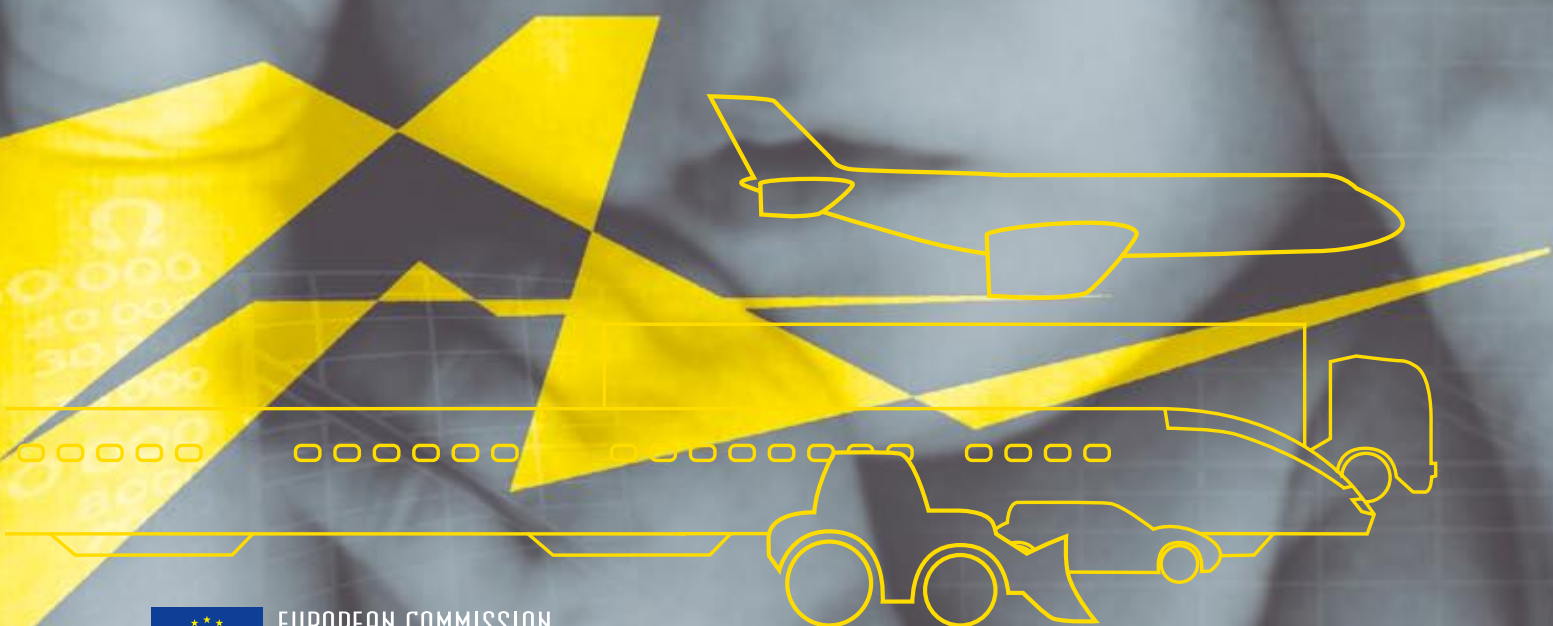


# Research for a **Quieter Europe** in 2020



EUROPEAN COMMISSION  
RESEARCH DIRECTORATE-GENERAL

**An Updated Strategy Paper of the CALM II Network - Feb. 2007**  
(funded by the DG Research of the European Commission)

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# Foreword

The two previous editions of the CALM Strategy Paper have been published as printed brochures. These were issued in July 2002 and Oct. 2004. This Strategy Paper is an updated version of the second edition, but on this occasion it is only provided in an electronic format on the CALM website. Compared with the issue of 2004, the major changes of this updated version refer to the chapters “Environmental Noise in Europe” and “The Vision”, the research road maps as described in Section 5.3 and a slight re-structuring of the whole paper.

It is a pleasure for the members of the CALM II network to present this updated plan for future research to reduce environmental noise in Europe<sup>1</sup>. 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 are 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 and from equipment used outdoors.

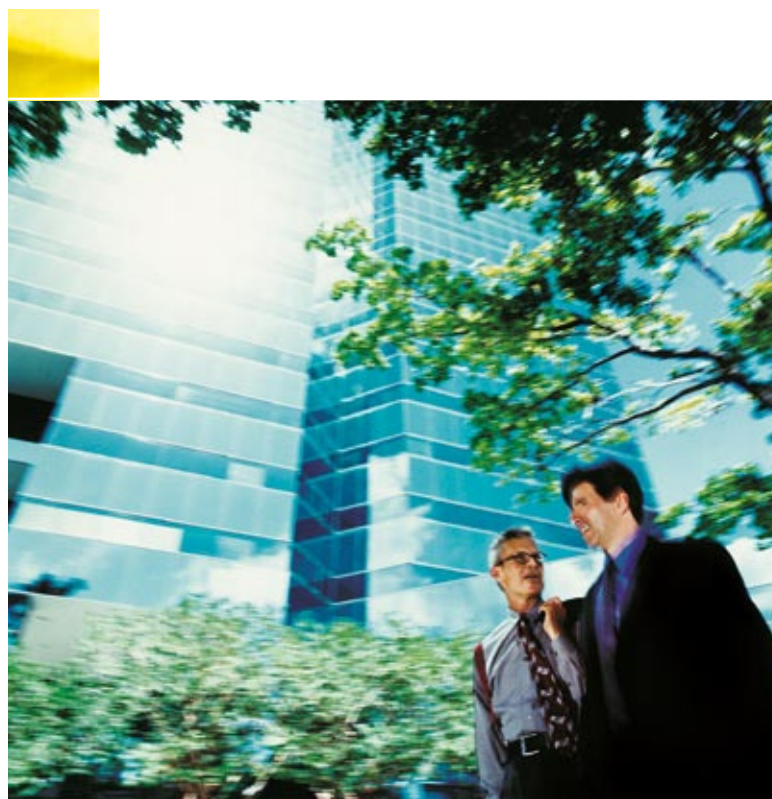
As with CALM, the CALM II initiative is the result of a close collaboration between DG Research and DG Environment the latter being the DG<sup>2</sup> responsible for coordinating the European environmental noise policy. This close collaboration should ensure that initiatives concerning research on noise 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 II network membership has been established with representation from three big national research programmes, from a New Member State and from the noise working groups that are supporting the implementation and further development of the Directive on Environmental Noise (2002/49/EC). In addition, a number of workshops have been held with a broad range of stakeholders in order to seek as wide an input to the project as possible.

This Strategy Paper will be revised and re-issued in September 2007 in printed format to take account of developments in the state-of-the-art concerning noise abatement and noise perception. To this end the CALM II network encourages input from all stakeholders, and in particular those who have not yet provided their comments.

It is the members hope that the work of the CALM II network will contribute to a quieter Europe. Finally, the members of the CALM II network would like to thank everyone who has contributed to this Strategy Paper.

The members of the CALM II network



<sup>1</sup> This Strategy Paper is a publication representing the opinion of an expert group. It is not an official EC document.

<sup>2</sup> Abbreviations used in this paper are explained at the end of the paper.



# 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 in order to control noise pollution. 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.

The Commission's Green Paper on Future Noise Policy (1996) marked the start of an extended "knowledge-based" approach with a special emphasis of assessing and managing the exposure to environmental noise. This approach led to the Environmental Noise Directive of 2002 as a second cornerstone of noise policy, complementing the set of existing cornerstones of 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 long-term objectives mainly based on the Sixth Environmental Action Programme of 2002, the mid-term review of the Commission's White Paper on Transport and the renewed Sustainable Development Strategy. The vision derived and proposed by CALM for the development of noise research targets up until the year 2020 is to

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

Meeting this vision means that 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 main goal of future research is, therefore, to support the implementation of the Environmental Noise Directive and the further development of noise policy.

This covers a wide range of research including assessment of noise exposure and perception, health impacts of exposure to noise, 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. Accordingly, the structure of the noise research strategy is split into perception and emission related research.

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**"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<sup>3</sup> 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

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 further update this Strategy Paper in autumn 2007 based on developments in the state-of-the-art and new research needs.

CALM II 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 transportation and outdoor equipment.

**“This noise research strategy plan shall contribute to current and future European research initiatives.”**

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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 II network<sup>4</sup> is working on the further development of the strategic plan for such future noise research activities.

This Strategy Paper has been prepared by the CALM II network as an update of the second edition issued in Oct. 2004<sup>5</sup>, and is intended as a contribution to the current research programme<sup>6</sup> and future research initiatives of



<sup>3</sup> 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; quoted as ‘END’ in this paper. See also: <http://www.europa.eu.int/comm/environment/noise/>

<sup>4</sup> “CALM II – Coordination of European Research for Advanced Transport Noise Mitigation” is a Coordination Action funded by the European Commission under the Sixth Framework Programme of the European Community for Research, Technological Development and Demonstration (2002 to 2006), contributing to the creation of the European Research Area and to innovation, Thematic Priority 6 Sustainable Development, Global Change and Ecosystems. (TCA4-CT-2005-516237, 1st Nov. 2004 – 31st Oct. 2007) See also: <http://www.calm-network.com>

<sup>5</sup> CALM Strategy Paper “Research for a Quieter Europe in 2020”, Oct. 2004. See also: [http://www.calm-network.com/index\\_preports.htm](http://www.calm-network.com/index_preports.htm)

<sup>6</sup> Seventh Framework Programme of the European Community for Research, Technological Development and Demonstration Activities (2007 to 2013). Decision No 1982/2006/EC of 18 Dec. 2006 (OJ L 412, 30.12.2006, p. 1). See also: [http://ec.europa.eu/research/fp7/home\\_en.html](http://ec.europa.eu/research/fp7/home_en.html)

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**David Delcampe** (DG Environment), **Michele Lepelletier** (DG Transport and Energy)





## 2. Environmental Noise in Europe

Nearly all human activities and the technical equipment associated with them generate SOUND. Sometimes sound is perceived as pleasant and amusing (like music). Or 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.

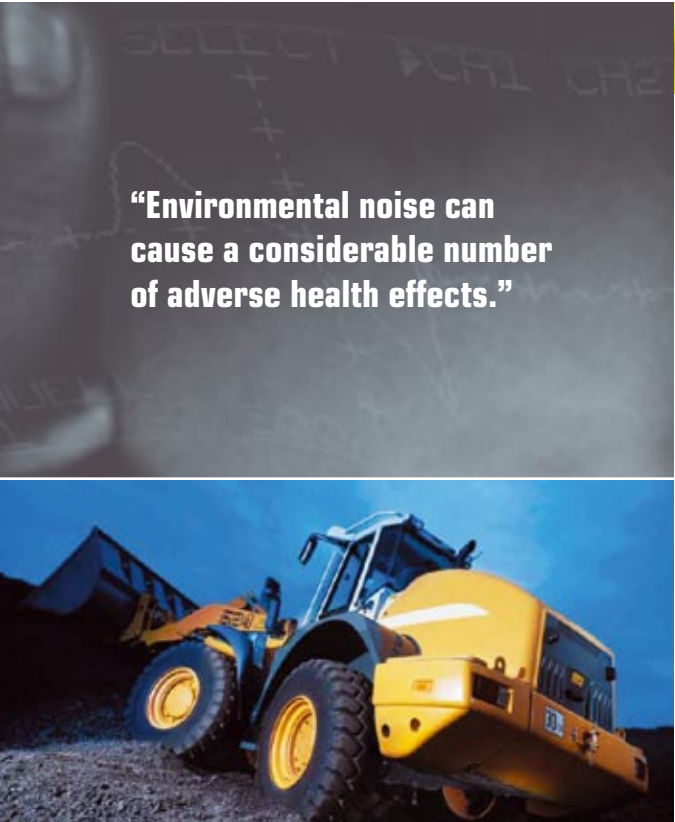
However, many of these sounds either exceed acceptable levels or provide no benefit to the person exposed to them and are hence unwanted, annoying, disturbing or even constitute a health risk. In this case, sound is perceived as NOISE. According to the EU legislation currently in force<sup>7</sup>, environmental noise means ‘*an 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, to which humans are exposed in particular in built-up areas, in public parks or other quiet areas in an agglomeration, in quiet areas in open country, near schools, hospitals and other noise sensitive buildings and areas*’.

### 2.1. The Situation of Noise Pollution

The adverse effects of environmental noise are various and can be described in many different ways. According to the World Health Organization (WHO)<sup>8</sup> “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<sup>9</sup> caused by environmental noise.

These specific effects can be medical related, such as insomnia, high blood pressure, ischemic 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. The estimation of adverse effects is complicated by the fact that we are, in addition to being exposed to environmental noise, also exposed to other environmental stressors such as chemicals, with possible additive effects.



**“Environmental noise can cause a considerable number of adverse health effects.”**

<sup>7</sup> Directive 2002/49/EC, OJ L 189, 18.7.2002, p.12-25.

<sup>8</sup> 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.

<sup>9</sup> See: <http://www.euro.who.int/noise/>

**“Transport noise is the main source of exposure to environmental noise.”**

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As regards exposure, the Commission Green Paper on the Future Noise Policy<sup>10</sup> highlighted that the available data on noise exposure are generally poor in comparison to that collected to measure other environmental problems and often difficult to compare due to the different measurement and assessment methods.

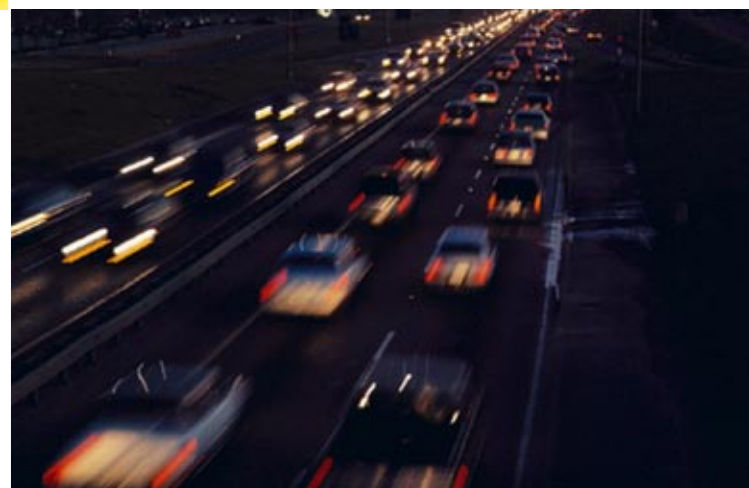
It estimated however that ‘(...) around 20 percent of the Union’s population<sup>11</sup> or close on 80 million people suffer from noise levels that scientists and health experts

in 2007, Member States have to publish first sets of strategic noise maps and report to the Commission harmonized statistics on exposure to environmental noise based on those maps.

On the basis of best available knowledge on exposure to noise and its related effects, external costs attributable to noise exposure can be derived by using economic models and assumptions. A wide variety of studies have examined the question of the external costs of noise to society especially transport noise which is by no doubt the main source of exposure to environmental noise. The Green Paper quoted that, for transport, these costs range between 0.2 and 2 percent of the EU GDP<sup>10</sup>. Taking the lower estimate, this implies an annual financial loss due to environmental noise of more than € 24 billions considering the today’s GDP. A recent study<sup>12</sup> carried out in 2004 estimated these costs to € 45 billions in 2000<sup>13</sup>.

*consider to be unacceptable, where most people become annoyed, where sleep is disturbed and where adverse health effects are to be feared. An additional 170 million citizens are living in so-called grey areas where the noise levels are such to cause serious annoyance during the daytime (...).*

The available knowledge on exposure to environmental noise should however be soon improved, because,



<sup>10</sup> Green Paper on Future Noise Policy, COM(96) 540 final, 4.11.1996.

<sup>11</sup> The Green Paper refers to EU-15.

<sup>12</sup> See: [http://www.uic.asso.fr/html/environnement/cd\\_external/](http://www.uic.asso.fr/html/environnement/cd_external/)

<sup>13</sup> This estimation refers to EU-15 plus Norway and Switzerland.



## 2.2. The Current EU Legal Framework

### 2.2.1. The Environmental Noise Directive

The main objectives of the END are the following:

- To assess the exposure to environmental noise using the harmonised noise indicators  $L_{den}$  (day-evening-night equivalent level) and  $L_{night}$  (night equivalent level).

**“Public information about environmental noise assessment and action plans will increase awareness concerning noise.”**

- To inform and consult the public about noise exposure, its effects and the measures considered to address noise, in line with the principles of the Aarhus Convention<sup>14</sup>.
- To adopt action plans based upon noise-mapping results *‘with a view to preventing and reducing environmental noise where necessary – particularly where exposure levels can induce harmful effects on health - and preserving environmental noise quality where it is good’*.
- To provide a basis for developing Community strategies and measures to reduce noise emitted by the major environmental noise sources.

The END consists of a main body and six supporting technical annexes:

**Annex I:** Noise indicators

**Annex II:** Assessment methods for the noise indicators

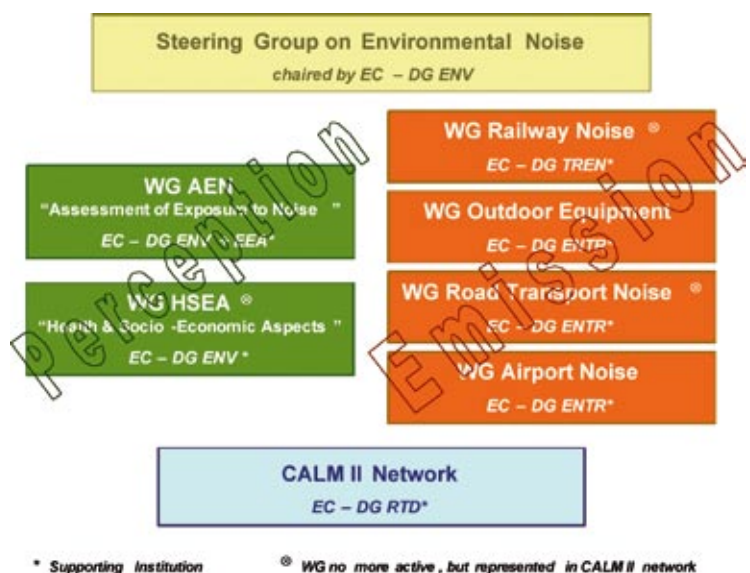
**Annex III:** Assessment methods for harmful effects

**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 technical content took into account – in line with the principle of “knowledge based approach” - the available findings of Community research and several expert groups (see scheme below) created to advise the Commission and Member States on the implementation of the directive. The annexes may be revised to take account of scientific and technical progress.



**Network of EU Noise Expert Groups<sup>15</sup>**

<sup>14</sup> See: <http://ec.europa.eu/environment/aarhus/>

<sup>15</sup> See: <http://ec.europa.eu/environment/noise/expert.htm>

The competent authorities in the Member States have to provide strategic noise maps and action plans for agglomerations, major roads, major railways and major civil airports designated by Member States. The first round of strategic noise maps (due by 30 June 2007) and action plans (due by 18 July 2008) will concern:

- more than 130 agglomerations with more than 250 000 inhabitants (80 millions of inhabitants in total);
- more than 72 000 km of major roads with more than 6 millions vehicles per year;
- more than 5 000 km of major railways with more than 60 000 trains per year;
- 63 major civil airports with more than 50 000 movements per year.

Detailed information on authorities responsible for implementing the Directive in Member States, as well as on agglomerations, major roads, railways and airports to be covered by the first sets of noise maps and action plans, are now published on the web<sup>16</sup>.

Authorities responsible for data collection in Member States will have to report data from strategic noise maps (mainly statistics on exposure to noise from separate sources) and action plans to the Commission no later than six months after the deadlines set to deliver the noise maps and action plans.

In a declaration published in the Official Journal of the European Union<sup>17</sup>, the Commission highlighted that such data are essential in order to allow the assessment of the impacts, costs and benefits of further strategies and measures aimed at reducing environmental noise.

### 2.2.2. The Directives Aimed at Limiting Noise of Sources

As stipulated by article 174 of the Treaty establishing the European Community, '*Community policy on the environment shall be based (...) on the principles that (...) environmental damage should as a priority be rectified at source (...)*'. Legislation at EU level governing noise emissions has, in general, a high importance. It links noise reduction measures to the source of environmental noise and its effects are therefore global rather than local. In following the "polluter pays principle"<sup>18</sup>, it encourages the development and implementation of the best available technology.

It is worth noting in addition that, according to the END, Commission's review on the implementation of the END, due by 18 July 2009, has to assess the need for further Community measures and, if appropriate, propose supplementary measures aimed at limiting environmental noise at source.

Meanwhile, as required by the END, the Commission recently reviewed the existing Community measures relating to sources of environmental noise. This review<sup>19</sup> was communicated to the European Parliament and Council in 2004. Basically, 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.

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

<sup>16</sup> See: [http://forum.europa.eu.int/Public/irc/env/d\\_2002\\_49/home](http://forum.europa.eu.int/Public/irc/env/d_2002_49/home)

<sup>17</sup> OJ L 189, 18.7.2002, p. 26, see: [http://eur-lex.europa.eu/pri/en/oj/dat/2002/L\\_189/L\\_18920020718en00260026.pdf](http://eur-lex.europa.eu/pri/en/oj/dat/2002/L_189/L_18920020718en00260026.pdf)

<sup>18</sup> See: Section 3.2

<sup>19</sup> See: COM(2004)160 final, 10.3.2004 on Existing Community Measures relating to Sources of Environmental Noise, available at: <http://ec.europa.eu/environment/noise/#3>

The first regulation with EU-wide application was the Directive on noise emission from motor road vehicles and dates back to 1970. Further important Directives mainly aimed at limiting transport and outdoor equipment noise followed:

- 70/157/EEC Motor vehicles
- 80/51/EEC Subsonic aircraft
- 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
- 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
  - Commission Decision 2006/66/EC relating to the sub-system “rolling stock - noise” and specifying limiting values for freight wagons, locomotives, multiple units and coaches

- 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

As regards equipments used outdoor, many Directives have been adopted between 1979 and 1986 to limit noise emissions from equipment 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 the Directive 2000/14/EC<sup>20</sup>, which covers some 57 different types of outdoor equipment and sets limits for noise emission or specifies the marking of sound power levels as information for the customer. This directive was amended in 2005<sup>21</sup> to modify the list of equipments falling under the scope of the stage II limits applicable from January 2006.



<sup>20</sup> See: [http://ec.europa.eu/enterprise/mechan\\_equipment/noise/index.htm](http://ec.europa.eu/enterprise/mechan_equipment/noise/index.htm)

<sup>21</sup> Directive 2005/88/EC, OJ L 165, 17.6.2006, p. 35



## 2.3. Limiting Environmental Noise and the Related Exposure

### 2.3.1. WHO Guidelines for Europe

Working in close co-operation with the scientific community, WHO has been developing indicators and guidelines for noise and health, and is now establishing exposure-response relationships for different health effects where long-term effects of night exposure

- The on-going Night-Time Noise Guidelines project<sup>23</sup> planned to be completed in 2007 that reviewed health effects due to exposure to night-time noise and will recommend guideline night-time values for the protection of health.

- The Environmental Noise Burden of Disease project<sup>24</sup> also planned to be completed in 2007 that reviewed evidence on the relations between environmental noise doses and health effects and will provide policy makers with methodologies (dose-response) to estimate the magnitudes of health effects due to exposure to environmental noise.



to noise such as long-term sleep disturbance and cardiovascular problems are being analysed.

Three particular initiatives from WHO are worth mentioning here, as they are already having consequences on policies aimed at managing environmental noise in the EU:

- The Guidelines for Community Noise<sup>22</sup> edited in 1999 consolidating scientific knowledge on the health impacts of community noise and proposing guidance and guideline values to policy makers with a view to protect people from the harmful effects of noise, including environmental noise.



<sup>22</sup> See: <http://whqlibdoc.who.int/hq/1999/a68672.pdf>

<sup>23</sup> See: [http://www.euro.who.int/Noise/activities/20040721\\_1](http://www.euro.who.int/Noise/activities/20040721_1)

<sup>24</sup> See: [http://www.euro.who.int/Noise/Activities/20021203\\_3](http://www.euro.who.int/Noise/Activities/20021203_3)

### 2.3.2. EU Objectives on the Reduction of Exposure to Noise

Besides the END adopted in 2002 and the sources related legislations presented before, which all constitute the core legally binding requirements in this area, the reduction of exposure to environmental noise is promoted by other pieces of the EU “acquis communautaire” in the form of political guidance or commitment conveyed by EU institutions.

The below most recent ones are worth noting in this respect:

- The 6<sup>th</sup> Environmental Action Programme<sup>25</sup>
- The mid-term review of the Commission’s White Paper on Transport <sup>26</sup>
- The renewed Sustainable Development Strategy<sup>27</sup>

The 6<sup>th</sup> Environmental Action Programme adopted in 2002 by the Council and the European Parliament identifies “Environment and Health and Quality of Life” as one of the four environmental priority domains. Under this priority, the Programme stipulates that Community’s environmental policy should take account of WHO standards, guidelines and programmes and aim at *‘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’*.

It moreover states that priority actions in this area should consist in:

- *‘supplementing and further improving measures, including appropriate type-approval procedures, on noise emissions from services and products, in particular motor vehicles including measures to reduce noise from the interaction between tyre and road surface that do not compromise road safety, from railway vehicles, aircraft and stationary machinery’;*
- *‘developing and implementing instruments to mitigate traffic noise where appropriate, for example by means of transport demand reduction, shifts to less noisy modes of transport, the promotion of technical measures and of sustainable transport planning’.*

Adopted by the Commission in 2006 the mid-term review of the Commission’s White Paper on Transport acknowledges that *‘[transport] noise pollution (...) needs continuous attention’*, that *‘[road traffic] noise will worsen’* and that *‘attention must also be paid to noise pollution from different modes of transport’*.

The renewed Sustainable Development Strategy adopted in 2006 by the Council sets overall objectives, targets and concrete actions for seven key priority challenges for the coming period until 2010, amongst which is “Sustainable Transport”. One of the operational targets set under this key priority area consists in *‘reducing transport noise both at source and through mitigation measures to ensure overall exposure levels minimise impacts on health’*.

<sup>25</sup> See: <http://ec.europa.eu/environment/newprg/index.htm>

<sup>26</sup> See: [http://ec.europa.eu/transport/transport\\_policy\\_review/index\\_en.htm](http://ec.europa.eu/transport/transport_policy_review/index_en.htm)

<sup>27</sup> See: <http://register.consilium.europa.eu/pdf/en/06/st10/st10117.en06.pdf>

### 2.3.3. Environmental Noise Limits and Targets in the EU

For most sources, international conventions or EU legislation set limit values on noise emissions which have to be met by individual products (cars, aircrafts, trains, etc.) when put on the market.

On the contrary, the END does not set any EU limit or target values on environmental noise that would bind Member States to consider implementing noise abatement measures. Therefore the setting of such values falls exclusively in the remit of the Member States.

Member States obligations in this area are restricted to inform the Commission on the limit values in force or envisaged and to include such information in the action plans required by the END. The information reported so far to the Commission is made available at the web<sup>28</sup>.

This information shows that Member States follow different approaches. For instance, some have set strict legally binding limits or targets whereas others publish recommended values. Some set limits triggering noise reduction measures for existing sources whereas others focus on the prevention of exposure to noise by setting maximum levels for new transport infrastructures or new buildings for instance. Some Member States set limits or targets for industries and transportation noise whereas others only focus on part of those sources. Moreover, values adopted or envisaged vary from one state to another, even for the same situations, and they do not necessarily correspond to WHO recommended values.

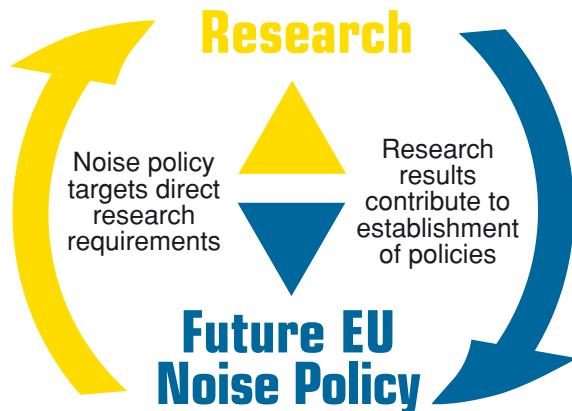


<sup>28</sup> See: [http://forum.europa.eu.int/Public/irc/env/d\\_2002\\_49/home](http://forum.europa.eu.int/Public/irc/env/d_2002_49/home)



## 3. Noise Policy and Research

### 3.1. The Need for Research



Research is crucially important in enhancing the knowledge base and enabling technological progress. Noise policy has to be built upon a solid base of knowledge about the roles and interactions of the essential factors of environmental noise and about the future technological possibilities.

Hence, there can be no progress in noise policy without research. The objectives of the noise policy have 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.

### 3.2. Research-Related Aspects of 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<sup>29</sup>.

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

1. To avoid or 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 not sufficiently efficient and effective).

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

**"Research is crucially important in enhancing the knowledge base and enabling technological progress."**

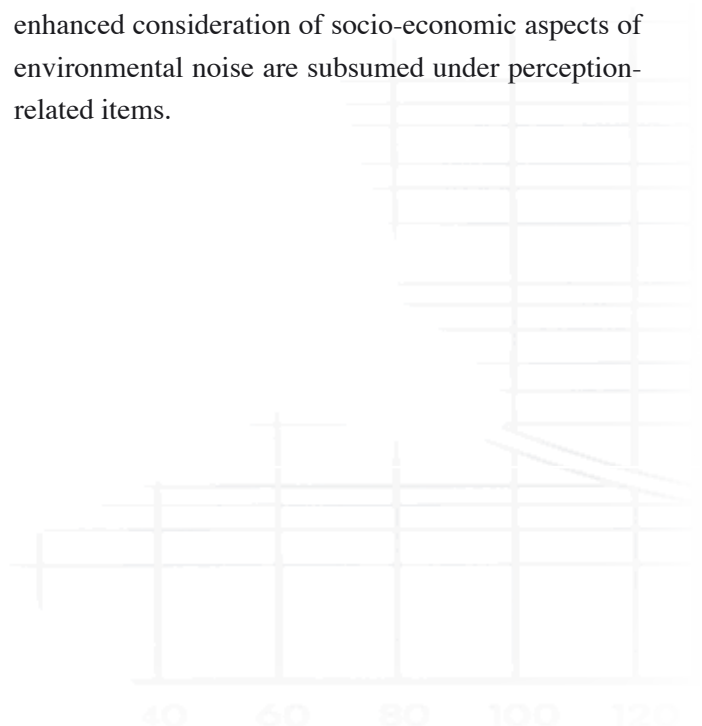
<sup>29</sup> Volker K. P. Irmer: Do We Need a Global Noise Policy? Intnoise 2004, Prague, 22 - 25 Aug. 2004.

- 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.

Considering these principles, in particular the technical principles, it is evident that the activities in research and technological development must cover all three technical fields of acoustics: the noise source, the noise propagation and the noise reception.

But besides these three fields related to noise mitigation, there are also other noise research topics to be considered which are of high priority for the assessment and management of environmental noise and hence for the further development of the Environmental Noise Directive. In the following chapters, such topics like harmonisation of assessment methods, deepening the insight into health effects of noise exposure and enhanced consideration of socio-economic aspects of environmental noise are subsumed under perception-related items.

**“The first aim is to avoid noise or to reduce it at its source.”**



## 4. The Vision: Less Noise by 2020


### 4.1. The Vision

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, exposure to noise in the general population may be increasing.

Although the targets in relation to this objective have been set only up to the year 2000<sup>30</sup>, the aim continues to be valid and has been adopted as a long-term vision. The proposed vision for the development of noise research targets 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<sup>32</sup>.



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

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<sup>30</sup>, 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'*<sup>31</sup>.



<sup>30</sup> Fifth Environmental Action Programme of the European Communities: Towards Sustainability. OJ C 138, 17. 5. 1993, p.5.

<sup>31</sup> Green Paper of the European Commission: Future Noise Policy. Annex I. COM(96) 540 final, 1996.

<sup>32</sup> 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..."



## 4.2. Reference Targets for Future Research

Several expert groups have elaborated values for reception-related targets<sup>33</sup> which can be used as reference for future research designed to achieve this vision. They can be classified as follows<sup>34,35</sup>:



Target Class	L <sub>den</sub> (dBA)	L <sub>night</sub> (dBA)	Expert Group
Minimum Target	65	55	UBA
Medium Target	55	45	WHO
Optimum Target	50	40	Dutch Ministry VROM + UBA

**Targets as Reference for Future Research**

Noise research and its following implementation into low-noise products will be justified, if the benefits due to the reduction measures will exceed their costs (i.e. cost-benefit ratio < 1). Basically, the monetary benefit of a noise reduction measure increases with the number of persons (households) benefiting from the lower noise exposure due to the reduction measure. A high number of benefiting persons can be reached first by global measures (i.e. noise control measures at the source) and second, if the cost-benefit analysis

considers a rather low “benefit threshold level” (e.g. near the optimum target), as the number of persons exposed to levels above the threshold increases, the lower the threshold is.

Consequently cost-benefit analysis for the reduction of vehicle noise emissions should be based on benefit thresholds close to the optimum target in order to promote noise control measures at the source thereby increasing the efficiency of the measures.

## 4.3. Deriving Emission Targets

Although the reference targets are clear in their intention, they are difficult to translate into engineering terms. Within the CALM II network, two approaches have been developed which in due course could lead to emission targets for different noise sources. These are either a health based approach and a cost-benefit based scenario approach<sup>35</sup>.

<sup>33</sup> Besides L<sub>den</sub> and L<sub>night</sub>, also other noise indicators are used, see Section 5.2.

<sup>34</sup> CALM Workshop “Road Maps for Future Research in Environmental Noise”, Brussels, 16 March 2006: Contributions of Michael Jaecker-Cueppers and Heinz Steven.

<sup>35</sup> Martin van den Berg: Targets for Noise Immission. CALM Workshop “Road Maps for Future Research in Environmental Noise”, Brussels, 16 March 2006. <http://www.calm-network.com>

### 4.3.1. Health Based Approach

As a first step, noise reception levels have to be set which guarantee the virtual absence of adverse health effects in the long term. Taking into account WHO recommendations, effect studies and limit setting practices in EU-countries, the optimum target levels of 50 dBA<sub>L<sub>den</sub></sub> and 40 dBA<sub>L<sub>night</sub></sub> are considered defensible. The next step is to take into account the differences in exposure distances e.g. airports and motorways are at larger distance from dwellings than urban streets. This leads to a series of design targets for transport vehicles in different user modes.

### 4.3.2. Scenario Approach

The following steps have to be performed:

- The building of scenarios with different grades of noise measures
- Undertaking impact calculations on a number of model areas
- Calculating cost-benefit ratios

Limit values result from adapting to the best performing scenario. This approach has already been applied in the EFFNOISE study<sup>36</sup> yielding interesting results. However, further studies will be necessary to investigate the influence of various model parameters on the outcome. In the EFFNOISE study, the effect of the calculation model for instance was taken into account, and it was shown that this did not influence the order of preference for most of the scenarios.

It is not entirely surprising, but still satisfactory that these different approaches seem to give comparable results. Applying best available techniques to all equipment currently in use brings the target within reach, and seems to present not a too big challenge from the technological point of view.

**“The health approach leads to a series of design targets for transportation vehicles.”**



<sup>36</sup> EU Project “EffNoise – Service Contract Relating to the Effectiveness of Noise Mitigation Measures”. Final Report, Volume I, Feb. 2004. <http://www.laermkontor.de>

## 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 provide an enhanced basis of knowledge for supporting 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.*

**“Improved computation methods  
will enable more accurate  
assessment of exposure to noise.”**





## 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<sup>37</sup>. 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 has 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<sup>38</sup>.

### ■ 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, meteorological 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.

<sup>37</sup> - 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](http://www.harmonoise.org).

- EU-Project IMAGINE "Improved Methods for the Assessment of the Generic Impact of Noise in the Environment". [www.imagine-project.org](http://www.imagine-project.org).

<sup>38</sup> The list of research topics is rather long. However, it has to be noted that with clever study design many topics can be covered and resolved within one study.

### ■ 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  
(It has to be emphasised here that recent studies were not able to show a direct relation between the degree of sound proofing and a number of long term effects. As the investment in sound insulation runs into multi-million Euro, a study is urgently needed.)
- Effects of a quiet side of a building and of quiet areas in the neighbourhood
- Effects of noise management measures on people's perception (reaction on changes of exposure situations)
- Effects of multiple noise sources (combined effects)
- Effects of simultaneous exposure to noise and other factors such as chemicals or air pollution (see also below)
- 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 modal-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.

#### ■ **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<sup>39</sup>.

#### ■ **Improvement and extension of noise valuation method**

- *Extension of method towards differentiating between different transport modes (road, rail, air)*
- *Influence of the pre-noise reduction level (i.e. noise level before applying the reduction measure) 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 per household/decibel/year is recommended<sup>40</sup>. However, this value was developed only for road transport noise reduction and does not consider the influence of the pre-noise reduction 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.

<sup>39</sup> EC DG Joint Research Centre launched a co-ordinated research activity through the organization - in collaboration with EEA, WHO and the CALM network - of an exploratory workshop on "Combined Environmental Exposure: Noise, Air Pollution and Chemicals" which took place in Ispra (Italy) on 15 and 16 January 2007.

<sup>40</sup> Position Paper of WG-HSEA on "Valuation of Noise". 21 March 2003.





**“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 3.2, research and technological development in the fields of noise control at the source play an important role in the noise policy and research strategy. Control of transport noise at the source results in global measures which have the advantage of acting not only locally, but globally leading to a good cost-benefit ratio, in particular, if the benefit threshold is set rather low (see section 4.2). In addition, 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.



Several European Technology Platforms (ETPs) have been established to define research and development priorities, time frames and action plans on a number of strategically important issues where achieving Europe's future growth, competitiveness and sustainability objectives is depending on major research and technological progress in a mid- to long-term<sup>41</sup>. The ETPs providing a wide framework for stakeholders are led by industry so that a high industrial relevance of the strategic research agendas developed by the ETPs is ensured. Amongst others, technology platforms which include aspects of transport noise exist for road traffic (ETP "ERTRAC"<sup>42</sup>), rail traffic ("ERRAC"<sup>43</sup>) and air traffic ("ACARE"<sup>44</sup>). Consequently, the noise research road maps for these transport modes have been developed by CALM in close cooperation with the related ETPs.

### 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<sup>45,46</sup>, but agreement could not be achieved so far. The research targets are defined individually for each noise category also in this Strategy Paper, but they should be related to the common minimum, medium and optimum targets for noise reception (immission) as stated in Chapter 4.



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

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<sup>41</sup> See: [http://cordis.europa.eu/technology-platforms/home\\_en.html](http://cordis.europa.eu/technology-platforms/home_en.html)

<sup>42</sup> ERTRAC – European Road Transport Research Advisory Council, see also: <http://www.ertrac.org/>

<sup>43</sup> ERRAC – European Rail Research Advisory Council, see also: <http://www.errac.org/>

<sup>44</sup> ACARE – Advisory Council for Aeronautics Research in Europe, see also: <http://www.acare4europe.com/>

<sup>45</sup> Michael Jaecker-Cueppers: Quieter Roads and Rails in Europe: a Vision for 2030.

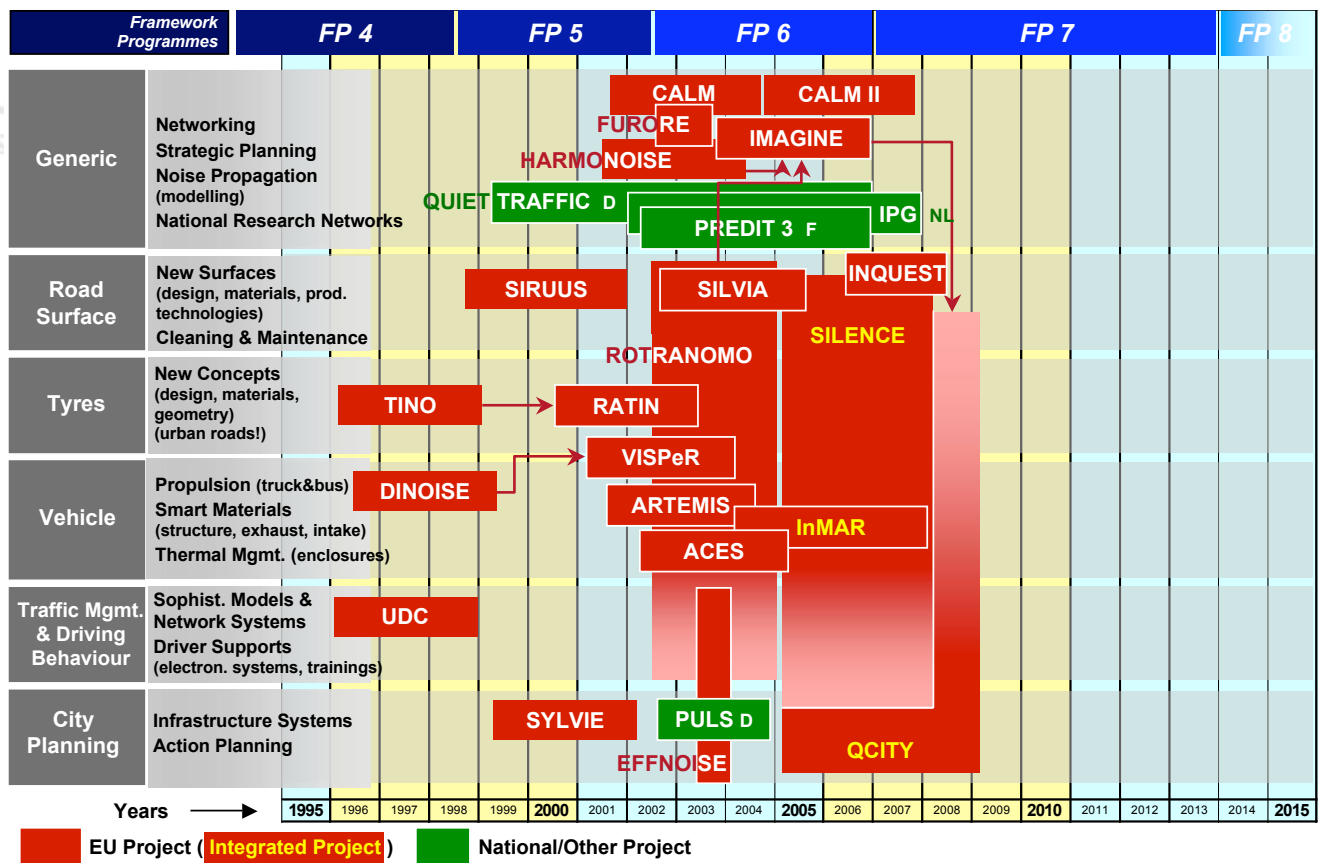
CALM Workshop with Stakeholders, Brussels, 18 - 19 March 2002.

<sup>46</sup> Martin van den Berg: Targets for Noise Immission. CALM Workshop "Road Maps for Future Research in Environmental Noise", Brussels, 16 March 2006. <http://www.calm-network.com>

### 5.3.2. Road Traffic Noise

The noise reduction targets for the noise emission from road traffic extend up to 10 dBA<sup>47</sup>. This kind of target typically in terms of  $L_{den}$ , refers to the average real traffic situation so that the whole variety of noise control measures for real traffic (e.g. low noise road surface, low noise tyres, vehicle-related measures,

traffic management, driving behaviour etc.) is to be considered. These examples of control measures form the main fields of research as illustrated in the graph below. The research activities of the last years, in particular those initiated by the 5<sup>th</sup> and 6<sup>th</sup> Framework Programme, cover most of the main fields. However, technology gaps and needs for further deeper research still exist and are summarised in the related noise technology road map.



Overview of Key Research in Road Traffic Noise

<sup>47</sup> 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.

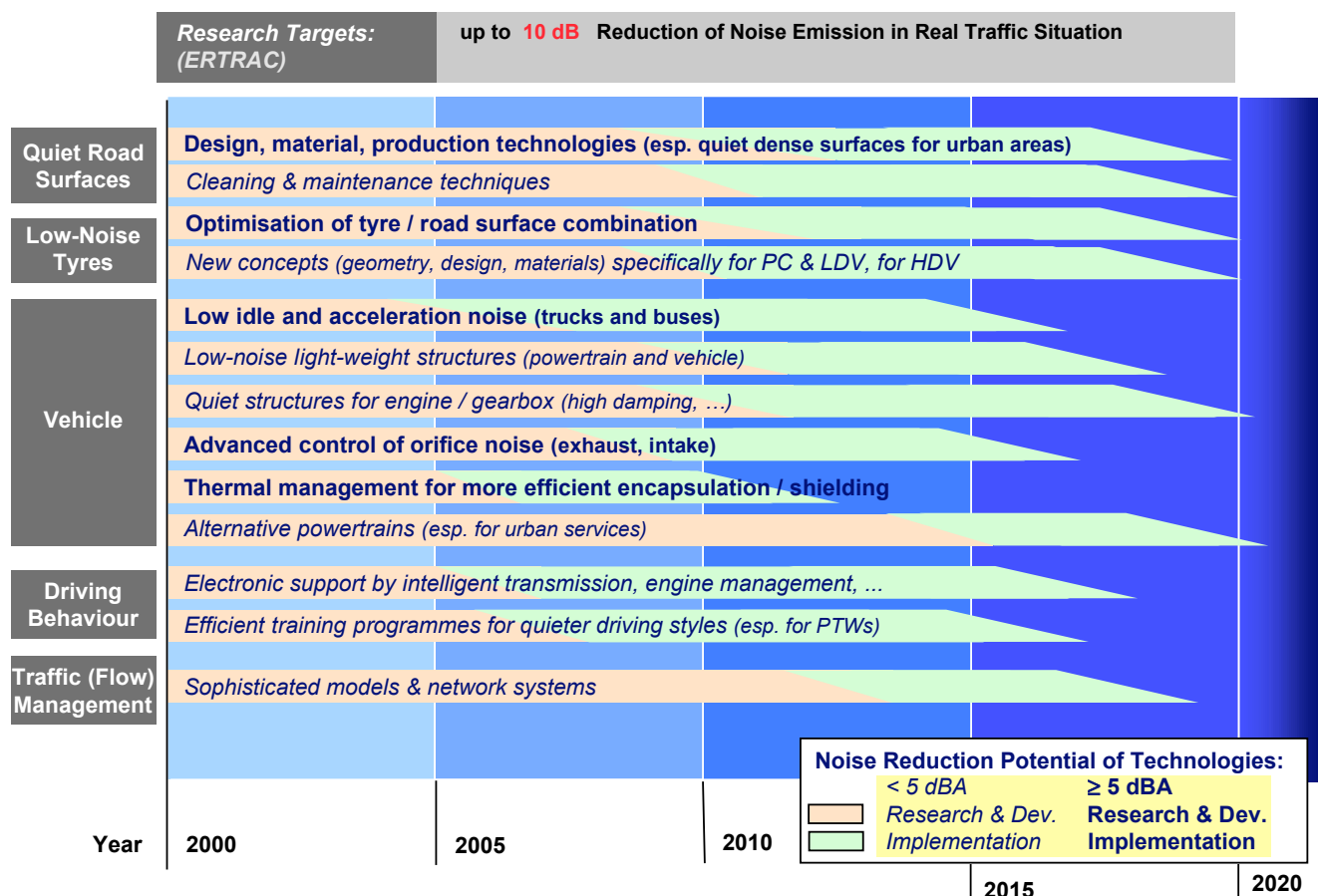
The same target is formulated in the Strategic Research Agenda of ERTRAC (Dec. 2004): "Transport noise will be reduced by up to 10 dBA through a system approach including better indicators and improvements to vehicles, tyres and infrastructure."

Applying this target to the situations of highest noise exposure ("hot spots of road traffic noise") would result in reaching the minimum level of the reception-related reference targets stated in Sect. 4.2 (see H. Steven: From Hot Spots to Research Needs in Road Transport Noise. CALM-Workshop "Road Maps for Future Research in Environmental Noise", Brussels, 16 March 2006).

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  $\geq 5$  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

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

several CALM workshops and a dedicated study<sup>48</sup>. The update of the road map is based on CALM workshops held in 2005 and 2006<sup>49</sup> and has a stronger focus on the needs for noise mitigation in urban areas.



**Noise Technology Road Map for Road Transport**

<sup>48</sup> 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](http://www.calm-network.com)).

<sup>49</sup> CALM Workshop “Research Priorities for Noise Mitigation in Urban Areas”, Brussels, 18 Oct. 2005  
CALM Workshop “Road Maps for Future Research in Environmental Noise”, Brussels, 16 March 2006.



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** (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 for optimised tyre-surface combinations)
- New concepts for low-noise road surfaces (design, material, production technologies), in particular quiet dense surfaces for urban areas
- 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. For urban areas, quiet dense surfaces are needed.

**"Emission-related legislation must be well adapted to the real world for efficient noise reduction."**





- **Vehicle noise** (also called propulsion noise consisting of engine, transmission and exhaust noise)
  - Acceleration noise (particularly for trucks and buses)
  - 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)
  - Advanced control of orifice noise (intake, exhaust; active systems)
  - 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.

- **Driving behaviour** (driver assistance systems, training programmes)

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<sup>50</sup> 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 and has already started to make the noise emission limitation a more effective and efficient tool for contributing to environmental noise reduction through 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.

<sup>50</sup> ACEM Report: Striving against Traffic Noise - How Powered Two-Wheelers can contribute. 2004.

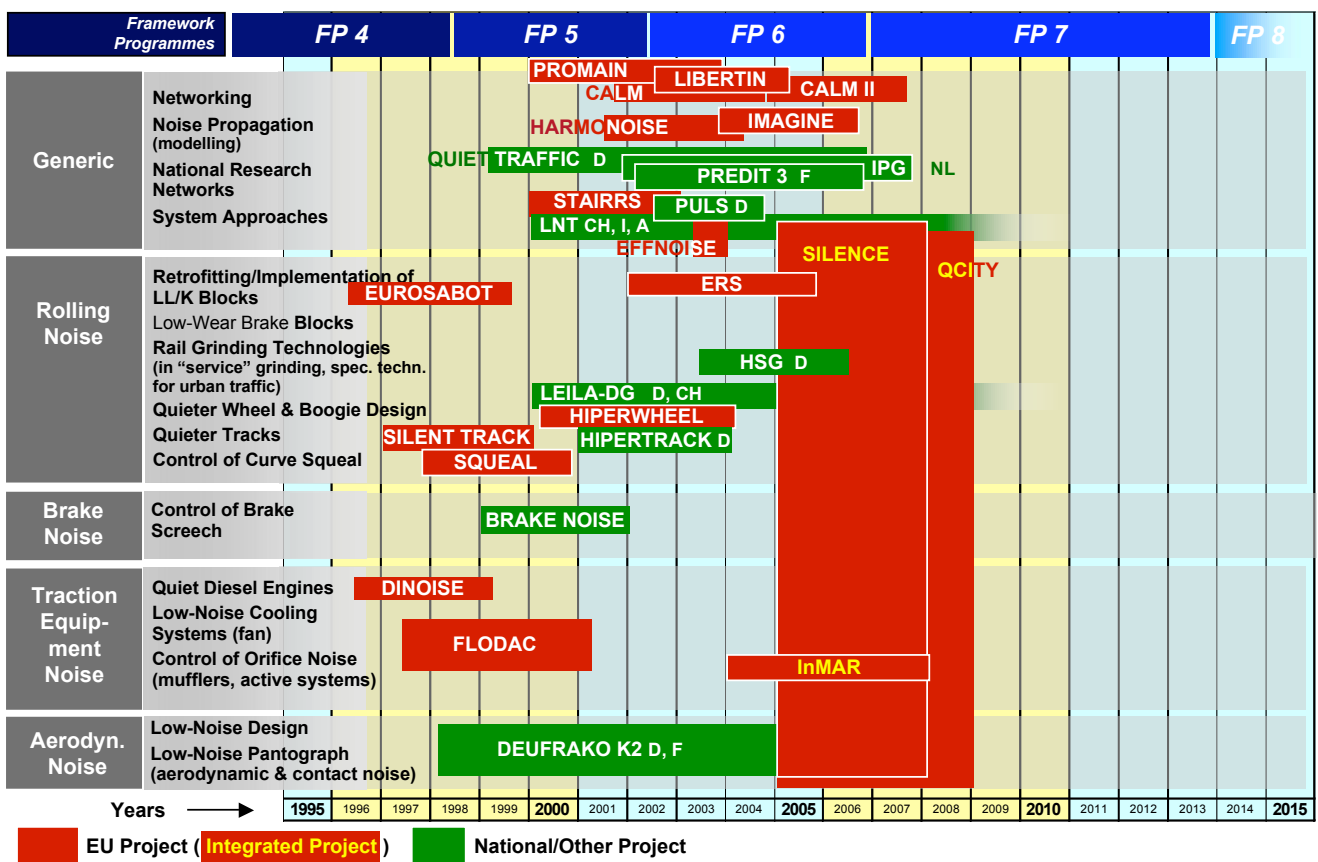
### 5.3.3. Railway Noise

The ERRAC target for noise emission by 2020 is 69–72 dBA for freight trains and to 83 dBA for high speed trains (at 300 km/h)<sup>51</sup>. This means noise emission reductions up to 20 dBA for freight trains and up to 8 dBA for high speed trains. These are challenging targets for railway noise research.

An overview of major research activities in the recent past and present is given below. The main research fields concerning railway noise are rolling noise, brake noise, noise from the traction equipment and aerodynamic noise. In addition to detail research in

specific topics, the challenging targets demand for a more holistic and systematic approach. This trend is evident in the research project overview, in particular with the EU Integrated Projects SILENCE and QCITY, the national research programmes and networks like Quiet Traffic, PREDIT and IPG and multi-national projects like Low Noise Train (LNT).

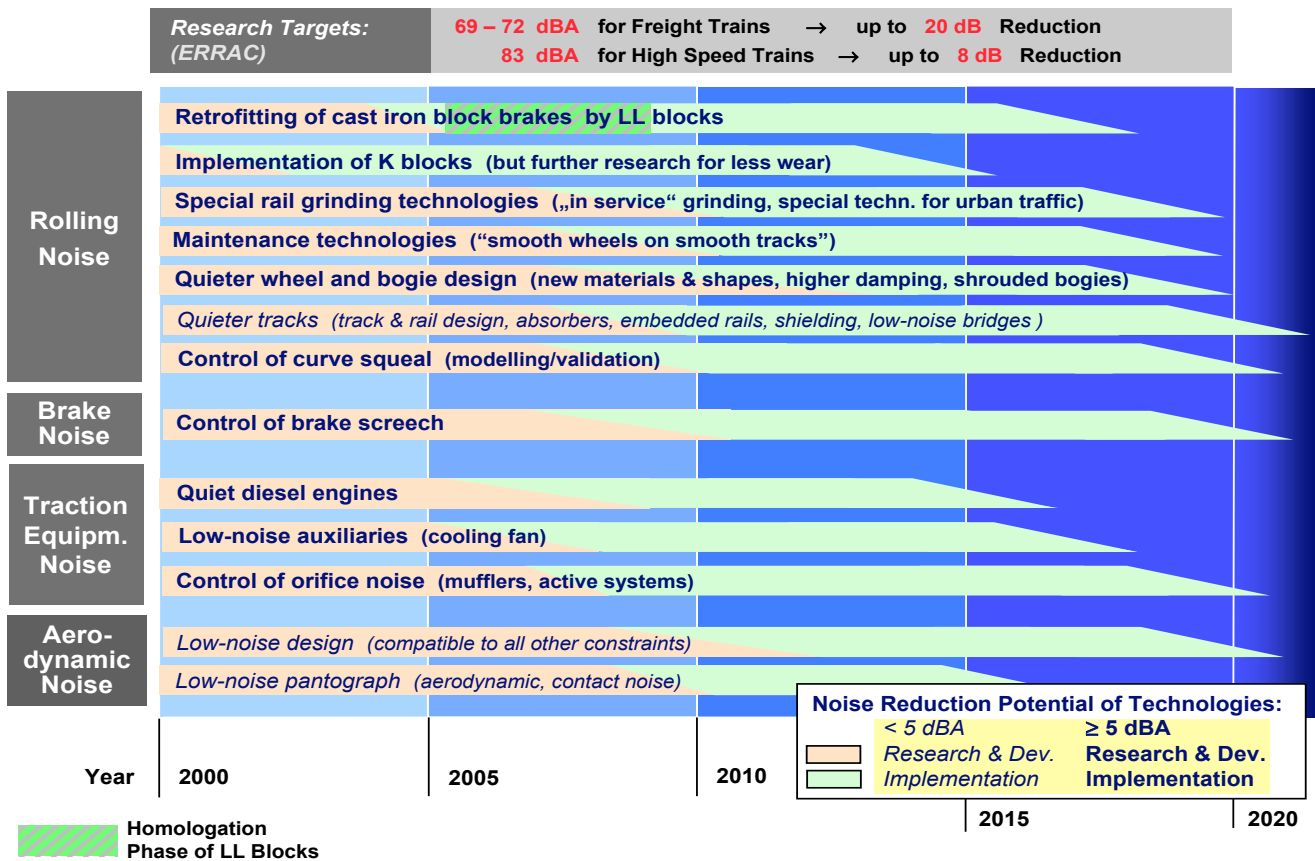
Based on former research and the direction of current research, the future demands are directed towards more thorough knowledge of existing systems and new technologies (including also new system approaches) leading to the following primary requirements of future railway noise research<sup>52</sup>.



Overview of Key Research in Railway Noise

<sup>51</sup> P.-E. Gautier, C. Cheron: Updating the Strategic Rail Research Agenda: Railway Noise Issues. Euronoise2006 Conference, Tampere, 30 May – 1 June 2006.

<sup>52</sup> 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.



**Noise Technology Road Map for Railway Transport<sup>53</sup>**

- **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 on the less expensive composite “LL-block” solutions is yet to be completed and evaluated. In parallel with retrofitting, rail grinding 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.

<sup>53</sup> 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.

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

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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 has now led to the implementation of the more stringent Chapter 4 noise limits<sup>54</sup>. As another major outcome of the process, 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 meant to help the assessment and resolution of noise problems at airports in the most cost-effective manner. The Balanced Approach 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.

Within Europe, through the early activity of the “Aeronautics Task Force” on “The Environmentally Friendly Aircraft” and the subsequent work carried out

issues on a problem-solving basis. Under the hat of the X-Noise network, major industrial partners have been involved with leading research establishments in supporting the development of strategic research agendas in the noise area. This has led to the effective implementation of a number of complementary projects in the frame of a well coordinated technical strategy. Through FP4 and FP5 projects, the effort aiming at the EC short/mid term improvement of 5 dB, also called “Generation 1 Solutions”, is now well under way culminating with the achievements to be reached by the large SILENCE(R) Technology Platform.

Taking up on the elements provided by the ACARE SRA-1, X-NOISE has in particular identified gaps and priorities, considering through a common methodology the research to be carried out on each engine / nacelle / aircraft component of interest as well as on generic enabling factors such as Computational Aero-Acoustics (CAA) techniques. As a result, a series of new projects aiming at Generation 2 solutions have been initiated. The figure below represents the projects involved in achieving the Generation 1 step as well as the early stages of the effort aiming at the 2020 goals.



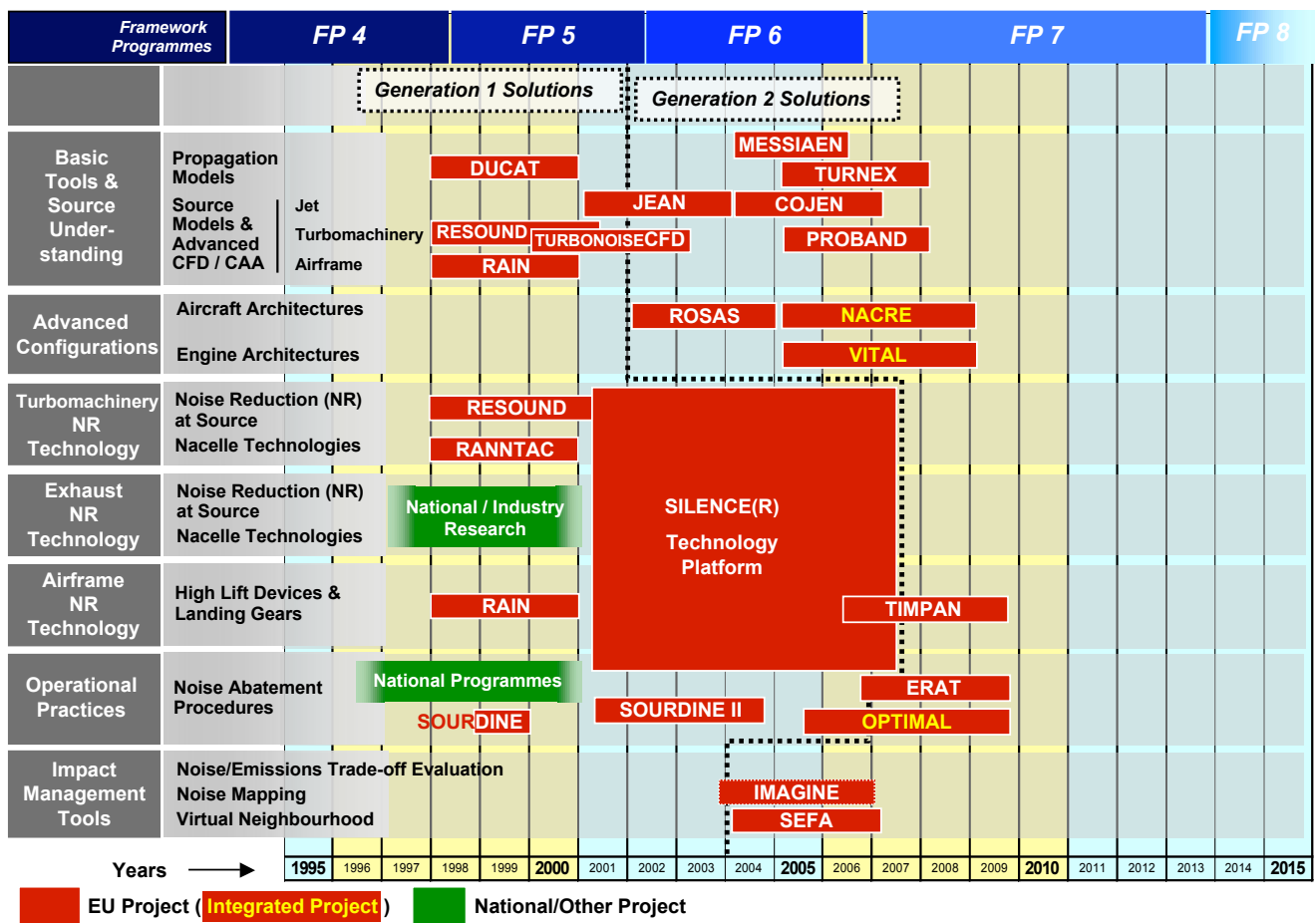
in ACARE for the SRA-1 and now SRA-2<sup>55</sup>, there has been a definite will to develop a consistent research strategy aimed at addressing aviation environmental



**“Noise is an important topic in the strategic research agenda of ACARE.”**

<sup>54</sup> Convention on International Civil Aviation, Annex 16 „Environmental Protection“, Volume I, Chapter 4. 2001.

<sup>55</sup> Strategic Research Agenda (SRA-1) of ACARE, Oct. 2002; this SRA has been updated end of 2004 as SRA-2. ACARE is the “Advisory Council for Aeronautics Research in Europe”, supported by the X-Noise network regarding noise topics. See also: <http://www.acare4europe.com/> and: <http://www.x-noise.net/>



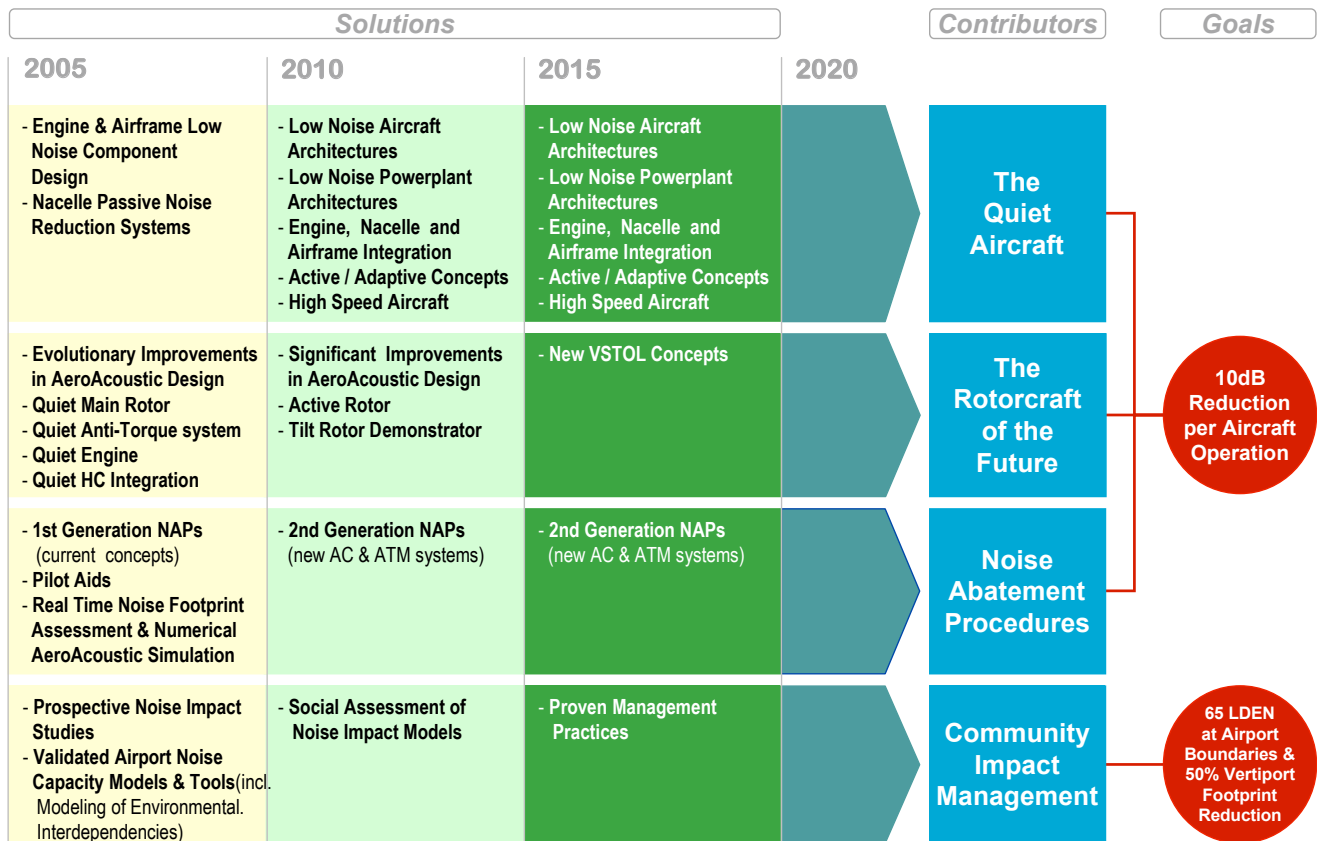
### Overview of Key Research in Air Traffic Noise

As indicated above, the on-going effort is fully consistent with the Strategic Research Agenda SRA-1 first published in October 2002 under the direction of ACARE. Its contents covered five key challenges to address for 2020, namely Quality and Affordability, Environment, Safety, Air Transport System Efficiency and Security. The SRA-1 challenge **Environment** was more specifically described as meeting a continually rising societal demand by reducing the environmental impact of operating, maintaining, manufacturing and disposing of aircraft and related systems.

To meet such challenges, quantified 2020 goals were set and specific “Contributors” were identified, representing the constituent elements contributing to the achievements of the goals. Each contributor has associated with it a set of technical and operational solutions which are not mutually exclusive, and which, if appropriately funded, researched and applied would be capable of meeting the 2020 goals. The goals, contributors and solutions

involved in the noise reduction aspects of the SRA-1 are represented below.

While the most significant element remains here technology development, other elements of the Balanced Approach are being considered as well, aiming at a combined noise reduction of 10 dB per aircraft operation as the first 2020 goal. The agenda is also stating the importance of research aiming at improving tools and practices involved in the management of noise impact to take full advantage of novel technology and successfully manage situations emerging in the transition period. Meeting the second 2020 goal would then translate into ensuring that such a global approach will limit noise nuisance to 65 dBA  $L_{den}$  at airport boundaries and lead, for rotorcraft, to a noise footprint area reduced by 50 percent around heliports or vertiports.



### Noise Technology Road Map for Air Traffic (ACARE)

A second edition of the Agenda was released by the end of 2004. One of the key development areas of SRA-2 has been then to examine the sensitivity of the Agenda to alternative views of the future. These future views are determined by the sets of unique characteristics that describe different drivers of the air transport system and the challenges to it (environment, security etc.). By exploring the technology implications of each of these unique characteristics along a particular research axis, it was then possible to see how they would be used within a system operational context.

This led to elaborate High Level Target Concepts (HLTCs) which extend thinking to a moderately extreme view in five different directions: protecting the environment, saving time, improving security, increasing choice and reducing cost. The component “Environment” of the SRA-2 is concentrated under the SRA-2 HLTC **Ultra Green Air Transport System**.

As such, the concept stretches the world’s sensitivity to environmental damage and examines possible technological responses to it, the most relevant

scenario being “Constrained Air Traffic Growth” under which there will be an increased public awareness in industrialised as well as in emerging countries of the need to protect the environment. In full consistency with the quantified SRA-1 goals detailed above, the HLTC “Ultra Green Air Transport System” addresses the whole range of vehicles for a future air transport system within the added dimension of an operational context described earlier.

Within the context of both SRAs, a number of conditions, prerequisites and enabling factors have been emphasized. They state in particular that the objectives are not achievable without important breakthroughs, both in technology and in concepts of operation, and that evolutions of current concepts will not be sufficient. In sum, the technological and operational future needs are as follows:



### ■ Aircraft

- *Low-noise architecture of powerplant and aircraft*
- *Individual component aero-acoustic design associated with low-weight technologies*
- *Optimised integration of engine, nacelle and airframe*
- *Innovative noise reduction techniques such as active / adaptive systems*
- *Low-noise concepts for high speed aircraft*

A significant and sustained effort is in fact needed to achieve the necessary technology breakthroughs, if the ACARE goals of environmental performance are to be met. Such breakthroughs aiming at “Generation 2 Solutions” will, in practice, encompass a wider range of areas as outlined above each providing technology building blocks along the multidisciplinary path leading to an environmentally optimised aircraft.

### ■ Rotorcraft

- *Evolutionary improvements in aero-acoustic design*
- *Quiet concepts of main rotor (incl. active rotor), anti-torque system and engine*
- *Optimised helicopter integration of components*
- *New concepts for very short take-off and landing (VSTOL)*

### ■ Noise abatement procedures (NAP)

- *Novel concepts of noise abatement procedures (2nd generation NAPs, new aircraft and air traffic management systems)*
- *Pilot aids*
- *Real-time noise footprint assessment and numerical aero-acoustic simulation*

As can be seen above, the European research effort is also increasingly tending to consider more global solutions addressing aviation environmental issues through a system approach as recommended in the ACARE SRA-2 (the Ultra Green Air Transport System concept). In the wake of current efforts such as SOURDINE II, effective implementation of novel Noise Abatement Procedures (NAPs) will substantiate the need for a sustained research activity.

### ■ Community impact management

- *Prospective noise impact studies and social assessment of noise impact models*
- *Validated airport noise capacity models and tools (incl. modelling of environmental interdependencies)*

Relatively little has been done so far in Europe in the area of understanding and modeling noise and emissions interdependencies, as well as defining their role in shaping future product design and possible future regulations. A serious effort needs to be initiated in this area starting with an analysis of the stakes and strengths and gaps of European assets, whilst at the same time formulating an active dialogue with US counterparts on the non-competitive aspects of this international issue.





### 5.3.5. Outdoor Equipment Noise

The target for the vision of 2020 is to halve the noise annoyance caused by outdoor equipment<sup>56</sup>. 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<sup>57</sup>.

#### ■ 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 situations. 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.

<sup>56</sup> Derived from CALM Workshop with Stakeholders, Brussels, 18 - 19 March 2002.

<sup>57</sup> 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](http://www.calm-network.com)).



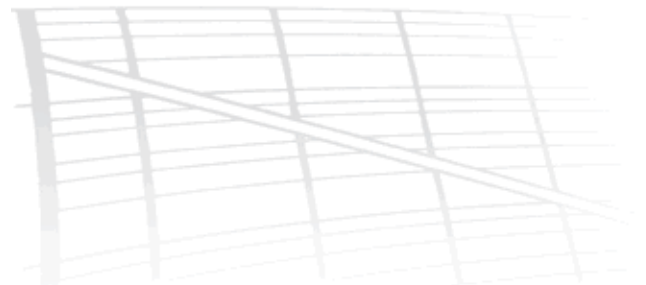
**“Real operation nuisance of outdoor equipment can differ widely from standard noise tests.”**

## 5.4. Implementation 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

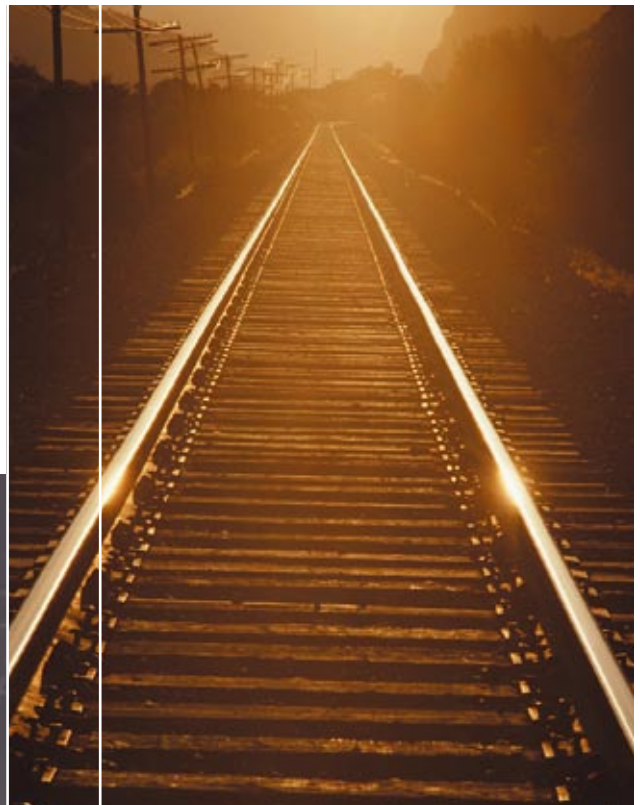
Such barriers have to be considered in implementation plans, and adequate actions to overcome such barriers have to be included. As implementation is more a political issue than a technical one, it is not the task of the CALM network to prepare and provide implementation plans. However, the topic is 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.



## 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<sup>58</sup>. 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.”**



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<sup>58</sup> “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>)

## 7. Abbreviations

<b>AC</b>	Aircraft	<b>HC</b>	Helicopter
<b>ACARE</b>	Advisory Council for Aeronautics Research in Europe	<b>HLTC</b>	High Level Target Concept
<b>ACEM</b>	Association of Motorcycle Industry in Europe (Association des Constructeurs Europeens de Motorcycles)	<b>HP</b>	Hedonic Price (Method for CBA)
<b>ACMARE</b>	Advisory Council for Maritime Research (meanwhile substituted by the Technology Platform WATERBORNE TP)	<b>HSEA</b>	Health and Socio-Economic Aspects
<b>AEN</b>	Assessment of Exposure to Noise	<b>ICAO</b>	International Civil Aviation Organization
<b>ATC</b>	Air Traffic Control	<b>I-INCE</b>	International Institute of Noise Control Engineering
<b>ATM</b>	Air Traffic Management	<b>IKA</b>	Institut fuer Kraftfahrwesen Aachen, Germany
<b>ATS</b>	Air Transport System	<b>IP</b>	Integrated Project
<b>CAA</b>	Computational Aero-Acoustics	<b>L<sub>den</sub></b>	Equivalent Sound Level over Day, Evening and Night Period
<b>CAEP</b>	ICAO Committee for Aviation Environmental Protection	<b>L<sub>eq</sub></b>	Equivalent Sound Level (over a certain period)
<b>CBA</b>	Cost-Benefit Analysis	<b>L<sub>night</sub></b>	Equivalent Sound Level over Night Period
<b>CFD</b>	Computational Fluid Dynamics	<b>NAP</b>	Noise Abatement Procedure
<b>COM</b>	Official Commission Document	<b>OE</b>	Outdoor Equipment
<b>CRF</b>	Centro Ricerche Fiat, Italy	<b>OJ</b>	Official Journal (of the European Communities)
<b>dBA</b>	decibel, A-weighted	<b>PTW</b>	Powered Two-Wheeler
<b>DG</b>	Directorate General (of the European Commission)	<b>RTD</b>	Research, Technological Development and Demonstration
<b>EC</b>	European Commission, European Community	<b>SP</b>	Stated Preference (Method for CBA)
<b>EEA</b>	European Environmental Agency	<b>SRA</b>	Strategic Research Agenda
<b>EEC</b>	European Economic Community	<b>TREN</b>	Transport and Energy, Directorate General of EC
<b>END</b>	Environmental Noise Directive	<b>TSI</b>	Technical Specification for Interoperability
<b>ENTR</b>	Enterprise, Directorate General of EC	<b>UBA</b>	Umweltbundesamt, Germany
<b>ENV</b>	Environment, Directorate General of EC	<b>UIC</b>	International Union of Railways
<b>ERRAC</b>	European Rail Research Advisory Council	<b>UNECE</b>	United Nations Economic Commission for Europe
<b>ERS</b>	Euro Rolling Silently (EU Research Project)	<b>US</b>	United States (of America)
<b>ERTRAC</b>	European Road Transport Research Advisory Council	<b>VROM</b>	Ministry of Housing, Spatial Planning and Environment, Netherlands
<b>ETP</b>	European Technology Platform	<b>VSTOL</b>	Very Short Take-Off and Landing
<b>EU</b>	European Union	<b>VTOL</b>	Vertical Take-Off and Landing
<b>FP</b>	Framework Programme	<b>WG</b>	Working Group
<b>GDP</b>	Gross Domestic Product	<b>WHO</b>	World Health Organization
<b>GIS</b>	Geographical Information System	<b>X-Noise</b>	Aircraft External Noise Network





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