CALM network

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Research for a Quieter Europe in 2020

EUROPEAN COMMISSION
RESEARCH DIRECTORATE-GENERAL

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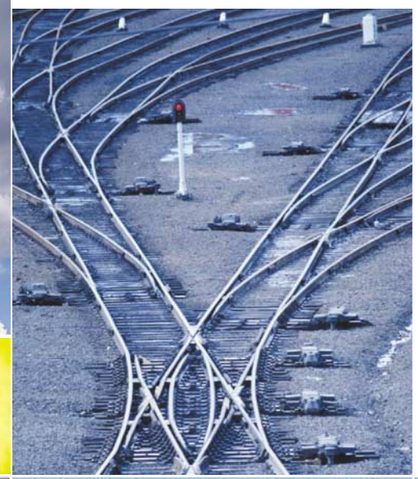

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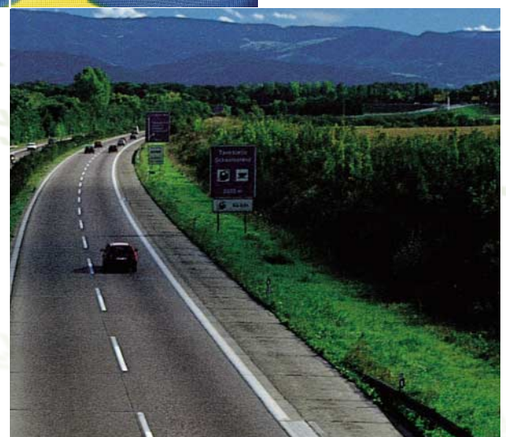


Foreword

This Strategy Paper is an update of the first edition issued in July 2002, and so it is again a pleasure for the members of the CALM network to present the updated plan for future research on reducing environmental noise in Europe. This plan should create a solid basis for initiating and promoting research to reduce the adverse effects of noise.

Noise is one of the environmental pressures that is an important issue for citizens. In public surveys, problems with noise are often rated at the highest level together with global warming. Research is a key element in reducing the effects of sound levels that are too high. This research should include work on how noise affects people when they are at school, at university or at home, or when they visit areas for recreational purposes. The research should also deal with the reduction of noise emitted by individual noise sources, especially noise from transportation traffic and from equipment used outdoors.

The CALM initiative is the result of a close collaboration between DG Research and DG Environment which is the part of the Commission responsible for coordinating the European environmental noise policy. This close collaboration should ensure that initiatives concerning research on noise reduction are in line with the requirements of the related EU directives, the EU noise policy and other environmental policies of the EU such as air quality.

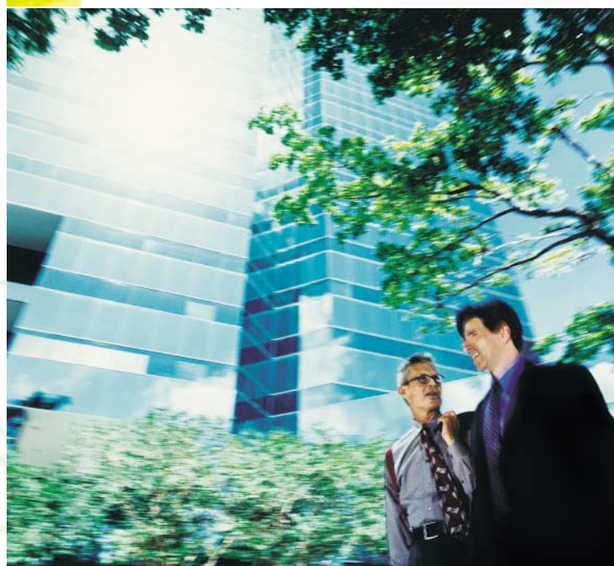
The CALM network membership has been established with representation from each of the working groups that are supporting the development of the Directive on Environmental Noise (2002/49/EC). In addition, a number of workshops with a broad range of stakeholders have been organised to get as wide an input to the project as possible.

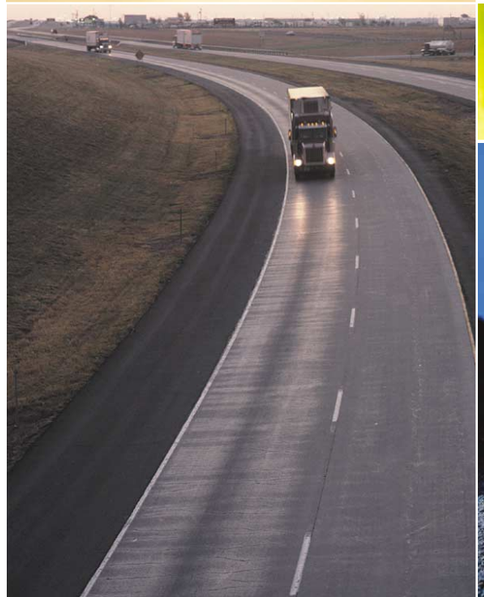
This Strategy Paper will undergo further revisions and will be re-issued at fixed intervals during the following years on the basis of the development of the state-of-the-art concerning noise abatement and noise perception. To this end the CALM network welcomes input from all stakeholders, and in particular those who have not yet provided their comments.

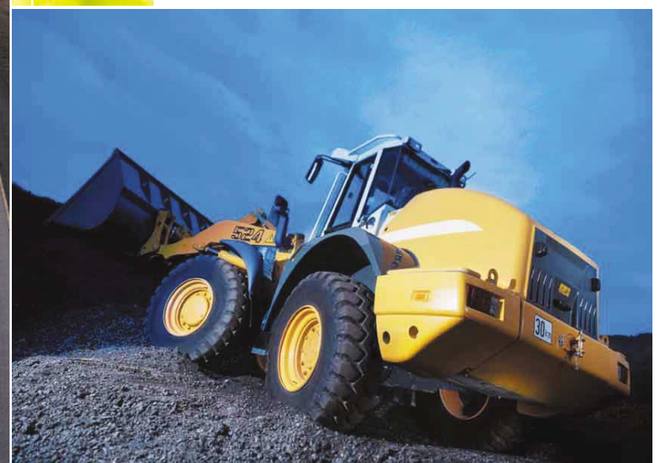
It is our hope that the work of the CALM network will contribute to a quieter Europe.

Finally, the members of the CALM network would like to thank everyone who has contributed to this Strategy Paper.

The members of the CALM network







Summary

Noise pollution remains high on the list of citizen concerns and noise reduction has increasingly become a focus for EU legislation and a priority for research.

Starting back in the nineteen seventies, successive Directives have laid down specific noise emission limits for most road vehicles and for many types of outdoor equipment. However, despite the enforcement of this increasingly stringent legislation on noise sources, and despite the considerable effort and progress made in noise control by the industry, there has been little improvement in the noise exposure levels suffered by citizens across Europe. In view of this, it was considered necessary to also direct noise policy towards actual noise reception (immission) in addition to noise source emission.

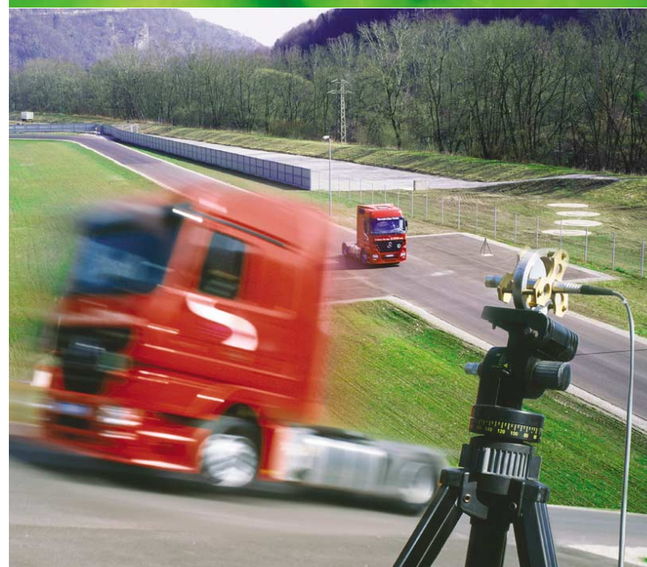
The Green Paper on Future Noise Policy (1996) marked the start of this additional approach leading to the Environmental Noise Directive of 2002 as a new second cornerstone of noise policy, to complement the set of existing emission related directives. The Environmental Noise Directive focuses on a common approach to address environmental noise, to be executed at the national, regional and local levels according to the principle of shared responsibility. It also provides a basis for future action at the EU level. The future noise policy is built on a long-term target based on the Sixth Environmental Action Programme of 2002. The vision supported by CALM for the year 2020 is to

“avoid harmful effects of noise exposure from all sources and preserve quiet areas.”

To meet this vision, intensive research is required to provide a solid base for the efficient and effective control of environmental noise in future.

The noise research strategy must be in line with the direction of the future noise policy. The first goal of future research is, therefore, to support the transposition of the Environmental Noise Directive. The Directive contains some preliminary texts since information (e.g. the text on common methods for noise mapping) was unavailable and has to be derived from further research. The second goal is to support on the further development of noise policy. This covers a wide range of research including assessment of noise exposure and perception, noise abatement including cost-benefit aspects, new technologies and system approaches for improved noise control at source and the further development of legislative standards. The major sources of environmental noise to be considered are transportation (road, rail and air traffic) and outdoor equipment. The structure of the noise research strategy is split into perception and emission related research combining these two goals.

“Intensive research is required to provide a solid base for the efficient control of environmental noise in future.”



1. Introduction

Despite existing EU and national legislation targeted at controlling noise pollution, public concern and anxiety about noise remain high. The Directive on the Assessment and Management of Environmental Noise[1] aims to create a quieter and more pleasant environment for European citizens within the framework of "Sustainable Development and Growth in Europe". In order to support the ongoing development of a comprehensive EU noise policy and the transposition and implementation of this Directive at national level, further noise research programmes have to be defined and initiated. The CALM network[2] is working on the development of a strategic plan for such future noise research activities.

"This noise research strategy plan shall contribute to current and future European research initiatives."

This strategy paper has been prepared by the CALM network as an update of the first CALM strategy paper issued in July 2002[3], and is intended as a contribution to the current research programme[4] and future research initiatives of the European Community. The identification of areas requiring urgent research is also intended to inform decisions on noise research made at national level.

It is planned to regularly update this Strategy Paper based on developments in the state-of-the-art and new research needs[5].

CALM research interests extend in principle to all sources of environmental noise such as road, rail, air and water borne transport, outdoor equipment, industrial noise, leisure activities like motor racing circuits, shooting ranges, recreational water borne craft etc. However, the focus of this paper is directed towards the main noise emitters of transportation and industrial noise.

[1] European Directive 2002/49/EC of 25 June 2002 relating to the Assessment and Management of Environmental Noise. OJ L 189, 18.07.2002, p. 12. See also: http://www.europa.eu.int/comm/environment/noise/
[2] CALM – Community Noise Research Strategy Plan. A thematic network over a period of three years started in Oct. 2001. See: http: www.calm-network.com
[3] CALM Strategy Paper "Research for a Quieter Europe", July 2002, EUR 20436. See also: http://www.calm-network.com/index_preports.htm
[4] Sixth Framework Programme of the European Community for Research, Technological Development and Demonstration Activities (2002 to 2006). OJ L 232, 29.8.2002, p. 1.
[5] As a continuation of CALM, the project CALM II is planned from 2004 to 2007 as a Coordination Action under the Sixth Framework Programme.

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2. Environmental Noise in Europe

2.1. The Situation of Noise Pollution

Nearly all human activities and the technical equipment associated with them generate SOUND. Sometimes sound is perceived as pleasant and amusing (like music). Sometimes the activity confers some other significant benefit (like driving a car, mowing a lawn or listening to the radio), and provided that the sound level does not exceed a certain threshold, the sound is perceived as useful or informative or at least acceptable. However, many of these sounds either exceed acceptable levels or provide no benefit to the person exposed to them and are hence unwanted, annoying, disturbing or even constitute a health risk. In this case, sound is perceived as NOISE.

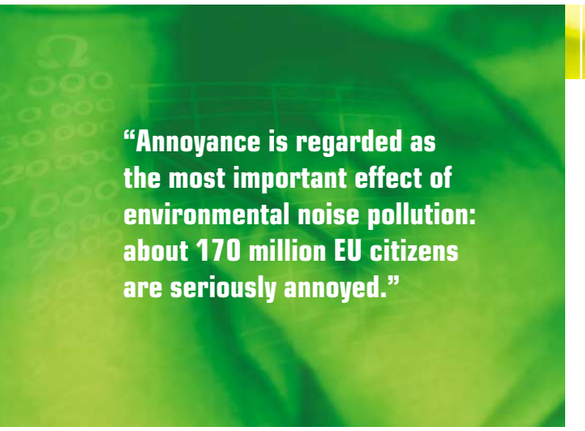
As far as the CALM project is concerned, environmental noise is considered to be the unwanted or harmful sounds generated by human activity outdoors (e.g. road, rail and air transport, construction and other industry, leisure activities) and perceived in sensitive environments (e.g. in and near the home, in public parks, near schools and hospitals etc.).
The adverse effects of environmental noise are various and can be described in many different ways. However, they can be grouped into three main categories[6]:

- Health effects
- Effects on the quality of life
- Adverse financial effects for the afflicted persons

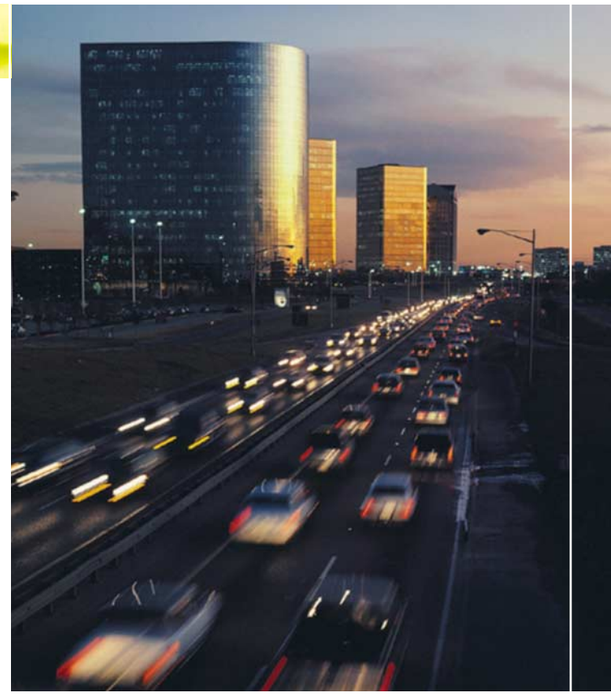
According to the World Health Organization (WHO)[7] "human health" is "a state of complete physical, mental and social well-being, not merely the absence of disease and infirmity". Based on this definition, WHO identified a considerable number of specific adverse health effects[8] caused by environmental noise. These specific effects can be medical related, such as insomnia, high blood pressure, ischaemic heart disease and hearing impairment, but can include also other effects like perceived sleep disturbance, psychophysiological stress or the negative effect on the learning capabilities of children.

Besides these specific adverse health effects, the non-specific "general" annoyance is considered as an overall effect of environmental noise and is regarded as the most important effect of environmental noise pollution. Therefore, it is widely identified as the basic health effect which needs to be controlled in the general population. Sleep disturbance is the second important effect to be controlled.

For the European Union (excluding the new member states) it has been estimated that about 80 million people



[6] Tjeert ten Wolde and William W. Lang: On the Possibilities for a Global Policy on Environmental Noise, Part 1. Internoise 2004, Prague, Aug. 2004.
[7] Preamble to the Constitution of the World Health Organization as adopted by the International Health Conference, New York, 19 - 22 June 1946; signed on 22 July 1946 by the representatives of 61 states (official Records of the World Health Organization, No. 2, p. 100) and entered into force on 7 April 1948.
[8] Guidelines for Community Noise. Ed. by Birgitta Berglund, Thomas Lindvall, Dietrich H. Schwela. WHO 1999. (http://www.who.int/docstore/peh/noise/guidelines2.html)



are exposed to noise levels considered unacceptable because they lead to sleep disturbance and/or other adverse health effects[9].

It has also been estimated that a further 170 million people live in so called "grey areas" where noise causes serious annoyance. The economic cost of noise to society is estimated as being between 0.2 and 2 percent of the gross domestic product[10]. Taking the lower estimate, this implies an annual financial loss due to environmental noise of more than 12 billion Euro.

2.2. Milestones in European Noise Policy

Transportation is the main contributor to environmental noise pollution. At the European level, the first measures taken against noise were legislative emission limits stipulating maximum sound levels for different road transport vehicle types. One of the most important noise-related Directives, Directive 70/157/EEC limiting the noise emission from road vehicles, dates back more than thirty years. Although the noise emission limits have subsequently been lowered in several stages by 8 dBA (for cars) to 11 dBA (for buses and trucks), the noise exposure of the public resulting from road transport has hardly changed. A significant improvement has been observed only in the case of medium-sized and heavy-duty goods vehicles and local public transport buses. In the case of cars, noise emissions in real traffic have become slightly lower only during starting and acceleration phases, and there has actually been a slight increase in noise emissions in free-flowing traffic. The main reasons for this situation are:

- The operating conditions of the type approval test method are not representative for real world driving[11]
- Changes in the type approval test method compensated or counteracted limit reductions
- Trends towards higher engine powers and wider tyres
- The traffic volume (number of vehicles-kilometres) increased significantly during the last decades. As the length of the roads increased less, the average intensity (number of vehicles per hour) increased. In the last few years, this increase concentrated on the night time.

Two examples illustrate this situation. Investigations of noise emission in real traffic showed that cars with type approval value of 72 dBA were in practice only about 2 dBA quieter than cars with an 8 dBA higher type approval value, even during starting and acceleration[12].

[9] Jacques Lambert: Report on Noise Exposure of the Population, Health Risks and Social Welfare Costs. Conference "Noise in Europe", Paris, Dec. 2000.
[10] Green Paper of the European Commission: Future Noise Policy. COM(96) 540 final, 1996.
[11] Ulf Sandberg: Noise Emissions of Road Vehicles - Effect of Regulations. I-INCE Report, July 2001.
[12] Heinz Steven: Investigations on Improving the Method of Noise Measurement for Powered Vehicles. UBA-Report 105 06 068, Dec. 1998.

"The Green Paper of 1996 marked a milestone in the European noise policy: the consideration of noise perception aspects and an EU-wide harmonised approach."

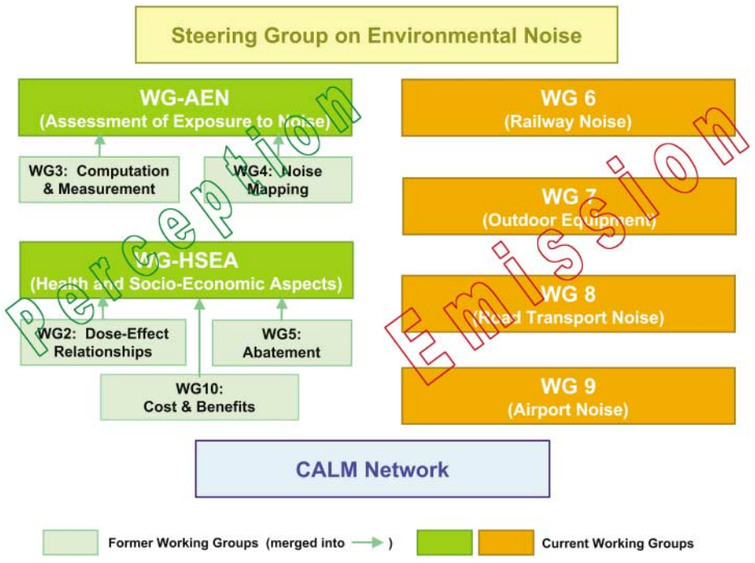
The trend to cars with a five-speed gearbox instead of four-speed gearbox resulted (on average) in 1.8 dBA lower type approval levels, because four-speed vehicles are measured in second gear only, while five-speed vehicles are tested in second and third gear.

Only recently the EU started to regulate noise emissions from rail transport with the first emission limit enforced for interoperable high speed train systems in December 2002. For aircrafts there are European regulations mainly based on standards elaborated at the international level of the ICAO.

The **1993 Fifth Environmental Action Programme**[13] included noise abatement targets to be achieved by the year 2000. When this programme was reviewed in 1995 the Commission announced the introduction of a noise abatement programme, the first stage of which was the **1996 Green Paper on Future Noise Policy**[10]. A conclusion of this paper was that a more harmonised approach to noise control was required among member states which led to "a proposal for a Directive providing for the harmonisation of methods of assessment of noise exposure and the mutual exchange of information. The proposal could include recommendations for noise mapping and provision of information on noise exposure to the public. In a second stage consideration could be given to the establishment of target values and the obligation to take action to reach the targets." This step marked a particular milestone in the development of EU noise policy, as it changed the focus from just emission-related noise control measures to include the harmonised assessment and control of noise at the perception side ("reception" or "immissions") and the presentation of information on these immissions to the public.

A Steering Group on environmental noise and a number of expert working groups were established to support the Commission in the development of the proposed framework Directive on Environmental Noise. Most of the working groups started their preparatory work for the new Directive at the **Copenhagen Conference** on Future Noise Policy in Europe in September 1998. Five working groups dealt with aspects of noise related to propagation and human exposure, such as indicators, dose/effects, computation and measurement, noise mapping and abatement. Other groups dealt with emission related aspects of rail, road and air transport and outdoor equipment. Also one group dealt with costs and benefit issues. The research working group complemented the other groups with the definition of research requirements and priorities.

In the autumn of 2001 the terms of reference of the working groups were reviewed with particular regard to the impending new Directive. The working group on indicators had already completed its task and was dissolved. The working groups on dose/effects, abatement and costs and benefits were merged into a new working group called "Health and socio-economic aspects". The groups on computation and measurement and noise mapping were combined to form the new group "Assessment of exposure to noise". The research working group was replaced by the CALM network, whose purpose is to establish a community noise research strategy plan in order to ensure co-ordinated and efficient noise research within Europe. Thus, the CALM network, the Steering Group on environmental noise and the new working groups form a EU network of noise experts.



The EU Noise Expert Network

[13] Fifth Environmental Action Programme of the European Communities: Towards Sustainability. OJ C 138, 17.5.1993, p.5.

2.3. The European Noise Legislation

2.3.1. The Directive on Environmental Noise

The Directive relating to the Assessment and Management of Environmental Noise[14], often referred to as the Environmental Noise Directive (END), aims at protecting the health and well-being of the population against harmful effects of environmental noise pollution. As such it contributes to the objectives of the EU Treaty, Article 174. Achievement of these aims is the shared responsibility of the EU and the Member States, since some aspects are best covered at EU level, and others at national and local level.

The Directive's main objectives are:

- **Monitoring the environmental noise situation** - by requiring competent authorities in member states to establish strategic noise maps for agglomerations, major roads, major railway lines and major airports, using the harmonised noise indicators L_{den} (day-evening-night equivalent level) and L_{night} (night equivalent level). These noise maps are to be used for the global assessment of noise exposure in a given area due to different noise sources.
- **Informing and consulting the public** about noise exposure, its effects and the measures considered to address noise, in line with the principles of the Aarhus Convention[15].
- **Addressing local noise issues** by requiring competent authorities to establish action plans to reduce noise where necessary and maintain environmental noise quality where it is good. The Directive does not set any limit, nor does it prescribe the measures to be used in action plans. Both of the issues remain at the discretion of the competent authorities.
- **Developing a long-term EU strategy** which includes objectives to reduce the number of people affected by noise in the longer term, and provides a framework for developing existing Community policy on noise reduction from source.

The Directive consists of a main body and six supporting technical annexes (see below), which reflect the large research effort leading up to the Directive. The technical content is based on the findings of the expert working groups that were specially created for this purpose. Despite some intensive work several of the technical annexes are expressed only in preliminary terms as opposed to final texts, since some complementary information has still to be derived from further investigations and research.

Annex I: Noise indicators
Annex II: Assessment methods for the noise indicators
Annex III: Assessment methods for harmful effects
Annex IV: Minimum requirements for strategic noise mapping
Annex V: Minimum requirements for action plans
Annex VI: Data to be sent to the Commission

The Commission published the Recommendation 2003/613/EC of 6 Aug. 2003 concerning guidelines on revised interim computation methods. The competent authorities in the Member States have to provide strategic noise maps for agglomerations (more than 100 000 inhabitants), major roads (more than 3 million vehicle passages per year), major railways (more than 30 000 train passages per year) and major airports (more than 50 000 movements per year) every five years, starting with five years after the Directive has entered into force[16]. The corresponding action plans must be made available by the competent authorities every one year after completion of the noise maps.

2.3.2. Directives on Noise Emissions

The regulatory focus in the past has been on the limitation of noise emissions of the most important means of transport and equipment for use outdoors. The first regulation with EU-wide application was the Directive on noise emission from motor vehicles and dates back to 1970. Further important noise Directives followed[17]:

- 70/157/EEC Motor vehicles
- 80/51/EEC Subsonic aircraft
- 86/594/EEC Household appliances
- 89/629/EEC Subsonic jet aeroplanes
- 92/14/EEC Limitation of the operations of aeroplanes
- 96/48/EC Interoperability of the Trans-European high-speed rail system:
  - Technical Specification for Interoperability (TSI) relating to high-speed rolling stock - Commission Decision 2002/735/EC
  - TSI relating to high-speed railway infrastructures-Commission Decision 2002/732/EC (limits not yet enforced)
- 97/24/EC Motorcycles
- 2000/14/EC Outdoor equipment
- 2001/16/EC Interoperability of the conventional Trans-European rail system:
  - Commission Decision 2004/446/EC specifying the basic parameters of the 'Noise', 'Freight Wagons' and 'Telematic Application for Freight' Technical Specifications for Interoperability

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"Promoting research in noise control at source encourages the development and introduction of the best available technologies."

- 2001/43/EC Tyres for motor vehicles and their trailers and their fitting
- 2002/30/EC Operating restrictions at community airports
- 2003/44/EC Recreational craft

Between 1979 and 1986, many Directives have been adopted to limit noise emission from equipment used outdoors such as construction machinery, compressors, generators, garden machinery etc. As the environmental situation and the technical features of such equipment changed over the years, adaptation to the new conditions became necessary. Therefore, the Directives have been revised and consolidated into a single new Directive, 2000/14/EC, which covers some 60 different types of outdoor equipment. It either sets limits for noise emission or specifies the marking of sound power levels as information for the customer.

Legislation at EU level governing noise emission has, in general, a high importance. It links noise reduction measures to the source of the noise and its effects are therefore global rather than local. In following the polluter pays principle, it encourages the development and introduction of the best available technology.

[14] European Directive 2002/49/EC of 25 June 2002 relating to the Assessment and Management of Environmental Noise. OJ L 189, 18.07.2002, p. 12. See also: http://www.europa.eu.int/comm/environment/noise/
[15] United Nations Economic Commission for Europe (UNECE) Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters, adopted in Aarhus on 25 June 1998, entered into force on 30 Oct. 2001. See also: http://www.europa.eu.int/comm/environment/aarhus/
[16] In the first step of 2007, strategic noise maps are required only for agglomeration with more than 250 000 inhabitants, major roads with more than six million vehicle passages per year, major railways with more than 60 000 passages per year and airports with more than 50 000 movements per year.
[17] Commission Report COM(2004)160 of 10 March 2004 on Existing Community Measures relating to Sources of Environmental Noise.

3. The Vision: Less Noise by 2020

Past noise policy in Europe has been concentrated on the regulation of noise emission from such substantial noise sources as road vehicles and outdoor machinery. Although noise emission limits have become increasingly stringent over the years, no corresponding reduction in noise immission in noise sensitive areas has been observed. On the contrary, the number of noise-exposed persons may be increasing.

In response to this unsatisfactory situation, European noise policy has been revised to focus on noise reception. Therefore, based on the Fifth Environmental Action Programme[13], the Green Paper of 1996 defines as the aim of future noise policy that "no person should be exposed to noise levels which endanger health and quality of life"[18].

Although the targets in relation to this objective have been set only up to the year 2000[13], the aim continues to be valid and has been adopted as a long-term vision. The proposed vision for the development of noise policy up until 2020 is:

... to avoid harmful effects of noise exposure from all sources and to preserve quiet areas.

This vision is in accordance with the political target of the Sixth Environment Action Programme for the period up until 2010[19].

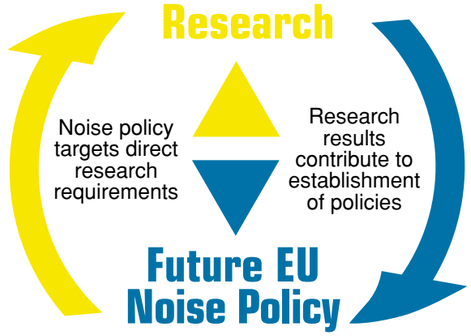
"A strong vision for 2020: no harmful effects of noise exposure."

[18] Green Paper of the European Commission: Future Noise Policy. Annex I. COM(96) 540 final, 1996.
[19] Decision No 1600/2002/EC of 22 July 2002 laying down the Sixth Community Environment Action Programme, OJ L 242, 10.9.2002, p.1. Art. 7: "...substantially reducing the number of people regularly affected by long-term average levels of noise, in particular from traffic which, according to scientific studies, cause detrimental effects on human health..."
[20] Volker K. P. Irmer: Do We Need a Global Noise Policy? Internoise 2004, Prague, 22 - 25 Aug. 2004.

4. Noise Policy and Research

4.1. The Need for Research

There can be no progress in noise policy without research. The vision has to be translated into specific targets and into time frames for the achievement of these targets. In many cases, the achievement of targets is dependent on new technological approaches, which must come from research initiatives. However, research is not only needed to turn regulations into practice but in many cases, initial research is needed in order to design and establish sensible regulations. Thus, research and regulation policy constitute an interactive loop.



"The first aim is to avoid or reduce noise at its source."

4.2. Key Elements of EU Noise Policy

The overriding aim of current noise policy is to reduce the noise exposure of people in order to avoid adverse effects. Thereby, the policy has to consider some general principles which exist both at a technical level and at a legal level[20].

The **technical principles** refer to the management and reduction of noise emission and exposure and have a clear ranking.

1. To avoid and reduce noise at its source (noise which is not generated cannot lead to noise exposure).
2. To reduce noise in its propagation (measures as close to the source as possible should be preferred, because such measures protect the highest number of people).
3. To reduce noise at the receiver (these measures should only be used if other measures are ineffective).

The **legal principles** are related to noise management, other environmental issues and sustainability.

- The polluter pays principle: persons or institutions that pollute the environment have to pay for measures to avoid or reduce the pollution or they have to pay for the harm caused by the pollution.
- The precautionary principle: in order to avoid or reduce pollution and to minimise environmental risks due to pollution, the emission of pollutants has to be avoided or reduced (using "best available technology").
- The principle of cooperation: protection of the environment is a common challenge for the citizens, the government, the industry and all other parties involved.
- The principle of subsidiarity and shared responsibility: ensuring that decisions are made at a level that is as close as possible to the citizen, and that constant checks are carried out as to whether action at Community level is justified in view of the possibilities at national, regional or local level.

Following these principles, the European Union has developed a comprehensive policy on environmental noise which is based on the two fundamentals "emission related legislation" and "Environmental Noise Directive" (END). The END defines the three key elements for future noise policy that constitute a standard approach to the management of environmental noise:

- Harmonised assessment of environmental noise
- Information and participation of the public
- Appropriate actions

The basis for the **assessment of environmental noise** are strategic noise maps, which are to be established with common noise indicators and methods. The common indicators to be used EU-wide are already available. They have been determined and defined by an expert working group[21]. However, currently there are no common methods (either measurement or computation methods) available to determine the sound levels in these indicators. The EC funded projects Harmonoise[22] and Imagine[23] are designed to provide such harmonised (common) methods for use after the first round of strategic mapping.
A limited number of dose-effect relationships is currently available[24] or under preparation[25] to assess the effects of noise on the population (such as annoyance, sleep disturbance etc.) in a reliable way. Such methods and relationships are to be introduced into the END at a later stage, following complementary research.

On the basis of the assessment provided by the strategic noise maps, competent authorities must draw up **action plans** to reduce noise where it is necessary, to maintain environmental noise quality where it is good and to protect quiet areas in agglomerations. The Directive does not set any limit value, nor does it prescribe the measures to be used in the action plans, which remain at the discretion of the competent authorities. Typical examples of actions might include:

- Traffic planning (including redirection of traffic, shifts between transport modes e.g. from road to rail transport or from car to bikes)
- Land-use planning
- Technical measures at noise sources (including road surfaces and railway tracks)
- Selection of quieter sources / products
- Reduction of sound propagation (noise barriers, tunnels, insulation of dwellings, etc.)

Although the END does not prescribe any measures to be used in action plans, the Commission may publish guidelines for the development of action plans. Further support for action plans will come from the continuing development of EU noise regulations relating to noise emitters (mainly road, rail and air transport and outdoor equipment) and possibly from Position Papers published by the Commission.

Information and participation of the public will comprise of noise maps and action plans. This information will be provided by member states. The Commission will establish an information database of noise maps (or noise mapping data) and publish summary reports on noise maps and action plans every five years.

These key elements of EU noise policy must form the basis of the strategies for future noise research and innovation.

[21] Position Paper of WG 1 (Indicators) on "EU Noise Indicators". 27 Aug. 1999.
[22] EU-Project HARMONOISE "Harmonised Accurate and Reliable Prediction Methods for the EU Directive on the Assessment and Management of Environmental Noise". www.harmonoise.org.
[23] EU-Project IMAGINE "Improved Methods for the Assessment of the Generic Impact of Noise in the Environment". www.imagine-project.org.
[24] Position Paper of WG 2 (Dose-Effect) on "Dose response relationships between transportation noise and annoyance". Luxembourg, Official publications of the European Communities, 20 Feb. 2002 (ISBN: 92-894-3894-0).
[25] H.M.E. Miedema, W. Passchier-Vermeer, H. Vos: Elements for a Position Paper on Night-Time Transportation Noise and Sleep Disturbance. TNO Inro Report 2002-59, Jan. 2003. (http://www.europa.eu.int/comm/environment/noise/noisesleepdisturbance.pdf)

5. Strategy for Noise Research

5.1. Strategic Priorities

The fundamental goals of any future research are to:

- Provide answers to open questions
- Find solutions for substantial problems
- Supply missing data

These fundamental goals have to be transformed to the requirements of the current and future noise policy. Bearing in mind the vision for 2020 and the need for increased efficiency of noise mitigation in Europe, the strategy for noise research focuses on supporting the European noise policy via its two cornerstones: the Environmental Noise Directive with its three elements assessment, information and actions which are closely related to the noise perception, and the emission-related legislation for controlling noise at source. This leads to the two following strategic research areas which have the same high priority level:

- **Perception-Related Research**
  This area comprises, in particular, research on the assessment of exposure to noise, health effects and socio-economic aspects. The main aim of this research area is to support directly the transposition of the Environmental Noise Directive. Therefore, it refers first of all to the need expressed in the END to adapt the annexes I, II and III of the END according to the technical and scientific progress.

- **Emission-Related Research**
  This area includes the two following research issues:
  - Research which is required to further develop source-related and transmission-related noise control technologies with a special focus on the noise emission from transportation (road, rail and air traffic) and outdoor equipment.
  - Research related to the further development of emission-related noise legislation.

5.2. Perception-Related Research

The Environmental Noise Directive has six technical annexes. For adoption by the European Parliament and Council in 2002, preliminary texts for the following annexes had been included in the Directive because of a lack of relevant information and research results:

• Annex I (point 3):	Special indicators
• Annex II:	Assessment methods (computation and measurement)
• Annex III:	Harmful effects (dose-effect relationships)

These annexes which, in particular, are related to noise perception, need to be adapted on the basis of new research results. Progress has been made in adapting the annexes[26]. However, there is still a clear need for research to achieve further improvements of the annexes and to support the transposition of the END. In addition, knowledge on specific subjects have to be acquired by research in order to further increase the efficiency of the EU noise policy and to continue its further development. This leads to the following research needs.

- **Advanced computation and measurement methods for more accurate assessment of noise exposure**
  - *Advanced source modelling of aircraft noise*
  - *Propagation modelling for noise at lower levels*
  - *Availability and quality of noise mapping input data including both geographical and source related data considering also digital data sources such as geographical information systems (GIS)*
  - *Methods using noise mapping data to estimate population exposure to environmental noise (linking noise mapping data with population location data i.e. number and location of exposed people)*

  All these items to be investigated are essential for increasing the accuracy and completeness of results and speeding up the assessment processes.

- **Definition and identification of urban and rural quiet areas**
  - *Identification of most appropriate indicators and limit values*
  - *Parameters influencing public's perception of quiet areas*

  Appropriate indicators and limit values are needed to define and delimit quiet areas and to determine the public response to noise exposure in quiet areas. Other influencing parameters have to be considered thereby.

"Information about environmental noise assessment and action plans will increase public awareness concerning noise."

[26]
- Commission Recommendation 2003/613/EC of 6 Aug. 2003 concerning the Guidelines on the Revised Interim Computation Methods for Industrial Noise, Aircraft Noise, Road Traffic Noise and Railway Noise, and Related Emission Data. OJ L 212, 22.8.2003, p. 49.
- Good Practice Guide for Strategic Noise Mapping and the Production of Associated Data on Noise Exposure. Position Paper of WG-AEN, Version 1, 5 Dec. 2003.
- EU-Project HARMONOISE "Harmonised Accurate and Reliable Prediction Methods for the EU Directive on the Assessment and Management of Environmental Noise". www.harmonoise.org.
- EU-Project IMAGINE "Improved Methods for the Assessment of the Generic Impact of Noise in the Environment". www.imagine-project.org.

- **Improvements in dose-effect relationships for L_{den} and L_{night}**
  - *Improved relationships (especially with L_{night}) for aircraft noise*
  - *Sleep disturbance (awakening) due to road and railway noise*
  - *Effects of the degree of facade insulation and of a quiet side of the building*
  - *Effects of noise management measures on people's perception (reaction on changes of exposure situations)*
  - *Effects of multiple noise sources (combined effects)*
  - *Influence of cultural differences between countries including the effects of different patterns of social behaviour*

  As annoyance is widely considered to be the main effect of environmental noise, a reliable transformation of dose data into annoyance data is of high importance. Current dose-effect relationships for aircraft noise are based on older data which do not represent the status of present aircraft fleets. At present, it is not clear if and how this relates to the current dose-effect relationships. This is also true for some cases of railway noise like high speed trains. These and the other topics described above have an influence on the confidence interval of the dose-effect relationships.

- **Additional noise indicators considering specific effects**
  - *Effect of low frequency noise and vibration*
  - *Effect of L_{max}*
  - *Effect of low number of noise events (determination of interval in number of events over which L_{den} and L_{night} is valid)*
  - *Effect of quiet periods*

  There are indications that the above specific properties have significant influence on the noise perception, but are not sufficiently described and represented by the common indicators L_{den} and L_{night}. Research in these fields shall also lead to specific dose-effect relationships such as for low frequency noise, L_{max} and infrequent events. The occurrence of quiet periods may provide considerable benefits.

- **Advanced methods of cost-benefit assessment**
  - *Improvement of benefit estimations based on SP (stated preference) method including valuation for quiet and undisturbed sleep*
  - *Improved benefit estimates based on HP (hedonic price) method*
  - *Improved benefit estimates due to changes in model-split (e.g. from car transport to cycling)*

  Cost-benefit analyses (CBA) are important elements for establishing action plans. Further development of the two most common methods is required to reduce uncertainties and to provide more accurate estimates.

"Improved computation methods will enable more accurate assessment of exposure to noise."

- **Combined effects between air pollution and noise (especially for road traffic)**
  There is evidence that living close to major roads is associated with adverse health effects (respiratory and cardiovascular effects). It is assumed that air pollution is an important source for these adverse effects, but the influence of environmental noise on cardiovascular functions cannot be excluded in these situations. In order to disentangle the role of concomitant environmental stressors, interdisciplinary research is required.

- **Improvement and extension of noise valuation method**
  - *Extension of method towards differentiating between different transport modes (road, rail, air)*
  - *Influence of the initial sound level on the valuation of noise reduction*
  - *Methods for the valuation of health impacts and other impacts of noise reduction*

  For valuation of noise reduction, a value of 25 EURO per household/decibel/year is recommended[27]. However, this value was developed only for road transport noise reduction and does not consider the influence of the initial sound level, the health impacts and other impacts of noise reduction measures like the effects on local air quality, the emission of greenhouse gases, traffic safety etc.

- **Improved or new socio-economic instruments to promote efficient noise abatement**
  Efficient instruments are required to direct consumers towards quieter products and quieter behaviour (based on positive or negative incentives related to the use of noisy devices, to the extent of noise nuisance or to the cost caused by the noise impact to the society). Further need is given for optimisation of the work split between different levels of noise abatement systems (local, regional, national, EC, international) depending on the abatement system to increase the efficiency of such split work and action plans.

"Research support for the stakeholders means quieter products and strengthened competitiveness in the market."

5.3. Emission-Related Research

Research on topics that are related to noise emission and transmission must follow two strategic directions. One direction is to provide support for the **further development of emission-related regulation**. The other direction is to provide support for the development of **new technologies and solutions** for the reduction of noise emission and transmission to an extent which cannot be achieved by existing technologies, but which is required to comply with the future regulation and market requirements. This includes also the technological development of solutions towards higher cost efficiency.
Following the first technical principle and most of the legal principles of noise mitigation as outlined in section 4.2, research and technological development in the fields of noise control at the source play an important role in the noise policy and research strategy. Promoting research in noise control at source automatically means research support for the stakeholders in the development of new technologies to make their products quieter which strengthens their competitiveness on the international market. The production of quieter products should provide not only reduced sound levels, but also, and most importantly, the reduction of perceived noise annoyance and adverse health effects.

The research requirements have to be focused on the main components of environmental noise which are the four noise categories of:

- Road traffic noise
- Railway noise
- Air traffic noise
- Noise from outdoor equipment

In future, the traffic volumes for the different transport modes will significantly increase which inevitably means an increase in the number of noise sources and an increase in noise emission. Based on the situation in 1998, road traffic is likely to increase by 20 % in passenger transport and 40 % in goods transport by 2010. For the railway sector, the political target is a doubling of passenger and trebling of freight traffic by 2020. Furthermore, with regards to air traffic, a doubling of passenger transport is predicted by 2020. This means that in setting targets for future noise research the increase of future noise emission due to increased traffic volumes has to be considered. It also means that the new noise reduction technologies also have to account for this volume-related traffic noise increase.

[27] Position Paper of WG-HSEA on "Valuation of Noise", 21 March 2003.
[28] Michael Jaecker-Cueppers: Quieter Roads and Rails in Europe: a Vision for 2030. CALM Workshop with Stakeholders, Brussels, 18 - 19 March 2002.

"The research targets of the different noise categories shall be harmonised on the basis of a broad acceptance by the related stakeholders."

5.3.1. Research Targets

Independent of the noise category considered, planning of research and technological development in the field of noise control at source shall be combined with research targets which identify necessary reductions of noise emission and achievable or expected reduction potentials. Currently, such research targets are defined for each noise category, but usually in different ways. It would be desirable to harmonise research targets between the noise categories in terms of noise descriptors, test methods and reference basis including a broad acceptance by the related stakeholders and taking into account the different annoyance from the various noise sources. Attempts towards harmonising targets have been made in the past[28], but agreement could not be achieved. The research targets are defined individually for each noise category also in this Strategy Paper.

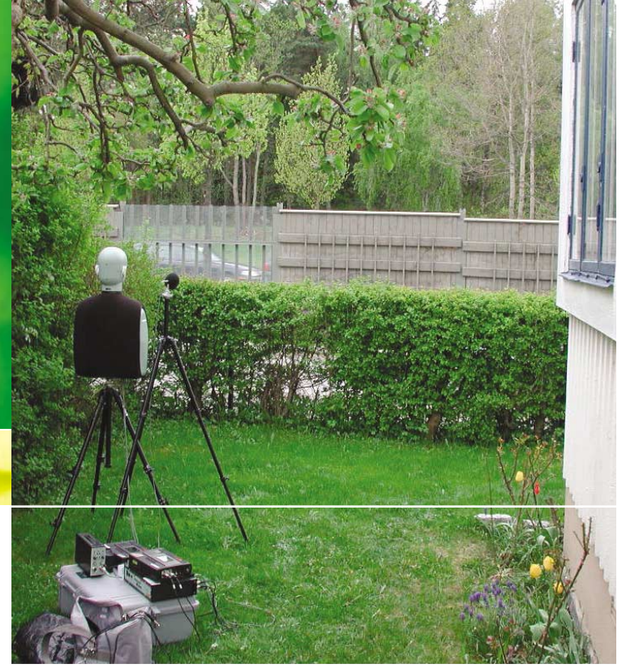
5.3.2. Road Traffic Noise

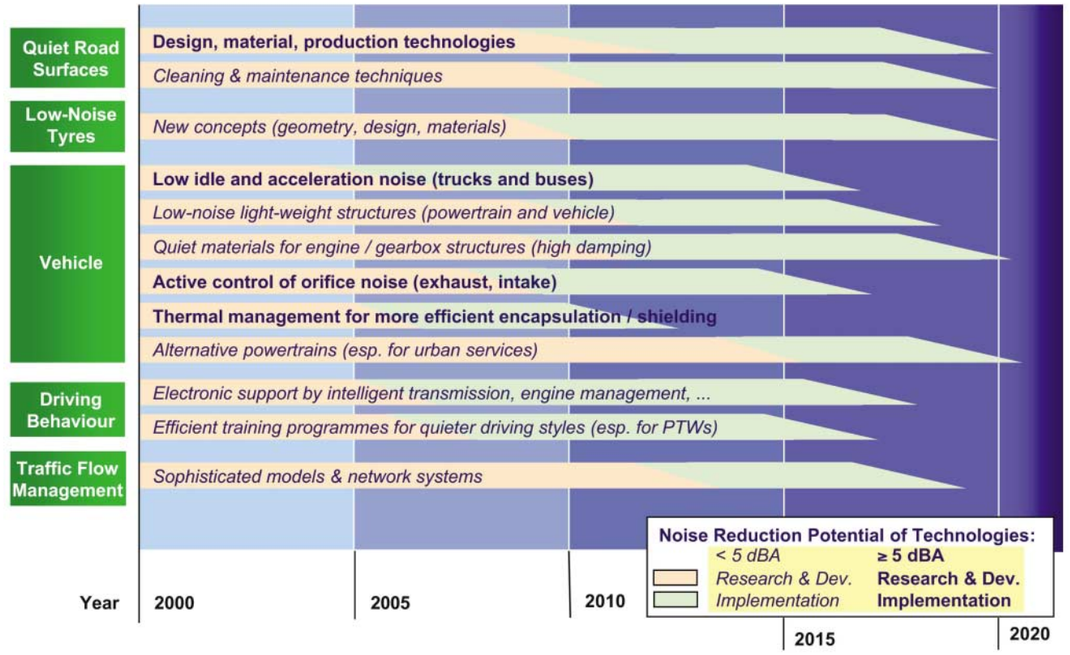
The noise reduction targets for the noise emission from road traffic extend up to 10 dBA[29]. This kind of target typically in terms of L_{eq}, refers to the real traffic situation so that the whole variety of noise control measures for real traffic (like low noise road surface, low noise tyres, vehicle, traffic management, driving behaviour etc.) is to be considered. This situation is reflected in the main noise research topics and the related noise technology road map.

The road map presents the major research topics with optional splits into sub-topics (noise reduction technologies) and estimated reduction potential per sub-topic at two levels (< 5 dBA or ≥ 5 dBA indicated by italic and bold characters respectively). These noise reduction potentials refer to noise reduction at the source and do not reflect the sub-topic's contribution to environmental noise. The road map also includes estimated time scales for the research and implementation phase of each sub-topic. The inclined transitions of the time bars are to give some indication of uncertainties of the time scale estimates. The road map for road transport is based on several CALM workshops and a dedicated study[30].

For the achievement of the above targets, research leading to a more thorough knowledge and new technologies (including also new system approaches) is required for the following primary issues relating to road transport noise:

"Rolling noise is predominant in many road traffic situations and currently limiting further significant progress in noise reduction."





Noise Technology Road Map for Road Transport

- **Rolling noise** (consisting of the two elements 'tyres' and 'road surface'):
  - *Better understanding of road-tyre interaction for improved simulation tools with increased accuracy*
  - *New concepts for low-noise tyres (geometry, design, material, matching to road surfaces)*
  - *New concepts for low-noise road surfaces (design, material, production technologies)*
  - *Cleaning and maintenance techniques for low-noise road surfaces (cleaning techniques, winter maintenance, renewal techniques)*

  Rolling noise is the predominant noise contributor in many traffic situations and this limits further significant progress in noise reduction. A deeper understanding of the interaction between the tyre and road surface is necessary to progress, especially in rolling noise modelling. New concepts for low-noise tyres and road surfaces have to be established based on models with increased accuracy (without jeopardising safety relevant features). For road surfaces, solutions are required for new production technologies as well as cleaning and maintenance techniques for open porous surfaces to achieve sustainable noise reduction.

- **Vehicle noise** (also called propulsion noise consisting of engine, transmission and exhaust noise)
  - *Acceleration noise*
  - *Cold start low idle noise of diesel powered vehicles*
  - *Quiet structures of powertrain and vehicle (low-noise design of light-weight structures, high damping in engine and gearbox structures)*
  - *Active control of orifice noise (intake, exhaust)*
  - *Thermal management concepts for improved encapsulation of powertrain*
  - *Alternative powertrains (especially for urban services)*

  Particularly in urban traffic, diesel powered vehicles are noisy and annoying at (cold) low idle and under acceleration (starts at traffic lights, especially of trucks and buses) requiring innovative solutions for quiet, clean and fuel-saving combustion systems. Light-weight vehicle structures are increasingly used for reasons of fuel-saving and lower exhaust emission, but they may sometimes be disadvantageous for the vehicle acoustics and require dedicated solutions. Further promising aspects for the future are new materials with enhanced damping properties, advanced thermal management for more efficient encapsulation, production of efficient systems for active noise control of intake and exhaust noise, and alternative propulsion systems preferably used for low or zero exhaust emission operation in urban areas. A further topic of importance is the efficient control of low frequency vibration from commercial vehicles which can cause considerable disturbance in urban environments.

[29] Derived from UBA Workshop "Further noise reduction for motorised road vehicles", Berlin, 17 - 18 Sep. 2001, and CALM Workshop with Stakeholders, Brussels, 18 - 19 March 2002.

[30] Study on the Time Scales for Availability and Implementation of New Future Key Technologies for the Reduction of Road Traffic Noise in the EU. IKA-Report 33290, Sep. 2003. (www.calm-network.com).

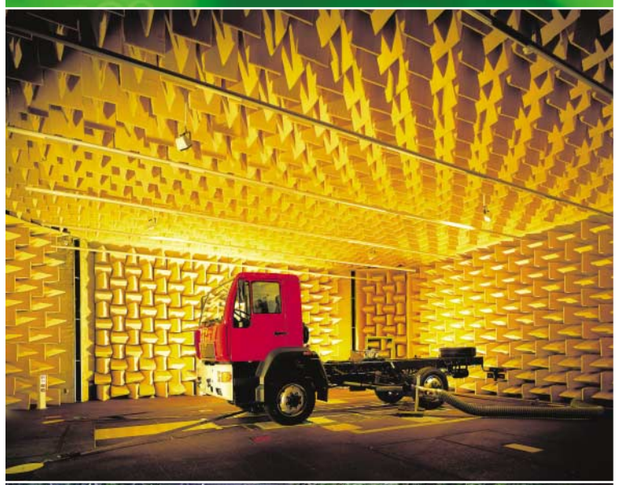
“Emission-related legislation must be better adapted to the real world for more efficient noise reduction.”

“The first aim of railway noise research are ‘smooth wheels on smooth rails’.”

- **Driving behaviour** (driver assistance systems)
  Systems are needed which support and promote low-noise driving styles e.g. by engine management, intelligent transmissions and electronic driver assistance systems. In the specific field of powered two-wheelers (PTWs), the driving style and the manipulation of the engine and exhaust system have a big impact on the noise emission[31] so that investigations towards efficient training and control programmes for quieter driving of PTWs are needed.

- **Traffic management**
  More sophisticated systems for traffic management are required to reduce noise emission, particularly with regard to preventing congestion and improving safety.

- **Improved regulations related to noise emission** (including test methods)
  The methods for legislative noise emission testing of road vehicles are based on operating conditions which are not sufficiently representative for the typical conditions in real situations. Better adaptation to the real situations is required to make the noise emission limitation a more effective and efficient tool for contributing to environmental noise reduction by noise control at the source. For the development of new regulations (e.g. for road surfaces), a comprehensive and reliable data base is required which must be derived from adequately resourced research.

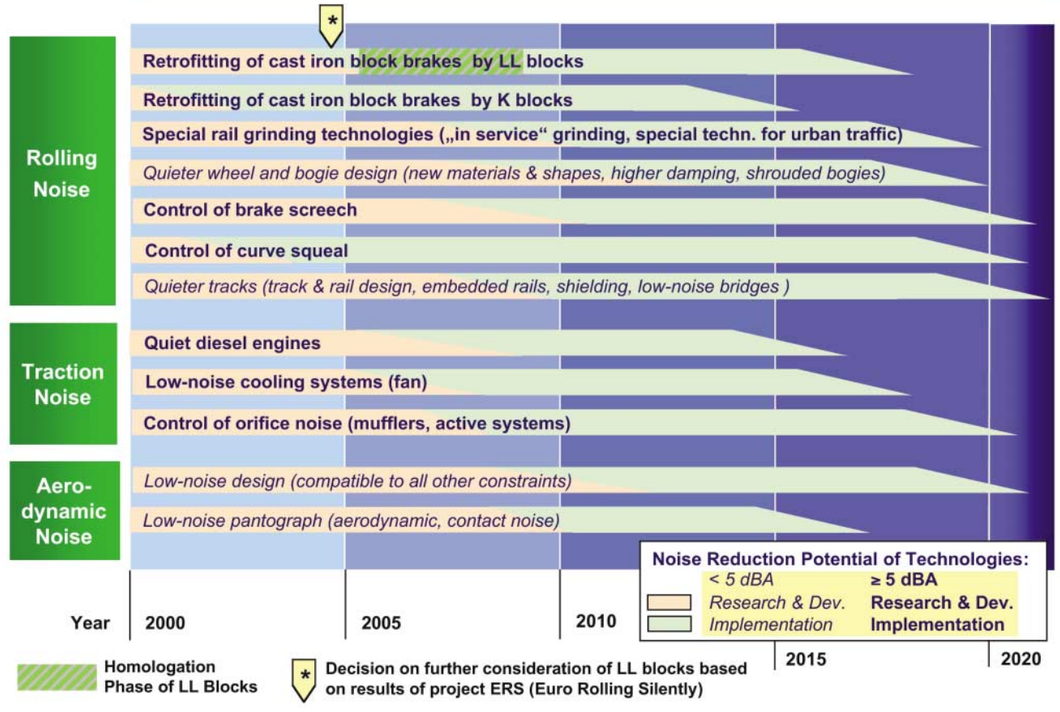


5.3.3. Railway Noise

For rail traffic, the targets for noise reduction at source extend up to 20 dBA for freight trains[32] and 5 dBA for high speed trains[33].
For the achievement of the above targets, research leading to a more thorough knowledge of existing systems and new technologies (including also new system approaches) is required for the following primary issues relating to railway noise[34]:

- **Rolling noise** (mainly for freight trains, arising from wheel and rail roughness caused by cast iron block brakes)
  - *Retrofitting technologies for cast iron block brakes (composite braking shoes for cost-neutral retrofitting)*
  - *Rail grinding technologies (especially “in service” grinding)*
  - *Quieter wheel and bogie design (new materials and shapes, higher damping, shrouded bogies)*
  - *Control of curve squeal and brake screech*
  - *Quieter tracks (track and rail design, embedded rails, shielding, low-noise bridges)*

Increased roughness of wheels and rails caused by cast iron block brakes resulting in increased rolling noise especially from freight trains is currently the predominant contribution to railway noise. Therefore, because of the high reduction target of up to 20 dBA for freight wagons, research and noise reduction technologies, first of all technologies for cost-neutral retrofitting of cast iron braking shoes, must have top priority. So-called “K-block” composite braking shoes are already homologated, but require costly adaptations when retrofitted. Current research in the cost-neutral composite “LL-block” solutions is yet to be completed and evaluated. In parallel with retrofitting, rail grinding



Noise Technology Road Map for Railway Transport[35]

[31] ACEM Report: Striving against Traffic Noise - How Powered Two-Wheelers can contribute. 2004.
[32] 2nd International Workshop "Abatement of Railway Noise Emissions - Freight Transport”, Berlin, 4 - 5 March 1998.
[33] CALM Workshop with Stakeholders, Brussels, 18 - 19 March 2002.
[34] See also: Position Paper of WG 6 (Railway Noise) on the “European Strategies and Priorities for Railway Noise Abatement”, 2003, and Technical Annex of the Strategic Rail Research Agenda 2020 of ERRAC (European Rail Research Advisory Council), Sep. 2002.
[35] The road map presents the major research topics with optional splits into sub-topics (noise reduction technologies) and estimated reduction potential per sub-topic at two levels (< 5 dBA or ≥ 5 dBA indicated by italic and bold characters respectively). These noise reduction potentials refer to noise reduction at the source and do not reflect the sub-topic’s contribution to environmental noise. The road map includes also estimated time scales for the research and implementation phase for each sub-topic. The inclined transitions of the time bars are to give some indication of uncertainties of the time scale estimates.

is as important ("smooth wheels on smooth rails"). New rail grinding technologies and procedures shall consider higher grinding quality, optimisation of grinding intervals, roughness monitoring and in-service grinding. In addition, basic research is required for a better understanding of the generation, growth and control of rail roughness.

Although curve squeal and brake screech are rather local noise issues, they can also lead to high (local) annoyance for short durations of time. For efficient solutions a better understanding of the wheel-rail contact including the interaction of different parameters is required. There is also a need for more accurate modelling.

Further advances in control of railway rolling noise at the source aims at innovative low-noise, low-cost and low-wear solutions (design, materials, damping) considering all components of the rail-wheel interaction (wheels and bogies, rails and rail support structures). Due to the deterioration of the rail and wheel running surfaces with service time, technologies and procedures to maintain low roughness levels are of high importance.

- **Traction noise** (including auxiliary systems)
  - *Quiet diesel engines*
  - *Low-noise cooling systems (especially fan noise)*
  - *Control of orifice noise (mufflers, active control systems)*

  Engines of diesel locomotives can be a significant source of pass-by noise. Transfer of automotive diesel engine technologies is needed including the adaptation to the specific railway requirements. The control of cooling system noise, in particular fan noise, requires advanced solutions which may be also based on technologies in the fields of automotive and construction equipment. Further reduction of orifice noise arising from diesel engines and cooling systems requires the increased acoustic performance of mufflers (considering the spatial and other boundary conditions) and advances in active control systems, in particular for covering broader frequency ranges.

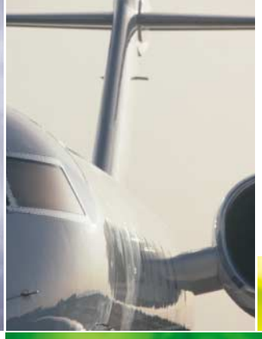
- **Aerodynamic noise** (from high speed trains)
  - *Low-noise design*
  - *Low-noise pantographs (airflow noise, contact noise)*

  In future, high speed trains need to be more streamlined and optimised in aeroacoustics. This requires improved and powerful simulation models for the airflow and the associated noise generating mechanisms. New solutions must be, of course, compatible with all other constraints, first of all with safety constraints. Pantograph noise is a special challenge at high speeds requiring sophisticated approaches for controlling both aerodynamic noise and contact noise.

- **Monitoring and type testing techniques** for noise emission

  Railway noise can be additionally controlled by traffic management. Monitoring of noise emission levels on a real-time basis is needed to include noise into traffic management systems.

  In future, more sophisticated type testing methods (including more rigid specifications of track conditions) are required for low-noise vehicle identification (e.g. incentives) and for better separation of the noise emission contributions from vehicles and tracks. Better identification of individual noise sources is also important as input for calculation schemes of reception levels.



5.3.4. Air Traffic Noise

Since 1991 a major review has been undertaken within the ICAO Committee for Aviation Environmental Protection (CAEP) which recently led to the definition of more stringent Chapter 4 noise limits[36]. As another major outcome of the process, the recommendations were made in favour of a "Balanced Approach" encompassing four elements: reduction of noise at the source, land-use planning, noise abatement procedures and aircraft operating restrictions. This concept implies the elaboration and implementation of a process which is meant to help the assessment and resolution of noise problems at airports in the most cost-effective manner. The Balanced Approach in effect challenges the ICAO member states to "study and prioritise research and development of economically justifiable technology", to foster the development of noise abatement procedures, while addressing airport land-use planning and management aspects.

The rotorcraft, as a means of transport, is of growing importance, especially in the civil sector. Flying close to populated areas being the "raison d'être" of VTOL (Vertical Take-Off and Landing) aircraft, environmental impact is obviously a major concern for the acceptance of rotorcraft operations. Rotorcraft noise is in fact widely recognised as one of the key factors which might prohibit wider civil use of rotorcraft in populated areas.

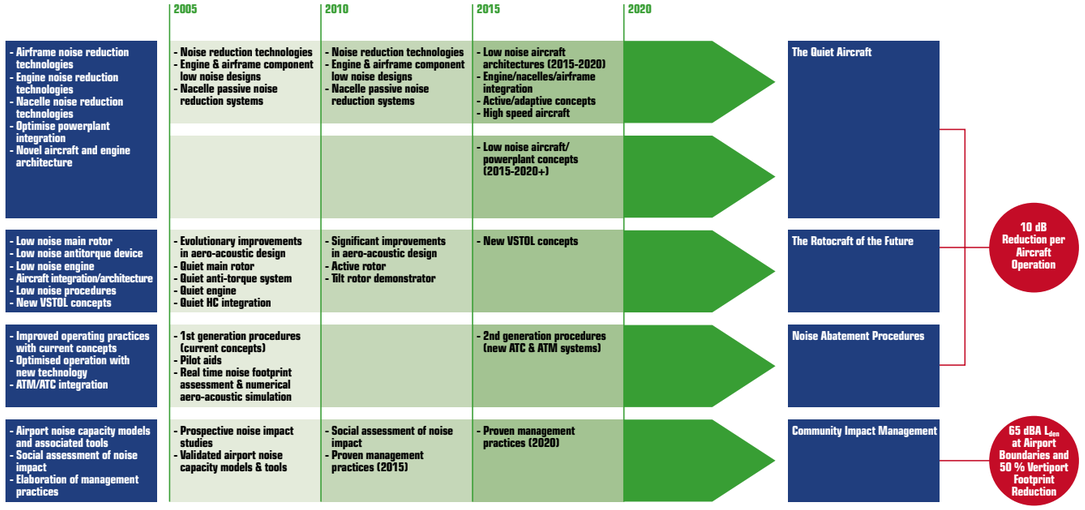
The development of an appropriate strategy, building on the existing effort, to address the 2020 vision goals within the larger frame of the Balanced Approach, and in the context of strong competition from United States, clearly calls for an effort encompassing:

"Noise is an important topic in the strategic research agenda of ACARE."

- The elaboration of technology development strategies aimed at a new generation of noise reduction solutions for both fixed wing aircraft and rotorcraft, including the associated adaptation of research infrastructures, in particular testing and computing facilities, and covering potential synergies with national efforts.
- The elaboration of an action plan aimed at taking advantage of technology advances in aircraft and air traffic systems to favour implementation of environmentally friendly operational practices such as noise abatement procedures.
- The elaboration of a development plan for impact assessment tools and instruments aimed at improved airport noise planning and environmental management practices.

Dealing in more detail with the global objectives set by the Group of Personalities[37], the first step has been to target a 10 dB reduction per operation goal for fixed-wing aircraft as representative of the global "reduce perceived noise by half" objective, on the grounds of previous psycho-acoustic evidence and general understanding with the noise stakeholders. Meeting the second global 2020 goal would then translate into ensuring that such benefit at source leads to limit noise

[36] Convention on International Civil Aviation, Annex 16 "Environmental Protection", Volume I, Chapter 4. 2001.
[37] European Aeronautics: A Vision for 2020. Report of the Group of Personalities. Jan. 2001. (http://www.acare4europe.com/html/background.shtml)



Road Map for Aircraft Noise Reduction[38]

nuisance to 65 dBA L_{den} at airport boundaries, provided the appropriate management practices are in place. Similarly, for rotorcraft, the following ambitious objectives have been set for the year 2020: an average of 10 dB reduction compared to existing rotorcraft, with an intermediate 6 dB reduction to be reached within ten years as well as a noise footprint area reduced by 50 percent, directly affecting the environment impact of heliports or vertiports.

Accordingly, as summarised in the above figure, contributors to noise reduction should encompass technology related elements such as the quiet aircraft and rotorcraft of the future as well as further actions aimed at establishing efficient environmental practices by way of noise abatement procedures and management of noise impact.

- **Noise reduction at the aircraft**
  Essential progress is to be expected from research and technological development of new generation noise technologies to be applied to novel aircraft and engine architectures. The related fields extend to low-noise designs for the engine and nacelle, low-noise aircraft designs with optimised powerplant integration, improved aircraft aerodynamics with optimised aero-acoustic design of inlet and nozzle and application of advanced active control technologies.

- **Optimised aircraft operation**
  Noise minimising procedures are needed, especially near airports, through advanced aircraft performance, improved avionics and optimised procedures for improved noise abatement.

[38] Strategic Research Agenda (SRA) of ACARE, Oct. 2002; this SRA is planned to be updated until end of 2004. ACARE is the "Advisory Council for Aeronautics Research in Europe", supported by the X-Noise Expert Group regarding noise topics.
See also: http://www.acare4europe.com/ and: http://www.x-noise.net/
[39] Derived from CALM Workshop with Stakeholders, Brussels, 18 - 19 March 2002.
[40] See also: Study on the Status of Research Related to the Noise of Outdoor Equipment in Operation. CRF-Report, Sep. 2003. (www.calm-network.com).

5.3.5. Outdoor Equipment Noise

The target for the vision of 2020 is to halve the noise annoyance caused by outdoor equipment[39]. A strong basis for the reduction of noise from outdoor equipment (OE) is given by the Directive 2000/14/EC relating to the noise emission in the environment by outdoor equipment which needs, however, further development towards higher efficiency in real world noise reduction. For the achievement of the above target, research leading to a more thorough knowledge and new technologies is required for the following prime topics of OE noise[40]:

- **Identification of the most suitable noise-relevant parameters** per OE class or type
  Due to the many different kinds and sizes of outdoor machinery, it is necessary to group them in classes and types as done in 2000/14/EC. Noise emission may depend on type and size via different parameters. It is essential for a good efficiency of the noise regulation that the most suitable noise-relevant parameters are known and considered in setting emission limits.

- **Correlation between noise emission, performance parameters and real operation nuisance**

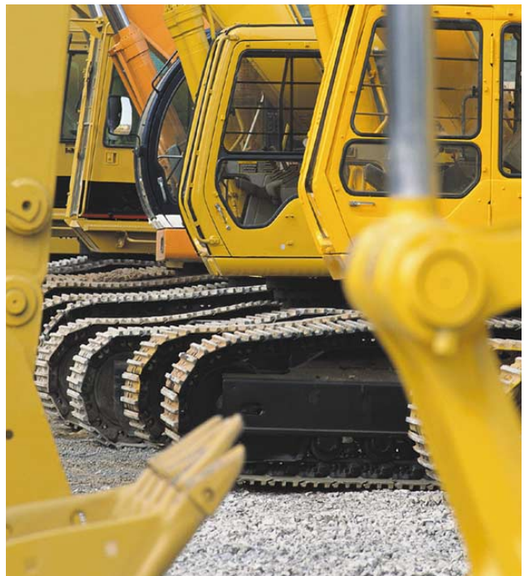
  - *Correlation / divergence between test cycle noise and real operation noise*
  - *Trade-offs between noise emission and performance parameters*
  - *Interaction with the ground or material to be handled*

  All research items related to the correlation (or divergence) of OE noise emission between test cycle operation and real use operation are important for a further development of the OE noise legislation towards an increased efficiency and a better knowledge about the lowest possible limit threshold.

- **Improved regulation related to noise emission** (including test methods)
  The methods for legislative noise emission testing of OE are based on operating conditions which are not sufficiently representative for the typical conditions in real situation. Based on the outcomes of research as described in the two items above, a better adaptation to the real situations is required to make the noise emission limitation a more effective and efficient tool for contributing to environmental noise reduction by noise control at the source.

- **Effect of single and combined noise sources on noise perception**
  Very often, several types of OE are in use on one site at the same time (e.g. on construction sites) so that the overall noise emission is a combination of several sources. For better protection against such combined noise patterns, deeper knowledge in the combined effects on the noise perception is required in comparison with the effect of single sources.

- **In-use compliance**
  Practicable test and maintenance methods are needed to avoid a noise increase during the life cycle of OE.



“Real operation nuisance of out-door equipment can differ widely from standard noise tests.”

5.4. Impementation of Research Results

Basically, research shall serve society. To make research results useable for the society, these results have to be implemented appropriately. Very often, however, the results of research are not implemented (or are delayed) for several reasons. Such reasons (or potential barriers of implementation) include:

- higher cost of the product
- conflict with other targets
- life cycle of the product

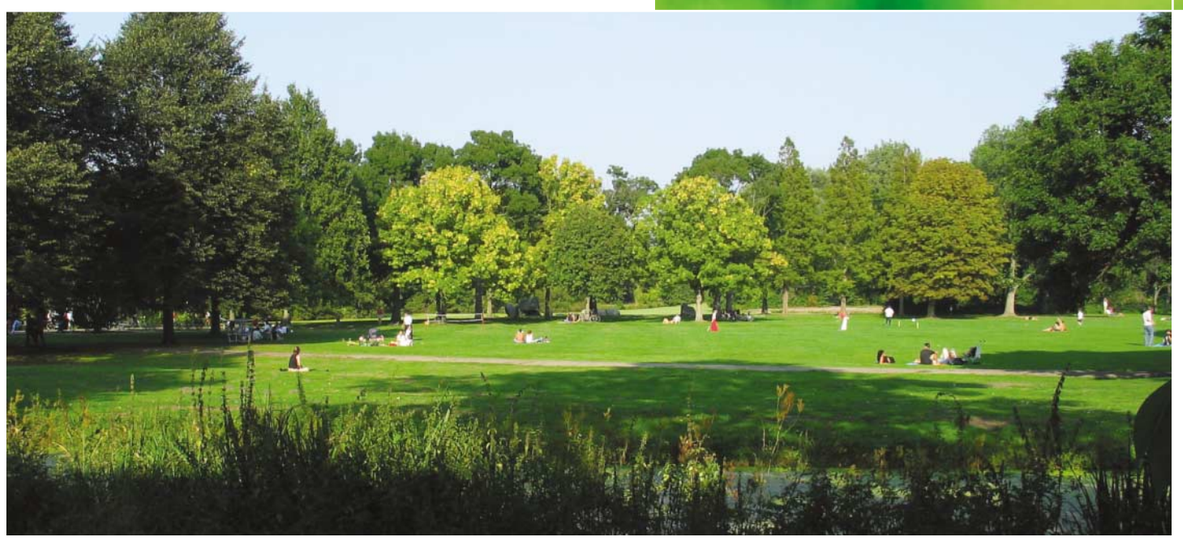
Such barriers have to be considered in implementation plans, and adequate actions to overcome such barriers have to be included. As implementation is more a political issue than a technical one, it is not the task of the CALM network to prepare and provide implementation plans. However, the topic is mentioned in this paper to draw attention to this task and to emphasise the importance of implementation as the logical next step after successful completion of research.

[41] “Environmental Health” comprises those aspects of human health and disease that are determined by factors in the environment. It also refers to the theory and practice of assessing and controlling factors in the environment that can potentially affect health. (http://www.euro.who.int/eprise/main/WHO/Progs/HEP/Home)

6. Conclusions

- The cornerstones of current and future noise policy in Europe are, without doubt, the Environmental Noise Directive and the set of source-specific emission-related directives.
- Experience to date has shown, however, that for the future development of effective emission-related directives, there must be a research-based focus on real-world situations, including environmental health[41]. Otherwise, stricter theoretical noise emission limits will not result in reduction of environmental noise in practice.
- Europe continues to need major efforts in research, if its citizens are to be freed from burden of unacceptably high levels of noise pollution. Future environmental noise reduction will depend, for its effectiveness and efficiency, on a well-balanced portfolio of research into noise emission, noise propagation, noise immission and human perception of noise. A co-ordinated programme of research in all these fields is of vital importance to the development of improved noise control strategies and improved regulatory legislation. For the effectiveness of research, the coordination of European and national activities including the research advisory councils of the different sectors is also of vital importance.
- Stakeholders supporting this research will develop improved products leading to a strengthening of their competitiveness in the international market.
- The outcome of future research applied to all thematic areas of environmental noise will substantially support a sustainable development towards a quieter Europe.

“A good balance of research in noise emission, propagation and perception will be essential for a sustainable development towards a quieter Europe.”



7. Abbreviations

ACARE Advisory Council for Aeronautics Research in Europe
ACEM Association of Motorcycle Industry in Europe (Association des Constructeurs Europeens de Motorcycles)
ACMARE Advisory Council for Maritime Research
AEN Assessment of Exposure to Noise
ATC Air Traffic Control
ATM Air Traffic Management
CAEP ICAO Committee for Aviation Environmental Protection
CBA Cost-Benefit Analysis
COM Official Commission Document
CRF Centro Ricerche Fiat, Italy
dBA decibel, A-weighted
DG Directorate General (of the European Commission)
EC European Commission
EEC European Economic Community
END Environmental Noise Directive
ERRAC European Rail Research Advisory Council
ERS Euro Rolling Silently (EU Research Project)
ERTRAC European Road Transport Research Advisory Council
EU European Union
GIS Geographical Information System
HC Helicopter
HP Hedonic Price (Method for CBA)
HSEA Health and Socio-Economic Aspects
ICAO International Civil Aviation Organization
IKA Institut fuer Kraftfahrwesen Aachen, Germany
L_{den} Equivalent Sound Level over Day, Evening and Night Period
L_{eq} Equivalent Sound Level (over a certain period)
L_{night} Equivalent Sound Level over Night Period
OE Outdoor Equipment
OJ Official Journal (of the European Communities)
PTW Powered Two-Wheeler
SP Stated Preference (Method for CBA)
SRA Strategic Research Agenda
TSI Technical Specification for Interoperability
UBA Umweltbundesamt, Germany
UNECE United Nations Economic Commission for Europe
VSTOL Very Short Take-Off and Landing
VTOL Vertical Take-Off and Landing
WG Working Group
WHO World Health Organization