more complex, and specialised software is needed for calculations (see for example Probst, 2006). The advantage of this method is that the weighing between highly and moderately annoyed people is open for political decisions. The equations of the calculations can be adjusted to decisions taken.
However, for both methods it has to be mentioned that results shown as numbers often seem to be very objective but are usually based on subjective decisions. In communicating with stakeholders and the public the presumptions behind the figures should be open for discussion.

In addition to or instead of these calculation methods, hot spots could also be identified by combining the results from noise maps with those from surveys questioning citizens on noise perception and annoyance. This approach will be followed in Bristol, UK, where citizens were surveyed on their noise perception.



Respondents to the Quality of Life Survey 2006 in Bristol reporting traffic noise as problem
Picture: Bristol City Council

Another or additional approach could include the criterion of sensible uses / vulnerable groups.

Based on a conflict map, sensible uses / vulnerable people (people with decreased personal abilities (old, ill, or depressed people), people dealing with complex cognitive tasks, people who are blind or have hearing impairment, babies and (young) children, and the elderly in general; Berglund et al., 1999, p. 35) or areas that shall be developed or renewed with priority (other than noise priority) could be used to set

priorities for intervention. The advantage of this approach is that clear political decisions need to be taken, which are open to public discussion.

Analysing noise sources and propagation

For planning and implementing adequate measures to reduce the noise in hot spot areas a thorough analysis of the different noise sources and the propagation as well as perception of noise has to be carried out. A number of questions – as shown in the table – could guide the analysis.

The END ...

does not address neighbourhood noise. Thus, dealing with neighbourhood noise is voluntary for local authorities. However, in consultation with the public this will certainly be an important issue.

Questions for the analysis of noise hot spots

Question	Aspects to be investigated
Which types of noise are relevant?	For road traffic noise: tyre-road noise, propulsion noise, noise from sirens and horns, etc. For rail traffic noise: curve squeal, breaking noise, noise from depots, etc. Neighbourhood noise: cafés and bars with terraces, loud music, people talking loudly when leaving these places; loud music in dwellings, air conditioning devices, etc.
Which factors influence the generation of noise?	Number of vehicles, average speed, share of HGV, road surface, congestion, etc.
Which factors influence the propagation of noise?	Architectural structure (reflection of buildings), urban furniture, green space, natural noise barriers, noise screens, etc.
When does the noise occur?	Time of the day when noise levels are exceeded; are high noise levels related to certain events (congestion during rush-hours, etc.)?
Who is affected?	Land use, number of people affected, vulnerable groups affected

The effort for analysing the noise hot spots will vary with the complexity of the noise scenario. Sometimes the analysis will be short and solely based on expert assessment, sometimes consultation of stakeholders and the public will be needed to clarify the noise problems and the most annoying aspects.

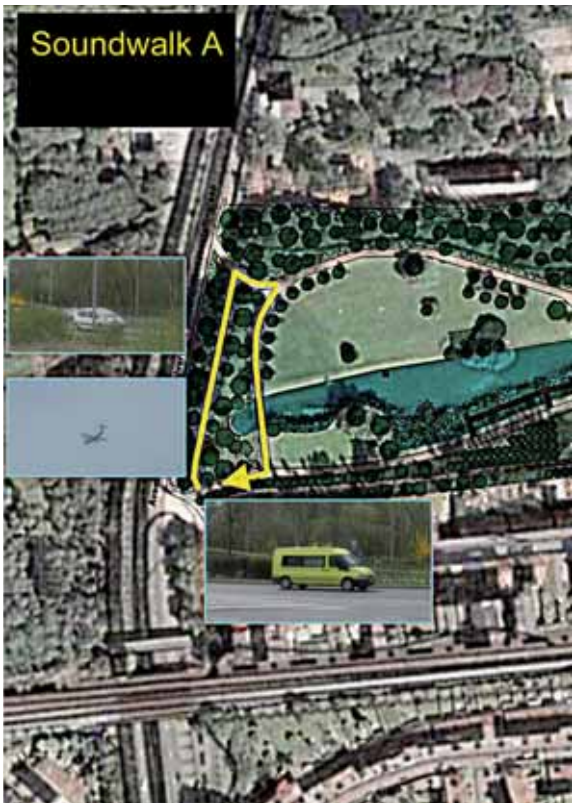
Analysing noise perception and annoyance – Soundscapes

Average noise pressure levels as indicated by L_{den} or L_{night} are a solid basis for noise maps and the general detection of hot spots. When it comes to analysing the annoyance of residents a more detailed view on the compilation of these averages is necessary. Noise peaks might occur – frequently or in relation to certain events – that can cause high annoyance even with the average sound pressure values being quite low. Furthermore, noise maps based on calculations only include traffic noise, while in practice other noise sources like neighbourhood noise might contribute as well to the dwellers' annoyance and overall perception of the sound environment.

These aspects show why it is necessary to learn about citizens' noise perception and to analyse the noise sources more in-depth.

Another aspect was already mentioned: different noise sources – like road traffic noise and rail traffic noise – cause different levels of annoyance at the same sound pressure level. Psycho-acoustical measurement methods like loudness, sharpness, or roughness represent the sound perception and evaluation better than measurements based on the sound exposure level (Schulte-Fortkamp, et al., 2007, p. 213). Besides these sound characteristics, the perception of a site's sound profile or "soundscape" (by analogy with landscape) – respectively the annoyance caused by this soundscape – is determined by other factors like esthetical aspects, atmosphere, and feelings related to a certain site. Research therefore suggests that analysing a site with respect to its soundscape needs to include aspects such as function of the site, urban structure, maintenance status of buildings, urban furniture, etc., and quality of private and public spaces (Schulte-Fortkamp, et al., 2007, p. 214). Furthermore, a person's socio-cultural background might also influence the way in which noise is perceived and the extent to which a person gets annoyed. When surveying citizens' noise perception, data concerning their social situation and personal background should therefore be gathered as well. The soundscape approach has been increasingly put forward over the past ten years as a possible tool to analyse users' perception of a site's sound situation in a holistic way. The approach usually includes interviews with users of the place under investigation and so called soundwalks: a "soundwalker" follows routes which are specific for the studied area and records the occurring sound events. The recordings are usually made with a binaural microphone system that allows for analysing the sound in a stereophonic way (like the functionality of the human ear) and thereby creates a more realistic image of the soundscape perception of users. The advantage of this way of recording compared to the simple measurement of the sound pressure level is that it allows for identifying the single sound sources and thus for analysing their quality (frequencies, intensity, spatial effect …).

Within the SILENCE project, the soundscape approach was used in Barcelona, Bristol, Brussels and Genoa to demonstrate the potential of this methodology and to provide useful data for the cities' planning activities. The study included stocktaking of morphological data (ground, buildings, plants and trees, urban furniture), activities present (means of transport, human activities, mechanical activities) and other elements (water, air, animals), as well as sound walks and surveys with pedestrians. On the basis of the collected data, recommendations were given on how to change the urban design in order to improve the soundscape for the site's users. To give a more concrete idea of the outcome of a soundscape analysis the results of the Barcelona case study are presented in annex 1 (Semidor, 2007b, p.5-9). The questionnaire used for surveying the opinion of passers-by in Bristol can be found in the annex (Semidor, 2007a, p.23-32). Further information can be obtained from the full reports on the CD-Rom (SILENCE I.D5 and SILENCE I.D6).



Soundwalk in the Roi Boudouin Park in Brussels
Photos: GRECAU

The END ...
makes a difference between quiet areas in agglomerations and in open country. While a "'quiet area in an agglomeration' shall mean an area, delimited by the competent authority, for instance which is not exposed to a value of L_{den} or of another appropriate noise indicator greater than a certain value set by the Member State, from any noise source" (Directive 49/2002/EC, Article 3 (l)), a quiet area in open country shall be "undisturbed by noise from traffic, industry or recreational activities" (Article 3 (m)).

Identification and protection of quiet areas

When developing strategies to reduce noise in the urban environment, the protection of quiet areas should not be forgotten. The END demands that noise action plans shall include measures to preserve quiet areas. Quiet areas can include a range of different sites such as parks, residential areas, hospital areas, playgrounds, or cemeteries.

When limit values for quiet areas in agglomerations have not (yet) been defined by the national (or regional) authorities, the responsible authorities for noise action planning have to define their own approach.

In Hamburg, Germany, a very practical approach towards quiet areas is used (Planungsbuero Richter-Richard, n.d.-b). The approach distinguishes between large open spaces (landscape), relatively quiet open spaces in the city centre, quiet footpaths and "urban oases".

- For large open spaces, it was decided to differentiate between "quiet" and "particularly quiet" areas. The limit values were set to 55 db(A) for quiet and 45 db(A) for particularly quiet areas. Empirical data were collected from noise maps in which minimum distance from major roads the noise levels would be under these limits. For Hamburg, this distance was found to be about 160 metres. This means that the edge length of quiet areas has to be at least 320 metres for the noise level at least in the middle of the open space (being 160 meters away from the road) being under 55 db(A). For particularly quiet areas the needed edge length goes up to 3,400 metres.

- Relatively quiet open spaces in the city centre are defined as areas where the sound pressure level is 6 db(A) lower compared to the surroundings, following the fact that a noise reduction by 6 db(A) is clearly perceivable. Without barriers for sound propagation a reduction of 6 db(A) is achieved in a distance of 100 metres from the road as noise source. This means that these quiet areas need to have an edge length of at least 200 metres.
- Quiet footpaths are considered as footpaths in attractive open spaces aside major roads with a length of at least 1,000 metres.

Areas of these three categories are firstly identified by means of GIS-data. In a second step, the identified areas are checked for plausibility, using the existing knowledge of the area within the responsible authorities.

- "Urban oases" are not defined by noise pressure levels but by qualitative criteria. They are considered as any space used for recreational activities that are evaluated by users as quiet. The identification of such areas is based on public consultation.

Step 6:
Identifying noise abatement measures and long-term strategies

Objective

To define appropriate noise abatement measures, including measures to tackle noise problems locally on a short-term basis as well as long-term strategies. Taking into consideration the advantages and disadvantages of the potential measures in the local context. To set up a concrete work plan for the implementation of measures and strategies.

Content

On the basis of the analysis of the noise conflicts, a bundle of measures will usually be determined to tackle the noise problem. In this decision making process, the noise reduction potential of the measures will be assessed. This will not only refer to the reduction of the noise level, but will also estimate the number of people that benefit from this reduction. Furthermore, the potential impact on other policy fields will be taken into account. Besides definite measures to tackle identified noise hot spots within the next five years, long-term strategies to reduce the noise level will be developed.

The list of measures will (then) be turned into a work plan that contains detailed information for each measure on the period of implementation, responsible agencies, financial resources needed, sponsors, and expected results. The work plan will set priorities and distinguish between measures to be implemented on a short-term, medium-term and long-term basis.

The END ...

requires that action plans include noise abatement measures to be implemented in the next five years as well as a long-term strategy. Furthermore, the action plan shall contain estimations in terms of the reduction of the number of people affected by noise and financial information (if available: budgets, cost-effectiveness assessment, and cost-benefit assessment).

Information needed

- Details on the noise problem to be tackled
- Benefits and disadvantages of possible noise abatement measures

Questions to consider

- What shall be the scale for determining the effectiveness of measures? A higher number of people benefiting from a lower reduction of the noise level or a lower number benefiting from a higher reduction? Is an increase of the noise level for a small number of people acceptable if a larger number of people is benefiting? Under which circumstances?
- Which measures and strategies would be the most efficient to tackle noise? Are they cost-efficient as well?
- If a bundle of measures is preferred, are possible synergies or conflicts between them taken into account? Are possible impacts on other policy objectives considered?
- When will the impacts of the measures become effective? Will this meet the expectations of the public? Are there alternatives that would become effective earlier? Is there a need for additional information and explanation towards the public concerned?
- Are the proposed measures accepted by the public (e.g. will residents accept the construction of a noise screen in front of their houses)? Could the acceptance of measures be raised through additional measures (e.g. through detailed information, turning a noise screen into a green wall with vegetation, etc.)?
- Who will be responsible for the implementation of the single measures? Which other stakeholders need to be involved?
- What is a realistic timeframe for implementing the measures (keeping in mind that the END requires a list of measures to be taken within the next five years)?
- With regard to limited resources, what are the priorities for implementation?

How to select adequate noise abatement measures?

Fortunately, a wide range of possible noise abatement measures exists. Thus, criteria are needed to make appropriate choices and to make the selection processes as transparent as possible. The following criteria are suggested:

- noise reduction effect;
- positive or negative impact on other policy objectives;
- costs;
- public acceptance and compliance.

Noise reduction effect

Similar to the assessment of noise hot spots, also for evaluating the effect of abatement measures the number of people affected respectively benefiting from the noise reduction is relevant rather than the reduction in terms of dB. This leads to the following questions to be discussed when selecting abatement measures:

- What is to be preferred? A higher number of people benefiting from a lower reduction of the noise level or a lower number benefiting from a higher reduction?
- Is an increase of the noise level for a small number of people acceptable if a larger number of people is benefiting? Under which circumstances?

Although noise regulation and abatement are based on noise levels for practical reasons, the overall aim must be to reduce the annoyance, sleep disturbance and adverse health effects that noise may cause. In this respect, it has to be considered that annoyance is not simply linked to noise levels. "Annoyance in populations exposed to environmental noise varies not only with the acoustical characteristics of the noise (source, exposure), but also with many non-acoustical factors of social, psychological, or economic nature" (Fields 2003, cited after Berglund et al., 1999, p. 33). Knowing this

it is not surprising that "reducing sound levels and reducing noise disturbances are two separate issues,

and that in some cases even a large reduction in sound levels will not be fully appreciated by those affected, whilst in other cases even small changes to sound levels may be perceived as a considerable improvement." (SMILE, n.d., p. 9) Studies suggest several explanations for this effect. One explanation is linked to the structure of the sound. Research in Berlin shows that residents might perceive the noise situation as improved when the number of very loud events is reduced even when the average noise level has not changed much (ibid., p. 10). Improvements in other policy fields might also lead to reduced annoyance even with only a small reduction of the sound level. For residential roads, slowing down vehicles thus reducing the dangers posed by car traffic, giving more space to pedestrians, and planting trees, bushes and flowers have proven to lead to greater annoyance reduction than what would have been expected based on the reduction of the average sound level (ibid., p. 11).

Some basics on noise reduction

- A change in sound pressure level of 1 dB(A) is barely audible.
- A decrease with about 3 dB(A) would imply halving the number of vehicles.
- A decrease by 10 dB(A) is necessary to be perceived as a noise reduction by half. This means a reduction of the number of vehicles to 10% of the original number!

Photo: PORTAL project

Positive or negative impact on other policy objectives

Measures designed to abate noise might interfere with other policy objectives, in particular in the fields of air quality, road safety, energy consumption, and congestion. Vice versa, measures taken to achieve objectives in other fields might impact on noise targets. Examples of synergies and conflicting impacts are:

Air quality

- Speed limits and HGV restrictions might reduce noise emissions as well as air pollution.
- Noise barriers might interfere with local air circulation, thus contributing to high concentrations of air pollutants.

Road safety

- Reducing the number of cars and HGVs might reduce noise and increase road safety.
- Road safety measures such as paving stone sections to make drivers aware of speed limits or road humps to reduce speed might increase noise.

Energy consumption

- Less noisy driving styles normally save fuel as well.

Congestion

- Smoothing the traffic flow, for example through replacing traffic lights by roundabouts might reduce noise and congestion.
- Night-time restrictions for HGVs might lead to (more) congestion in the early morning hours.

Implications of noise abatement measures on other policy fields depend very much on the concrete design and the local settings. Thus, the impact of potential measures should be checked for each individual application.

What if all the measures together don't achieve a sufficient noise reduction?

There will certainly be scenarios where a sufficient noise reduction cannot be achieved. Because the needed reduction of traffic volume on a certain road is not possible or politically not accepted, because there is no alternative to HGVs passing by a recreational area because neighbouring industry is dependent on the delivery, because …

Even if a reduction in terms of db(A) seems impossible, a reduction in terms of annoyance could still be achieved. Noise sources which are not visible tend to annoy less than visible sources. To place a vegetation shield between a major road and a park might help. Another option is to try to draw the attention of visitors to pleasant sounds in the overall soundscape. Adding a fountain might reduce annoyance caused by traffic noise. Furthermore, the physical design of the site impacts on the perception of the soundscape as well (see step 5). This gives additional possibilities for reducing annoyance.

At-source abatement most cost-effective, but ...

'One disadvantage of at-source measures at the vehicle level, however, is that penetration of the vehicle fleet takes several years for tyres and almost a decade for motor vehicles. Local measures like speed reduction and low-noise road surfaces are therefore also needed. Given the very long life spans of railway rolling stock, this is even truer of railway noise reduction measures. The optimal strategy will need to comprise a mix of local and at-source measures, including noise barriers at hotspots.' (CE Delft, 2007a, p. 27)

Costs

The following questions can help to assess the cost aspects of potential measures:

- What will the implementation of the measure cost?
- Which resources can be used? Are there any funding schemes at regional or national level?
- Are maintenance or renewal measures scheduled anyway that can be combined with noise abatement?
- Polluter pays principle: Can those generating the noise be charged for abatement measures?
- Can people benefiting from noise reduction contribute?

Cost-benefit estimations can support decision-making. The Working Group on Health and Socio-Economic Aspects, supporting the European Commission, concludes in this regard, that

'with a well-conducted cost-benefit analysis, it is possible to develop a noise action plan where the benefits of noise reduction are clearly higher than the costs of noise mitigation.

Cost benefit analysis can also help to prioritise between options so as to ensure that limited funds are spent to the best effect.' (WG Health, 2003, no. 5)

However, to valuate the benefits of noise reduction is obviously not a simple task. How to valuate an increase of risk for heart diseases or the improved quality of life in general?

Two methods to valuate benefits of noise abatement

Research in this field has mainly used two different methods to valuate the benefits of noise reduction. The first method – Stated Preference – refers to the people's 'willingness to pay' to reduce their noise exposure. This can for example be the willingness to pay higher rent for a quiet dwelling. The second method – Hedonic pricing – is based on price differences on the housing market that result from traffic noise.

A Danish study for example concludes that in Denmark the 'the prices of houses affected by road noise above 55 decibel (dB) situated near "ordinary" roads decline by 1.2% pr. dB. The prices of houses placed by motorways decline by 1.6% pr. dB.' (Miljøstyrelsen, 2003, p. 9)

A Dutch study applied this method not only to houses and dwellings, but to building land as well. This results in the amount of 10.8 billion Euros as total reduction in market value of dwellings and building land in urban areas in the Netherlands caused by noise from road and rail traffic (Jabben, Potma, Lutter, 2007, p. 14). In addition to the often-used approach where the external costs of noise increase on a linear base above the threshold of 55 dB, the authors of the Dutch study also used dose-response curves by Miedema. The results clearly show that in the case of motorway and aircraft noise there is also a substantial amount of 'noise damage' below this threshold

value (ibid., p. 11). Noise levels below 55 dB should therefore be taken into account as well. To calculate benefits of noise reduction for recreational zones, the Dutch study used the 'willingness to pay' approach. Using data on the willingness to pay of visitors to enjoy undisturbed nature, it was assumed that noise damage in nature areas and noise abatement zones in rural parts of the Netherlands increases linearly from 0 euro/m² at and below 35 dB(A) up to 0.3 euro/m² at and above 55 db(A) (ibid., p. 13).
These kinds of studies are quite complex and can clearly not be conducted in the same way for setting priorities and choosing options at the level of local noise action plans.

However, these studies are very valuable for local decision makers for two reasons:

- They point out the high benefits of noise reduction in monetary terms. Even though different studies come up with different results (due to different calculation approaches and different local conditions in the countries), they clearly show that costs of abatement measures often are much less than benefits to be achieved.
- The studies result in figures that can be used for much simpler estimations of benefits at the level of local action planning.

Based on a review of 'Stated preference' studies and taking into account average values from each European country

the Working Group on Health and Socio-Economic Aspects recommends a value of the perceived benefit of noise reduction of 25 euro/ household/dB/ year

(WG Health, 2003, no. 18). In the absence of robust data on whether people valuate each dB the same regardless the initial noise level, the working group suggests this value as a constant value across the range of noise levels (ibid., no. 19).
For more comprehensive approaches, software tools have been developed that calculate the external costs of noise for given noise scenarios, thus allowing for the comparison between different noise reduction measures and bundles. One example is City-Sustain which is based on property costs (loss of rental prices) and health costs (increasing health risks with higher noise levels). The software manages all needed noise data sets and combines them with population data coming from urban GIS. Results can be presented in figures and maps (Schmedding et al., 2005).
A good overview on the valuation of noise effects can be found in CE Delft, 2007b.

Public acceptance and compliance

Many noise abatement measures – such as speed limits – need public compliance to become (fully) effective. The expected public acceptance should therefore be assessed when selecting noise abatement measures. Answers to the following questions can support this assessment.

- Are the proposed measures accepted by the public, and will people comply with restrictions like speed limits and limited-access zones?
- Can the compliance be increased by additional measures?
- Is the measure effective even with many people not complying?

Decision Support Systems

To compare various potential measures with regard to the noise reduction effect and the other criteria suggested can easily grow into a complex exercise. Furthermore, many major cities will face the situation that noise limit (or target) values are exceeded in large parts of their territory. Due to limited financial resources, priorities for intervention have to be set. (Political) decision making in this situation is a complex task.
Decision Support Systems (DSS) are tools that have the potential to deliver valuable input to this process. DSS in the context of noise can be defined as an

'Environmental Management Systems' that collect, analyse and transform complex activity and environmental data into results that can form the basis

for supporting tactical and strategic decisions.

A DSS includes the following main features:

- Collect and analyse relevant data;
- Use computer models (e.g. emission- and dispersion models);
- Support Scenario calculations and forecasts;
- Report and present the data and results;
- Address different spatial and temporal structures.

Photo: Polis

The level of involvement of decision makers, the availability of data, and the nature of the decision making process will define the structure and extent of the DSS. It is obvious that there is no unique solution or even a unique approach for a DSS, as the approach and the speed of development of these systems is strongly influenced by a multitude of local constraints. The available resources and the political priorities given to an environmental burden are dominating factors in this respect. The development of DSS is usually based on existing data, databases and modelling tools. Thus, each city starts from a unique position and develops a unique (approach towards a) DSS.

In the context of the HEAVEN project, a DSS concept was developed that can be used to assess the environmental impacts of transport measures in large urban areas. The concepts and tools allow cities to assess the impacts of traffic on air quality and noise pollution in near-real time and to assess the impacts of planned measures prior to implementation. More information on the HEAVEN DSS can be obtained from http://heaven.rec.org. Within the SILENCE project, 5 cities/regions (Brussels, Dublin, Genoa, Munich and Paris-Ile-de-France) worked on the upgrading of their existing approaches in data collection and analysis in direction of a DSS. The cooperation with the cities in the course of the SILENCE project has revealed a number of aspects which are undoubtedly important for other cities wishing to follow the same direction and enhancing their approaches and systems for noise assessment. From the lessons learned, some recommendations for follower cities can be given. More information on DSS can be obtained from report SILENCE I.D12 on the CD-Rom.

Specify the assessment objectives and boundary conditions

A clear specification of the assessment objectives and the boundary conditions is unavoidable. The way the objectives are set may have a large impact on the work to be undertaken and on the required resources. The spatial scale to be covered has a significant impact on the way noise assessment is implemented. The number of sources to be included in an assessment defines to a large extent how much effort to calculate the noise impact is needed. Although computer sciences have made significant progress, there might be physical limitations to address large areas. The same accounts for the temporal scale to be addressed. In case the noise assessment should be done, for example once per year, the constraints are less prominent than for a higher time resolution.

Legacy systems and data availability

The modelling process calls for a wealth of data that need to be available either as static or dynamic data. The update frequency depends on the required temporal resolution. The amount of data is defined by the size of the domain and the spatial resolution. Usually, a lot of the required data are already available from legacy systems (e.g. traffic loops, traffic modelling). It is strongly

Noise assessment in Brussels ...

is jointly performed by two regional bodies. IBGE, responsible for environmental issues in the region, is operating a noise model which is fed with static traffic data. The second body is AED, which is in charge of traffic management in the Brussels Capital Region and delivers traffic data as input to the noise model. The main challenge for Brussels was the availability of accurate traffic data both from traffic counts and from traffic models. In the course of the SILENCE project, AED has developed a detailed plan to enhance the traffic counting and traffic modelling and to deliver comprehensive and up-to-date traffic data via structured databases as a dynamic input to the noise modelling process. This will be a major step towards a DSS, as the availability of accurate traffic data and related data on the road network are crucial for the quality of any noise assessment. These activities are in progress and are expected to yield tangible results in the future. Subsequently, IBEG will establish the dynamic link between the traffic data bases and the noise model.

Dublin is using a noise model ...

which is fed with static traffic data to prepare the noise maps as they are required by the European Noise directive. Similar to the case in Brussels, Dublin faces the challenge to feed dynamic traffic data into the noise modelling process. Dublin is currently undertaking further research in the context of the Urban Environment Project (UEP). The objective of this study is to utilise the existing SATURN transportation model and other traffic data to deliver better traffic data for the assessment of noise and air quality impact of urban traffic. At this stage, an exploratory action to facilitate this link is in progress.

When preparing the first noise map, Genoa ...

only used noise monitoring, no noise model was deployed. The challenge for Genoa was to replace this complicated and expensive approach by the adoption of a noise model and to integrate it into an existing DSS for traffic management purposes which already includes a component to assess the air quality impact of traffic. A noise model was selected and is currently under implementation. Meanwhile, the departments for Traffic and for Environment have started a joint project whose implementation will enhance the actual DSS and offer Genoa the possibility to assess the environmental impacts of traffic in an integrated manner.

The situation in Munich ...

is characterised by the fact that they are operating basically two different sets of tools for noise assessment. One set is used in an off-line manner mainly for planning and licensing tasks. For traffic management purposes, on the other hand, Munich is operating an integrated system which includes (since 2002) an Environmental Module to assess air quality and noise impacts from traffic. This system has links to near real-time traffic data. The challenge for Munich was to update the existing environmental module and the noise model especially to meet the demands of the European regulations. Another challenge is the migration of MS-Windows to a Linux operation system. It is expected that Munich will have a DSS for the integrated assessment of noise and air quality impacts from traffic in operation by the end of 2008.

Due to the size and the complexity of the Paris-Ile-de-France Region ...

around 240 authorities are cooperating in about 60 local projects to complete the noise mapping as a response to the European Noise Directive. This complex situation has led to a two stage approach. When the mapping projects are finished, the maps will be integrated forming the 'noise information layer' in the regional Geographical Information System (GIS). In parallel, work is in progress to create a 'dynamic environmental noise map' for the city of Paris, which constitutes a part of the whole region. The aim is get a higher time resolution of the noise levels than in the strategic noise maps. This requires not only cooperation with different bodies responsible for traffic, air quality and noise, it also requires an optimisation of the noise modelling process, which is currently explored in a test-area. It is expected that the dynamic noise assessment will be integrated into the HEAVEN DSS, which is already in place to assess the air quality impact of traffic.

recommended to investigate the availability of existing systems, to scrutinise them in detail and make efficient use of them. In some cases, it might be necessary to enhance the existing data to meet the specifications of the noise model.

Institutional cooperation and synergies

As the above mentioned data might be owned by different local or regional actors, it is strongly recommended to establish close cooperation with all parties involved. This cooperation has the clear potential to exploit or even create synergies. An excellent example is the joint use of data, such as traffic data, information on the road network or on the topography, which are usually needed by different departments and should be used jointly. Another example is clearly the integration of noise assessment into an already existing DSS for traffic and air quality, which could create large synergies.

Political commitment and resources

The assessment of noise, possibly in conjunction with air quality, is a challenge and needs time and substantial resources. The success of such an activity is largely influenced by the political commitment. Only with a strong political commitment it is possible to define the overall objectives of the assessment, establish well functioning local/regional cooperation and to make the required resources available.

Turning it into a work plan

Identifying measures and strategies which are effective, reasonable in price, and do not unacceptably conflict with other policy objectives is one thing. Turning this into a work plan is another. The work plan should show who is responsible for implementation, when implementation is scheduled, the expected costs and which resources will be used. Due to limitations in staff capacity and financial resources, it is obvious that not all defined measures can be taken immediately. When scheduling the implementation it also needs to be taken into account that some measures might be linked to each other or to other measures (like maintenance works). Setting priorities for intervention can cause as much debate as the selection of the measures themselves. Transparent decision-making is therefore advisable, as well as involving stakeholders in this process.

Step 7:
Drafting the plan

Objective

To summarise all findings and decisions in a comprehensive and easily accessible plan that meets the needs of the municipality (to have a concrete plan to follow), of the public (to have easily accessible information of what is planned), and the requirements of the END respectively the national legislation.

Content

The final document will summarise the findings on the noise problems, measures to be taken, strategies to be implemented, responsibilities, allocated resources, and expected results in the form of text, tables and maps.

The END ...

requires that action plans include

- a description of the agglomeration,
- the authority responsible,
- the legal context,
- any limit values in place,
- a summary of the results from noise mapping,
- the estimated number of people exposed to noise,
- the identification of problems and situations to be improved,
- a record of the public consultations organised,
- any noise-reduction measures already in place and under preparation,
- measures to tackle noise to be taken within the next five years,
- a long-term strategy,
- financial information and provisions envisaged for evaluating the implementation and results.

It is not necessary to wait with preparing this document until the end of the action planning process. In fact, a lot of content is already needed as input for the planning process (e.g. summary of noise mapping results, description of measures already in place, etc.). It is advisable to give some thought to the design of the action plan document in order to make it as useful and easy to read as possible.

Questions to consider

- Which requirements do national regulations set for the content and form of the plan? (Keep in mind that the END is to be transposed into national legislation.)
- In addition to that, are there any national or regional requirements concerning the plan?
- What could the plan look like? Are there any documents available that have proven useful and can be used as template?
- How shall the plan be published? Keep in mind that there are different design requirements for printed copies and for internet presentation.

Norderstedt Action Plan – an Example

The city of Norderstedt in Germany has delivered its Noise Action Plan following the END in 2006. It contains (Planungsbuero Richter Richard, 2006):

- Aim and scope of the report
- Current situation and context regarding legal framework, description of the studied area, changes since the last report, summary of data from the noise mapping, long-term strategy for noise protection
- Conceptual framework for action, including
  - a) Fields of action (promotion of sustainable transport, HGV strategy, management of parking space, etc.)
  - b) Consulting the public (results of working groups, opportunities for participation for housing companies)
  - c) Protection of quiet areas
  - d) Overview of measures and cost estimations
- Achievable noise reduction
- Annex
  - a) Limit values in place
  - b) b) Zones for noise protection in airport areas
  - c) Double noise exposure due to different noise sources (road traffic, aircraft noise)
  - d) Suggestions for the protection of quiet areas developed by the working group
  - e) Characterisation and description of quiet areas
  - f) Overview of measures grouped by financial years

Following the Norderstedt example the overview of measures grouped by financial years could be presented as follows:

Start date for implementation (Year – month)	Area / hot spot	Measure to be taken	Expected effect in db (A)	Estimated costs	Remarks (e.g. conflicts)	Added value for other policy fields	Other noise sources than road traffic
2008-08	Street / square / neighbourhood	Concrete description	- x db(A)	xx,xxx EUR	e.g. noise reduction effect could be increased if traffic calming measures foreseen in the mobility plan for 20xx would be implemented already in 20xx	in terms of air quality, road safety, support for other objectives of transport planning, etc	e.g. aircraft noise
Example from the Norderstedt Noise action plan							
2008-03	Hot spot "Marommer Strasse"	Speed limit, reduction from 50 to 30 km/h	-2.4 db(A)	11,400 EUR 10,000 EUR per chicane	In addition: chicane as speed reducing element	Road safety	

Step 8:
Adopting, monitoring, and reporting

Objective

To adopt the plan at the political level, ensuring that there is enough support for its implementation. To follow up the implementation, make sure that agreed measures are taken in time, and readjust the measures and/or the timetable whilst necessary to gain optimal results.

Content

The Local Noise Action Plan will be adopted by the city council or the board of deputies, depending on responsibilities. The leading department will coordinate the implementation of the action plan, monitor the progress made and report to the decision making body, the stakeholders and the public. Monitoring of the progress will include measures implemented, results in terms of noise level (measurements) and number of people affected, as well as any delays or difficulties, reasons for that and potential solutions. It is advisable to deliver a complete monitoring report for every financial year. Short progress reports in between could be useful.

Questions to consider

- Is it useful to involve the political level at an earlier stage of the process to get acceptance for the plan?
- Can the formal approval be used to raise public awareness?
- Are there any similar monitoring and reporting procedures at local level that could be used as template?
- Which bodies and stakeholders in particular are to be informed about progress and results? Especially consider neighbourhood initiatives that actively demanded improvement of the noise level.
- Are there any demands on the action planning process to facilitate monitoring and reporting later on (e.g. to consider in the implementation period any financial periods / bookkeeping periods (other than the financial year) that allow for short-term financial monitoring?)

Step 9:
Review and revision

Objective

To keep the action plan up to date with regards to (major) changes in the noise situation.

Content

The action plan will be reviewed whenever major changes of the noise situation are expected, e.g. when speed limits are to be changed or a new development is planned that generates additional traffic. Noise levels, reduction targets and measures will be checked and if necessary revised. Smaller changes of the plan will typically be within the competence of the leading department, while major changes might need approval by the city council. If there are no major changes in the noise situation, a formal review of the plan is due for 5 years after the approval of the action plan.

The END ...

states that action plans shall be reviewed, and revised if necessary, when a major development occurs affecting the existing noise situation, and at least every five years after the date of their approval.

Questions to consider

- What shall be considered as "major" changes of the noise situation? It might be useful to discuss this question with relevant stakeholders during the process of drawing up the plan.

Part 4:
Long-term strategies to avoid and abate noise

This part focuses on strategies that can help to avoid the development of noise conflicts. These strategies will only become effective on a long-term basis. This might make their implementation more difficult, as politicians prefer to spend money on measures that give results on a short-term basis. However, for offering citizens a good soundscape it is much more sensible to avoid the generation of noise conflicts than to try to abate them afterwards.

Public awareness raising

Informing and consulting the public on the development of a noise action plan is important and will certainly raise awareness about the noise problem among those involved. However, usually only a small group of citizens will be actively involved in such planning processes or will closely follow the results in the media. Other tools are needed to reach the broader public.
Objectives for awareness raising in this field are to increase the knowledge about the (health) impacts of noise exposure and the relation between own behaviour (in particular driving behaviour) and noise generation, thus increasing the general acceptance of noise abating measures. Even more ambitious aims would be to change attitudes towards public transport and cycling and walking as less noisy alternatives to private car use and finally to change travel behaviour to a less noisy mode.

Aims of communication

Before developing any kind of information tools or campaign, it is necessary to clearly define the aims and the target groups of the communication strategy. Applying the recommendations on "Communicating air quality" developed within the INTERREG project CITEAIR to noise, the following questions could guide the development of an information campaign (van den Elshout, 2006, p. 15ff.).

The aim is to give information and to raise the level of knowledge on noise

For example, the LDEN in a certain area was 70 db(A). This exceeds the limit value by 5 db(A). If the communication is only meant as a way to improve the noise knowledge of the receiver of the information the following questions should be answered:

- For whom is this information useful? Which target groups need this information?
- How much knowledge does the target group already have on this subject? In case of low knowledge levels, it must be explained "how noisy 70 db(A) are" and how a reduction by 5 dB(A) would make a difference.
- What is the target group's need for information on noise?
- What is the preferred way of being informed: an article in the newspaper, on a website, etc.?

The aim is to create understanding, to touch the "attitude-level"

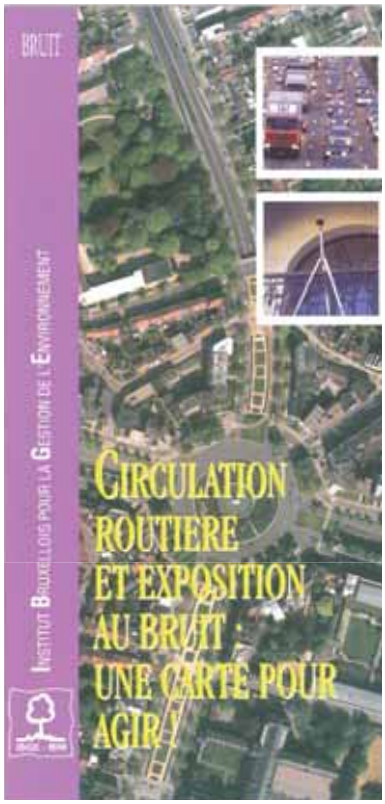
For example, the L_{DEN} in a certain area is 70 db(A). This exceeds the limit value by 5 db(A). This noise level is caused for 90 percent by cars and trucks. The traffic department is considering measures to make sure that for residents in this area the noise exposure meets the limit values as soon as possible but in any case by 2012.
If communication is meant to influence the attitude of the receiver of the information, one must show the usefulness of this information for the receiver, or at least indicate the general usefulness. It is important to make a link between the contents of the message and the receivers. The following questions need to be considered:

- How useful is the information to the receivers?
- What is important to the receivers? How do they "feel" about noise?
- Can worries be taken away or problems solved?
- When do receivers need this; when are they receptive for noise information?
- What is the preferred way of being informed?

The aim is to change people's behaviour

For example, the L_{DEN} in a certain area is 70 db(A). This exceeds the limit value by 5 db(A). This noise level is caused for 90 percent by cars and trucks, of which half relate to traffic that needs to cross this area. The other half however, relates to cars making short trips (less than 4 km). Taking the bike or using public transport could have avoided most of these trips. Changing people's behaviour to reduce noise, could target on quieter driving styles or use of public transport or cycling and walking, e.g. "If this regards you, before taking the car, wonder if it is necessary. You will be helping those living in this area and besides, cycling is good for your own health!"

However, it has to be mentioned, that influencing people's behaviour is very difficult.
Communication can make people aware of their behaviour, but generally it won't change it. To change behaviour, sanctions or rewards are a more appropriate means.
Anyway, communication targeted at influencing attitudes or behaviour is important to create support for usually unpopular policies, such as speed limits or traffic bans. This in turn might help to convince politicians to implement such necessary measures.
Another option could be to draw on economic arguments instead of noise arguments. In times of high fuel prices, many drivers are more likely to comply with speed limits to save fuel than to reduce their noise emissions.



Information brochure from Brussels: Road traffic and noise exposure: a map to act!
Source: IBGE-BIM, 2002

Target groups

Considering the questions mentioned before, it becomes clear that the answers will depend significantly on the groups targeted for communication. Different groups have different know-ledge about noise, different needs, and different attitudes and behaviour. To successfully communicate the needs and possible measures for abating noise, it is necessary to get a clear understanding of the addressees of the information. Relevant data on the various target groups can be gathered via questionnaires, focus group discussions, or other instruments. The following table gives an overview of possible target groups for communicating noise issues at local level (based on van den Elshout, 2006, p. 17).

Target groups	Subgroups
Citizens	City dwellers People working in the city Tourists Public transport users Car drivers Cyclists and pedestrians (Parents of) babies, toddlers, small children Migrants / minorities Elderly people Shop owners
Freight delivery sector	Truck drivers People responsible for delivery schemes of businesses Shop owners
Educational sector	School children Teachers Parents
Health sector	Hospital staff General practitioners Public health service Patients in hospitals
Journalists / Media	Regional and local newspapers Target group-specific papers
Non-governmental organisations (NGOs)	Environmental groups / Interest groups Organised citizens at neighbourhood level Research institutes Consulting companies
Government / decision makers	City council Regional authorities

Tools

There is a range of tools for communicating with the different target groups. All kinds of leaflets, brochures, posters, websites, questionnaires, information desks in hot spot areas, children's competitions, etc. can be used. It is important to find the right tool, the right style and tone, and the right time for delivery for each target group.

Another interesting way could be to inform citizens with tools dedicated to noise, such as "sound barometers" in the streets, just as is done for air quality. For example in the French city of Clermont-Ferrand, the air quality in the city is displayed on an "air quality barometer".

The following scale, based on common standards, could be used to present sound levels to the public in a similar way:

Air quality barometer in the French City of Clermont-Ferrand

Photo: Melanie Kloth, Polis

More than 85 dB(A)	Harmful sound levels in case of long exposure
>75 – 85 dB(A)	Communication is very difficult
>65 – 75 dB(A)	Mediocre soundscape
>55 – 65 dB(A)	Acceptable soundscape
>45 – 55 dB(A)	Good soundscape
Less than45 dB(A)	Excellent soundscape

Land use planning and building design

As mentioned earlier, avoiding and mitigating noise should be an integral part of land use planning and building design. The noise reduction potential is much higher when taken into consideration from the very beginning of a new or re-development.

Land use planning

Typical tools for land use planning are land use plans or zoning plans that cover the entire territory of the city (or the district). These plans can be used for noise abatement planning by

- indicating (relatively) quiet spaces that are to be protected against new noise immissions;
- allocating land use in such a way that the distance between future noise emissions and noise-sensitive areas is big enough. However, research has shown that a sprawled city structure (as particularly promoted in the middle of the 20th century) compared to a compact structure does not offer a solution to the noise problem (WG 5, 2002, p. 22). The separation of land uses reduces noise on the one hand but generates additional (motorised) traffic and thus noise on the other hand;
- avoiding the generation of additional traffic by sensible allocation of land use categories.

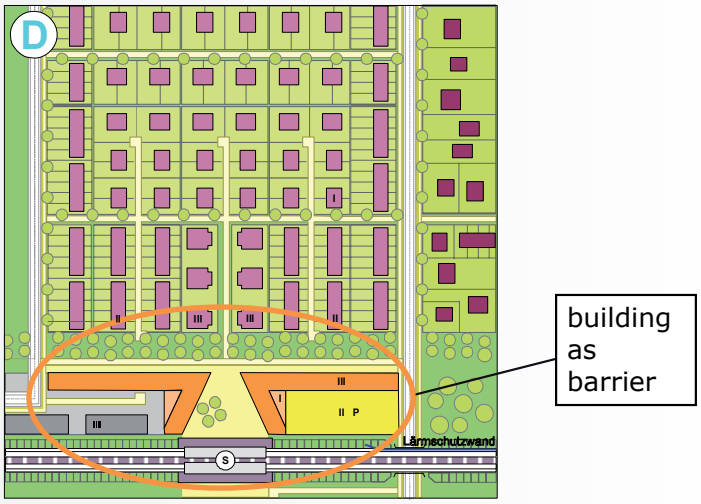
Land use plans often have a time horizon of 15 or more years. Decisions taken in those plans will not directly impact on the noise exposure of dwellers. Noise reducing effects become only measurable when – on the basis of land use plans – concrete development plans are implemented.

Land use plans thus are often underestimated as to their relevance for noise abatement

(Lärmkontor, BPW, konsalt, 2004, p. 78). They are however an important planning level when it comes to avoiding future noise conflicts.
On the next level, planning tools that cover only parts of a city such as development plans or plans for urban renewal / redevelopment offer the opportunity to stipulate concrete measures to avoid or abate noise. The following measures can be used for the redevelopment of existing housing areas as well as for the development of new neighbourhoods on inner-city brownfields or as town expansion. The possibility of using these measures depends on the size of the available space, the terrain, the zoning policy applied, as well as other restraints like objectives for high population density on the site, the necessity to provide for HGV access to existing shops, etc.

a) Noise-compatible buildings as noise barriers

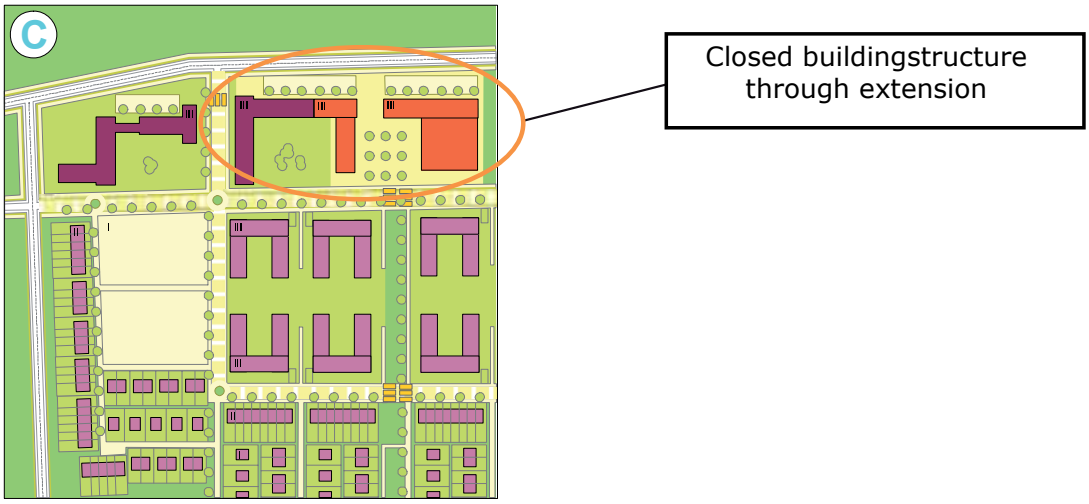
A cost-effective way to protect residential buildings from traffic noise can be to place buildings with noise-compatible uses like shops and offices between the road or railway line and the housing area. In particular at inner-city locations this noise abatement solution responds to the request for an intensive use of rare and expensive building land. However, this solution requires a sufficient demand for additional space for offices and/or shops.



Buildings as noise barriers along a railway line
Source: Lärmkontor, BPW, konsalt, 2004, p. 35

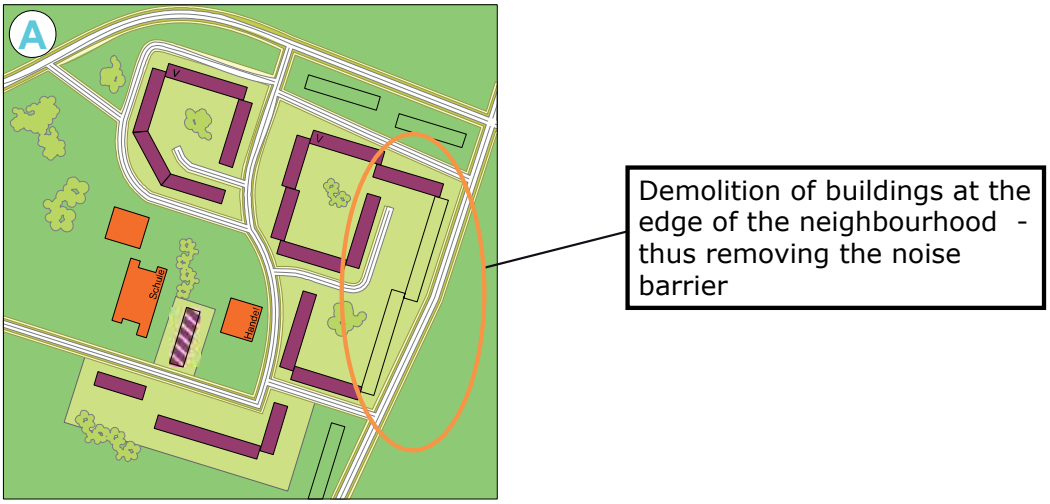
In this example the form of the new building is especially designed to reduce the propagation of noise towards the residential houses located behind.

In redevelopment areas, additional buildings can form a noise barrier together with existing buildings.



Noise abatement through extension of buildings
Source: Lärmkontor, BPW, konsalt, 2004, p. 29

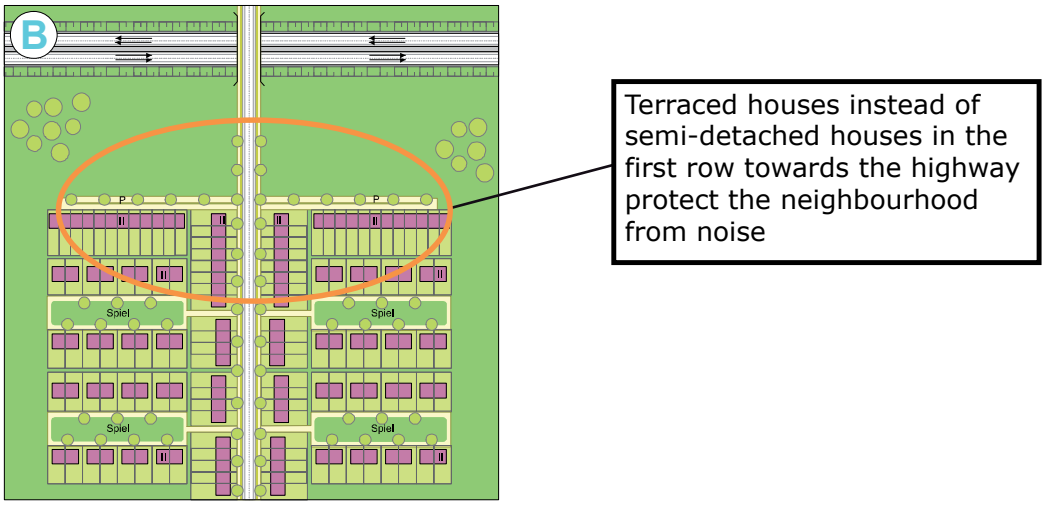
The noise abating effect of buildings is not only relevant for the development of new neighbourhoods. In shrinking cities, where the demolition of residential houses is under discussion, the noise issue also has to be considered. Taking away houses at the edge of a neighbourhood could lead to an increase of the noise level in the centre. Alternative options on how to reduce the number of dwellings or additional noise abatement measures should be discussed.



Demolition of houses in shrinking cities
Source: Lärmkontor, BPW, konsalt, 2004, p. 72

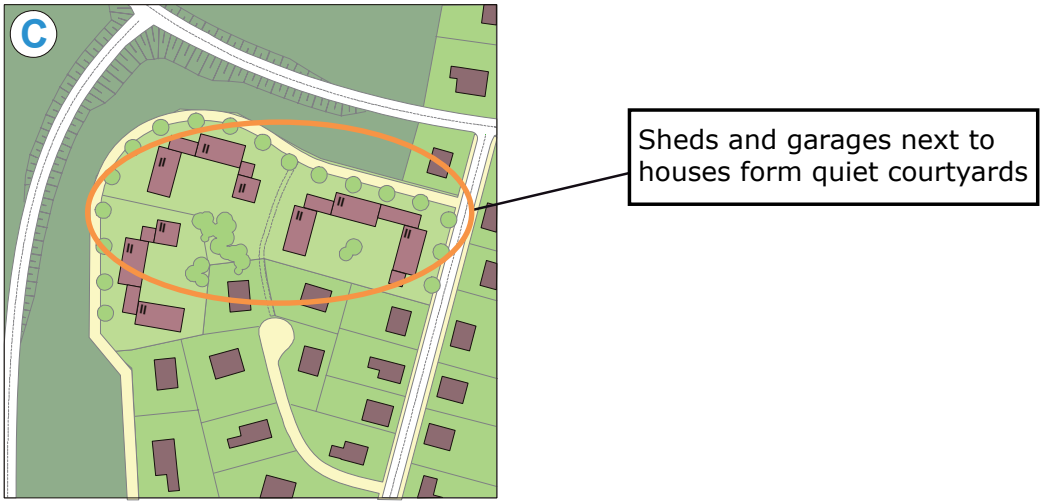
b) Building structure

Another opportunity is to design the residential houses themselves in such a way that the propagation of noise is reduced. Compared to detached or semi-detached houses, terraced houses reduce the sound propagation and offer at least one quiet façade to the houses.



Closed front of houses forms noise barrier
Source: Lärmkontor, BPW, konsalt, 2004, p. 30

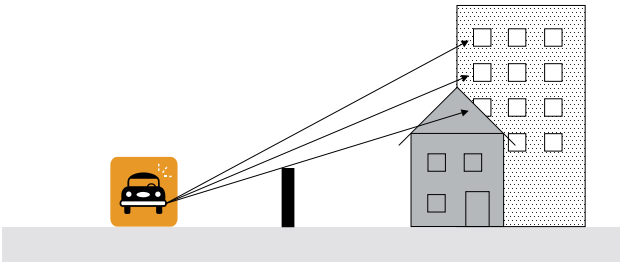
Sheds and garages can be used to form a kind of courtyard that gives one quiet façade to the houses.



Sheds and garages forming quiet courtyards
Source: Lärmkontor, BPW, konsalt, 2004, p. 49

c) Allocation of buildings in combination with noise barriers

Screens or barriers can be used to protect residential areas from noise. Noise screens abate the propagation of noise depending on their height and the distance from the noise source. Thus, low-rise buildings are easier to protect from noise than high-risers. High-rise buildings therefore need to benefit from the longer distance from the noise source rather than from the effects of noise screens. In areas with a mix of houses, low-rise houses should be placed next to the barrier whereas high-rise houses should be placed as far from the noise source as possible. Unfortunately, high-rise buildings for social housing or dwellings for rent are often placed directly at the noise source to protect the low-rise buildings behind from the noise.



Noise screens protect low-rise buildings

d) Distance

Placing as much distance between the road or railway line and the residential buildings is maybe the most obvious option to reduce the noise immission on residents. Doubling the distance will in general lead to a reduction by 3 to 5 dB, depending on the attenuation of the ground in between (WG 5, 2002, p. 21). For motorways this means that on a distance of less than 100 meters the noise level will seldom fall below 70 dB (ibid., p. 22)!

Thus, distance might be a solution for rural areas. For urban areas it is rarely an option!

Besides its low noise protection effect, in many cases distance is contradictory to other objectives of urban development. For example, in order to enhance the use of public transport it is advisable to place a new neighbourhood as close to a railway station as possible and to avoid 100 meters of open space (with bad noise quality) in between the houses and the station (Lärmkontor, BPW, konsalt, 2004, p. 35).

Noise zoning

The Danish project "The city without noise annoyance" has developed a noise zoning tool as an easily accessible plan showing the city area divided in 4 different noise categories. The aim with this plan is to support municipal planning, traffic planning and noise action planning as well as to serve as an easily understandable tool for consulting the public on noise issues. It is suggested to use 4 different zones with specific requirements (L_{Aeq}, 24h) for dwellings and institutions in each zone (Ellebjerg Larsen, Bendtsen, 2006, p. 3):

- "A. Quiet areas, where noise levels may not exceed 45 dB. No through traffic at night.
- B. Residential areas with reasonable noise conditions, where noise levels may not exceed 55 dB. No through traffic at night.
- C. Noise polluted central areas, where noise levels may not exceed 65 dB. No heavy vehicles at night.
- D. Heavily noise polluted areas that are typically located near main roads and intersections. As far as possible no heavy vehicles at night. In longer perspective, traffic planning and urban planning should secure that there are no dwellings in these areas.

In areas labelled as zone C or D, there should be public open spaces such as parks, playgrounds or similar areas that have relatively low noise levels (<55 dB) within 10-15 minutes walk from dwellings. In all zones the noise levels inside dwellings should not exceed 30 dB. In zones C and D, the dwellings should have a 'quiet façade' where the noise level does not exceed 55 dB, and sleeping rooms should be located towards this façade. In zone D, living rooms should also be located towards the quiet façade."
For END related use and the required noise maps,

the noise levels could be adjusted to L_{DEN} instead of L_{Aeq}, 24h. Compared to noise maps showing the contour lines for 55, 60, 65 and 70 dB – as demanded in the END –

those zoning maps are a more comprehensive way of explaining the issue to the public

because they include both the actual status of noise exposure as well as requirements to keep this level respectively to improve the situation.

Planning new routes for roads and railway lines

When planning a new route it should be considered that – as mentioned before – noise levels in dB from two distinct noise sources do not simply sum up arithmetically. This phenomenon can be used when planning a new road or railway line. A good solution might be to place the new road along an existing railway line. The noise level will increase little, while avoiding the creation of new noise in a formerly quiet area.

Building design

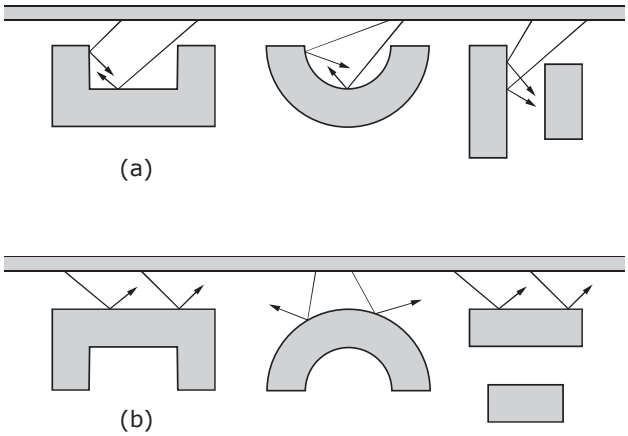
In the section on land use planning, the relevance of the building structure for the protection of the house itself and buildings lying behind has been mentioned. In relation to the single building, there are more aspects to be considered for reducing the inside noise level. They concern the room plan, the shape and orientation of buildings, as well as sound insulation of walls and windows (the latter will be presented in Part 5 of this handbook).

a) Room plan

In dwellings and offices, rooms for less noise-sensitive activities can be placed towards the road or railway line, thus forming an additional noise barrier to the other rooms (WG 5, 2002, p. 31). Such rooms include kitchens, bathrooms, stairways and storages. Noise-sensitive rooms should be placed towards the quiet façade.

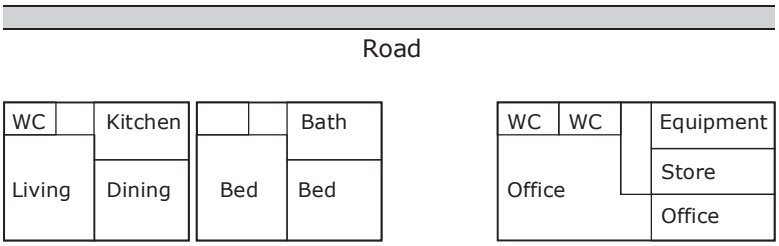
b) Shape and orientation of buildings

The shape and orientation of buildings should be planned with due consideration of their impact on the indoor noise level of the building itself, as well as of other buildings nearby. Sound will be reflected by the façade. It should be avoided that the noise is reflected towards other façades, thus provoking additional annoyance.

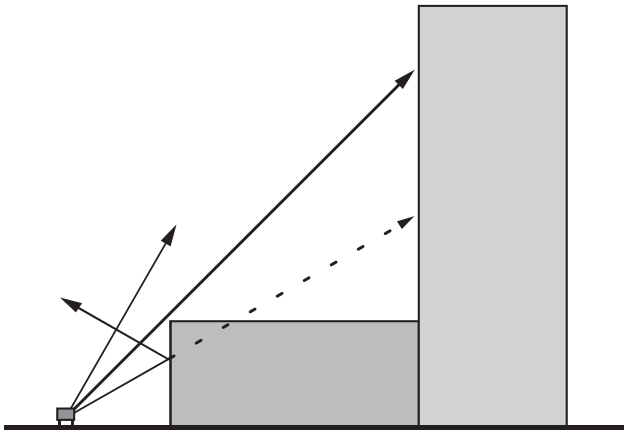


Noise reflection at buildings:
a) to be avoided b) preferred
Source: WG 5, 2002, p. 27

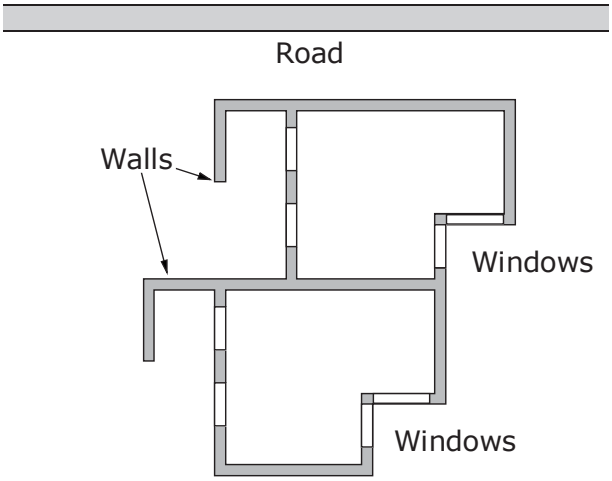
A more comprehensive way of building design is utilising parts of the building itself as noise barriers for the noise-sensitive rooms. In particular balconies, wing walls and adjoining buildings can be used for such 'self-protecting buildings' (ibid., p. 32). Orienting the windows away from the road or railway line and protecting them through wing walls can reduce the inside noise level significantly.



Noise compatible arrangement of rooms
Source: WG 5, 2002, p. 31



Adjoining building used for a self-protecting building
Source: WG 5, 2002, p. 32



Wing walls protect the building
Source: WG 5, 2002, p. 32

The noise reduction potential of balconies ranges from 5 to 14 dB depending on the width of the windows, the angle between the road and the window, the depth of the balcony and the height of the boundary wall. If balconies are located well above the street level, their underside should be designed to reflect noise away from the façade or be covered with a noise absorbing material (ibid., p. 33).

Design of parks and green spaces

In inner-city areas with a relatively high noise exposure of dwellings it is especially important to provide for quiet parks and green spaces. However, many parks are affected by road and railway noise as well. The primary concern in this case should be to reduce the noise emissions.

If there is no opportunity to achieve an adequate noise level in the entire park, a careful allocation of uses in the green space is important.

The following recommendations can help to place different activities with respect to their noise sensitivity (Lärmkontor, BPW, konsalt, 2004, p. 11):

- areas for very noise-sensitive activities like reading or sunbathing should be placed as far as possible from the noise sources;
- areas foreseen especially for communication between visitors should be carefully protected from noise because communication is very easily disturbed by noise;
- rail traffic noise implies less subjective annoyance than road traffic noise; if no quiet areas are available, the noise-sensitive activities should be placed in vicinity of the railway rather than of the road;
- sporting activities are the least noise-sensitive and can be placed in the noisier areas of the park.

Taking advantage of changes

This chapter wants to highlight (again) that not all efficient measures to abate noise necessarily cost (a lot of) extra human and/or financial resources. The public fleet – including waste collection vehicles, public transport and all other vehicles used by the local authorities – has to be renewed at some point anyway. Why not choose less noisy vehicles then?

The same principle applies to road surfaces. They need to be replaced at some stage when they are old and worn anyway. Very effective and cost-efficient low-noise road surfaces are now available. Whenever a surface is to be replaced a low-noise alternative should be considered.

Another issue is to make sure that the noise impact of new transport infrastructure is controlled. In many countries, for new infrastructure and other construction projects an environmental impact assessment has to be done. These evaluations should include impacts on the noise situation. When a future noise conflict is detected during the planning phase, amendments can still be made that help to reduce the noise impact.

Photo: Joël Dozzi

Environmental permits in Brussels

The Brussels noise action plan mentions environmental permits (IBGE-BIM, 2000, p. 20). Since 2002, environmental permits for the design of public space have been more specifically evaluated from an acoustic point of view, taking into account the specific context of the project (surroundings, residential or not, current annoyance levels, etc.) and formulating recommendations as to materials choice or processing, speed limits or traffic flow control. Special attention is paid to locations where public transport (tram or bus) is passing.

Promoting less noisy transport modes - modal shift

Private cars are responsible for a great part of the noise annoyance in urban areas. Encouraging residents to use alternative transport modes is therefore highly advisable to reduce the noise level. As many inner-urban car rides are shorter than 3 km, walking, cycling, skating, and public transport are good alternatives. Measures to promote a modal shift in favour of these modes can include:

- more attractive public transport (clean and comfortable vehicles, good accessibility of stations, higher frequency, shorter travel times through separated bus lanes etc., easy ticketing system, …);
- high quality cycling facilities;
- integrated car parking policy, park & ride facilities;
- mobility management;
- awareness raising campaigns.

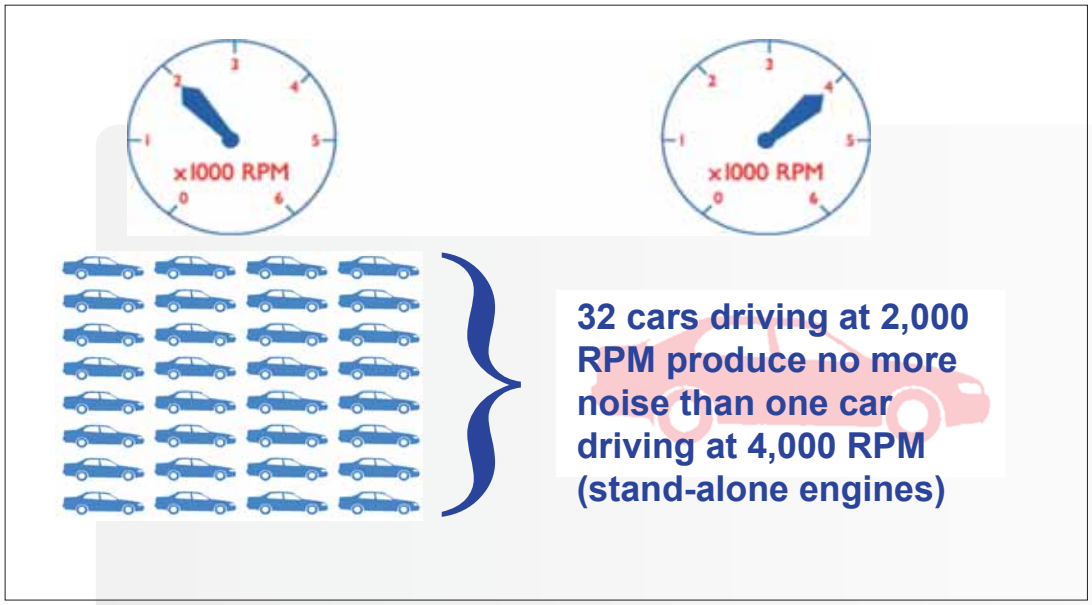
Photo: PORTAL project

Promoting modal shift …

is a huge subject on its own and cannot be discussed here in more detail. A range of literature and practice examples are available. For example, the following websites present successful measures in the case study section: http://epommweb.org/index.phtml?Main_ID=816 and http://www.eltis.org/.

Photo: PORTAL project

Influencing driver behaviour



Engine speed significantly impacts on noise
Source: VVCR

Driving styles have a high impact on the noise that is generated. Using low engine speeds and avoiding unnecessary high acceleration and vehicle speed values achieve a significant reduction of the propulsion noise of a vehicle. There is a correlation between acceleration and noise for passenger cars. For low speeds of around 30 km/h, the average noise increase due to acceleration is 2 dB. For speeds around 50 to 60 km/h, the increase is 1 to 1.5 dB (Steven, 2005). It is possible to drive with very low engine speeds, if one does not use the full acceleration potential of the vehicle. The acceleration values that are necessary to follow the traffic flow are normally much lower than the full acceleration potential of the vehicle.
Other sources mention even higher noise reduction potentials. Less aggressive or passive driving styles are believed to reduce the noise on average by approximately 5 dB for cars and commercial vehicles and 7 dB for motorcycles. Furthermore, they result in considerable fuel savings, improve traffic safety and reduce gas exhaust emissions (WG 5, 2002, p. 14).

These figures make clear that it is worth invest in influencing driver behaviour.

Especially the fuel saving potential can be used as argument in campaigns to convince drivers of a more passive driving style. Saving fuel brings an immediate economic value for drivers, which probably is more convincing than health effects. So far, noise has not been a central aspect of ecodriving campaigns. However, ecodriving, i.e. driving in a mode that saves fuel and reduces air pollution, also reduces noise emissions. Ecodriving training and campaigns including additional information on the noise issue therefore can be used to raise awareness for noise as well. Examples can be found at www.ecodrive.org and at www.treatise.eu.com. The figure below gives an example of how to present the relationship between engine revolutions and noise: one vehicle travelling with 4000 rpm produces the same amount of noise as 32 vehicles travelling at the same speed with only 2000 rpm (http://www.ecodrive.org/Benefits-of-ecodriving.277.0.html).

Such campaigns could be supported by in-vehicle systems assisting the driver in eco-driving, e.g. by giving advice to shift to a higher gear when the engine speeds reaches 2,000 rpm. To enforce less-noisy driving styles, a system of noise sensitive areas and vehicle based engine speed and acceleration limiters could be installed in the future. The cities would need to define the noise sensitive zones and equip them with systems to send information to vehicles entering the zone. The limiters then could be activated by the monitoring system when the vehicle enters a noise sensitive area and could be deactivated when leaving this area.

Complaint management

The systematic collection and analysis of citizens' complaints about noise can provide useful information about noise annoyance. In this respect a clear strategy on where to collect complaints and which data to collect is necessary. This strategy needs to be disseminated to all agencies of the local authorities which might be addressed by complaining citizens. This will certainly include the local police, the environment department, any on-site departments like offices for neighbourhood renewal, etc. Of course the strategy should not only refer to how to handle the data but also how to go back to the citizens to explain what the local authorities will do about the problem.

However, it has to be mentioned that such data are not representative.

There are various target groups that typically don't complain towards public authorities, among them migrants, people with lower levels of education, children. Information gathered through complaint management can contribute to the detection and analysis of hot spots, but always needs to be accompanied by other types of data collection on noise.

Promoting Night time noise service in North Lanarkshire
Photo: Environmental Protection UK

Part 5:
Tackling noise

This part presents a choice of measures that help to reduce noise levels in hot spot scenarios. Included are measures that (in general) can be implemented at the local level. Other measures, such as low-noise tyres or driver assistance systems – also being investigated within the SILENCE project – can contribute to noise abatement in urban areas as well. They however are usually not within the competence of local authorities and therefore not discussed here.

The measures presented offer solutions to different types of noise problems. Based on the analysis of the hot spot, an informed choice can be made. There are no "one-size-fits-all" measures. Tailor-made solutions have to be developed for each hot spot, taking into account the local context and the impact of the measure on other policy objectives. This is particularly important when a bundle of measures is implemented that might have multiple effects on other policy fields. Only few measures for specific roads have no impact on parallel routes or the road network in general. In fact, most measures will lead to a shift of traffic to other roads. Impacts of measures therefore need to be considered for a larger area.

This chapter is mainly based on findings of the SILENCE project, thus focusing on rail and road transport noise; other research has been included where necessary. A range of recommendations on how to tackle aircraft noise can be found in literature (e.g. WG 5, 2002, p. 16ff.).

The presentation of the measures includes a short description, benefits in terms of noise reduction, rough estimations of the related costs, and comments on advantages and related problems; these also include remarks on effects on other policy fields such as air quality, road safety, congestion, and energy consumption. This is followed by more technical details for those interested in implementing the measure.

The first part of measures refers to the infrastructure, the second part to the rolling stock and the third part to traffic management.

Low-noise road surfaces

What is it about?

Road surfaces influence the generation of noise by tyre/road interaction and the propagation of noise from the vehicle engine and transmission system. The relevant factors for noise emission are the texture of the surface, the texture pattern and the degree of porosity of the surface structure. Low-noise road surfaces today are either thin layer surfaces or porous asphalts with one or two layers. Thin layers are different bituminous layers with a maximum thickness of 3 cm and a small aggregate size (4-8mm as maximum chipping size).

Porous asphalt has an open structure with about 20-25% air void inbuilt. As a result, it absorbs noise and drains water, thus increasing road safety. The noise reduction potential of porous asphalt is higher than for thin layers. However, for use in urban areas, the porous asphalt still shows significant disadvantages in terms of costs, durability, winter maintenance, ravelling caused by shear forces, drainage systems and difficult repair after trenching for pipes and cables and after accidents. Thus, the use of porous asphalt is only recommended for higher speeds (>60km/h), homogenous traffic flow, roads with only few crossings / traffic lights and without sharp bends.

There are also new, low-noise solutions for paving blocks that can be used as alternative to cobble stones, keeping a very pleasing and different (compared to asphalt) visual appearance. Paving stones normally cause increased noise levels of 3-5 dB because of their very uneven surface structure. In SILENCE, a special type of very smooth paving blocks has been developed and full scale tested. These paving blocks have about the same noise emission as ordinary pavements.

Benefits in terms of noise reduction

For thin layer surfaces, an initial noise reduction of up to 3 dB in relation to dense asphalt concrete with 11mm maximum aggregate size has been measured. However, the noise reduction effect decreases in the order of 0.1 dB per year (for light and heavy vehicles at low and high speed). In the SILENCE project, thin layers with an optimised surface texture for noise reduction have been developed and full scale tested in Denmark. An initial noise reduction of 4 dB was achieved.

Single layer porous pavements have an average noise reduction of 3-4 dB on highways (in relation to dense asphalt concrete).

Two-layer porous pavements have a noise reduction potential of around 4 dB or more (in relation to dense asphalt concrete).

For porous asphalts, the noise reduction effect decreases by 0.4 dB per year for light vehicles at high speeds and by 0.9 dB at low speeds. For heavy vehicles, this amounts to 0.2 dB at high speeds. No effect is assumed for low speeds.

What does it cost?

The cost of thin layers normally is about the same as the price for ordinary pavements. The price is to some extent related to the condition of the old pavement on the road. In Denmark, it is expected that the lifetime of thin layers is around one year less than of ordinary pavements due to their open surface structure.

Two-layer porous asphalt surfaces cost about 30 EUR/m² more than conventional surfaces.

Compared to other noise abatement measures (like barriers, sound proof windows), the costs for low-noise road surfaces remain relatively low.

Advantages

Noise reducing pavements can be used in the ongoing pavement maintenance process and thus be a cheap and simple noise abatement measure to implement. In the SILENCE project, procedures for the integration of noise in Pavement Management Systems were developed.

The replacement of road surfaces can be done on short notice. No compliance of drivers is required to make this measure fully efficient. In most cases, low-noise surfaces reduce the rolling resistance, thus they might decrease fuel consumption as well.

Problems

Good craftsmanship and accuracy in the laying process are important to achieve the best results. No special maintenance has to be performed on thin layers. For porous surfaces, cleaning is necessary on a regular basis. Once the surface is strongly clogged, cleaning has no more impact on the noise performance. Attention has to be paid to maintenance and repair. Discontinuities reduce the noise reduction effect, at least locally.

The text is based on the findings from SILENCE subproject F 'Road Surface'.

Technical details

A number of mechanisms are responsible for the generation of noise from vehicles passing over a road surface (Sandberg, U.; Ejsmont, J. A., 2002). One noise source is the engine and transmission system where the most important frequencies typically are smaller than 1,000 Hz. This noise propagates from the vehicle directly, and as reflected noise from the road surface. The surface structure is therefore important for the propagation and reflection. If the surface absorbs to some degree, the total noise may be reduced.

The second main source is the tyre/ road interaction noise, which can be subdivided and described by different mechanisms:

- The aerodynamic noise generated by air pumping, when air is forced out (and sucked in) between the rubber blocks of the tyre and the road surface as the tyre rolls by: this source is typically the most important in the frequency range between 1000 and 3000 Hz. If the road surface is porous with a high built-in air void, the air can be pumped down into the pavement structure, and the noise generated from air pumping will be reduced. If the pavement has an open but not porous surface structure, the air pumping noise will also be reduced to some extent.
- Noise from vibrations of the tyre surface: the aggregate at the top layer of the pavement forms the pavement texture. When the rubber blocks of the tyre hit these stones, vibration is generated in the tyre structure. These vibrations generate noise typically dominated by the frequency range between 300 and 2000 Hz. With a smoother pavement structure, the generation of vibrations and noise is reduced. The vibration generated noise can also be reduced if the pavement is elastic.
- In the driving direction, the pavement surface and the curved structure of the tyre forms an acoustical horn which amplifies the noise generated by the tyre/road interaction. If the pavement side of this horn is noise absorbing, the amplification by the horn is reduced.

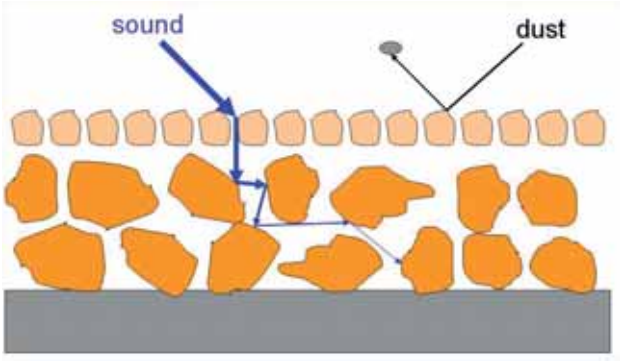
The most effective low noise surfaces are currently porous asphalt and thin-layer asphalt. Thin layer surfaces either can be open graded asphalt concrete, stone mastic asphalt or a combination pavement. The noise reduction potential is based upon a low aggregate size of the mixture (e.g. a maximum aggregate size of 6mm on urban roads and 8mm on highways).

Thin layer surface from Ellenborgsvägen in Malmo
Photo: Danish Road Institute

Porous asphalt reduces the noise generated by air forced out between the rubber blocks of the tyre and the road surface (air pumping effect) and reduces propagation of noise from the engine and transmission system of the vehicle (sound is not reflected but absorbed by the porous layer). In the SILENCE project, it was found that for highways single layer surfaces achieve the best noise reduction with a maximum aggregate size of 8mm, a built-in air void of around 20-23%, and a thickness of 40mm. For urban roads, this single layer is not suitable because the porous layer is clogged with dust and the noise reducing effect disappears after around 2 years.

Porous asphalt from Lyngbyvej in Copenhagen
Photo: Danish Road Institute

For urban roads, two-layer porous surfaces have proved successful. The top layer should have an aggregate size of 8mm, the bottom layer of 16 to 22mm. The top layer reflects the dust, but lets the sound pass, which is absorbed in the bottom layer. These surfaces need to be cleaned regularly using high pressure water (e.g. twice a year).
In SILENCE, an experiment has been conducted in Copenhagen where an 8 year old and clogged top layer of a two-layer porous pavement has been milled off and replaced by a new porous top layer. This was done successfully. An initial noise reduction of around 6 dB was achieved. However, considering the disadvantages of porous asphalts for use in urban areas (as mentioned earlier), thin layer surfaces are normally to be preferred.



Principle of double-layer porous asphalt
Picture: Manfred Haider @ arsenal research

Next generation of surfaces – available for use on medium-term

Within the SILENCE project, further research was carried out regarding existing and new road surfaces. The objective of the SILENCE work package 'New production technologies for surfaces on urban main roads' was to develop and test concepts for new noise reducing thin pavements for urban roads, focussing especially on Stone Mastic Asphalt (SMA) pavements. Altogether, 8 different test sections have been constructed on Kastrupvej in Copenhagen. Samples of 4 SMA pavements were also acoustically tested at the drum test facilities of BASt (Federal Highway Research Institute, Germany).
Full-scale acoustical testing was carried out in compliance with the SPB and the CPX methods. Initial noise reduction measured by the SPB method was in the range of 0.9 to 4.3 dB, relative to the reference surface DAC 0/11 for passenger cars at 50 km/h at 20 °C. OGAC 0/6 yielded the best noise reduction, followed by a SMA 6+ /5/8 (Opt.) of 3.7 dB. Two SMA 6+ /5/8 yielded a just noticeable noise reduction of 0.9 and 1.3 dB. The SMA 0/6 and SMA 4+ /5/8 also yielded a promising initial noise reduction of 3.2 dB and 3.0 dB, respectively.
Noise reduction relative to the reference DAC 0/11 at 50 km/h and 20°C expressed in CPXI was in the range of 1.1 dB to 2.9 dB with SMA 0/6 as the best performing, followed by SMA 0/4 of 2.8 dB. At the other end of the scale, the SMA 6+ /5/8 yielded a 1.1 dB noise reduction. OGAC 0/6, SMA 4+ /5/8 and SMA 6+ /5/8 (Opt.) yielded the same noise reduction of 2.5 dB. Big variations in CPXI at the OGAC 0/6 were experienced indicating a non homogenous surface.
1/3-octave band SPB frequency analysis showed in general that below 800 Hz similar tendencies were seen, while above 800 Hz especially the SMA 6+ /5/8 (Opt.) stood out yielding a significant reduction in high frequencies (reduction in air pumping noise). Other surfaces that showed reduction in air pumping noise were SMA 4+ /5/8, SMA 0/6 and OGAC 0/6. Efforts were made in

comparisons of the shape of SPB and CPXI spectra, which for some pavements showed remarkable good resemblance.

The statistical uncertainty of L_{veh} levels for passenger cars was in an acceptable range of 0.1 dB to 0.2 dB. Dual/multi-axle trucks/buses showed remarkably higher levels of uncertainty, which makes it difficult to draw any sensible conclusions. The standard deviation of CPXI ranged from 0.3 dB to 0.4 dB (except for the two inhomogeneous surfaces).

Simulated CPX measurements of four optimized SMA surfaces at the drum test facilities were in good agreement with real life CPX measurements in Copenhagen, yielding the same ranking (least noisy to noisiest). Differences in absolute noise levels were in the range of 0.1 dB to 1.2 dB.

Comparisons of CPB measurements at laboratory and real life SPB measurements yielded different ranking (least noisy to noisiest). Differences in absolute noise levels were in the range of 0.4 dB to 2.8 dB.

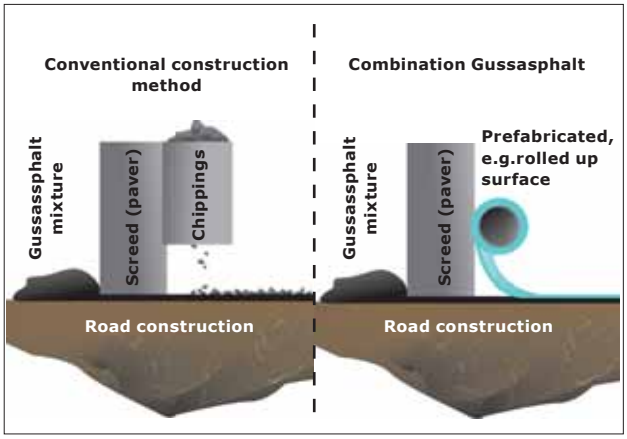
A new production method for Combination Gussasphalt with flat top chippings has been developed.

Compared to stone mastic asphalt and asphalt concrete (with a concave type of surface texture), the disadvantage of Gussasphalt in terms of noise is the convex (or positive) type of surface texture. An optimised texture is concave (or negative). This means that the surface should resemble "plateaus with ravines" after the road has been constructed (Beckenbauer et al. 2002). Small plateaus of the same height are located irregularly next to one another, so that interim spaces (ravines) are left, allowing the tyre profile to release a certain amount of air. This reduces the air-pumping effect of the tyre profile. The resultant surface is also smooth, which means that the tyre vibration excitement is as low as possible at least for small aggregate sizes.

The idea behind Combination Gussasphalt with flat top chippings is to combine the good properties of the construction material Gussasphalt (GA) (e.g. durability and water tightness) with the possibility to apply a concave type of texture above.

In principle, a prefabricated surface is glued to the GA layer during the production process, when the hot and liquid mortar appears after the screed (paver). The production principle is as follows:

1) Chippings are temporarily fixed to a base (a carpet-like flexible layer) by means of an adhesive layer. The chippings adjust themselves with a flat side to the adhesive layer.
2) The base with its chippings is placed upside-down on the hot GA layer.
3) After the GA has cooled down the base is removed and the chippings remain in the surface with a flat top.



Principle of Combination Gussasphalt
Picture: Oliver Ripke

The advantages of the Combination Gussasphalt could be:

- the Gussasphalt base and the surface layer are produced in one step;
- the surface is prefabricated under the best possible conditions, e.g. no influence of the weather;
- the Gussasphalt base is watertight and can be laid in thin layers down to 2 cm;
- designing the texture of the surface with the help of a tyre-road model for low noise generation is possible;

Further research is necessary to transform the production process from the laboratory scale into large scale.

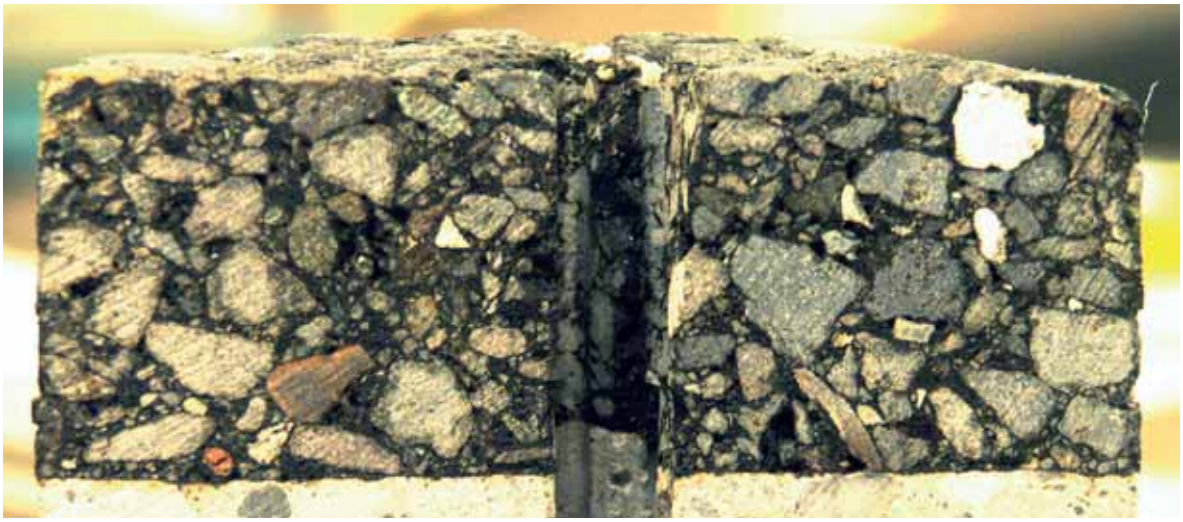
Dense asphalt with high content of polymer-modified binder

In the USA, mainly in Arizona, a type of dense asphalt with a high content of polymer-modified

binder, "Asphalt Rubber Friction Course" (ARFC), has been developed and used. It appears that the ARFC is almost as effective in reducing noise as the best European porous asphalt surfaces, while showing a much longer durability. Current data suggest that the initial noise reduction is reduced at a rate of approximately 0.3 dB per year, which is a slower decay than typical for porous asphalt. ARFC surfaces differ from conventional surfaces in two major ways:

- the binder is mixed with crumb rubber (granules 0.5-2.0 mm) with a proportion of approx. 15% (by weight);
- the amount of binder (including the rubber) is typically about 10% of the total weight of the surface.

Thus, in total the amount of rubber in the surface is around 1.5% by weight. The surface texture has two rather distinct features: 1) aggregate of a "medium" size dominates; this should give a texture which is well optimised for low noise tyre/road emission; 2) there is a substantial amount of binder covering the aggregate.
It is believed that the noise reducing effect depends on the open but not porous surface texture minimising the air pumping effect, and the relatively smooth surface, making the impact between tyre tread elements and the road texture peaks somewhat damped.



A typical bore core of an Asphalt Rubber Friction Course (ARFC) produced by Arizona DoT
Photo: Ulf Sandberg

Road surface maintenance

What is it about?

Unevenness and discontinuities are a threat to the noise performance of all road surfaces. Thus, good maintenance is always required to keep noise levels as low as possible. When low-noise surfaces where chosen to reduce noise in hot spot areas, maintaining the low-noise features is even more important.

Low-noise pavements on urban roads have the potential to provide a significant noise reduction. However, these pavements often fail to keep this property over their working life. This means that their acoustic working life as an effective noise abatement measure is shorter than their existence as road pavements. Maintenance specialising in low-noise road surfaces has the goal of prolonging their acoustic service life.

The first step to ensure the low-noise performance, is a frequent and consistent monitoring of the road surface properties. Maintenance actions as the second step should always be carried out in view of remaining the low-noise features, and not with respect to speed and low costs. In order to secure the low-noise properties, the following rules apply:

- repairs should always be carried out with the same material as in the original construction and the surface structure should be maintained;
- porous surfaces require early enough cleaning (with high-pressure water) if the sound absorption performance is to be preserved. Reliance on self-cleaning effects is not justified in urban areas, with typical vehicle speeds at 50 km/h or even below;
- for two-layer surfaces, the replacement of the top layer can solve the problem of clogging and ravelling at once.

On the other hand, conventional maintenance actions should be avoided in order to maintain the low-noise performance:

- milling or grinding of the top layer: often applied when unevenness or skid resistance problems arise. The original surface texture is destroyed. Thus, the new surface will be louder than standard surfaces;
- surface treatments including sealing: the sound-absorbing properties of porous surfaces would be completely removed, even though sealing of porous pavements can increase the lifetime of a porous layer.

Benefits in terms of noise reduction

Accurate maintenance helps to keep the low-noise properties of road surfaces.

What does it cost?

Regular cleaning of porous surfaces, frequent monitoring and careful repairs might cause additional costs. However, compared to other noise abatement measures, the costs for low-noise road surfaces including good maintenance are relatively low. No special extra costs are related to maintaining noise reducing thin layers.

Advantages

The same advantages as for choosing low-noise surfaces apply: no compliance of drivers is required to make this measure fully efficient. In most cases, low-noise surfaces reduce the rolling resistance, thus decreasing fuel consumption as well.

Problems

Good craftsmanship and accuracy in the repair process are important to achieve the best results.

The Text is based on the findings from SILENCE subproject F 'Road Surface'.

Bottom-layer after high pressure water cleaning and vacuum

Photo: Jørn Bank Andersen, NCC

Technical details

Low-noise road surfaces should exhibit the following properties:

- low level of unevenness and surfaces discontinuities;
- low excitation of tyre vibrations by surface texture;
- sufficient air ventilation under the tyre contact patch;
- high void content to achieve sound absorption;
- adapted dynamic stiffness (if applicable).

Regarding unevenness and surface discontinuities, singularities like manhole covers, humps and bumps, as well as tram crossings are relevant. Within the SILENCE project, measurements were carried out to identify the impact of these devices on the noise level. It was found that the difference in noise levels for

- smoothly textured and evenly built-in manhole covers in a speed range of 30 to 70 km/h is negligible (less than 1 dB(A));
- roughly textured or unevenly built-in manhole covers in the same speed range is moderate (+ 3 dB(A));
- modern even humps made of smooth concrete block stones with smooth ramps for a speed up to 40 km/h is negligible (less than 1 dB(A)) and for speeds between 40 and 50 km/h moderate (between 2 and 5 dB(A));
- old uneven humps made of rough cobble stones or for severe bumps in a speed range of 30 to 50 km/h is high (8 to 10 dB(A));
- tram crossings with an angle of less than 80° to the driving direction and with even surface in a speed range of 30 to 70 km/h is low (1-2 dB(A)) if in good condition, and moderate (2-5 dB(A)) if in bad condition;
- tram crossings with an orientation perpendicular to the driving direction but even surface in a speed range of 30 to 70 km/h is high (5-9 dB(A));
- tram crossings with uneven surface made of rough cobble stones in a speed range of 30 to 70 km/h is high (8-12 dB(A)).

For the monitoring of low-noise road surfaces, regular SPB measurements only constitute the bare minimum. SPB and CPX measurements together with sound absorption/drainability measurements, and texture measurements combined with optical inspections provide a much more complete picture of the surface status.

Suitable indicators that can be used to judge the noise performance of road surfaces can be divided into two groups: direct acoustic parameters and indirect measures.

These are presented in the following table with an evaluation of their usefulness. When possible, direct acoustic parameters should always be analysed, while non-acoustic parameters are important for determining the causes of performance degradation.

Acoustic noise performance indicators for road surfaces	
Method	**Evaluation**
Statistical Pass By Method (SPB, ISO 11819-1[1]) Pass-by Noise and speed are measured for individual vehicles (100 cars, 80 trucks) at a specific location. The method is widely used and might be used for noise labelling of pavements.	The SPB method is a standardised method with a low level of uncertainty. It is standardised by ISO. However, it is only an evaluation at one point of the road, time-consuming and has severe restrictions as to the acoustic environment. If a representative location meeting the requirements can be found, it is the best method for the evaluation of maintenance operations (before/after comparison).
SPB method with backing board A modified version of the SPB method, especially suitable for urban environments. It works even with reflecting objects behind the measurement position.	This variant retains the advantages of the SPB method while widening its applicability. It will be especially useful in the presence of noise barriers.
Controlled Pass By Method (CPB) This variant of the SPB method uses the noise from a few selected test cars.	CPB is less time consuming, but also less representative of real traffic. It allows more control over the test setup and is especially suited for dedicated test sites.
The Close Proximity Method (CPX, ISO/CD 11819-2 [2]) The sound field close to the tyre/road contact zone of a test tyre mounted in a trailer or especially designed vehicle is measured. Noise emission can be measured continuously along long distances. Two or four different tyres are normally used for measurements.	This method can be easily used even in normal traffic flow. It is very flexible and not dependent on the acoustic environment. It is very well suited for fast and frequent evaluation of complete construction or maintenance sections. However, it only measures the tyre/road noise component of vehicle noise emission. Moreover, it only partially represents the effects found with truck tyres and sound-absorbing road surfaces.
Acoustic absorption Several methods are developed where the noise absorption of a pavement can be measured on site by portable equipment. (Kundt's tube [3] [4], extended surface method according to ISO 13472-1 [5])	This method is only relevant for porous pavements and yields information on their sound absorption. It can be used to monitor the effect of clogging on absorption to trigger maintenance actions like pore cleaning (de-clogging).

Non-acoustic noise performance indicators for road surfaces	
Pavement texture Texture is measured with mobile laser profilometers. Results can be presented as Mean Profile Depth (MPD) or as a texture spectrum (ISO 13473-1 to -5 [6] [7] [8] [9] [10])	Texture measurements can be performed relatively fast over longer road sections. Models for predicting noise emission based on texture spectra are under development. Repaving with different materials can alter the vibration excitation due to pavement texture.
Pavement unevenness and discontinuities Traditionally these parameters were monitored by visual inspection or simple mechanical means. Currently, unevenness and crack detection are moving towards automated laser or camera based methods.	While these parameters are mainly relevant for ride comfort, sufficiently affected older pavements can also exhibit a rise in noise emission, especially with high crack densities and many patch repairs.
Permeability The permeability of pavements can be measured by the Becker method (EN 12697-40, see [27]). An open tube is placed on the pavement and water is poured into the tube. The time it takes for the water to run out through the pavement structure is used as an expression of the permeability of a given pavement. Permeability can also be measured by the use of air under pressure instead of water.	Permeability is mainly used as a measure of the remaining porosity of sound-absorbing surfaces. It is a proxy measurement for direct sound absorption measurements and shows the state of clogging.
Elastic properties Measurement methods for the dynamic stiffness with regard to noise generation are being developed.	These methods will only be important for poro-elastic road surfaces. They will likely rely on spot checks.

International Standardization Organization - Sources

[1] ISO 11819-1, First Edition, 1997-09-15, "Acoustics – Measurement of the influence of road surfaces on traffic noise – Part 1: Statistical Pass-By method". International Standardization Organization

[2] ISO/CD 11819-2, 2000-12-13, "Acoustics – Measurement of the influence of road surfaces on traffic noise – Part 2: The close-proximity method", Draft Standard of working group ISO TC43/SC1/WG33

[3] ISO 10534-1, 1996-12-15, "Acoustics - Determination of sound absorption coefficient and impedance in impedance tubes - Method using standing wave ratio", International Organization for Standardization

[4] ISO 10534-2, 1998-11-15, "Acoustics - Determination of sound absorption coefficient and impedance in impedance tubes - Transfer-function method", International Organization for Standardization

[5] ISO 13472-1, 2002-06-15, "Acoustics - Measurement of sound absorption properties of road surfaces in situ - Extended surface method", International Organization for Standardization

[6] EN ISO 13473-1, 2004-07-01, "Characterization of pavement texture by use of surface profiles – Part 1: Determination of Mean Profile Depth", International Organization for Standardization and European Committee for Standardization

[7] ISO 13473-2, 2002-09-15, "Characterization of pavement texture by use of surface profiles – Part 2: Terminology and basic requirements related to pavement texture profile analysis", International Organization for Standardization

[8] ISO 13473-3, 2002-11-01, "Characterization of pavement texture by use of surface profiles – Part 3: Specification and classification and of profilometers", International Organization for Standardization

[9] ISO/DTS 13473-4, 2006-09-15, "Characterization of pavement texture by use of surface profiles – Part 4: Spectral analysis of surface profiles", International Organization for Standardization

[10] ISO/CD 13473-5, 2005-06-06, "Characterization of pavement texture by use of surface profiles – Part 5: Measurement of Megatexture", International Organization for Standardization

Low-noise tracks for trams

What is it about?

Rolling noise is the most prominent noise source for trams during running. Within the SILENCE subproject 'Rail Infrastructure & Operation' it was identified that 'noise hotspots' exist where floating slab tracks are used in street tracks in order to reduce ground-borne noise transmission to neighbouring buildings. Although the floating slab track is necessary to reduce ground-borne noise inside the buildings, it gives rise to a distinctive low-frequency rumbling noise radiated from the slab itself. Unlike normal tram rolling noise, this very high level of low-frequency noise stands out in the urban soundscape as a source of acute annoyance. The project therefore has developed a *new track form and a new floating slab*, which are specifically designed to reduce ground-borne noise without leading to the high level of low-frequency noise.

A general problem in terms of noise emission is the *roughness of the tracks* (and wheels). Where the track becomes corrugated (rapid periodic wear of the rail-head that occurs in certain track, curving and traction conditions that are difficult to control), the rolling noise can be up to 20 dB higher than in normal conditions. Regular grinding helps to keep noise levels down.

A way to further reduce noise in the line of propagation is *lawn tracks*. Filling elements covered with lawn are inserted between the two rails. The top of the lawn should be in line with the rail top.

Other noise reduction options include rail dampers, reducing vibration noise at bridges, and reducing curve squeal. The latter can for example be reduced by lubrication.

Benefits in terms of noise reduction

The pre-compressed and sealed base plate track design eliminates the low-frequency rumbling noise (as was shown by calculations using the TWINS model). A small increase in rolling noise at higher frequencies is a necessary consequence of the design, but this is normally masked in the frequency range. The noise level in dB(A) remains the same, but the annoying rumbling is eliminated. (In the case study it was reduced with about 15 dB. Thus it is insignificant in the spectrum of noise.)

The difference between severely corrugated and regularly ground tracks is up to 20 dB.

Lawn tracks are in general believed to reduce the noise by about 2 dB(A), depending on the layout before. Measurements in Dresden - Germany, concluded a noise reduction of about 5 dB for their lawn tracks.

What does it cost?

A conventional floating slab installation in an urban environment is a very costly and complicated solution. In addition, experience has shown that it is indeed very difficult for contractors to properly execute its construction. The solution developed within SILENCE is expected to cost about a quarter of that of a floating slab with similar performance, and its design guarantees a properly working solution after completion.

Advantages

Lawn tracks tend to accumulate rainwater and they have a potential to reduce particulate matter, thus locally improving air quality. They can also improve the urban environment visually, especially in inner-city areas.

The text is based on the findings from SILENCE subproject G 'Rail Infrastructure & Operation'.

More information on the example from Dresden can be found at http://www.eltis.org/study_sheet.phtml?study_id=1339&lang1=en.

Tram on lawn tracks in Dresden, Germany
Photo: DVB AG

Technical details

The new solution developed within SILENCE consists of a pre-compressed soft base plate track design with all but the rail-head sealed under the road, thus reducing the noise radiation at low frequency significantly. The rails themselves are also completely isolated from the roadbed in which they are embedded to enable them to move freely during vehicle passage. The embedding material minimises the exposed surface of the rail to the top of the railhead, thus ensuring that the noise created by the vibrating rail is negligible.

Railway and tram depots

What is it about?

Depots are often located close to residential areas, which makes them a factor of noise annoyance. Local authorities trying to reduce the annoyance need to cooperate with the parties responsible for the depot, which will be the operator, the infrastructure manager and/or the depot runner. The first step will be to clarify the concrete distribution of responsibilities between these stakeholders.

The operation of the depot generates different types of noise which all cause a different kind of annoyance. Within the SILENCE subproject 'Rail Infrastructure & Operation', 9 relevant types of noise were studied and compared by means of subjective listening tests:

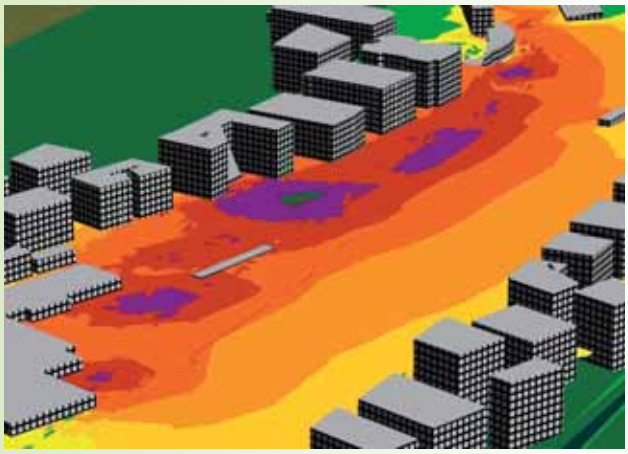
1. Coupling noise
2. Curve squeal
3. Noise of train rolling through switches
4. Rolling noise
5. Stationary diesel noise
6. Fan electric loco
7. Air pressure release
8. Compressor noise
9. Braking noise

The annoyance caused by each source varies with the noise level. An annoyance study carried out within the SILENCE subproject 'Noise Perception and Annoyance' indicates that sources like rolling noise, air pressure release and brake noise can have much higher sound pressure levels than for example rolling through switches and stationary diesel and can still be less annoying. Thus, the first step to reduce annoyance is to clarify which noise sources are most relevant in the local situation. This can be done by surveying the perception and annoyance of residents or by transferring findings from other studies to the depot under discussion.

Usually, the processes at a depot have developed throughout the years and the lay-out of the tracks and switches is used in a practical way. Houses often appear to be close to the shunting tracks, curves, switches etc. and many tracks and switches in a depot are not used or not necessary for use.

Choosing intelligent locations for static source types like washing plants, cleaning, refuelling, can yield a major improvement of the noise situation at a depot. Putting the static activities in-line would reduce the number of shunting movements and reduce the noise levels and noise events even further.

Besides re-allocating the activities, reduction measures at the source (e.g. reducing roughness of tracks, lubrication of tracks in curves) and the reduction of the number of movements in the depot can contribute to noise reduction.



Noise map of the railway depot in Genoa
Picture: SNCF

Recommendations

The following suggestions for noise abatement concerning the lay-out, the processes and the behaviour of users can be given.

Lay-out

- Keep sources far from residents
- Build buildings around the depot which then function as barriers
- Locate signals for entering the depot far from the houses
- Keep crossings and switches away from living areas
- Minimise the number of paths and the number of switches where possible
- Make welded joints where possible
- Remove unused switches

Processes

- Reduce the number of movements for shunting
- Find alternatives for horns like separate low level devices (whistle or electric device). Electric devices like broad band warning horns have been developed for road vehicle reversing alarms. These are less disturbing than beeps
- Apply less noisy coupling
- Keep delivery of equipment far from houses
- Delivery of equipment preferably during day hours
- In-line processes

Behaviour of users

- Don't use horns if not necessary
- Apply minimum power when running or idling
- Accelerate gradually
- Keep train speeds slow
- Teach less noisy ways to handle materials
- Don't use loud voices outdoors
- Keep speeds of car driving low
- Establish rules for car idling
- Education of delivery drivers: don't use horns, turn off engine, don't use loud voice during night hours

Even with these noise mitigation measures in place, the depot will still emit noise. Therefore it is advisable to establish a communication process with the residents. It has been found that understanding of the necessity of activities can improve the acceptance and reduce the annoyance experienced by the residents. The communication strategy could include

- information sessions to explain the activities at the depot and planned measures to reduce the noise;
- a survey on noise perception and annoyance;
- invitation of residents to visit the depot (open day).

The text is based on findings from SILENCE subproject G 'Rail Infrastructure & Operation': SILENCE G.D9: Beuving, M., 2008. Annoyance of depot noise - Guidelines for best practice. Lay-out, processes, communication. The report is available on the CD-Rom attached.

Noise screens and tunnels

What is it about?

Noise barriers or screens are an effective, but very costly measure to reduce noise propagation alongside roads or railway lines. The main requirement is that the barrier should be sufficiently high and long enough. For the construction of barriers, a range of materials with different characteristics regarding absorption and reflection of sound is used. Besides walls and parapets, also buildings or vegetation can be used. Another possibility is to cover the road / railway line partially or completely (tunnel).

Benefits in terms of noise reduction

In theory, noise screens could reduce noise levels by up to 15 db(A). However, in practice, when the buildings are relatively close to the road (and the screen), the reduction is between 5 and 10 db(A). At greater distances, the screening potential may be substantially lower. In some extreme cases, the sound level far from the screen may even be higher with the barrier than without, due to a phenomenon called refraction, i.e. if the noise source is lower than the surrounding terrain and if the screen is relatively small. Tunnels allow removing traffic noise from the surface.

What does it cost?

With about 300 EUR per m², the construction costs of noise screens are quite high. A barrier of 4m height and 500m length at both sides of the street costs about 1,200,000 EUR. The cost benefit ratio has to be assessed for the site studied, as it highly depends on the population density, the allocation of buildings and the type of barrier to be built. Tunnels are the most effective means of noise screening, but the most expensive as well. They are hardly ever used for specific noise abatement purposes.

Advantages

Noise screens can have significant impact on noise abatement. Contrary to sound insulated windows, they also offer noise protection for outside areas like balconies and gardens. Tunnels may also locally improve air quality.

Problems

Noise screens affect the visual scene of the area and in particular the view of the residents and cause or increase difficulty of crossing the road. Both might lead to resistance from residents. Noise barriers can block important air flow, which might impact negatively on local air quality.

Open questions

Depending on their shape and the material used, barriers offer different levels of noise reduction. For some types, data on the acoustic performance are not yet sufficiently available to allow predicting the impact on noise for specific local settings.

The text is based on WG 5, 2002, p. 24ff.; Witteveen+Bos, 2004.

Technical details

Noise screens can be constructed with a range of materials. These include earth mounds, wood, steel, aluminium, concrete, masonry bloc, acrylic sheeting and rubber mats. Widely used are absorbing barriers of different constructions, as absorptive facing on the traffic side reduces reflected sound. This is believed to improve the positive impact of the screen.

The following barriers may show improved performance over simple reflecting barriers and should therefore be the first choice when considering setting up a noise screen:

- absorbing barriers: barriers with absorbing elements on the traffic side, which absorb part of the incident sound and thereby reduce sound reflection, which is part of the overall noise. Such barriers are commonly used, but relatively expensive compared to simple barriers;
- capped barriers: barriers with a specially shaped top section which is meant to reduce sound waves over the top of the barrier;
- angled and dispersive barriers: barriers which reflect the sound upwards or in other direction away from the sensitive area through tilted walls or contoured surfaces. These kinds of barriers should be considered as an alternative to absorbing barriers, especially when built on both sides of the road;
- embankments and earth mounds: can be used in addition to other barriers;
- covering barriers: for example as a grid set over a road in a cutting or as a complete cover on both sides of and above the road. Such complete covers are quite expensive, but offer very significant noise reduction (WG 5, 2002, p. 24f.).

The following types of barriers are promising in noise protection …

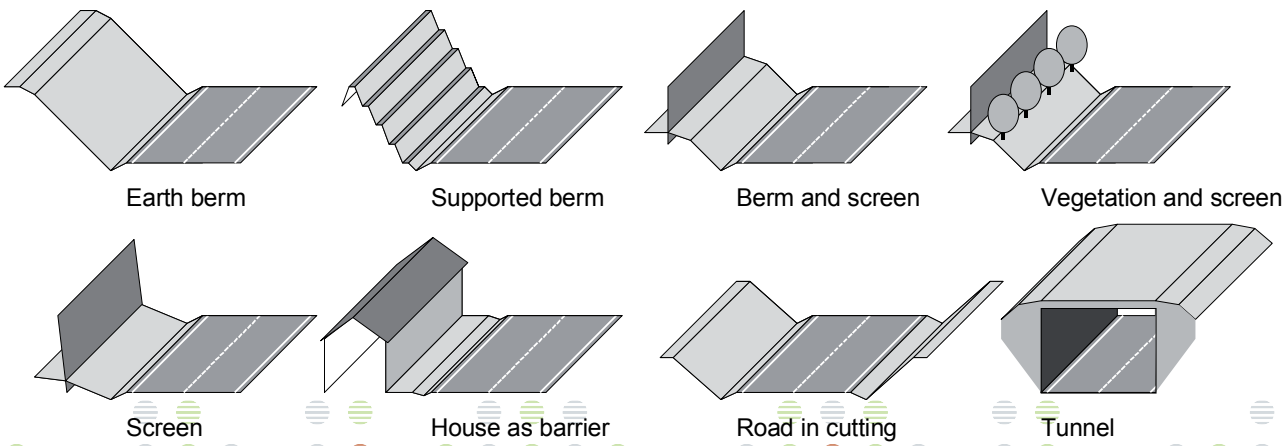
… but their performance needs to be tested further:

- barriers with different height along their length (Longitudinal profiled barriers): their shape is designed to create destructive interference effects on the road side that reduce noise on the other side;
- Double barriers: two simple barriers installed in parallel rows along one side of the road. Traffic noise is thought to be diffracted over the edges of both barriers. This kind of barrier is used very rarely. Their effectiveness has so far only been shown by theoretical models.

Vegetation is often used as noise screen.

To be really efficient, however, vegetation needs to be very high, dense and large

(approximately 1 dB(A) reduction per 10 m depth of planting). Its impact is therefore more psychological and esthetical: If people cannot see the noise source (e.g. a highway), this fact can also reduce their awareness of the sound level and thereby their annoyance. (WG 5, 2002, p. 28)



Examples of Noise Barriers
Source: WG 5, 2002, p. 26

Building insulation

What is it about?

Sound insulation of dwellings, i.e. of the windows and outer walls of a building, is the last, but necessary option if other measures to reduce noise at the source or to abate its propagation fail to be sufficient. The main solution are sound insulated windows. They, however, reduce noise only sufficiently when closed. To solve this problem, other solutions have been developed, such as double pane windows with a special ventilation system or additional glass façades with separate ventilation that allows for opening the windows behind the façade.

Building insulation today is widely considered as necessary when outdoor sound levels exceed 55 dB during the day and 45 dB L_{Aeq} at night.

Benefits in terms of noise reduction

Modern windows with double panes achieve a sound reduction of around 30 dB. Solid well-fitting doors achieve 25-30 dB. Special windows are available that reach up to 40 dB sound reduction. However, the overall noise level in the dwelling depends on the insulation characteristics of the wall and the share of windows and doors.

What does it cost?

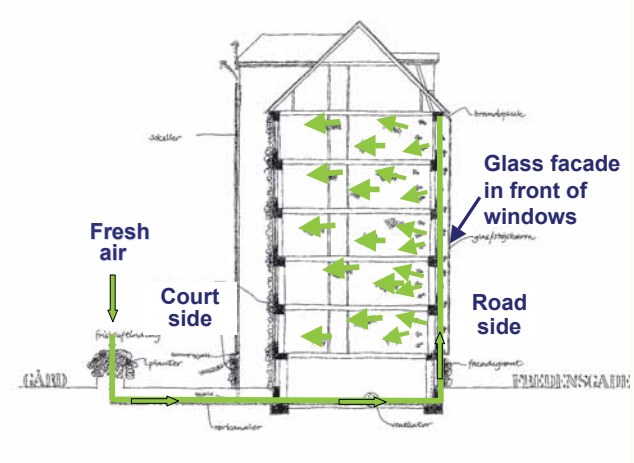
Costs per dwelling are very high compared to other measures that reduce noise at source or in line of propagation. However, for new buildings with high thermal insulation standards, additional costs will be low.

Advantages

A high noise reduction can be achieved exactly where needed with building sound insulation. Sound insulation can be linked to thermal insulation, which reduces energy consumption for heating.

Problems

Sound insulated windows only have an impact when closed. Building insulation only protects the inside from noise; outside areas like balconies and gardens remain unprotected. Retrofitting of outer walls might be difficult or very expensive.



Fresh air supply behind a closed glass façade at Fredensgade, Copenhagen

Source: Green Noise, 2005, p.7

Technical details

In situations with high outdoor sound levels during the night, sufficient ventilation for bedrooms should be foreseen without the need to open the window. Mechanical ventilation systems or air conditioning systems might be necessary. Their air vents or inlets should be placed at the less noisy side of the building or be equipped with silencers to avoid noise transmission (Working Group 5, 2002, p. 30).

An example of such a ventilation system has been installed in Fredensgade in Copenhagen. The building has been fitted with an additional glass façade behind which fresh air circulates coming through pipes from the quiet back side of the house. The sound improvement with closed windows was 11 dB at the ground floor and 7 dB at the second floor. With a small window open, the improvement was 17 dB at the ground floor and 15 dB at the second floor compared to the situation before (small window open, no glass façade) (Rasmussen 2008; more details can be obtained – in Danish – from Green Noise, 2005).

If fresh air is to be taken in from the noisy side, one possible solution is sound shutters installed in front of the windows. These shutters allow the fresh air flowing in, while reducing the indoor noise level significantly compared to the open window situation (Rasmussen 2008).

The text is based on WG 5, 2002, p. 29f.

Low-noise trams

What is it about?

Noise emission from modern tram and metro vehicles is much lower than for older rolling stock. The renewal of the existing tram fleet can therefore contribute significantly to the reduction of noise exposure. The main noise sources from trams are: curve squeal noise due to sharp bends, rolling noise due to poorly maintained wheels and tracks, noise from ventilation and climate systems, noise from driving system (electric equipment and motors).

When new trams are ordered, low-floor trams are usually chosen. The T3000 tram from Bombardier, part of the Flexity Outlook product family, is a modern low-floor tram and well representative for the state-of-the-art in terms of noise performance of trams today. It has resilient wheels to reduce noise and ground-borne vibrations. The wheels are prepared with fixing holes on the rim to allow additional noise absorbers to be mounted if considered necessary to reduce curve squeal and rolling noise. Bogie sides are completely covered with skirts for aesthetic and noise reasons. Traction motors and gears are mounted in compact units. The traction motor noise and the rolling noise are the two most prominent noise sources during running, with an overweight for the latter. The rolling noise is mainly caused by the roughness of the tracks and the wheels. It is dominated by the track noise, which is about 10 dB higher than the wheel noise. To keep the noise level low, good maintenance of both tracks and wheels is necessary.

Benefits in terms of noise reduction

Compared to older tram vehicles (an average lifetime of trams of 30 years can be considered), the noise emission from these kinds of modern trams is at least 10 dB less.

What does it cost?

If the tram fleet is to be renewed anyway, there are no additional costs for low-noise trams.

Advantages

Investing in low-noise trams, allows for reducing the noise level along the complete tram network in a city. In particular for city centres with a dense network and a high frequency of trams, the use of low-noise trams is highly advisable. These trams can also help to improve the attitude of citizens towards public transport, thus supporting approaches towards a modal shift in favour of public transport.

In addition, modern trams reduce energy consumption (e.g. by less braking resistance, more efficient use of energy, and recovery of energy) and improve road safety. The vehicle

Bombardier T3000 tram as used in Brussels, Belgium

Photo: Bombardier Transportation

design has been improved in order to protect pedestrians and passengers in case of an accident. Inside the vehicle, rounded shapes reduce the severity of injuries in case of an accident. Outside covers protect pedestrians from getting beneath the vehicle.

Problems

As the renewal of the fleet normally is not being done on the short run, the overall noise reducing effect will only become effective after several years. However, the new trams could be concentrated on those tram lines with the highest noise problems.

At low speeds, for example in pedestrian areas, the rolling noise is very low. Other noise sources like ventilation and converters are much less noisy for modern trams than for the older rolling stock. This might cause problems for blind people (and others relying on the sense of hearing) recognising the approaching vehicle.

The text is based on findings from SILENCE subproject E 'Rail Vehicle'.

Technical details

The German association VDV has issued recommendations for noise limits for mass transit vehicles (VDV 154) (see table). These recommendations are de facto standard for tram contracts in Germany and are increasingly used also in other European countries.

Recommendations for exterior noise limit values issued by VDV	
Standstill (1.2 m/ 3.5 m mic height)	60/63 dB
Passby (60 km/h)	79 dB
Starting	75 dB
Exterior microphone distance 7.5m; L_{pAeq} for all cases except "starting" (L_{pAmax})	

With low-floor trams, the equipment is placed on the roof. For the example of the T3000 tram, this includes two ventilation and air conditioning units – separate ones for the driver's cab and the passenger compartment. Also the converter for traction motors and auxiliary equipment are positioned on the roof. Noise sources in the bogie are wheel-rail, traction motor and gear.

Estimated source contributions to the wayside noise (with skirts)		
Source	**SPL at 7.5m/1.2m (v=40 km/h)**	**SPL at 7.5m/1.2m (v=60 km/h)**
Wheel-rail	75 dB(A)	80 dB(A)
Traction motor & gear	67 dB(A)	76 dB(A)
HVACs	< 55 dB(A)	< 55 dB(A)
Converters	< 60 dB(A)	< 60 dB(A)

Further developments

Provided that wheels and rails are kept smooth, the self-ventilated traction motor will dominate the noise emission for the higher speeds. In the SILENCE project, research was carried out on how to reduce the noise emission of fans. Efforts were focused on optimising the shape of the blades, improving the inlet and outlet flow, and closing the gap between blades and stator. On a classical fan, a noise reduction of around 8 dB(A) can be reached.

Renewal of public transport fleet

Photo: Polis

What is it about?

Modern tram and bus vehicles in general emit much less noise than the older stock (see example on low-noise trams above). Renewing the fleet therefore can significantly contribute to noise abatement.

If the local authorities are not the owner of the fleet, they can conclude agreements with the transport operators to tackle the noise issue and can include noise criteria in tenders.

Those criteria could refer to the complete fleet, single vehicles or only to new vehicles and define requirements to be achieved in different time periods. Such requirements for buses could be for example: 3 years after signing the contract, 80% of the fleet must comply with the limit value of 77 dB(A); the other 20% must not exceed 80 dB(A). New vehicles must comply with the limit value of 77 dB(A). Buses running at night-time must comply with the 77 dB(A) limit. All vehicles must run with low-noise tyres. (Bund-Länder Arbeitsgemeinschaft für Immissionsschutz, 2007, p.24).

Benefits in terms of noise reduction

For example for trams, the noise emission of modern vehicles is about 10 dB(A) less than for older vehicles (about 30 years old). Even with a (realistic) gradual exchange of the fleet a significant noise reduction can be obtained.

What does it cost?

The fleet must be renewed anyway.

Advantages

In general, modern vehicles are also of benefit in terms of air pollutant emissions, energy consumption and road safety.

Tram bonus

Within the frame of the SILENCE subproject 'Noise Perception and Annoyance', experiments were carried out to investigate the annoyance caused by the passage of one tram and one bus. These psychoacoustic listening tests have shown that the tram was equally annoying as the bus with a 3 dB lower sound pressure level (Griefhahn, Gjestland, Preis, 2007, p. 29; this report SILENCE A.D7 is available on the enclosed CD-Rom). This 'tram bonus' could be taken into consideration when decisions on the long-term development of the public transport system are taken.

Agreements with transport providers in Brussels

73% of the inhabitants of the Brussels-Capital region consider that noise is one of the most distracting harmful environmental effects in their city. The noise action plan 2000-2005 therefore asked for agreements between the Region and the Belgian Railways National Company (SNCB) and between the Region and the Brussels Inter-communal Transport Company (STIB).

Within this context, two environmental conventions relating to noise and vibrations were signed between the Brussels-Capital Region and the transport providers. The convention with SNCB was signed on January 24, 2001. The convention with STIB is specific to the metro and tram modes of transport and was signed on June 25, 2004.

The convention with SNCB envisages in particular:

- the analysis of a list of acoustic black spots (done);
- the realisation of a land register of the railroads noise (in progress);
- the installation of two permanent measuring sites (done);
- a bilateral follow-up of the complaints (done);
- a study on the noise generated by the SNCB work sites (done);
- a reflection on the habitat in edge of the railway tracks;
- the signing of specific conventions for all infrastructure works completed by SNCB.

The convention with STIB envisages in particular:

- the purchase of efficient rolling stock and infrastructures;
- the respect of reference values of the airborne noise for the vibrations of the metro and the new trams - infrastructures;
- the drivers' awareness of a less noisy driving;
- establishment of a black spots improvement plan;
- common complaints management;
- the realisation of a land register of the tram-metro transport noise (in progress);
- the conclusion of a specific bus noise and vibration convention.

To evaluate and steer the progress, biannual meetings between the Region and SNCB respectively STIB are held.

Responsible agencies and co-operation partners

- Belgian Railways National Company (SNCB)
- Brussels Inter-communal Transport Company (STIB)
- Brussels-Capital Region (MRBC) and more precisely Brussels Environment (IBGE-BIM)

Why is it regarded as good example?
Such a voluntary partnership between a public transport company and a public authority allows defining objectives on which the parties agree to progress quickly. A good convention (with the intention to succeed across the various parties) is better than a bad law.

Tips for copying
Such a convention must be fully discussed between the partners before arriving at an agreement. It is important to understand the expectations and reserves of each party.

For more details contact...
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Low-noise waste collection vehicles

What is it about?

Compared to conventional vehicles, new waste collection vehicles designed to reduce noise emissions can contribute significantly to a lower noise level. This is particularly important, as waste collection in many cities is carried out during evening or early morning hours in order to reduce congestion.
RENOVA, responsible for waste management in Gothenburg - Sweden, has used gas-electric hybrid vehicles for waste collection in the city centre since 2004. The engine works on gas. When the vehicle stops for waste collection the engine stops automatically after 30 seconds. The waste collection system works on electricity from batteries.

Benefits in terms of noise reduction

A reduction of up to 25 dB(A) has been observed compared to conventional vehicles.

What does it cost?

The vehicles cost about 22,000 to 32,000 EUR more than conventional vehicles. Maintenance is only slightly more expensive. During the lifetime of the vehicle of about 10 years, the batteries needs to be exchanged at least once. This costs about 8,000 EUR in addition.

Advantages

Noise from waste collection in residential areas can be reduced significantly. Air pollution is reduced as well.

Problems

The trial in Gothenburg started in 2004. Until now the lifetime of the batteries remains unclear. If they need to be changed sooner than after 5 years, the aim for vehicle operation time of 10 years cannot be reached without another change of batteries.

The text is based on www.renova.se; www.krets.goteborg.se.

Technical details

The waste collection vehicles combine engines working on gas, a hydraulic system for emptying the waste bins and pressing the waste inside the vehicle working on electricity from batteries, with an effective catalyst converter. The engine works on natural gas or biogas. It automatically recognises the gas quality and adapts to it. The gas tank contains 480 litres. Filling can be done during the night or using a faster procedure during the day. The engine turns off automatically after 30 seconds when the vehicles stops for waste collection. The catalyst converter works with significantly higher temperatures than conventional converters do. Thus, 80% of marsh gas is reduced. The engine complies with the EURO 4-standard for emissions.
Five hours of working need 50% of the batteries' capacity for the hydraulic engine. At the same time, 25% of the capacity is reloaded. After 10 hours of working, 50% of the capacity needs to be reloaded. The vehicles have been in use since 2004. It is expected that the batteries have a lifetime of 4.5 to 5 years. Thus, this year it will become clear how the batteries work and if one exchange during the lifetime of the vehicle of 10 years will be enough.

Quiet waste collection with gas-electric hybrid vehicles
Photo: RENOVA

Check on noisy vehicles

Example of a pass-by roadside enforcement test
Photo: BASt

Check on noisy mopeds in the UK
Photo: Environmental Protection UK

What is it about?

Excessive noise emissions can be produced by vehicles equipped with illegal silencers, especially for motorcycles. In-service controls are necessary to achieve a reduction of the noise impact. The in-service controls are currently based on a stationary noise test close to the exhaust pipes. The efficiency of this test is rather poor however. Field studies show that only one third of the illegal systems can be detected by means of this test. A drive-by test similar to the type approval test would be much more efficient.

From questionnaire surveys on road vehicle noise among roadside residents in Japan, it is known that 30% of the motorcycles and 6% of the cars are equipped with replacement silencers, most of them being illegal and much noisier than the original equipment. The percentage for trucks is less than 1%. The mentioned percentages are daily averages; the percentages during the night time period are significantly higher than those for the day time period. It can be expected that the situation in EU member states is similar or even worse.

Two main conclusions can be drawn from the survey results: in-service control can be an effective noise reduction measure but it can be restricted to motorcycles and cars.

Benefits in terms of noise reduction

Roadside enforcement checks are especially efficient for motorcycles. Measures to reduce the use of illegal silencers could reduce the noise caused by motorcycles with about 5-10 dB(A) (EffNoise 2004).

Advantages

Besides the contribution to the overall noise level, motorcycles raise (additional) annoyance because of the generated noise peaks. Reducing the noise level of these noise peaks not only decreases overall sound levels, but will probably especially reduce annoyance.

Problems

Roadside enforcement checks often fail due to costs and experienced staff as a precondition for high effectiveness (and efficiency).

Turn-off the engine scheme

The City of Norwich has set up a Low Emission Zone which includes an engine switch off scheme. Taxi and bus drivers have to turn their engines off while waiting. Non-compliance faces an on-the-spot fine of about 80 EUR.

The text is based on findings from SILENCE subproject H 'Road Traffic Flow'. Further information can be obtained from the report H.D3 'Practicalities of enforcing noise controls at the roadside or on vehicles', which can be found on the enclosed CD-Rom.

Low-noise night time delivery

Night time delivery in Barcelona
Photo: City of Barcelona

What is it about?

Delivery vehicles parking on the road during unloading can cause congestion during daytime. To avoid such congestion problems, delivery during nighttime can therefore be desirable. Furthermore, nighttime delivery can improve the delivery scheme of shops, in particular of grocery stores with daily fresh products.
Using low-noise vehicles and (un)loading equipment and training the staff for quiet operation can make the delivery quiet, thus tolerable during the night. Low-noise vehicles and unloading equipment (e.g. fork lifts) can be provided for by the shop owners (see Barcelona example below) or by the city. An example of this is the City of Vicenza, Italy, which organises a central warehouse where deliveries for single shops are compiled and then distributed with quiet vehicles.

Benefits in terms of noise reduction

By using adequate equipment and training the staff on low-noise operation, a significant noise reduction compared to conventional loading procedures can be reached. The Dutch PIEK project suggests a realistic maximum sound equivalent level (LAeq) of 60 dB(A) for deliveries during the night.

What does it cost?

Re-fitting of the existing (un)loading equipment or purchase of new material causes costs. However, the example from Barcelona (see below) shows that the financial advantages for shop owners compensate for these investments after a few years.

Advantages

Quiet night-time delivery is of advantage for the delivery scheme of shops, reducing congestion caused by parking delivery vehicles during the day.

Problems

Good communication between shop owners, the municipality and the residents is necessary when introducing night-time delivery schemes.

Further information about the Dutch PIEK project can be obtained from www.piek.org.

Quiet Night-time Deliveries in Barcelona

Previous experiments involving Barcelona Municipality's Mobility Services had led to a supermarket operator being allowed to use an adapted 40T truck to make quiet night-time deliveries[1]. SILENCE has embedded this experimentation in a collaborative programme involving the Municipal Mobility Services, the Municipal Noise Unit and (to date) 5 of the city's 10 districts, as well as 3 private transport operators. Together, they have made trials comprising 14 noise measurements[2] at 11 sites in the period March '06 to May '07, with consultancy support from Altran DSD, of Altran Technologies España.

This programme enables goods operators to gain exemption from the traffic regulations that limit on-street un/loading (08.00 – 20.00) provided that they can demonstrate that this activity does not exceed the ambient noise conditions. The operators - Mercadona, Condis and Lidl - participate because they save money delivering at night (time and operating transport costs) and because this enables them to ensure to have fresh foodstuffs in stores for the next morning.

The local authority costs for setting up this type of programme include the minor works for pavement modifications, ramps etc. (Mobility Services: approx. 20,000€ per site), plus the costs of noise measurements (Noise Unit sub-contract: 30,000€), plus a considerable amount of staff time (especially during set-up, but also for residents' consultation). The operators are not charged for these services, but it is the operator who assumes the investment in vehicles, and decides which noise-reducing techniques to implement (insulated carpets, quiet refrigeration units and lifts, plastified roll-containers, etc.). For the 16T and 40T truck trials, the financial rate of return for the operators ranges from 18 to 36 months.

Responsible agencies and cooperation partners
Local authorities: Mobility Services, Noise unit; operators

Why is it regarded as good example?
The collaborative programme involves transport operators participating in the Mobility Services-led Mobility Pact, but it goes further by involving the environmental compliance of supermarket outlets and the residents' noise complaints databases, which the Noise Unit consults before proposing (to Mobility Services) to investigate a specific site. It is a collaboration where operators are invited to innovate, and where residents are consulted as part of the programme process.

This measure is cost-effective – both from the local authority and the operators' points of view. The programme has generated improved knowledge; it shows that operators are only partially successful (in 45% of cases) in unloading within the ambient noise conditions; it also identifies which are the most important noise sources (truck arrival in 62% of cases, goods unloading in 15% of cases).

Working together, the actors integrate their specialist skills (of noise measurement, traffic management and vehicle operations) and thus achieve a meaningful result.

Tips for copying
This type of initiative can be led by a municipal Mobility Department which is engaged in on-going dialogue with goods operators, but the quality of the programme result is improved when the authority's specialist Noise Unit is integrated into the process.

In deciding whether or not to grant exemptions, the difficulties of achieving the necessary noise reductions need to be assessed against residents' acceptance as well as the longer-term potential that such programmes can achieve.

The focus now aims to involve vehicle manufacturers, since the noise levels of general vehicle movements are of as much concern as the correct organisation and execution of unloading activities.[3]

For more details contact...
Simon Hayes at shayes@altrandsd.com

[1] MIRACLES project, see www.civitas.org

[2] L_{Aeq} and L_{Amax} for truck arrival, unloading set-up (opening of vehicle and shop doors, etc.), unloading goods, closure and vehicle departure.

[3] The 15th noise measurement will be realised in Feb.'08, involving the Condis operator trialling a Renault 12T Midlum truck with a low-noise mode of operation – see FIDEUS project.

Traffic management: Basic traffic noise relations

This chapter is based on findings from SILENCE subproject H 'Road Traffic Flow', in particular on report H.D2 'Noise Reduction in Urban Areas from Traffic and Driver Management – A toolkit for city authorities' and report H.D1 'Effectiveness and Benefits of Traffic Flow Measures on Noise Control'. The full reports can be found on the enclosed CD-Rom.

Most of the traffic flow measures presented here have not been subject to surveys aimed at assessing their effects on noise emissions. Therefore, the possible impacts of these measures are based on the effects of traffic volume, traffic composition, speed and driving pattern on noise emissions. This chapter gives an overview of these effects.

The traffic-noise relations can also be used to assess the effects of various traffic management measures for which the impact on traffic flow and therefore on noise is so dependent on local conditions that it cannot be generally presented here. One example of this, could be improvements in public transportation or conditions for cyclists, which may lead to a shift in people's choice of transport modes and thereby to a decrease in car traffic.

Traffic volume

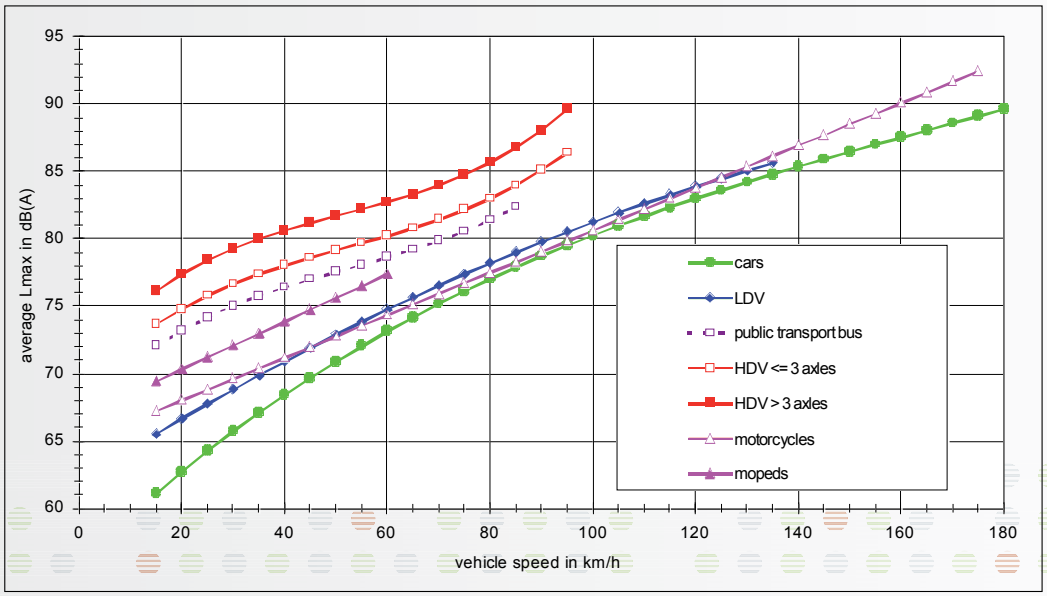
Changing the traffic volume affects the noise levels. Given that the traffic composition, speed and driving patterns are unchanged, the logarithmic nature of the dB scale means that a 50% reduction of the traffic volume results in a 3 dB reduction in noise levels, regardless of the absolute number of vehicles.

Reduction in traffic volume	Reduction in noise (L_{Aeq})
10 %	0.5 dB
20 %	1.0 dB
30 %	1.6 dB
40 %	2.2 dB
50 %	3.0 dB
75 %	6.0 dB

A reduction in the traffic volumes on a road will often lead to increases in speed because the remaining vehicles can drive more freely, unless measures are taken to keep the speed down.

Increased speed will work against the reductions in noise caused by the reduced traffic level. If traffic flows more freely, this is also a change in driving pattern. Decreases in the number of accelerations and decelerations are likely to result in lower noise levels. However, more room for driving may also lead to harder accelerations, which will increase the noise emissions.

The reduction of traffic volumes is a measure which is mainly applicable on minor roads or for certain (smaller) areas, where a variety of measures may be used to move the traffic onto major roads.



Average L_{Amax} values for different vehicle categories and free flowing traffic

Source: Steven 2005
LDV is "light duty vehicle" (a van), HDV is "heavy duty vehicle" (a truck)

On major roads, it is hardly ever realistic to reduce traffic to an extent that it will significantly reduce noise levels.

Some reduction may be achieved through long-term town and traffic planning which aims at moving people from cars to other modes of transport.

Traffic composition

The composition of the traffic in terms of vehicle categories is important for the noise levels. The figure below shows German results of noise emission as L_{Amax} from various categories of road vehicles in free flowing traffic. There are clear differences in noise levels depending on the size of the vehicles. At 60 km/h for instance, the L_{Amax} level from a truck with more than three axles is 83 dB, from a truck with up to three axles it is 80 dB, for a public transport bus it is 79 dB, for vans it is 75 dB, for motorcycles 74 dB and for passenger cars it is 73 dB. This means that a public transport bus at 60 km/h makes as much noise as 4 passenger cars, a truck with up to three axles as much as 5 cars and a truck with more than three axles as much as 10 passenger cars.

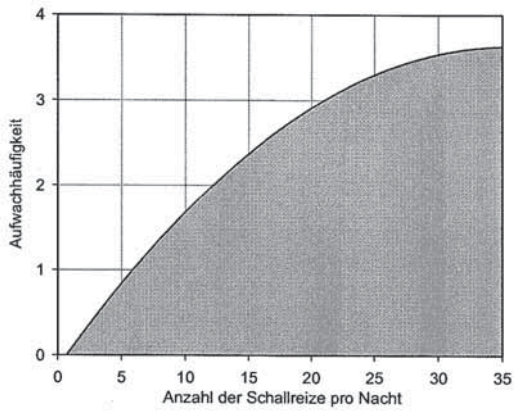
In reality, the effect of heavy vehicles is usually not as important as these figures suggest.

On most urban roads, heavy vehicles only account for a small percentage of the total traffic. In combination with the often higher speed of the light vehicles, the effect is that the light vehicles usually dominate the noise emissions. On most high-speed roads, especially on motorways, the speed of the light vehicles is considerably higher, and they therefore also dominate the noise emission in these situations even though the percentages of heavy vehicles often are fairly high. Only in cases with very high percentages of heavy vehicles and/or small or no differences in the speed of light and heavy vehicles, the heavy vehicles will dominate the L_{Aeq} levels of a road. Although heavy vehicles usually do not dominate the noise emissions given as L_{Aeq}, they represent peaks in the emitted noise, which may annoy and disturb those living, working or walking along the road.

At night, the peak levels caused by heavy vehicles represent noise events that may wake up or cause alterations in sleep depth to people living along the road.

Awakening frequency ...

increases with the number of noise events exceeding a certain L_{Amax} level up to a certain number of events per night (35 events in the figure) (Griefahn 1985; Griefahn 1992). An event is defined by Griefahn as a maximum noise level (L_{Amax}), which exceeds the equivalent sound pressure (L_{Aeq}) by 10 dB. Both awakenings and alterations in sleep depth depend on the actual level of the events, the number of events and on individual differences such as age. Alterations in sleep depth occur at lower noise levels than awakenings.



Number of awakenings (y-axis) as a function of the number of noise events per night (x-axis)

Source: Griefhahn 1985

A number of traffic flow measures may lead to changes in the traffic composition.

For example: traffic calming schemes may cause heavy vehicles to choose other routes; night-time bans on heavy vehicles – and perhaps on two-wheelers – will reduce the number at night but may lead to increased numbers during the day; and city logistics may reduce the overall number of trucks entering central city areas as well as the distance travelled by trucks within the areas. The effect of these types of initiatives will have to be assessed individually for each location in which they are implemented, as this depends on local road and traffic conditions.

Speed

The figure below shows the emissions of a single vehicle – a compact car – during acceleration. The propulsion noise (L_{prop}) increases with increasing engine revolutions. That is, it increases with increasing speed within the same gear, but drops when the driver shifts to a higher gear. There is, however, also an overall tendency towards increasing noise levels at higher gears, and thereby at higher speed.

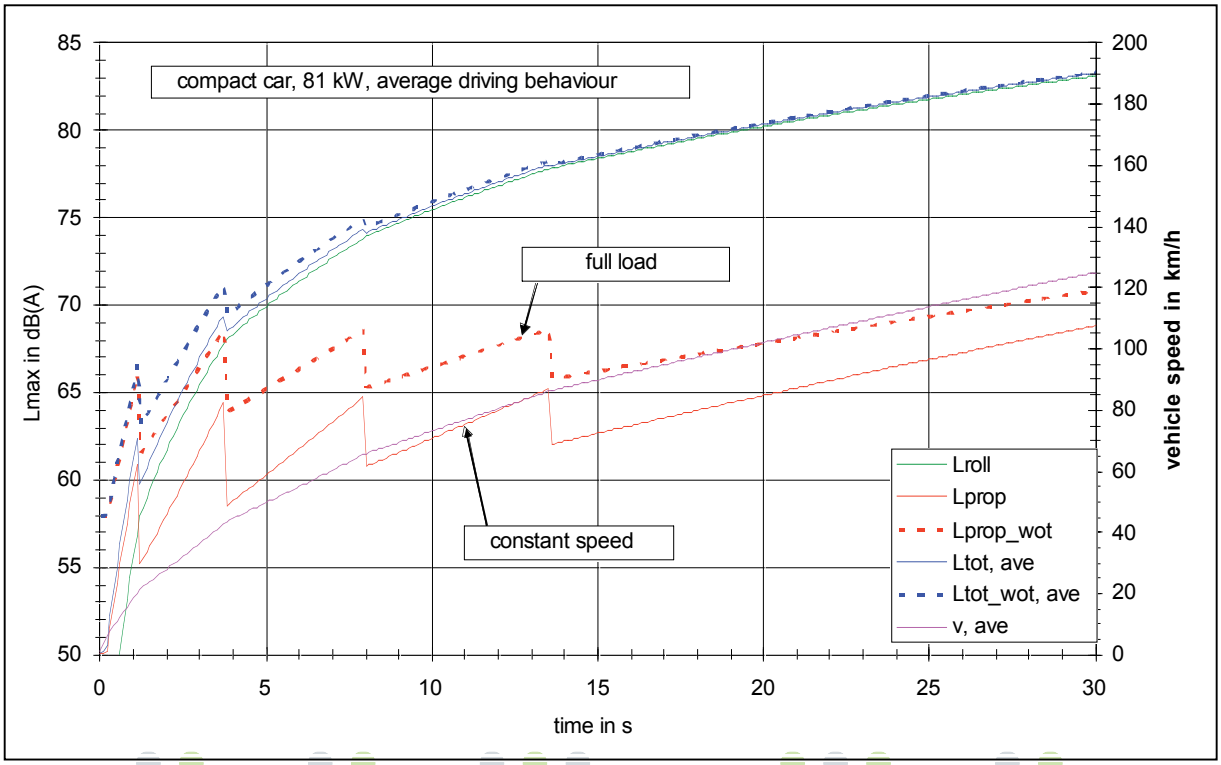
The effect of changes in speed is derived by Andersen (2003) from measurements of more than 4,000 vehicles carried out in 1999 and 2000. The effect of speed changes (driving with constant speed) is given in 10 km/h intervals in the table.

The effect of speed reductions on noise

Reduction in actual driving speed (km/h)	Noise reduction (LAE, dB) - light vehicles	Noise reduction (LAE, dB) - heavy vehicles
130 to 120	1.0	-
120 to 110	1.1	-
110 to 100	1.2	-
100 to 90	1.3	1.0
90 to 80	1.5	1.1
80 to 70	1.7	1.2
70 to 60	1.9	1.4
60 to 50	2.3	1.7
50 to 40	2.8	2.1
40 to 30	3.6	2.7

Driving pattern

The effect of the driving pattern on noise is important to take into account when evaluating the noise effect of various traffic management measures. Installing road humps, changing the layout of road sections and intersections, setting up signs of speed reduction, etc. are all initiatives which may change the way people drive. This may

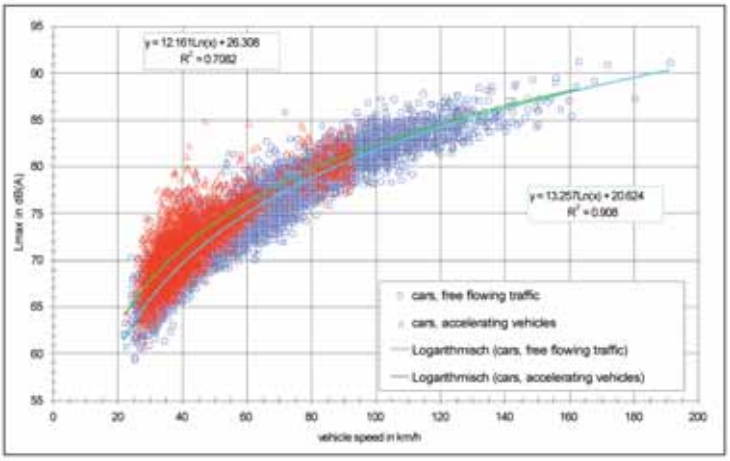


Contribution of vehicle noise sources during acceleration, exemplified by a compact car

Source: Steven 2005

The dotted lines are the noise from the accelerating car. The fully drawn lines show the noise level as it would be at the given speed without acceleration. The line labeled 'v, ave' shows the vehicle speed.

cause an increase or decrease in the number and intensity of accelerations and decelerations. There is a correlation between acceleration and noise for passenger cars. For low speeds around 30 km/h, the average noise increase due to acceleration is 2 dB. For normal urban speeds around 50 to 60 km/h, the increase due to acceleration is 1 to 1.5 dB. At high speeds, the increase is marginal. In each individual case the noise increase depends on the level of acceleration.



Correlation between acceleration and noise. L_{max} values versus vehicle speed for cars in free flowing traffic and during acceleration

Source: Steven 2005
The measurements have been done on actual traffic.

Similar relations are drawn by Steven (2005) for light goods vehicles (LGV), heavy goods vehicles (HGV) with power ratings below 75 kW, between 75 and 150 kW, between 150 and 250 kW and higher than 250 kW. The same tendency to an increase in noise during acceleration is seen for all these vehicle categories. The differences at 30 and 50 km/h are shown in the table.

Differences in noise emissions (Lmax) between accelerating vehicles and vehicles driving at steady speed at 30 and 50 km/h

Vehicle category	At 30 km/h	At 50 km/h
Car	2.0	1.4
LGV	3.5	2.3
HGV, Pn < 75 kW	4.4	3.5
HGV, 75 kW ≤ Pn < 150 kW	4.4	3.6
HGV, 150 kW ≤ Pn < 250 kW	3.5	3.0
HGV, Pn ≥ 250 kW	3.5	2.7

Steven 2005

The effect of individual traffic management measures on noise levels is often small, and the main effect is usually due to changes in speed.

However, even when noise is reduced due to reduced speed, annoyance to those living along the road may increase because the measures also result in uneven driving patterns with accelerations and decelerations.

These do not necessarily change the L_{Aeq} level very much, but where the noise without the measures may have been a steady sound, the accelerations and decelerations cause the sound pattern to shift, thus making it more noticeable. This is important to consider when implementing traffic management measures.

Reducing and enforcing speed limits

Static speed limit sign
Photo: Hans Bendtsen, DRI

Interactive speed limit sign
Photo: Hans Bendtsen, DRI

What is it about?

As reductions in driving speed have substantial effects on traffic noise emissions, especially at urban speeds, lowering speed limits appears to be a feasible approach to reducing noise emissions from road traffic. Possible are speed reductions on certain roads or for complete areas. Common are 30 km/h zones. Another concept for residential areas are home zones where priority is given to non-motorised users. Speed limits are well below 30 km/h, sometimes as low as walking speed, which is about 3 to 5 km/h.

However, experience shows that reducing speed limits by for instance 10 km/h (only) through posting new or changing existing static speed limit signs has little or no effect on actual driving speeds.

The use of variable signs for posting speed limits or informing drivers of their speed is more effective than static signs when it comes to reducing driving speed. The speed reductions vary from location to location, and therefore effects on noise will also vary. Reductions of up to 3 dB L_{Aeq} can be expected. The results regarding variable speed signs indicate that the signs increase driver awareness of speed limits and/or actual driving speed. Therefore, the effect of such signs may decrease if the signs are more widely used and the individual signs therefore become less noticeable to drivers.

A way to make – particularly static – speed limit signs noise effective is by massive police enforcement or automatic traffic control (ATC). The noise effect of implementing ATC depends on the speed effect. However, with fixed roadside cameras there may be a tendency towards speed increasing between cameras. This may lead to increased noise and/or annoyance due to accelerations and decelerations. New radar systems – based on automatic recognition of the number plate – calculate the speed between two measurement points. If known by drivers, such systems can avoid the effect of acceleration and deceleration between cameras.

Results of noise measurements along the Nantes Ring Road, undertaken within the SILENCE project before and after implementing ATC, shows, that there is no effect on daytime noise levels. This is explained by the fact that the density of the traffic in itself keeps speeds down, so that there is little effect of implementing ATC. Night-time noise levels, when the traffic levels allow drivers to drive freely, are reduced by more than 2 dB at the locations of the ATC (Bérengier & Picaut 2008, SILENCE report H.R2; the full report can be obtained from the CD-Rom attached).

Benefits in terms of noise reduction

Reducing actual driving speed can result in significant noise reduction. For example, reducing the driving speed (not only the speed limit!) from 50 to 40 km/h leads for passenger cars to a decrease of noise by 2.8 dB(A). However, static speed limit signs tend to have no impact on the actual speed. Variable signs and those informing drivers of their speed can bring up to 3 dB L_{Aeq}. The benefits of ATC depend very much on local conditions.

What does it cost?

Static signs are comparably cheap (costs about 300 EUR per sign, (Lärmkontor GmbH, et al., 2004, Annex 8, p. 3)), whereas variable signs are quite cost-intensive. Installation of an ATC system is comparably expensive, but costs can be covered with the fines after implementation.

Advantages

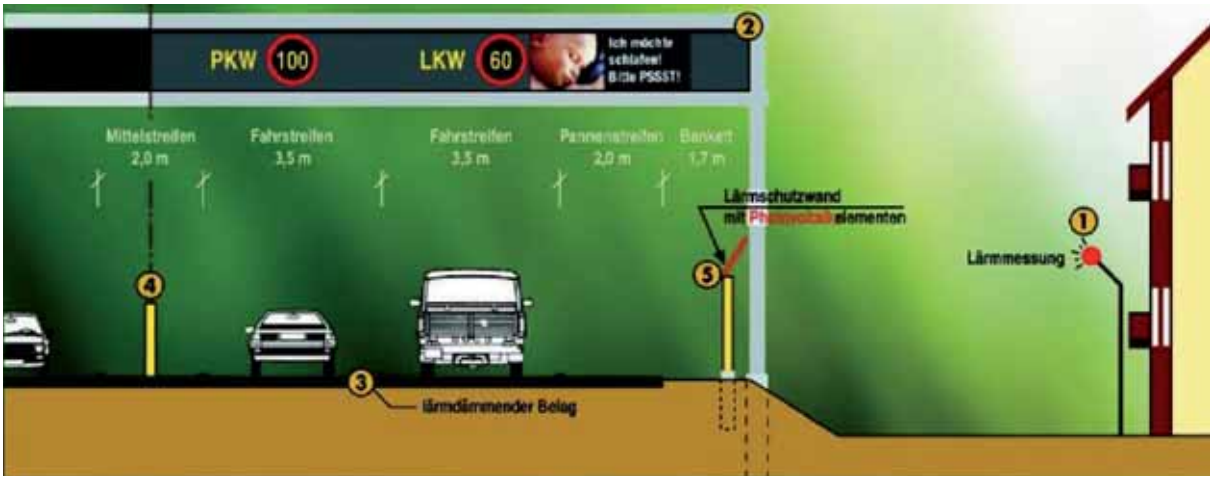
In general, reducing the speed will also contribute to road safety and improved air quality.

Problems

A speed reduction measure should lead to a sufficient decrease of speed without drivers changing to a lower gear, which could increase noise levels. Another problem is to make drivers comply with the speed reduction measures.

The text is based on the findings from SILENCE subproject H 'Road Traffic Flow', more precisely on the reports H.D1 Effectiveness and Benefits of Traffic Flow Measures and Noise Control and H.D.2 Noise Reduction in Urban Areas from Traffic and Driver Management - A toolkit for city authorities. Both reports provide further details and can be obtained from the attached CD-Rom.

In Gleisdorf, Austria, an interactive system has been implemented, which reduces speed limits when noise limits are exceeded. Under normal conditions, the speed limit for passenger cars and heavy vehicles is 130 km/h. At a first stage of exceeded noise limits, the speed limits are reduced to 100 km/h for passenger cars and 80 km/h for heavy vehicles. This leads to a noise reduction of 1 to 2 dB(A). In a next step, the speed limit for heavy vehicles is reduced to 60 km/h. This limit however is only accepted by 10% of the heavy vehicles. Thus, further noise reduction is not observable (Bendtsen et al. 2004).



Interactive speed limit system from Gleisdorf, Austria

Source: Bendtsen, 2005, p. 67
(1) Immission noise measurement. (2) Emission noise measurement. (3) Noise reducing pavement. (4) Central noise barrier. (5) Noise barrier with photovoltaic cells. The sign reads: "I want to sleep. Quiet please!"

Urban motorway speed limits - Bristol

A study was carried out as part of the SILENCE subproject 'Road Traffic Flow' into the effect of reducing the speed limits of traffic on Bristol's urban motorway, the M32. This indicated that reductions of up to 3.5 dB(A) as L_{den} could be achieved at the façade of nearby residential properties, if average speed was reduced from 70 mph to 40 mph (from 113 to 65 kph). The study was expanded to examine the effect of speed reduction on CO_2 emissions and on a key pollutant for local air quality, nitrogen dioxide.

This work is now feeding into a study being undertaken on a proposal within the Joint Local Transport Plan for greater Bristol. The proposal is for the Greater Bristol Bus Network (GBBN), which includes speed limits on the motorway and a dedicated bus lane. This includes assessment of options for the elevated section of the motorway, which passes very close to houses and causes noise and air quality problems for residents. Bristol City Council are lobbying the Highways agency for noise reducing infrastructure to be installed as part of the refurbishment programme and it should be possible to show the potential benefits of this through a noise mapping / modelling study. However this will depend on resources for noise management.

Bristol City Council are ensuring that the environmental impacts and potential mitigation measures are being considered in the options for GBBN and the M32 through dissemination of the SILENCE studies and liaison with the consultants contracted to assess the options.

Unfortunately, the Highways Agency recently stated that they no longer intended to consider handing control of the M32 to the local authority. This means that Bristol will not be able to directly set the speed limits on the motorway and will need to negotiate with the Highways Agency on this matter.

Consultation with partners is ongoing (November 2007).

Responsible agencies and cooperation partners
Bristol City Council (Planning, Transport and Sustainable Development departments), Highways Agency, Interroute (Consultants)

Why is it regarded as good example?
It is too early to say whether this can be considered a good example as there is not yet any agreement on mitigation for noise.

To some extent we are pre-empting the development of noise action plans. This is because we have a "golden opportunity" to influence design of the urban motorway due to the work on GBBN. There is a high potential for noise reduction through speed limit reduction, and also though implementing physical changes on the road, such as low-noise surfacing and noise barriers. Ideally, we will be able to demonstrate a benefit to residents through pre and post mitigation monitoring of perception of road noise and road noise itself. This monitoring will obviously depend on whether we can agree mitigation measures.

The long-term success of this initiative will also depend on the level of involvement of Bristol City Council in noise action planning, as so far in the UK the central government is the sole responsible body. Bristol City Council and the UK government department for noise action planning (DEFRA) are currently discussing the way forward for noise action planning in Bristol.

Tips for copying

- early involvement with stakeholders (transport planners);
- support from road owner/manager;
- local authority should have responsibility for noise action planning;
- use other impacts to make the argument (air quality, CO2 emissions);
- incorporate Noise, Air Quality and Climate Change in the Local Transport Plan;
- plan pre and post monitoring;
- be able to show potential benefits with modelling tools – e.g. noise map;
- include detailed information on impacts, e.g. number of people exposed to noise levels = health impacts.

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Humps and cushions

Round top humps
Photo: Melanie Kloth, Polis

Narrow cushions
Photo: Lars Ellebjerg, DRI

What is it about?

An effective and widely used means of speed reduction is vertical deflections in the form of humps or cushions. Both the design of and the spacing between the humps and cushions influence traffic noise emissions. Proper spacing is important to maintain a steady driving pattern. If the distance between humps is too large, drivers tend to accelerate and decelerate rather than maintain a steady speed at and between the humps. This may increase noise levels and cause shifts in the sound pattern, which makes the noise more noticeable and increases annoyance.

Benefits in terms of noise reduction

The noise reduction effect of humps and cushions depends on the speed reduction achieved.

Advantages

Besides keeping speeds down, humps and cushions may lead to a reduction in traffic levels on a road if the obstacles cause the preference of drivers to shift towards other routes.

Problems

The design of humps and cushions needs to be chosen carefully. Cushions should be designed in a way that HGV can pass with their wheels. However, experience shows that drivers do not always care, which will increase the noise level.

Technical details

The design of humps and cushions is of little importance to noise emissions from light vehicles as long as the design matches the desired speed. Studies show that noise emissions from light vehicles are determined by the driving speed regardless of the type of hump or cushion.

For heavy vehicles, on the other hand, round-top humps and narrow cushions (up to 1700 mm wide) are to be preferred.

If round-top humps are selected, it should be ensured that heavy vehicles do not pass the humps at speeds exceeding 25 km/h, even when there is no other traffic to keep speeds down. At higher speeds, L_{Aeq} levels may increase by up to 8 dB. Flat-top humps and wide cushions should be avoided on residential roads with heavy vehicles as they may lead to significant increases (up to 10 dB) in both L_{Aeq} and L_{Amax} levels from heavy vehicles.

At a desired speed level of 30 km/h, a distance between cushions of 50 meters is to be preferred. 30 km/h corresponds to a driving time between humps of 6 seconds. Assuming that it is the driving time between humps, which determines the incentive for drivers to accelerate, the preferable distances between cushions at speeds of 40 and 50 km/h are likely to be 67 and 83 meters respectively. This, however, needs to be verified. Similar distances seem appropriate for humps, in order to keep driving patterns even. This also needs verification.

Chicanes

What is it about?

Chicanes reduce the width of a street in order to make drivers slow down. Single lane working chicanes reduce the street to one lane. Drivers have to slow down to be able to check for oncoming traffic before driving into the chicane area. If vehicles are approaching from both sides at the same time, one or both of them need to stop entirely. The more traffic there is on a road with such chicanes, the more often vehicles will have to decelerate and accelerate. This may increase noise levels and will certainly cause shifts in the sound pattern which are likely to make the noise more noticeable and annoying to the neighbours.

Two-way working chicanes only reduce the width of the lanes. Light vehicles still can pass each other.

Generally, single lane working chicanes can be expected to cause braking and accelerating because vehicles have to wait for oncoming traffic to pass.

Both single lane and two-way working chicanes have a greater speed reducing effect for heavy vehicles than for cars. It is therefore likely that chicanes which cause cars to drive evenly at a desirable speed will cause large vehicles to brake and accelerate, which may cause annoyance to the neighbours. For the largest trucks, such chicanes are even likely to be impassable so that overrun areas are necessary. These, however, are also likely to cause unwanted shifts in noise levels and/or patterns, so that annoyance to the road neighbours is increased.

A study carried out as part of SILENCE (Bérengier, Picaut 2008; report H.R2, see attached CD-Rom) indicates that chicanes may increase noise levels from individual passenger cars by more than 3 dB due to accelerations after passing a chicane. These results need to be verified.

Benefits in terms of noise reduction

The effect in terms of noise levels depends on the achieved average speed and the change in driving pattern. Depending on traffic volumes and traffic composition, effects have to be calculated for each scenario before implementing chicanes. However, a negative impact on the noise level and/or annoyance is likely.

What does it cost?

The design of chicanes can vary greatly. Thus, also costs will vary. For redesigning streets, the EffNoise study mentions 2,000 EUR/m² as mean value (Lärmkontor GmbH, et al., 2004, Annex 8, p. 4).

Advantages

Chicanes can give additional space, for example for trees or bicycle parking.

Problems

Further surveys are necessary to gather knowledge on the noise and annoyance effects of chicane and road narrowing schemes. Thus, from a noise perspective these measures should be used with some caution, especially on roads carrying many heavy vehicles.

Chicanes force drivers to reduce speed
Photo: Laboratoire Régional des Ponts et Chaussées de Blois

Redesign of street space

What is it about?

Urban roads are usually designed to give priority to motorised traffic modes and to allow for speeds of 50 km/h. Efforts to reduce the speed on these roads often face the problem that drivers don't comply with the new speed limit. One possibility to increase drivers' compliance is massive police enforcement or automatic traffic control (as discussed above). Another possibility is to change the street design in such a way that it induces drivers to slow down intuitively.

Drivers usually adapt their driving speed to the local context, where the clarity of the situation is one important factor. Clarity for the driver is for example influenced by the possibility to oversee a long part of the street, the street width, the space given to different traffic modes (e.g. by attributing part of the lane to cyclists), the right of way, pedestrian crossings, etc.

Against this background, a range of measures is available to give drivers the impression not to be privileged compared to cyclists and pedestrians, thus making them reducing speed. Potential measures include narrowing the lanes by giving more space to pedestrians, cyclists or parking, planting trees to create the impression of a narrow road (without necessarily reducing the lane width in reality), narrowing lanes at junctions, improving the surroundings to highlight that the street space serves other uses than (car) traffic as well, reducing the strict separation between lanes, cycle lanes and foot paths, etc.

Benefits in terms of noise reduction

The effect in terms of noise levels depends on the achieved average speed and possible changes in the driving pattern. Depending on traffic volumes and traffic composition, effects have to be calculated for each scenario prior to implementing any measures.

Besides reducing the noise level, redesigning the street space can reduce the annoyance caused by noise. Experiences from German towns 'confirmed that for residential roads, the reduction in noise disturbance achieved by slowing vehicles down and thus lessening the dangers posed by car traffic, improving the surroundings by planting trees, bushes and flowers, and giving pedestrians more space by reducing the space allocated to motor traffic will be far greater than may have been expected based on the reduction in average sound level' (SMILE, n.d., p. 11).

What does it cost?

The EffNoise study mentions 2,000 EUR/m² as mean value for redesigning streets (Lärmkontor GmbH, et al., 2004, Annex 8, p. 4).

Advantages

Redesigning street space supports compliance with speed limits, can improve the visual impression of the street, and can support less noisy transport modes by attributing more space to pedestrians and cyclists. Road safety will most likely improve as well.

Junction design

Round about
Photo: Hans Bendtsen, DRI

Mini-roundabouts
Photo: Hans Bendtsen, DRI

What is it about?

The design of a junction – roundabouts, ordinary intersections with or without traffic lights - has influence on the traffic noise emissions. A number of European surveys have documented the effect of replacing ordinary intersections with or without signalisation by roundabouts. Any reductions at roundabouts compared with crossings are likely to depend upon the traffic and the layout of both the intersection and the roundabout. How these parameters influence the noise generated is unclear.

Mini-roundabouts – small paved or painted circles in the centre of intersections – are used as traffic calming measures to reduce speed. The little evidence found on the noise effects of mini-roundabouts indicate that these, when properly designed, may lead to noise reductions due to reductions in speed as well as to more even driving patterns. Based on this, the potential seems to be a noise reduction (L_{Aeq}) of up to 4 dB.

Benefits in terms of noise reduction

Results from surveys indicate that roundabouts without overrun areas may reduce noise levels (L_{Aeq}) by 1-4 dB compared with ordinary intersections, signalised or non-signalised. An Australian study refers to the benefit of roundabouts in terms of annoyance. 'Noise from roundabouts appears to create less community annoyance than other traffic calming devices.' (Austroads, 2005, p. 43) This needs further validation.

What does it cost?

The EffNoise study mentions 7,500 EUR for the construction of mini-roundabouts and 2,000 EUR/ m² as mean value for redesigning streets (Lärmkontor GmbH, et al., 2004, Annex 8, p. 3f.).

Advantages

If roundabouts create a steadier driving pattern than ordinary intersections, this might contribute to the objectives of air quality protection.

Problems

There is a need for further studies to clarify which factors explain the better performance of roundabouts before roundabouts can be fully utilised as a measure to reduce road traffic noise. Roundabouts with smaller diameters are often built with overrun areas with paving stones at the centre in order to allow large trucks to pass the roundabout. If cars use these areas to drive through the roundabouts at high speed, this may generate high impulsive-like noise levels, which may increase the annoyance experienced by those living next to the roundabout.

For mini-roundabouts, the effect on noise from heavy vehicles needs to be studied further. The influence of the roundabout design on the noise emission also needs further clarification.

Technical details

Experiments in Trondheim, Norway carried out by SINTEF as part of the SILENCE project indicate that L_{Amax} levels from individual vehicles driven in an economic, normal or aggressive manner do not differ between various types of junctions (Berge 2007). At all intersection layouts (4 different T- and X-crossings, with and without signalisation) and roundabouts (three different sizes and layouts), maximum engine speed and thereby L_{Amax} levels from aggressively driven vehicles are 1,000 rpm/6 dB higher than from normally driven vehicles, which in turn are 5-600 rpm/3 dB higher than from economically driven vehicles.

This indicates that the differences in noise levels between crossings and roundabouts, which are reported in the literature, may be fully or partially ascribed to drivers behaving less aggressively at roundabouts than at crossings.

Based on the driving patterns recorded by SINTEF, TUEV Nord has calculated L_{Aeq} levels for sections of road between 50 m before and 50 m after the junctions. These calculations indicate that the posted speed limit on the roads to and from the junctions influences noise levels. If 30 km/h is posted, this leads to 1 dB lower noise levels compared to when 50 km/h is posted, even if the average driving speed is the same. The calculations also show that crossings with traffic lights lead to 1-2 dB higher noise levels than roundabouts at the same average speed. This difference may, however, disappear if a roundabout leads to higher average speeds.

Calming green waves

What is it about?

Green waves – coordinated signalisation at a number of intersections in order to allow traffic in a direction to flow without having to stop at red lights – cause smoother driving and therefore most likely also lower noise emissions.
Simulations done as part of the SILENCE project, comparing a road with signals coordinated in a green wave with the same road without coordination (red wave), indicate that L_{Aeq} levels may go down by 4 dB at intersections, but also that levels may increase by as much as 3 dB between intersections due to higher speed and increased traffic flow (Bérengier & Picaut 2008). These figures are indications based on simulations and should be subject to further studies for verification.
The concept of calming green waves as presented by Ellenberg and Bedeaux (1999), aims at designing the green wave schemes in such a way that it is avoided that drivers speed in order to catch up one signalisation cycle between two intersections. By changing the design parameters of a green wave scheme (reducing design speed, cycle time and green time), Ellenberg and Bedeaux achieve a reduction of the average speed by 10 to 15 km/h. This corresponds to a noise reduction of 2.5 to 3 dB.

Benefits in terms of noise reduction

The potential of this measure is highly dependent on local road network conditions and the design of existing green wave schemes.

Reducing traffic volume

What is it about?

Reducing the traffic volume can contribute to noise reduction. However, as explained above, a high decrease of traffic volumes is necessary to decrease the noise level significantly (e.g. 50% reduction for a decrease of 3 dB). Thus, reducing traffic volumes to reduce noise levels can be a solution for minor roads or smaller areas. A range of measures is at hand to reduce traffic volumes: giving priority to public transport and rerouting private vehicles, banning through traffic by signs or by cutting roads, turning lanes into bus lanes, implementing low-emission zones or limited-access zones based on other criteria (e.g. access only for residents), constructing new bypass roads, etc. However, most measures only reduce the traffic volume slightly and should be considered as complementary within a whole package of measures.

Benefits in terms of noise reduction

The benefits in terms of noise levels depend on the achieved reduction in traffic volume, the traffic composition, the average speed, and the driving pattern. Thus, effects have to be calculated for each scenario.

Reducing traffic volumes on one road often implies increasing the volume on other routes. This does not necessarily lead to higher noise levels, because increasing the traffic volume on an already heavily used road might not or only slightly increase the noise level there. This, however, does not apply to newly built bypass roads. Their effect on reducing traffic volumes should not be overestimated as experiences show the share of urban traffic that might use the new route is usually less than 40% (SMILE, n.d., p. 12).

What does it cost?

The costs vary greatly with the concrete measure and local situation. Signs, for example, for banning through traffic cost about 300 EUR each, whereas the costs for new bypass roads amount to about 10,000,000 EUR/km (Lärmkontor GmbH, et al., 2004, Annex 8, p. 3f.).

Advantages

Most measures mentioned usually serve other objectives as well, such as promoting public transport, improving road safety, etc.

Problems

As mentioned earlier, a reduction in the traffic volume is only effective in terms of noise reduction if speeds are kept low and driving patterns don't change in a negative way.

Congestion charging – no positive impact on noise

Congestion charging has also proven to reduce the traffic volume and is therefore often believed to reduce noise levels. However, noise reductions due to reductions in traffic volumes are likely to be counteracted by increases in speed. This is what occurred in the congestion charging areas of London and Stockholm, where noise levels were unchanged in spite of decreases in traffic volumes. Thus, congestion charging and other measures which reduce traffic volumes cannot be expected to reduce noise levels if reduced congestion leads to an increase in vehicle speed.

Congestion charge system in Oslo
Photo: Hans Bendtsen, DRI

Implementation of the Urban Traffic Plan in the city centre of Genoa – promoting public transport and reducing noise

Reducing traffic volume around Piazza Verdi in Genoa

Source: Comune di Genova

In 1995, the first Urban Traffic Plan (PUT) for the centre of the City of Genoa was carried out and in 2000 it was reviewed.

The main objectives of the plan were to:

- decrease traffic flows crossing the city centre;
- redesign the city centre from an architectural and environmental point of view;
- redistribute the internal traffic flows.

There were two implementation phases for the city centre between 2000 and 2004. In the meantime, other Urban Traffic Plans for specific areas of the city have been developed. The following step should be a new comprehensive review of the PUT, covering the complete municipal territory.

Various measures implemented in the frame of the PUT for the city centre also had positive impacts on the noise levels. For two locations, the changes in noise levels were explicitly monitored and the results are presented here.

- Via XX Settembre, a main road in the city centre: one lane for private vehicles was turned into a bus lane and the circulation direction on the remaining lane was reversed;
- Piazza Verdi - Railway station Genova Brignole: change of direction of circulation around the square in front of the station. Access restricted to public bus fleet. Some parking facilities around the station were eliminated, to use the space for the new bus station. Two parking areas near the station were reallocated to two-wheelers and to short stops. Several parking facilities are available for longer stops (park&ride) in the vicinity of the station. This way, the area has become one of the most important intermodal interchanges of the city. The area has been improved from an environmental and urban point of view. However, the road network around the station still shows some critical aspects during peak hours.

The measures taken in both areas resulted in a significant decrease in private traffic flows crossing the city centre, resulting in an increase of traffic flows on the road network outside the city centre. This led to a significant noise reduction as presented in the following table:

Measure	LeqA ex-ante [dB]	LeqA ex-post [dB]
Via xx Settembre	77	73
Piazza Verdi	74	61

In general, the implementation of the PUT has led to a better distribution of traffic flows over the city centre network, even if some crucial points haven't been regulated in the best way yet.

Responsible agencies and cooperation partners

- Municipality of Genoa
- Public Transport Companies (bus and railway)
- Municipal Police Department
- Consultants
- District
- Organisations of citizens, shop owners, etc.

Why is it regarded as a good example?

From the design and implementation point of view, the PUT represents a good example of cooperation between public offices, transport companies and the public. In spite of the usual administrative problems, the implementation of the plan has reached all the main objectives fixed in the design phase.

At the beginning, some of the proposed measures (pedestrian zone, decrease in parking places, change of lane direction…) were not well accepted by the public, in particular by certain groups such as shop owners. This opposition has been mitigated however, thanks to the evident benefits coming from the implementation of the plan.

The area around one of the main squares of Genoa, Piazza De Ferrari, has been completely renovated. Changes in traffic circulation were followed by architectural and environmental redesign, which increased the interest for this area both from tourists and citizens.

Tips for copying

To implement a complex traffic plan such as a PUT in a successful way, one of the most important steps is the information campaign both at political/organisational level as well as at citizens involvement level. Each step of the plan must be very intensively explained, showing the potential benefit coming from its implementation.

From the technical point of view, it is necessary to create a core working group with all the necessary stakeholders (public and private) who are useful for the planning and implementation phases.

For more details contact…

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www.comune.genova.it

Bans on trucks

The sign bans HGVs between 11am and 7am. Only low-noise HGVs with official administrative authorisation are allowed 24 hours per day.
Photo: Hans Bendtsen, DRI

What is it about?

A ban on trucks (all day, night-time, or 11.00 to 7.00, thus allowing un/loading only in the morning hours) on specific roads or in larger areas will – in most cases – have little effect on L_{Aeq} levels, but it is likely to reduce the number of noise peaks and thus may mitigate sleep disturbances and annoyance to those living along the roads.
If the effect is to shift traffic to less vulnerable roads, reductions in night-time peaks and perhaps L_{Aeq} levels may be the only effect. If, on the contrary, a night-time ban forces delivery trucks and others to drive during day-time instead, increases in the number of peaks, and perhaps in L_{Aeq} levels and annoyance may be an adverse effect of such a ban.

Benefits in terms of noise reduction

Both night and day-time effects depend on local traffic conditions. Night-time bans on trucks have been implemented in several places in Austria and Switzerland. Austrian surveys have shown effects on night-time (22-05) L_{Aeq} levels as high as 7.2 dB (Bendtsen et al. 2004).
As part of SILENCE, the City of Bristol modelled the effects on noise of a ban on trucks on a specific road (the A4 Portway). In this case, reductions in L_{den} levels of around 6 dB are achieved. These results are based on scenarios, where all traffic drives at the speed limit. In reality light vehicles will – in most cases – drive somewhat faster than heavy goods vehicles. This will reduce the potential effect somewhat, but not by 6 dB.

What does it cost?

To implement bans for specific roads, signs are needed (costs about 300 EUR per sign, (Lärmkontor GmbH, et al., 2004, Annex 8, p. 3)). If the ban is to be implemented for larger areas, additional measures certainly will be necessary (e.g. for informing HGV drivers, upgrading roads designated for HGV, etc.).

Advantages

Reducing the share of HGV in general improves air quality and road safety as well.

Problems

The main drawback of night-time bans is a large increase in HGV traffic in the early morning at the end of the restriction period (Bendtsen et al. 2004).

City logistics

Reductions in the number of heavy vehicles in central urban areas may be achieved through city logistics. Such schemes, where goods for delivery in an area are reloaded at a terminal, and distributed by trucks with high load factors and following optimised routes, are unlikely to affect L_{Aeq} levels but likely to reduce the number of high peaks and thus disturbance and annoyance.

HGV ban in Munich without significant noise reduction

Within the frame of SILENCE, the City of Munich calculated the noise reducing effect of banning HGVs from crossing the inner-city. The ban concerns HGVs above 3.5 tons with exemptions for deliveries to premises in the inner-city and is in force 24 hours. Violation of the ban will be punished with a fine of 20 EUR. Compliance is controlled by the police. Calculations of the number of HGVs and the resulting noise effects were carried out for a certain part of the inner-city. They resulted in a reduction with about 1,200 HGVs a day in this part of the city, spread over various roads. In terms of noise levels on single roads no significant reduction could be found.

The HGV strategy and HGV ban for Dublin city

View of the South Bound Entrance of the Dublin Port Tunnel
Photo: Answers.com

The Dublin Canal Cordon which outlines the area for the HGV ban within the city
Picture: Dublin City Council

The HGV strategy was implemented in conjunction with the Dublin Port Tunnel and the M50 C-ring motorway around Dublin city. The HGV strategy bans all vehicles with 5 or more axles from entering the canal cordon area around Dublin city centre between 07:00 and 19:00, seven days a week. Vehicles who must gain access may apply for a permit.

The aim of the strategy is to remove all vehicles with 5 or more axles from transiting Dublin city centre within the canal cordon. This reduces traffic within the city centre region, therefore reducing pollution, congestion and improving the quality of life for residents, cyclists, motorists and pedestrians within the city. An OECD report detailing challenges to urban goods transport (OECD, 2003) points to the fact that although trucks account for only 10 percent of all transport operations in urban areas, they produce over 40 percent of the pollution and noise caused by local traffic.

From the view of logistics, it will reduce the time it takes for a HGV to get to the M50 motorway to about 6 minutes as this would be a dramatic increase on the standard time without the tunnel. It was also hoped to reduce the number of accidents involving HGVs (over a 42 month period ending April 2006 there were 19 fatalities within the city centre due to accidents involving HGVs). A fundamental aim of the strategy is to reduce the number of permits issued over time to an absolute minimum and therefore the amount of HGVs within the city.

The permits are issued by the Dublin city council and enforcement of the single use permit system is carried out by the police. The premises receiving deliveries by HGVs are obliged to submit mitigation plans to show how they intend to reduce the number of deliveries using five axle vehicles.

The tunnel was part of the Dublin Transport Initiative in 1993 and the planning process commenced circa 1993; work on site started in June 2001. The tunnel was opened in December 2006 with the HGV strategy operational from February 2007. In the future, it is intended that the ban will also cover vehicles with 4 or more axles.

The cost of the Dublin Port Tunnel was in the region of €700 million. The M50, M1 and other adjoining motorways were not part of the cost of the Dublin Port Tunnel.

Responsible agencies and cooperation partners
Dublin City Council, National Roads Authority (NRA), An Gardai Siochana (police), a consortium of consultants and sub-contractors.

Why is it regarded as good example?
Residents that may be affected by the construction work of the Dublin Port Tunnel were consulted and regular meetings at various stages of the process were held. The Irish Road Haulage Association (IHRA) was consulted on the best possible solution to the permitting issues.

Since the introduction of the HGV ban and opening of the Dublin Port Tunnel, there has been an average daily reduction of 36% of PM10 values, journey times to and from Dublin port to the M50 have been reduced to 6 minutes. The quantity of HGVs entering the canal cordon is closely monitored on a monthly basis. The routes that the HGVs can use with a permit are restricted, which further helps to reduce traffic within the canal cordon.

Tips for copying
In discussions with the Irish Road Haulage Association it was concluded that the permitting system must be possible to apply for a permit 24 hours per day. This led to the creation of the permitting website www.hgv.ie which is multi-lingual, requires no paperwork, enforceable and the whole transaction can be completed on-line. This means that for a HGV arriving in Dublin port, no paperwork is required to be submitted other than the on-line application. In order to stop transiting through the city with HGVs using a false delivery address, the premise must be registered for receiving deliveries and the route to and from the premises must also be submitted.

Particular roads saw a reduction of HGV traffic of between 33% and 90%. By 2012, it is hoped that 5-Axle HGVs will be removed entirely from the city streets or only used whenever a smaller vehicle will not suffice.

For more details contact…

- The HGV permitting service: www.hgv.ie
- Dublin City Council: www.dublincity.ie
- Dublin Port Tunnel: www.dublinporttunnel.ie

Part 6:
Annex

… where the sources are summarised and illustrating material on the soundscape approach can be found.

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Soundscape approach – Example from Barcelona

Below the results of the soundscape analysis for Barcelona are presented. The analysis was carried out by GRECAU, Bordeaux – France. The conclusions and recommendations represent the view of GRECAU. The City of Barcelona does not necessarily agree. The municipality particularly disagrees with the recommendation to remove the traffic lights (in order to generate a steadier traffic pattern) because of road safety reasons for pedestrians.

BARCELONA : La Rambla

Presentation of the site

Location of the site in the town

La Rambla in Barcelona is one of the most famous avenues in the world. It is a long, wide boulevard between the port and the central hub/square Plaça Catalunya (popular focal point and important public transport interchange). There are plenty of people at any time of day and night. This avenue is used both for leisure purposes (walking and shopping) and for business (near City Hall and different office buildings). The studied area is located between the subway station Gran Teatre del Liceu and Plaça Catalunya.

Access to the site

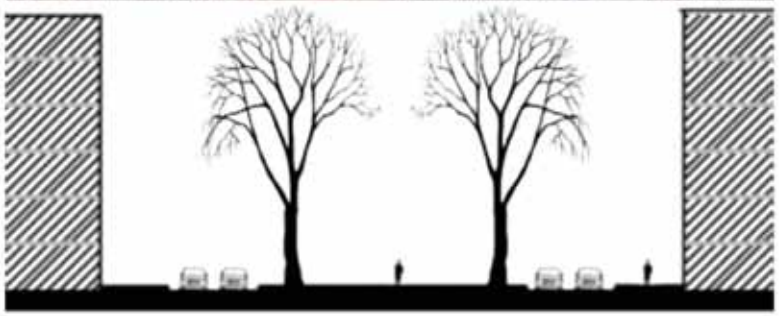
La Rambla is served by buses 14, 38, 59 and 91 and on foot from Plaça Catalunya (underground and bus))

BARCELONA : La Rambla

Description of the site

Volumetric analysis / Buildings / Vegetation / Surface material / Urban furniture

This avenue has two sidewalks and two roads, one in each direction, plus a very wide central promenade. There is a slight slope rising from the subway station to Plaça de Catalunya.
Buildings are high but far enough away from each other on each side of the avenue. The central area of la Rambla can be considered as an open space. The central area of la Rambla is tree-lined on each side.
There is a lot of urban furniture on the la Rambla site. None of them is a sound source, but because of their position (for example the different kiosks), they are as much a visual as an acoustic barrier between the central area and the sidewalks of the avenue.



2

BARCELONA : La Rambla

Sound sources

Human activities

Mechanical activities

Transport

Animals

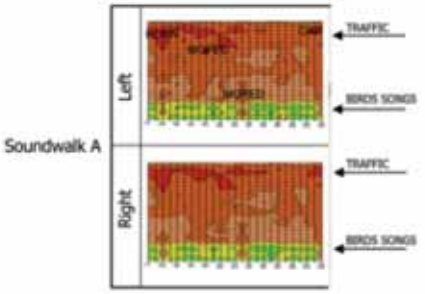
3

BARCELONA : La Rambla

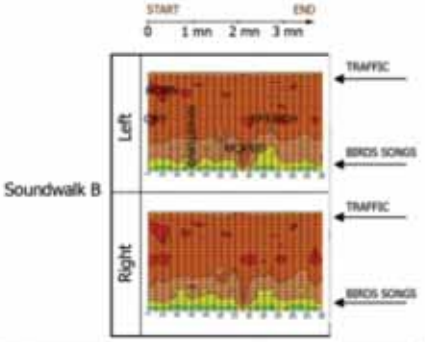
Soundscape analysis

Modification of the soundscape following the location in the site

Soundwalk A



Saturday Noon



Soundwalk B

On the two routes the prevailing components of the soundscape are: traffic noise, voices/speech, human activities and bird song.
The characteristic frequency bands of main urban sound sources can be spotted on the acoustic images:

- traffic, in the low frequency band around 80 Hz (soundwalks A and B)
- human voices in the medium frequency band around 500 Hz (soundwalk B)
- bird song between 3,15 kHz et 12,5 kHz (mainly soundwalk B)

All these noises are audible on the two recordings but in different proportions. For route A, traffic noise is predominant throughout the soundwalk, whereas speech is as loud as traffic on route B.

4

BARCELONA : La Rambla

Recommendations

Conclusion from the subjective data analysis

La Rambla is a very famous place, frequented by the dwellers of Barcelona, new residents as well as old ones. The site is frequented all day long by people who go there alone or with friends and is used for all kind of activities such as strolling around, relaxing or meeting friends. Although more than half of the users frequent the place and are attached to it, they evaluate the different approached topics concerning the environment of la Rambla in a contrasted way.
Thus, on the level of the site arrangement, the much frequented site suffers from a congested pedestrian space and an insufficient number of benches to sit down. Regarding social life, La Rambla is considered as a real meeting point, a lively place, but also, for a percentage of the interviewees, as not very secure and not very convivial.
The physical environment of La Rambla does not satisfy the majority of the people questioned. Concerning the acoustic aspect, the interviewees give a contrasted evaluation of the sound environment (qualitative dimension) but are much more unanimous in the evaluation of the noise level (quantitative dimension): La Rambla is considered a noisy place for more than 88% of the users.
The most frequently heard sources refer, mainly, to the traffic and the types of vehicles (public transport, mopeds/motorcycles). Moreover, all these sources are evaluated as being most unpleasant.
Proportionally, on this site human conversations constitute frequently heard sources, but seem this time to belong to the most pleasant sources, together with birdsong, the latter, however, is not heard much in La Rambla.
Finally, there are two types of sources: traffic and people, which are representative of the soundscape of La Rambla because of their continuous presence and acoustic intensity. Reduction of traffic or its deviation are therefore suggested the most to improve the sound environment of La Rambla.

Conclusion from the soundscape data analysis

Route A: For the whole length of the route, traffic noise prevails whatever the day of the week or time. Only the passage under the arcades is quieter.
Route B: The studied site can be divided into several parts in accordance with their soundscape characteristics: café terraces, the flower market, the bird market and two "no man's lands". In these parts, the first one is between the markets and the second one is at the entrance to Plaça Catalunya, traffic noise prevails.

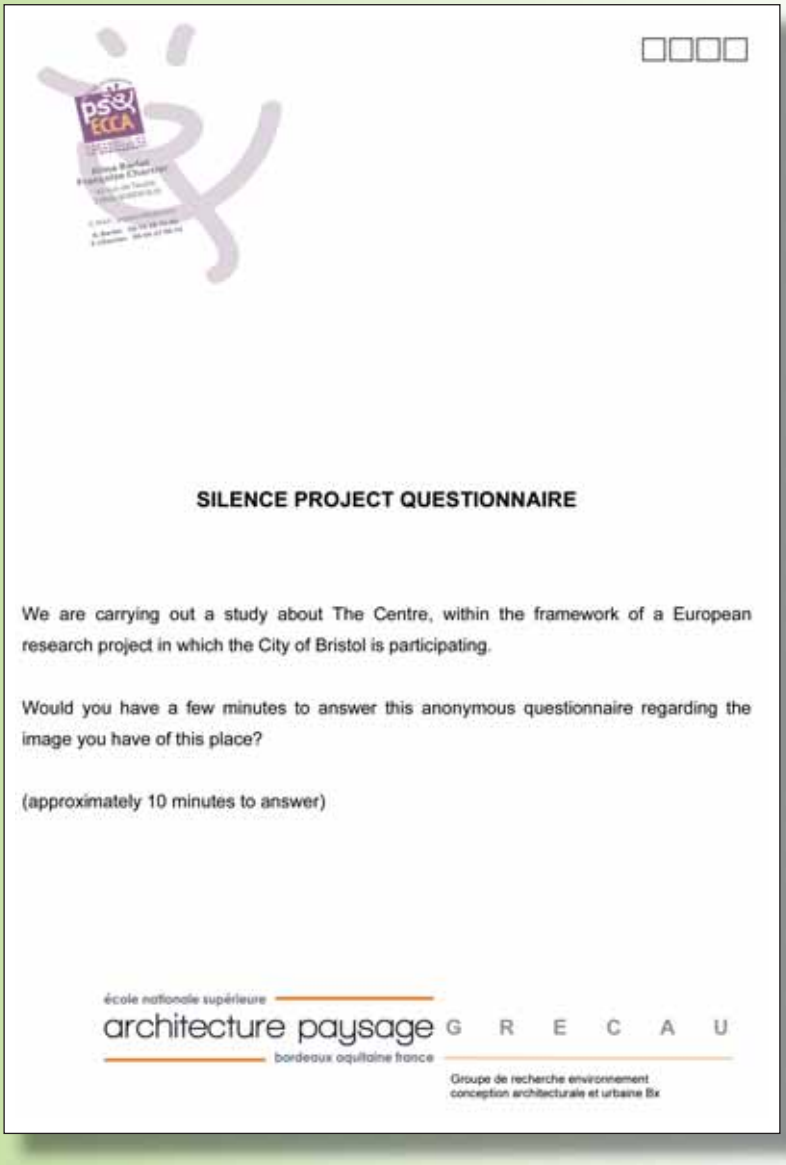
Recommendations to improve the soundscape:

.Reduce truck and bus traffic and promote electric vehicles for city buses;
.Promote a more harmonious flow of traffic, avoid traffic lights which create pulsing traffic, encourage slower driving through urban arrangements (zigzags...);
.Favour the most pleasant activities on La Rambla, i.e. the human ones;
.Try to extend urban furniture such as the existing kiosks all along La Rambla, as they modify the perception of traffic noise. .

5

Questionnaire to survey citizens' perception

The questionnaire below has been developed by GRECAU, Bordeaux – France, within the SILENCE subproject 'City Planning'. The questionnaire was used for surveying the perception of passers-by in the centre of Bristol.



□□□□

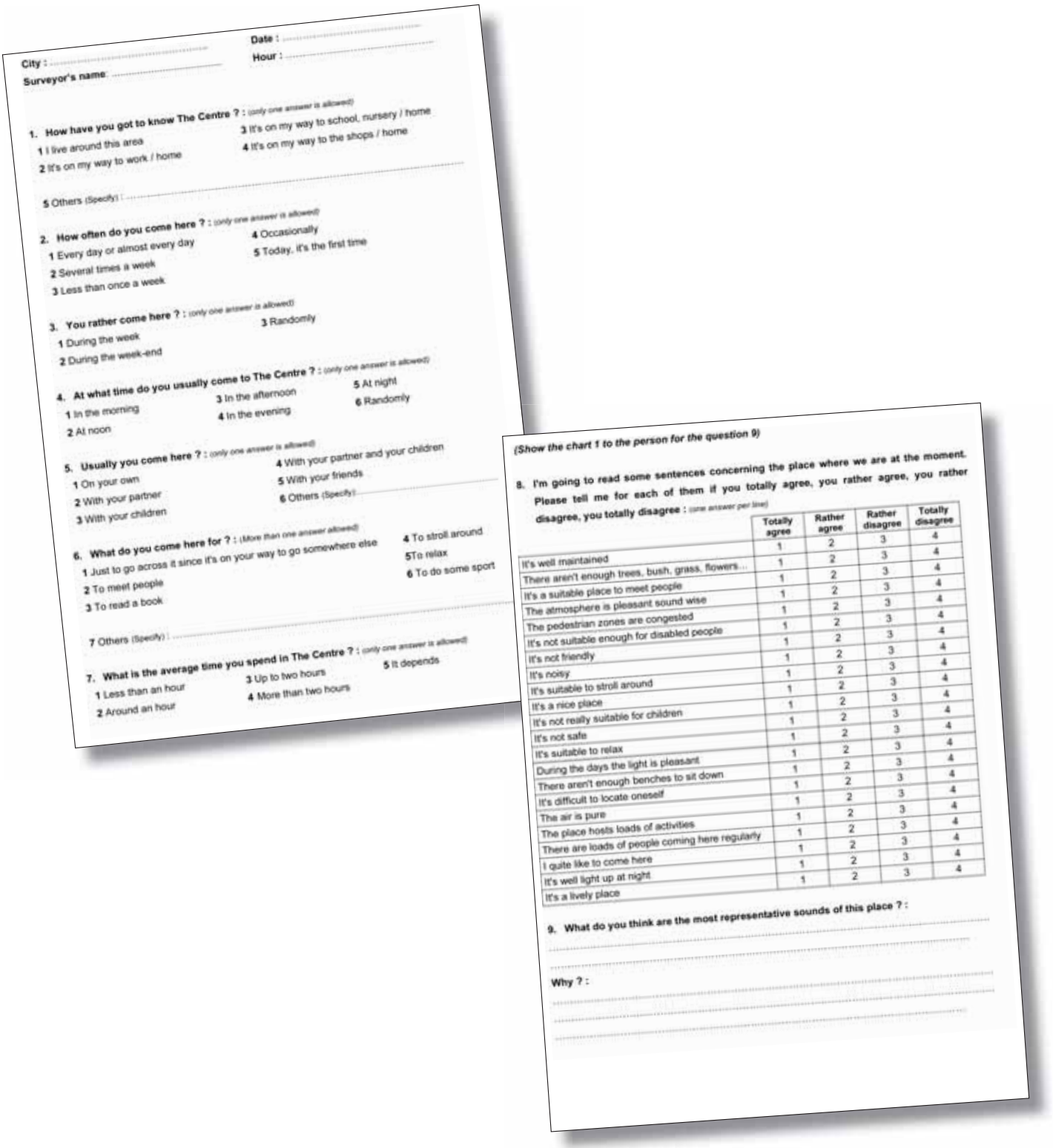
SILENCE PROJECT QUESTIONNAIRE

We are carrying out a study about The Centre, within the framework of a European research project in which the City of Bristol is participating.

Would you have a few minutes to answer this anonymous questionnaire regarding the image you have of this place?

(approximately 10 minutes to answer)

école nationale supérieure
architecture paysage
bordeaux aquitaine france
G R E C A U
Groupe de recherche environnement conception architecturale et urbaine Bx



City : .....
Date : .....
Surveyor's name: .....
Hour : .....

1. **How have you got to know The Centre ?** : (only one answer is allowed)
1 I live around this area
2 It's on my way to work / home
3 It's on my way to school, nursery / home
4 It's on my way to the shops / home
5 Others (Specify) : .....

2. **How often do you come here ?** : (only one answer is allowed)
1 Every day or almost every day
2 Several times a week
3 Less than once a week
4 Occasionally
5 Today, it's the first time

3. **You rather come here ?** : (only one answer is allowed)
1 During the week
2 During the week-end
3 Randomly

4. **At what time do you usually come to The Centre ?** : (only one answer is allowed)
1 In the morning
2 At noon
3 In the afternoon
4 In the evening
5 At night
6 Randomly

5. **Usually you come here ?** : (only one answer is allowed)
1 On your own
2 With your partner
3 With your children
4 With your partner and your children
5 With your friends
6 Others (Specify) : .....

6. **What do you come here for ?** : (More than one answer allowed)
1 Just to go across it since it's on your way to go somewhere else
2 To meet people
3 To read a book
4 To stroll around
5 To relax
6 To do some sport
7 Others (Specify) : .....

7. **What is the average time you spend in The Centre ?** : (only one answer is allowed)
1 Less than an hour
2 Around an hour
3 Up to two hours
4 More than two hours
5 It depends

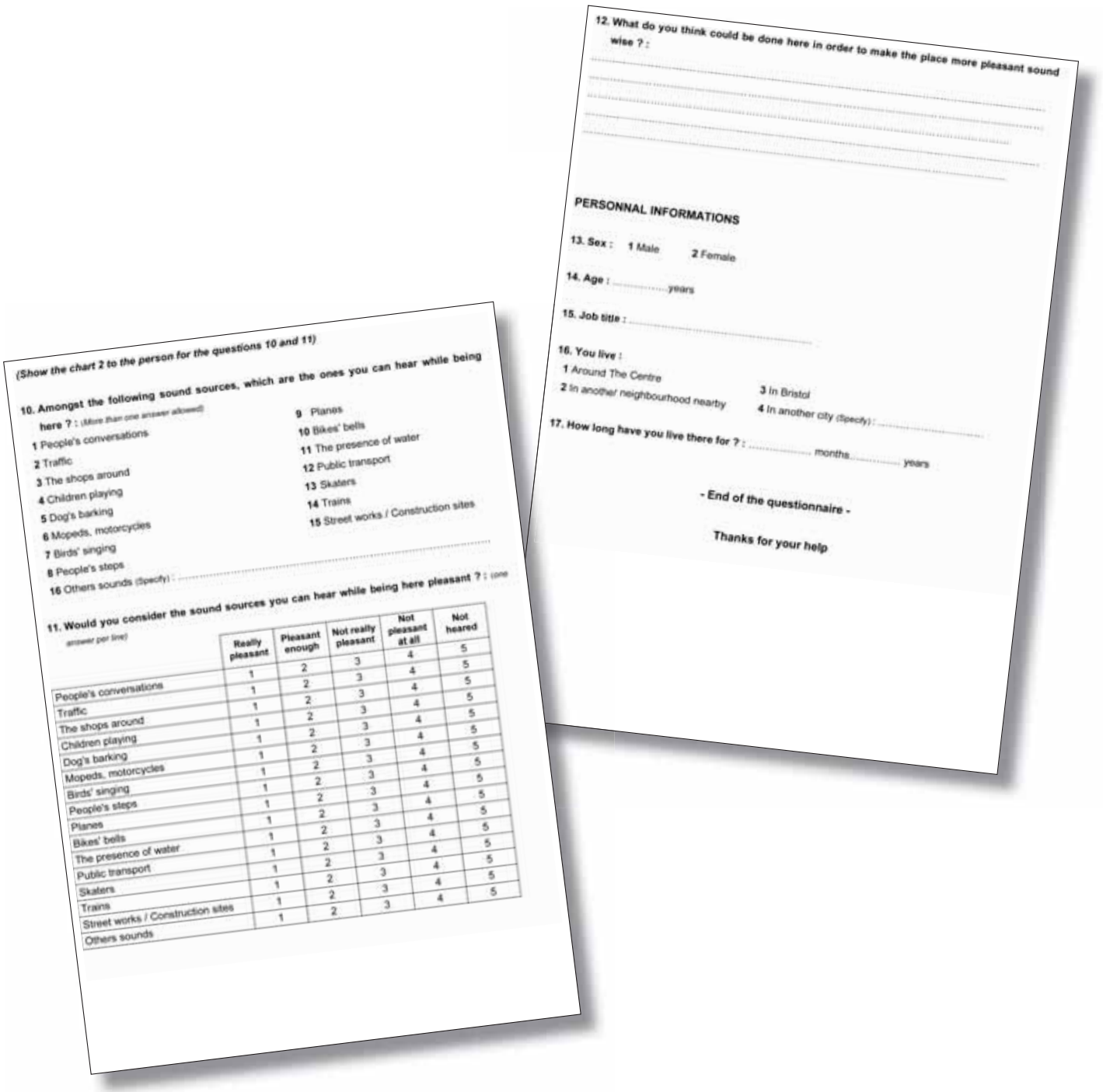
(Show the chart 1 to the person for the question 9)

8. **I'm going to read some sentences concerning the place where we are at the moment. Please tell me for each of them if you totally agree, you rather agree, you rather disagree, you totally disagree :** (one answer per line)

	Totally agree	Rather agree	Rather disagree	Totally disagree
It's well maintained	1	2	3	4
There aren't enough trees, bush, grass, flowers...	1	2	3	4
It's a suitable place to meet people	1	2	3	4
The atmosphere is pleasant sound wise	1	2	3	4
The pedestrian zones are congested	1	2	3	4
It's not suitable enough for disabled people	1	2	3	4
It's not friendly	1	2	3	4
It's noisy	1	2	3	4
It's suitable to stroll around	1	2	3	4
It's a nice place	1	2	3	4
It's not really suitable for children	1	2	3	4
It's not safe	1	2	3	4
It's suitable to relax	1	2	3	4
During the days the light is pleasant	1	2	3	4
There aren't enough benches to sit down	1	2	3	4
It's difficult to locate oneself	1	2	3	4
The air is pure	1	2	3	4
The place hosts loads of activities	1	2	3	4
There are loads of people coming here regularly	1	2	3	4
I quite like to come here	1	2	3	4
It's well light up at night	1	2	3	4
It's a lively place	1	2	3	4

9. **What do you think are the most representative sounds of this place ?** :
.....
.....

Why ? :
.....
.....
.....



(Show the chart 2 to the person for the questions 10 and 11)

10. Amongst the following sound sources, which are the ones you can hear while being here ? : (More than one answer allowed)

1 People's conversations
2 Traffic
3 The shops around
4 Children playing
5 Dog's barking
6 Mopeds, motorcycles
7 Birds' singing
8 People's steps
9 Planes
10 Bikes' bells
11 The presence of water
12 Public transport
13 Skaters
14 Trains
15 Street works / Construction sites
16 Others sounds (Specify) : .....

11. Would you consider the sound sources you can hear while being here pleasant ? : (one answer per line)

	Really pleasant	Pleasant enough	Not really pleasant	Not pleasant at all	Not heared
People's conversations	1	2	3	4	5
Traffic	1	2	3	4	5
The shops around	1	2	3	4	5
Children playing	1	2	3	4	5
Dog's barking	1	2	3	4	5
Mopeds, motorcycles	1	2	3	4	5
Birds' singing	1	2	3	4	5
People's steps	1	2	3	4	5
Planes	1	2	3	4	5
Bikes' bells	1	2	3	4	5
The presence of water	1	2	3	4	5
Public transport	1	2	3	4	5
Skaters	1	2	3	4	5
Trains	1	2	3	4	5
Street works / Construction sites	1	2	3	4	5
Others sounds	1	2	3	4	5

12. What do you think could be done here in order to make the place more pleasant sound wise ? :

.....
.....
.....
.....
.....

PERSONNAL INFORMATIONS

13. Sex : 1 Male 2 Female

14. Age : ..... years

15. Job title : .....

16. You live :

1 Around The Centre
2 In another neighbourhood nearby
3 In Bristol
4 In another city (Specify) : .....

17. How long have you live there for ? : ..... months ..... years

- End of the questionnaire -

Thanks for your help

SILENCE Quieter Surface Transport in Urban Areas

This practitioner handbook was written in the framework of the SILENCE project on Quieter Surface Transport in Urban Areas. SILENCE is an integrated research project, co-funded for 3 years by the Sixth Framework Programme of the European Commission. The SILENCE project provides relevant and world leading methodologies and technologies for the efficient control of noise caused by urban road and rail transport, and innovative strategies for action plans on urban transport noise abatement and practical tools for their implementation. SILENCE includes research in the fields of road surfaces, tyres, and road vehicles, rail infrastructure and rail vehicles, as well as road traffic flow.

The SILENCE team

SILENCE involved the right mix of European expertise to develop appropriate solutions. The project gathered city authorities, public transport operators, research and engineering institutes, European associations, vehicle manufacturers, equipment, systems and technology suppliers, and specialised SME's. It was co-ordinated by AVL List GmbH (Austria).

SILENCE partners:
AMU, ALSTOM Transport, Altran DSD, AnsaldoBreda, Autostrade, AVL, Bombardier Transportation, Bristol City Council, BKSV, Bruitparif, Brussels Mobility, CNRS, Centro Richerche Fiat, Chalmers Tekniska Högskola, City of Munich, Comune di Genova, Continental, Corus, D2S, DeltaRail, Deutsche Bahn, DIT, FEHRL, Uni Hannover, IfADo, INSA Lyon, Kungliga Tekniska Högskolan, Lucchini, M+P, Polis, RATP, Renault, Rieter Automotive, TUEV Nord, SINTEF, Skanska Sweden, SNCF, STIB, TU Berlin, TRENITALIA, Università Politecnica delle Marche, ISVR, VIBRATEC, Volkswagen, Volvo Technology.

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