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Noise Research Concept

The need to update the basis for noise assessment

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Foreword

Among other things, the Federal Noise Abatement Commission (FNAC) has the task of advising the Federal Department of the Environment, Transport, Energy and Communications on scientific issues relating to the effects of noise on the health and well-being of the population. In particular, the FNAC should develop methods for noise impact assessment and propose exposure limits for the protection of the population. The FNAC has undertaken the scientific research necessary for all the threshold values currently enshrined in the Noise Abatement Ordinance (NAO). The first recommendations date from 1979 and relate to road traffic noise. Most recently, the FNAC has developed the basis for the noise assessment of military installations.

The task of developing principles for assessing the impact of noise also includes the task of ensuring that these fundamentals always correspond to the current state of science and experience. Since the recommendations of the Commission from the 1970s, noise impact research has seen significant developments. On the other hand, there has been criticism of the present thresholds, especially in relation to railway and aircraft noise. Finally, it must be assumed that the population's lifestyle, and in particular the sleeping/waking rhythm, has changed considerably since the 1970s and 1980s.

The objectives of noise abatement have not yet been achieved. In the future, in order to ensure the legally required protection of the population from noise, additional technical measures directly at the sources of noise are essential, supported by mechanisms of guidance and support. Also, given this modified focus, the objective remains to protect the population from significant disturbance to its well-being. Therefore, there is a need in the future for a noise assessment system which takes into account the current state of knowledge.

These factors and the corresponding research findings of the members of the FNAC itself have finally led to the Commission to examine in depth whether the basis of the currently applicable thresholds are still up to date, in order make scientifically valid statements about the disturbing effect of noise. On the basis of the work of an interdisciplinary team of experts documented in this report, the FNAC has come to the conclusion that, from the scientific point of view, there is currently a requirement to update the basis of the recommendations of the FNAC, particularly in relation to types of traffic noise.

It will take several years to complete the update of the scientific basis for noise assessment. It does not bring into question the currently applicable impact thresholds. It is impossible today to estimate how the update will eventually affect the current state of science, and thus the existing regulation of the Noise Abatement Ordinance. The ongoing efforts relating to noise abatement should therefore be continued in a targeted fashion.

Prof. Dr. iur. Anne-Christine Favre, President of the FNAC

The essentials on three pages

Existing situation and motivation

In the 1980s, the Environmental Protection Act EPA and the Noise Abatement Ordinance NAO entered into force, among other things with the aim of protecting the population from harmful or onerous noise. For the evaluation of the harmfulness and annoyance, impact thresholds are laid down in the NAO for road and rail traffic; thresholds later also followed for civil aviation and for other types of noise. The impact thresholds are defined according to the state of science or experience in such a way that noise below these levels does not significantly adversely affect the population's well-being.

Since the impact thresholds were laid down, the volume of traffic has evolved enormously. The volume of traffic has increased markedly and the composition of the vehicles, their specific noise emissions and the traffic distribution throughout the day have changed considerably. The day-night demarcation chosen in the Noise Abatement Ordinance no longer necessarily corresponds to current sleeping-waking rhythms. In addition, recent studies suggest that the population tends to feel more disturbed by noise at the same sound levels.

The objectives of noise abatement have not yet been reached. To date, the implementation of the Noise Abatement Ordinance has focused on action in the propagation path (noise barriers) and the installation of soundproof windows. In the future, in order to achieve the legally required protection of the population from noise, additional technical measures directly at the sources of noise are essential, supported by mechanisms of guidance and support. Even given this modified focus, the objective remains to protect the population from significant disturbance to its well-being. Therefore, there is a need in the future for a noise assessment system which takes into account the current state of knowledge.

Updating the scientific basis for noise assessment does not bring into question the impact thresholds currently in effect. It is impossible today to estimate how updating the basis will eventually affect the current state of science, and thus the existing regulation of the Noise Abatement Ordinance. In the communication of the upcoming research, great weight will attach to this aspect, in order not to hinder the targeted continuation of today's efforts to reduce noise.

The problem

In order to be able to judge in the future the effectiveness and efficiency of new noise abatement measures, there will continue to be a need for a noise assessment system which corresponds to the latest state of knowledge. Against this background, the Federal Noise Abatement Commission FNAC, in consultation with the Federal Office for the Environment FOEN, wishes to examine the issue of whether there is a scientifically substantiated need to examine or update the basis for noise assessment in general and the impact thresholds in particular.

Methodology

The question raised concerns regarding various aspects of the noise environment, from the level of noise exposure and its acoustic characterisation by means of noise rating measures to the effects on the people affected by noise in the form of nuisance, disturbance, health consequences and social restrictions. To analyse this broad spectrum, a total of 21 key questions was defined by an interdisciplinary research team. The questions were analysed in detail individually in five specific input papers, with particular reference to any changes and new information emerging since the impact thresholds were defined and whether the new information justifies a need for action. The results of the analysis were discussed in detail and consolidated at a workshop with national and international experts (see Annex A).

Results

The main results are summarised in the Table below (page 6). The project team identified a high need for action on 8 of the 21 key questions.

There is a high need for action on the **Noise Impact dimension:**

- There are various indications that the exposure-effect relationships on which the threshold definitions is based have changed over time, so that the nuisance at a given level is now greater than previously – which is best illustrated in the case of aircraft noise. (→key question NI 1)
- The original empirical principles which formed part of the definition of the impact thresholds can generally be considered scarcely adequate, particularly by today's standards.(→key question NI 2)
- The distinction in the Noise Abatement Ordinance between day (6 a.m. – 10 p.m.) and night (10 p.m. – 6 a.m.) no longer reflects the current pattern of activity of the population. (→ key question NI 4)
- There is an urgent need for research into how to handle the impact of combined noise. It is not known how noise from several sources should be acquired and there is a lack of information on the annoying or harmful effects of combination noise. (→ key question NI 7)
- Furthermore it must also be recognised that other dimensions apart from nuisance, such as health, should be incorporated in the threshold definition. For instance, assessment of noise nuisance cannot be made while asleep, even though the noise can have health consequences.

In the **Technology & Operations dimension**, an urgent need for action is identified for one question on road traffic noise (T&O 1) and two on railway traffic noise (T&O 4, 6):

- With regard to **road traffic**, it is primarily the huge increase in traffic on very busy roads that causes permanent noise exposure which hardly decreases at night. It is assumed that merely increasing the rating sound level does not fully address the associated nuisance and disturbance experienced by the population. A separate disturbance correction may be required for roads subject to continuous and very busy use.

- With regard to **railway traffic,** the significant increase in train density (train numbers per unit time) raises the question of whether the bonus for railway over road traffic is still justified. The high proportion of freight traffic at night and the increasing train lengths also raise doubts about the appropriateness of the method of determining the level correction, because it gives an advantage in its present form to trains at night over those during the day, if less than 79 trains run in the relevant period.

In the **Acoustics** dimension, there is urgent need for action on only key question (A 4). This is because some previous national studies to determine exposure-effect relationships used calculations to derive noise levels rather than measurement at the location of the sampled population, due to budgetary constraints. It has now been shown that some of the noise calculation models that were used systematically underestimated the noise exposure, particularly at night.

In the **Law** dimension, the legal requirements for definition of impact thresholds for noise were examined but no immediate need for action was identified. People must continue to be protected from annoying or harmful effects in the future.

Conclusion

The project team and the FNAC recommend that the empirical principles for noise assessment, in particular noise impact (nuisance, disturbance, medical and social effects) on the Swiss population be updated.

Need for action to review the impact thresholds for noise Table 4-1, p. 52)

Dimension	Key question	Need for action* Project team	Expert Ø	No. of expert answers
Technology & Operations				* 0: None; 1: Low; 2: Average; 3: High
T&O 1	How have road traffic volumes changed over the last 25 years, particularly on the motorways, and what are the forecasts?	3	2.5	(4)
T&O 2	How have road traffic emissions changed over the last 25 years and what are the forecasts?	1	1.6	(5)
T&O 3	How has the distribution of road traffic throughout the day changed over the last 25 years and what are the forecasts?	2	1.8	(5)
T&O 4	How have rail traffic volumes changed over the last 25 years, particularly on the main lines, and what are the forecasts?	3	2.4	(5)
T&O 5	How have rolling stock emissions from rail traffic changed over the last 25 years and what are the forecasts?	2	1.8	(5)
T&0 6	How has the distribution of rail traffic throughout the day changed over the last 25 years and what are the forecasts?	3	2.8	(5)
T&O 7	How have aircraft movements around airports changed over the last 25 years and what are the forecasts?	1	1.2	(6)
T&O 8	How have emissions from air traffic changed over the last 25 years and what are the forecasts?	1	0.7	(6)
T&O 9	How has the distribution of air traffic throughout the day changed over the last 25 years?	1	2.2	(5)
Acoustics				* 0: None; 1: Low; 2: Average; 3: High
A 1	Is the concept of the rating sound level, which is the sum of an average level and one or more corrections, appropriate to describe the noise impact (nuisance, sleep disturbance, health risk?)	1	1.6	(5)
A 2	Is the point of application for the impact thresholds in the NAO appropriate in acoustic terms for recording the disturbance experienced by the noise sufferer?	1	0.0	(3)
A 3	Since entry into force of the NAO, have the technical facilities for acoustic measurement changed or improved to the extent that that this would possibly affect definition of the noise impact thresholds?	2	1.6	(5)
A 4	Since entry into force of the NAO, have the methodology approaches and the acoustic simulation technologies (calculation of noise exposure) changed or improved to the extent that this would possibly affect definition of the noise impact thresholds?	3	2.8	(5)
A 5	Measurements and calculations are affected by quantifiable uncertainties. What significance do these uncertainties have in the definition of impact thresholds?	2	1.2	(6)
Noise Impact				* 0: None; 1: Low; 2: Average; 3: High
EB 1	What changes in exposure-effect relationships have taken place over time and do they indicate a need for action?	3	2.9	(8)
EB 2	Are the previous empirical studies adequate for current threshold definition requirements?	3	2.9	(7)
EB 3	Are the observation periods implemented in the NAO (e.g. averaging over one year) still appropriate for the impact and occurrence of noise?	1	1.4	(8)
EB 4	Are the time of day rating periods in the NAO still appropriate for the impact and occurrence of noise?	3	3.0	(8)
EB 5	Are all the sources covered in the NAO adequately described in acoustic terms?	2	2.1	(7)
EB 6	What impact dimensions must be considered if a threshold definition is to reflect current knowledge and experience?	2	2.4	(8)
EB 7	Does failure to include the combined impact of various noise sources of both similar and different types indicate a need for action?	3	2.8	(8)

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Readership

This summary is addressed to a broad readership and not primarily to a technical audience. For ease of reading, there is very little specialist technical explanation of acoustics, the methodology of noise impact research or the data sources and the text concentrates on presenting and interpreting the results.

Readers who are particularly interested in finding out more about how the results were obtained are referred to the scientific policy framework and input papers listed in the bibliography on the dimensions studied – History, Law, Technology & Operations, Acoustics and Noise Impact.

1 Introduction

1.1 Starting point and motivation

A large number of people are affected by noise from road, rail and air traffic. As early as the 1960s, the first attempts were made to protect people from excessive traffic-related noise exposure. The real breakthrough in noise abatement was achieved in the 1980s.

Article 74 of the Federal Constitution and the subsequent adoption of the Environmental Protection Act (EPA) in 1985 established the legal basis for the currently applicable objective according to which people are to be protected from harmful or onerous noise. In this context, noise is considered harmful or onerous if the well-being of the population is significantly disturbed. The threshold of harm or annoyance was defined in the 1987 Noise Abatement Ordinance; in particular, this set mandatory impact thresholds in relation to noise exposure for road and rail noise.

Subsequently various measures have been taken to protect of the population from excessive noise. The implementation of the Noise Abatement Ordinance has predominantly focused on action in the propagation path (noise barriers) and the installation of soundproof windows. More recent publications now indicate that despite the extensive measures. noise pollution from transport, especially road transport, is continuing to have significant adverse effects on the population's well-being throughout Switzerland. At present, it therefore seems somewhat questionable whether the EPA's objective of protection can be fully achieved with the existing measures. In the future, in order to achieve the legally required protection of the population from noise, additional technical measures directly at the sources of noise are essential, supported by mechanisms of guidance and support. Information is also useful in order to make the population appropriately aware of its options concerning action - anyone can cause a noise nuisance, or suffer from one.

However, the principle of protecting the population from significant adverse effects will remain unaffected, even given the increased focus on technical measures, support mechanisms and information. In order to be able to judge in the future the effectiveness and efficiency of new noise abatement measures, there will therefore continue to be a need for a noise assessment system which corresponds to the current state of knowledge. In this regard, since the impact thresholds were established there have been developments which raise some questions. For example, the volume of traffic has increased not only in terms of quantity, but the traffic composition has also changed significantly (persons and freight); its evolution throughout the day and other noise-related properties (for example, tonality) have also changed markedly. In addition, recent studies suggest that the population tends to feel more disturbed by noise at the same sound levels. Furthermore, the day-night demarcation chosen in the Noise Abatement Ordinance no longer necessarily corresponds to current sleeping-waking rhythms. The Federal Court has also already levelled criticism at individual thresholds, and jurists see shortcomings in particular in relation to the impact thresholds for airports. Therefore, the Federal Noise Abatement Commission seeks to clarify whether the scientific basis on which the impact thresholds are based need to be updated.

It should be emphasised here that updating the scientific basis for noise assessment does not bring into question the impact thresholds currently in force. These continue to be appropriate, according to the current state of science and experience, in order to correctly assess the disturbance effect of noise within the meaning of the statutory provisions. It is impossible today to estimate how updating the basis will eventually affect the current state of science, and thus the existing regulation of the Noise Abatement Ordinance. In the communication of the upcoming research, great weight will attach to this aspect, in order not to hinder the targeted continuation of today's efforts to reduce noise.

1.2 Purpose

The first phase will examine whether changes in the “noise environment” indicated a **scientifically based need** for a detailed review of the principles of the noise exposure thresholds. The following questions required answers:

- Do the principles on which the definition of impact thresholds specified in Annexes 3, 4 and 5 of the Noise Abatement Ordinance (NAO) are based reflect current knowledge and experience?
- What are the requirements for definition of the impact thresholds under the Environmental Protection Act?
- Do the rating sound levels appropriately reflect the disturbance?
- Is there a need to review and reassess these factors?

These questions are answered on the basis of an analysis of selected or presumed changes (see section 1.3) over the past 25 years, mainly in the dimensions of:

- Technology & Operations
- Acoustics
- Noise Impact (medical/psychological)

The temporal and historical component is also taken into consideration for the three dimensions in terms of the original starting point and the changes since then. On the basis of this scientific principle, an overall assessment will be produced and the decision taken as to whether or not the situation for the dimensions listed indicates a need to review the basis for noise exposure thresholds.

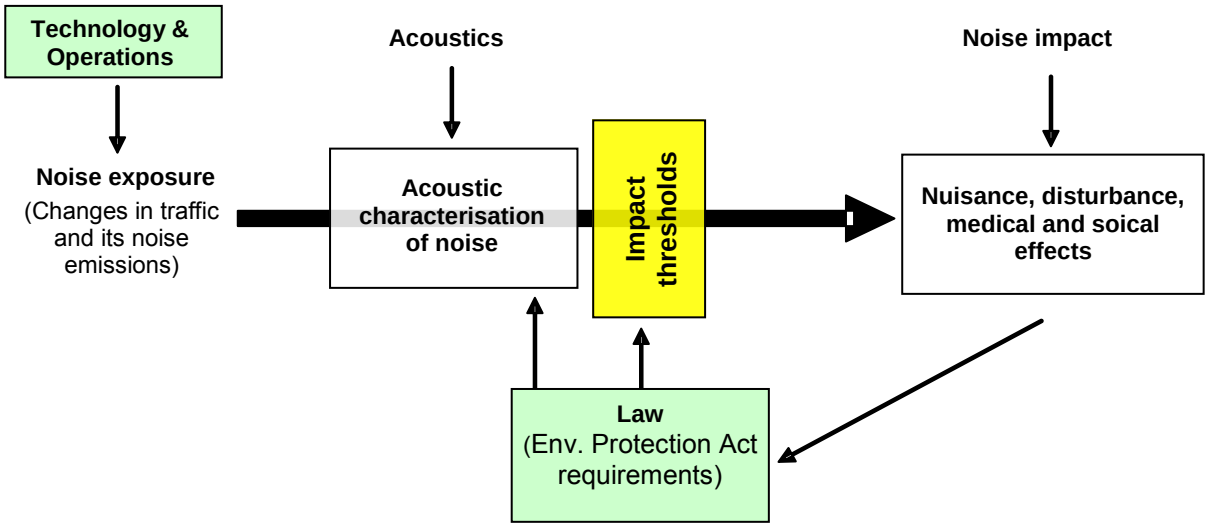
Only when the results of these reviews are available will the FNAC be able to propose any future action to the FOEN. A full range of options is open to them - to discontinue the project if there is no need for action, through one-off clarifications in some areas to an in-depth investigation of the interdependencies.

1.3 Methodology

The study concept used for the problem is illustrated in Figure 1-1. At the centre of the current protection concept are the impact thresholds, which are intended to ensure that residual noise exposure below this threshold does not seriously disturb the well-being of the population. Based on the legal requirements for impact thresholds, the link connecting noise exposure via its characterisation or recording to its effect or nuisance is investigated. The aim is to examine whether there have been changes or new knowledge in any of the three dimensions (Technology & Operations, Acoustics, Noise Impact) and in their overall interaction. It is clear that this analysis cannot be comprehensive and cover all possible problems in the exposure-effect relationships but instead must concentrate on selected aspects considered to be important in terms of the potential need for action in the experience of the project team, the experts and the client.

In particular this review must take account of the temporal component. It needs to clarify whether the level of exposure, its physical acquisition and characterisation (e.g. day/night) and its disturbance effect (e.g. due to changing social value judgements) have altered over time or new information on the subject is available (e.g. in the medical field).

Figure 1-1: De l'exposition au bruit à la gêne



Based on this study concept, the work was structured in four phases:

- In the **first phase**, selected subject areas and questions were assembled for each dimension which might have altered since the impact thresholds were defined and could potentially trigger action to review the basis. On the basis of these, 21 key questions were identified.
- These key questions were analysed and answered in the **second phase** by the project partners responsible. The results, with an evaluation of the need for action on each question, were summarised in the following individual papers:
  - R. Hofmann (2009), policy framework paper: The historical development of noise thresholds
  - Office for Legislation (C. Zäch) (2009), input paper 1: Law
  - Planteam (R. Höin, B. Buchmann) (2009), input paper 2: Technology & Operations
  - EMPA (R. Bütikofer, K. Eggenschwiler, K. Heutschi, G. Thomann, J.M. Wunderli) (2009), input paper 3: Acoustics
  - ETH Zurich MTEC Public & Organizational Health (M. Brink) (2009), input paper 4: Noise Impact
- In the **third phase**, the information was discussed with national and international experts[1] at a day-long workshop. For each key question, the experts carried out their own evaluation of the need for and relevance to a review of the scientific basis for the definition of the impact thresholds. The information from the workshop was used to finalise the input papers.
- In the **fourth phase**, this summary report was prepared. It contains a summary of the main results and information from the input papers and an overall assessment of the need for action. The summary is addressed to a broad readership, so that detailed and specific technical discourse is avoided as far as possible. Interested readers can find out more about the derivation of the results and the sources used in the relevant input papers.

[1] See the Annex for the list of experts.

1.4 Content and structure of the summary report

Chapter 2 contains the principles for analysis of the need for action. After a brief definition of the term “noise” in section 2.1, the currently applicable impact thresholds for noise are presented (section 2.2). There is then an overview of the historical development of these thresholds (section 2.3). Section 2.4 contains the current requirements for the impact thresholds for noise from a legal standpoint.

Based on these principles, **Chapter 3** gives an analysis of the need to review the scientific basis of the impact thresholds for noise. The three sections 3.1 to 3.3 present an overview of the study results for the three dimensions of Technology & Operations, Acoustics and Noise Impact. At the end of each section there is a conclusion on the need for action identified.
Chapter 4 summarises the results from the different dimensions in an overview and gives a recommendation on need for action and the relevance of the various key questions. A proposal for further action is also developed.

2 Principles

2.1 Noise: What is it and how is it measured?

Noise has a variety of specific forms and is perceived in different ways: Rock music is pure pleasure for some people but a terrible din for others; the tinkling of cow bells has a soothing effect on some people but others find it disturbing.

As a result of this variety of form and perception, the following definition has become established for noise “Noise is unwanted sound which can harm people exposed to it physically, psychologically, socially and economically.”[2] It is also generally accepted that chronic and excessive noise represents a health risk, diminishes quality of life and the attractiveness of the areas affected and generates high costs to the national economy.

The noise **exposure** is defined physically by the sound pressure level, which is expressed in decibels (dB). “Because the human ear is less sensitive to low and high frequency sounds than medium frequencies of the same sound pressure, the values measured are weighted according to frequency. Most countries define sound using the so-called A-curve which allows the decibel to be used as the standard measure for all frequency ranges. The sound pressure level is then expressed as dB(A). The decibel is a logarithmic rather than a linear scale. An increase in a given dB(A) value of 10 dB(A) corresponds in terms of human hearing sensitivity to a doubling of the volume. If two equally loud noise sources coincide, the sound level increases by 3 dB(A).

Measurements in dB(A) only express the sound pressure level at a specific time and do not indicate the duration of the exposure. However, this has a decisive influence on the perceived disturbance. Therefore a mean value called the average level or equivalent continuous sound pressure level Leq is calculated which is equivalent in energy terms to the actual pollution. To allow for the variations in interference between different types of noise, various pressure level corrections called K-values are applied in Switzerland. The corrected average pressure level is called the rating sound level (Lr). It is used in Switzerland for rating of noise nuisance or degree of disturbance under legal requirements (Environmental Protection Act, Noise Abatement Ordinance).[3]

[2] According to the FOEN (2009), Noise Pollution in Switzerland, p. 8.

[3] According to the FOEN (2009), Noise Pollution in Switzerland, p. 15-16.

2.2 The currently applicable impact thresholds for noise

To protect against harmful and annoying noise, the legislators defined so-called exposure limits in the Noise Abatement Ordinance (NAO). It distinguishes between impact threshold, planning and alarm values:

- "The impact thresholds for noise are defined so that, on the basis of the latest know-how or experience, noise exposure levels below these levels do not significantly interfere with the well-being of the population.
- Planning values: The planning values are defined for the design of new development zones and protection from noisy new fixed installations. The planning values are 5 dB(A) stricter than the impact thresholds.
- Alarm values: The alarm values are defined for assessment of the urgency of remediation measures for noise emissions. They are above the impact thresholds."[4]

As stated in the contract, the discussions below relate only to the impact thresholds.

"In order to take into account the sensitivity to disturbance of zones with different uses, four sensitivity levels were developed. The different sensitivity levels defined by spatial planning result in stricter exposure limits being applied e.g. to leisure zones than to industrial zones.

- Sensitivity level I: Zones with higher noise abatement requirement, notably leisure zones.
- Sensitivity level II: Zones without disturbance from operations, notably residential zones and zones for public buildings and installations.
- Sensitivity level III: Zones with moderate disturbance from operations, notably residential and industrial zones (mixed zones) and agricultural zones.
- Sensitivity level IV: Zones with high disturbance from operations, notably industrial zones."[5]

The currently applicable impact thresholds for the three traffic categories Road, Railway and Airfields are listed in the table below.

[4] FOEN (2009), Noise Pollution in Switzerland, p. 19.

[5] FOEN (2009), Noise Pollution in Switzerland, S. 19.

Table 2-1: Impact thresholds for Road, Railway and Civil Airfields (under the Noise Abatement Ordinance[6])

Sensitivity levels	Roua traffic Lr in dB(A)		Rail traffic Lr in dB(A)		Aircraft noise (civil airfields) Lr in dB(A)		
	Day (6–22:00)	Nuit (22–6:00)	Day (6–22:00)	Nuit (22–6:00)	Day (6–22:00)	1st night hour (22–23:00)	2nd (23–24:00) and last night hour (5–6:00)
I	55	45	55	45	55	45	45
II	60	50	60	50	60	55	50
III	65	55	65	55	65	55	55
IV	70	60	70	60	70	60	60

Source: Noise Abatement Ordinance (NAO), Annexes 3, 4 and 5

The impact thresholds always refer to the **rating sound level Lr**. This is obtained from the Leq plus appropriate corrections which vary according to the type of traffic or noise:[7]

- For **road traffic,** the rating sound level Lr corresponds basically to the A-weighted equivalent continuous sound pressure level Leq for the relevant day or night time span. Although there is a graduated level correction of -5 to 0 dB(A) at below 100 vehicles per hour or 1,600 during the day and 800 at night, these corrections are usually only applied to new access roads and residential streets.
- **Railway traffic** generally benefits from a bonus which is at least -5 dB and when train frequency is lower (less than 79 per day or per night) can rise to -15 dB. Otherwise the rating sound level is calculated in the same way as for road traffic (average equivalent continuous sound pressure level over the relevant day or night time period).
- On **airfields** with large aircraft (over 8,618 kg) the rating sound level is calculated separately for daytime and the first, second and last night hours.
  - The daytime rating sound level (Lr_t) is the A-rated equivalent continuous sound pressure level Leq caused by the average annual aircraft movements between 06:00 and 22:00.
  - A general flight ban applies for part of the night, namely from midnight to 5 a.m. For the rest of the night the rating sound level Lr_n is determined separately for the first (10-11 p.m.), second (11 p.m. - midnight) and last (5-6 a.m.) night hours.[8] An important aspect of this method is that these three night hours are rated separately, unlike road and railway traffic.

[6] Noise Abatement Ordinance (NAO, SR 814.41) of 15 December 1986 (1 July 2008 version).

[7] The notes on determination of the rating sound level Lr and the corrections are based on a summary and partly simplified representation. For a more detailed description of the calculation method please refer to Annexes 3 (Road Traffic), 4 (Rail Traffic) and 5 (Civil Air Traffic) of the NAO.

[8] The hourly rating sound level Lr_n corresponds to the A-weighted equivalent continuous sound pressure level Leq caused by aircraft movements in the hours from 10-11 p.m., 11 p.m. to midnight or 5-6 a.m.

2.3 The history of noise thresholds[9]

The impact thresholds currently defined in the NAO are the result of a long development history. The main stages of this history, with its many influences, are summarised below. This brief account of the bases and studies used and the tracing of the most important interim results and decisions form a central foundation for the analysis of the need for action which follows in Chapter 3.

In highly simplified form, the historical development can be divided into four stages:

- The first stage began in 1957 with the appointment of a national Expert Commission for comprehensive treatment of the subject of noise and ended in 1963 with the publication of the final report containing provisional guide limits for noise.
- The second stage ran from 1963 to 1975 and was characterised by use of the provisional guide limits in court cases and official practice. In this period experience was gathered which later played a crucial part in defining the first legal limits.
- After a Constitutional article on environmental protection was approved in 1971 by the electorate, the Federal Council set up an Expert Commission for Analysis of Noise Thresholds. This began the third stage in which the legal bases for noise abatement in the Environmental Protection Act and the Noise Abatement Ordinance and their thresholds were developed. The entry into force of the Noise Abatement Ordinance in 1987 brought this stage to a decisive conclusion.
- In the fourth stage, which extended to implementation of the Noise Abatement Ordinance, the thresholds for aircraft noise up to the present were defined. Recently the FOEN drew up the thresholds for military firing range noise. They are now in Annex 9 of the NAO and have been in force since 1 August 2010. This is an area not previously regulated in the NAO.

a) From the beginnings to the final report of the first Expert Commission

With the industrialisation of the economy and the use of machinery and transport, noise became a serious problem from the beginning of the 20th century, particularly in the cities. Action was initially limited only to a quality rating of the noise pollution. The development of electro-acoustics then provided a means of measuring acoustic signals. In an attempt to mimic the way that hearing functions, the logarithmic decibel scale was introduced to record the sound intensity level. Right from the beginning there was pressure to establish mean values so that a conclusive noise scale could be obtained from the rapid fluctuations in intensity with time. The most suitable way of averaging was a matter of dispute in scientific circles for many years. A popular method was to characterise the noise by the statistical level fre-

[9] The information is based on Hofmann R. (2009), Review of the Impact Thresholds for Noise, Policy Framework Paper: The History of Noise Thresholds.

quency distribution, such as the 10%, 50% and 90% percentiles[10] for characterisation of the peaks, the average level and the background noise level. Measures which combined different percentiles were soon discussed (e.g. the Traffic Noise Index TNI). An alternative which surfaced at an early stage was the Leq[11], which extended the idea of instrumental smoothing systematically to the whole measuring period. As a measure of average sound intensity, it is physically very simple and therefore suitable for noise prediction with propagation models.

Taking into account these developments, the Expert Commission set up by the Federal Council in 1957 worked on its final report until 1963. It contained various important principles which have greatly influenced noise abatement up to the present day:

- The primary scale used for noise exposure is now the A-weighted sound pressure level in decibels - dB(A). The 50%, 1% and 0.1% percentiles (L_{50}, L_1 and $L_{L0.1}$) are used to describe a noise situation. The 0.1% percentile $L_{0.1}$ was soon considered unsuitable and was dropped.
- A position at an open window was defined as the measuring point for rating of the noise exposure.
- A limit guide diagram containing a total of 36 values (6 zones, day/night, 3 exposure measures) was postulated. If the provisional guide values are exceeded, unacceptable noise exposure is indicated and detailed investigations by the authorities are required.

b) Amassing experience from 1963 to 1974

This period saw the first Federal Court judgments on noise abatement. The “Noise Abatement on National Roads” working group defined the following guide noise thresholds for residential areas along national roads on the basis of the information then available without conducting its own studies:

- For the median level L_{50} (50% percentile) 60 dB(A) day, 50 dB(A) night
- For the peak level L_1 (1% percentile) 70 dB(A) day, 60 dB(A) night

In 1971 and 1972 the “Socio-psychological aircraft noise survey” was carried out and documented in a final detailed scientific report in 1974. It is doubtless the most thorough investigation of the relation between noise exposure and nuisance ever carried out in Switzerland. The exposure was determined by extensive measurements around the homes of the sampled population. Nearly 4,000 personal interviews were also conducted in Zurich, Geneva and Basel. The interviewees were asked to define the noise nuisance experienced by them on a scale from 0-10 (no nuisance to intolerable nuisance). The correlation was significantly better for the Noise and Number Index NNI than for three further scales also studied.[12]

[10] The x% percentile is the level which is only exceeded for x% of the measuring period.

[11] Leq (L_{eq}) “Equivalent continuous sound level”. L stands for level, eq for equivalent. The correct ISO designation is $L_{A,eq}$.

[12] Leq, $L_{0.1}$ and LNP (Level of Noise Pollution).

It is interesting that the definition of "serious nuisance" (designations 8, 9 and 10 on the scale) is used in the final report. The study indicated that the probability of serious disturbance or nuisance is about 25% for an NNI of 40. For road noise – which was also surveyed in part of the study – in the L_{50} exposure class from 60 to 63.9 dB the analysis shows that the probability of serious disturbance is about 20%.

Based on the results of the study, three aircraft noise zones were defined, beginning at 45 NNI. This figure is astonishing because the study found that some 1/3 of respondents described themselves as seriously annoyed at an NNI of 45. This percentage is nearly double that of the provisional guide values for road noise.

c) Developments from 1975 to the Noise Abatement Ordinance

After incorporation of the environmental protection article in the Constitution (1971) and a first draft environmental bill which failed at the consultation stage, a new "Expert Commission for Rating of Noise Thresholds" was set up to bring the previous basic principles up to date and extend them if necessary through systematic studies. Three studies were carried out on behalf of the Commission:

- Living in new buildings[13]: 705 interviews were conducted into the noise nuisance from road traffic. The noise exposure was measured at 392 survey points over a comparatively short period in April. The level at a further 313 survey points was calculated from the traffic numbers using the EMPA model for road noise available at the time. The study indicated that for L_{50} in the 60.5-65 dB(A) level class some 21% of people were seriously annoyed. Since the Leq is at least 2 dB(A) above the L_{50} near the road, this result would support a Leq limit of 65 rather than 60 dB(A).
- Nuisance due to noise and air pollution[14]: The noise nuisance experienced by 1,297 people in the city of Zurich was determined using written questionnaires. The noise exposure was determined for each district by two 24-hour measurements. In the 61 to 65 dB(A) L_{50} class, some 20-25% of respondents experienced "serious nuisance". The study therefore indicated a limit of 63 to 67 dB(A) Leq for 25% seriously affected.

[13] Wehrli B., Hauser S., Egli H., Bakke P. and Grandjean E. (1976), Living in new buildings.

[14] Wanner H.U., Wehrli B., Nemecek J. and Turrian V. (1977), Nuisance to Residents on Busy Roads due to Noise and Air Pollution.

- Noise disturbance at night[15]: 1,607 questionnaires from six regions were analysed in the study. The exposure was recorded by long-term measurements near the road (reference position), supplemented by short-term measurements from which the level reduction compared with the reference position was determined. The study showed that 24% of respondents described themselves as "seriously annoyed" at exposures of 55-60 dB(A) Leq at night. At the places exposed to 60-65 dB(A) Leq during the day, a similar percentage (27%) described themselves as seriously annoyed. When day and night are compared, similar percentages are found at night for levels some 5 dB lower, which is contrary to the 1963 guide limits where there is a difference of 10 dB between day and night.

Based on these studies and the previous investigations in connection with aircraft noise, the Expert Commission defined the thresholds for **road traffic noise**. Important decisions were reached:

- The Leq was specified as the critical noise exposure scale, with differentiation for day (6 a.m. – 10 p.m.) and night (10 p.m. – 6 a.m.).
- The level of [impact] thresholds must be specified so that no more than a significant minority (about 25%) feel seriously annoyed.
- The proposal for impact thresholds was:
  - For residential areas (both urban and rural) Day 60 dB(A) Night 50 dB(A)
  - Homes, shops, offices Day 65 dB(A) Night 55 dB(A)

From a perusal of the details of the decision process it is clear that experience and previous practice were probably accorded greater weight than information derived in scientific studies.

In relation to **railway noise**, a socio-psychological study (SPU78) was commissioned in 1978. Its main focus was on the noise nuisance and disturbance experienced by local residents on the line. Subsequently, the noise nuisance due to road traffic in the same region was included in the study to shed light on the presumed "railway bonus" in the rating:

- 2,473 questionnaires were available for analysis for the line noise study. Systematic measurement of the noise exposure at the respondents' locations did not take place for financial reasons. The noise exposure was calculated using the recently developed EMPA railway noise model. Analysis of the survey data produced arguments in favour of correction of the Leq by a function which allows for the number of daily (or nightly) trains passing in progression. With today's high volumes of railway traffic, this rating method is therefore also applied to conditions which involve extrapolation beyond the empirically safe range.
- Four survey regions (Bülach, Frauenfeld, Lengnau and Zurich) were selected for the road noise section. A continuous measurement programme was not carried out for reasons of

[15] Wehrli B., Nemecek J., Turrian V., Hofmann R. and Wanner H. U. (1978), Disturbance Effects of Road Traffic Noise at Night.

cost. The process was limited to a combination of estimates based on traffic counts and a few control measurements. The empirical relation between the daytime exposure in Leq and the nuisance determined from the scale showed that for a level of 61 dB, some 25% of respondents were seriously annoyed (8, 9 and 10 on the scale).

On the basis of this single railway noise study, the Commission set the thresholds for standard and narrow gauge railways in the line and station areas. The Leq was again taken as the basic noise scale. As far as the level of the threshold was concerned, however, the process used for road traffic was not followed (25% seriously annoyed) but was based on the respondents who described themselves as averagely or seriously annoyed (≥5 on the scale). A correction factor K of between -15 and -5 dB depending on the train passing frequency (number of trains per hour) was also introduced. This was intended to allow for the fact that the disturbance is lower for railway noise than for road noise at the same Leq. The corrected Leq is called the rating level Lr. Good correlation with road noise could then be achieved for the proportion experiencing average and serious noise nuisance at 60 dB. This was also the reason for using the Lr as the exposure scale and setting its threshold at the same level as for road noise.

In general it is clear that the socio-psychological study (SPU78) leaves considerable scope for interpretation.

d) Thresholds for aircraft noise

In this section we present only the history of the thresholds for civil aviation. Implementation of the Ordinance on Noise Zones at National Airports enacted in 1973 was delayed for decades – due initially to problems of reliable calculation and then to a flood of objections. In 1989 it was decided to commission a new study (Noise Study 90). Some 1,300 people in the Zurich area and 750 in Geneva took part in an oral interview. The aircraft noise exposure was calculated using the EMPA FLULA-2 simulation method which was already well advanced. The Noise Study 90 showed that the disturbance effect of aircraft and road noise at equal Leq was approximately the same. This result led the Expert Commission to set the daytime limits at the same level as for road noise.

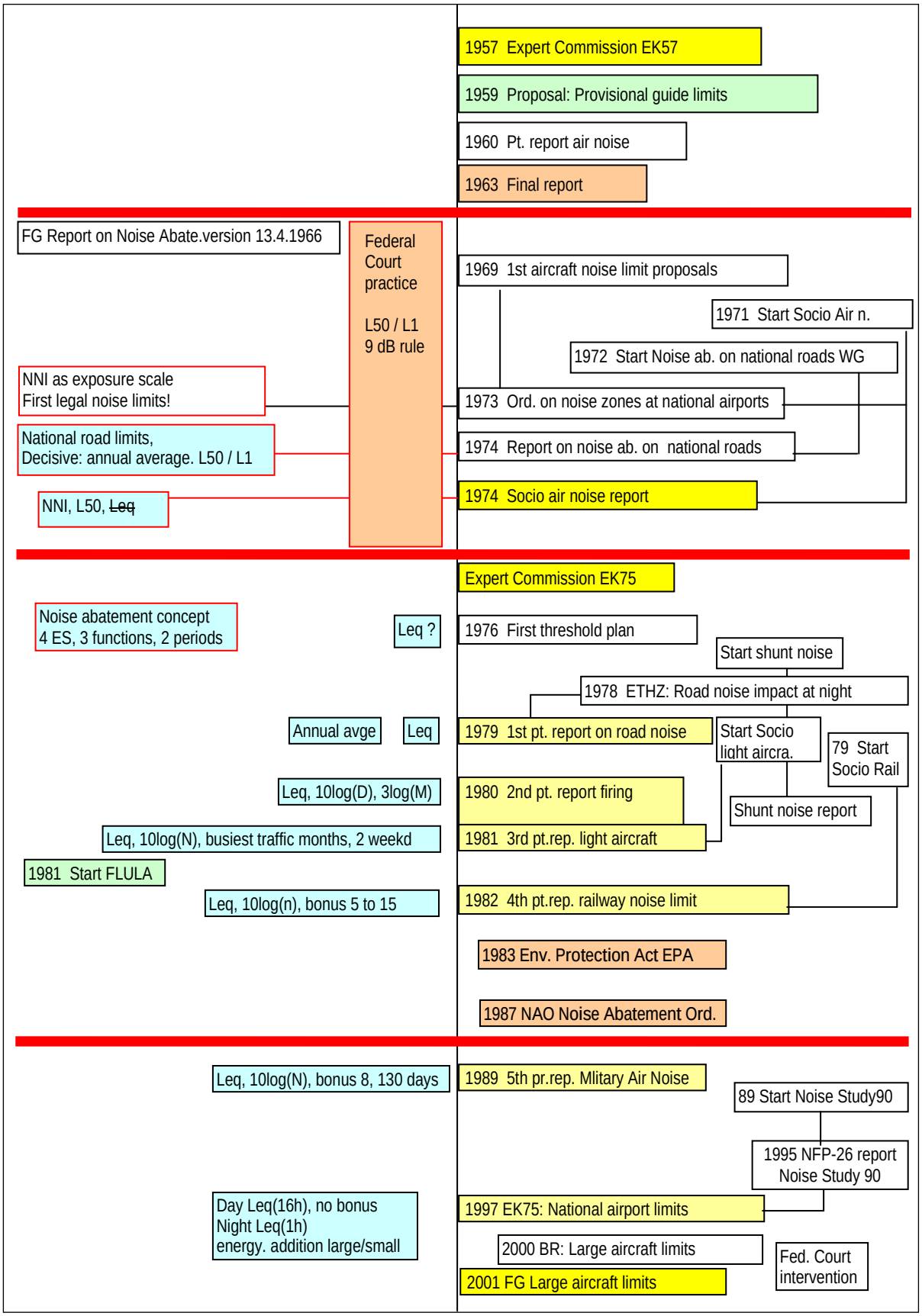
For night-time, however, an approach which was completely new for Switzerland was adopted and was intended to reduce the probability of waking responses. To do this, the **hourly** sound energy is limited to a level already reached by a few loud flights. Therefore, for the three night hours 10-11 p.m., 11 p.m. - midnight and 5-6 a.m., thresholds for the one hour average level (1-h-Leq) were defined. The proposals by the Expert Commission were finally implemented, but only after intervention by the Federal Court, which prevented an attempt by the Federal Council to set high thresholds without justification.

e) Summary

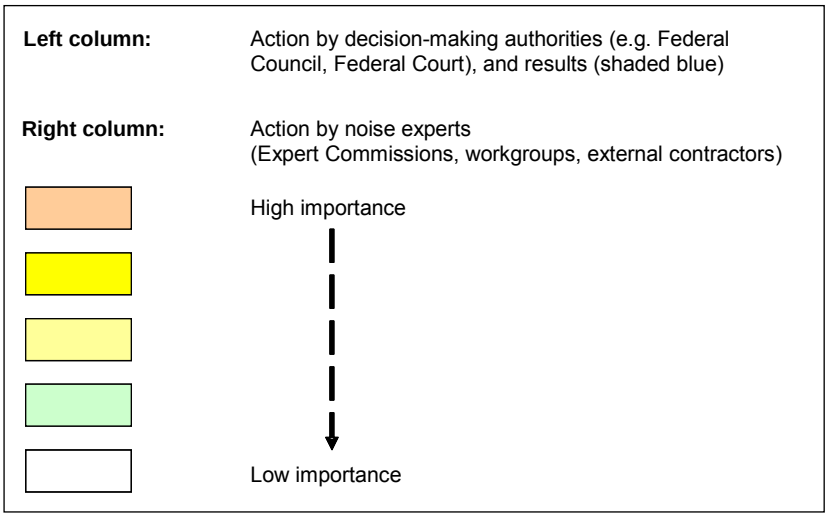
A summary of the origins of the current noise thresholds is shown in Figure 2-1. The history of development of the Swiss noise thresholds is marked by great pragmatism. It is true that various empirical studies on aircraft and road noise (1974, 1978), civilian firing range noise (1978), light aircraft noise (1979) and railway noise (1979), and belatedly on noise from civil aviation, were carried out. Their translation into specific thresholds was not fully transparent and comprehensible according by today's standards.

The sequence of events for road noise is illustrative: Because the provisional guide limits from 1959/1963 had proved themselves in practice, standard Federal Court practice was based on them and because limits already applied to national road building, the levels introduced were incorporated in the 1st preliminary report of the Expert Commission in 1979, slightly modified by the changeover to the new Leq exposure scale. This occurred after the Commission had decided in 1976 to set the impact threshold at a proportion of about 25% "seriously disturbed" (in the sense of seriously annoyed) people. However, the results from Basel (SPU74) showed that at 60 dB(A) Leq only 16% were seriously disturbed. The ETH study (1978) on road noise at night indicated a night threshold of 55 dB(A) Leq. Despite this, the night threshold was set at 10 dB(A) below the day threshold, i.e. at 50 dB(A). There are many plausible arguments for these decisions and they are not to be criticised in principle. Nevertheless, the fact remains that experience with the 1963 guide limits was the factor which determined the road noise thresholds and not first and foremost the results of the survey.

Figure 2-1: Synoptic representation of the history of the development of noise limits



Legend to Figure 2-1



The fact that the principle adopted for railway noise was to use “high disturbance” (8, 9 and 10 on the scale) as the criterion for threshold definition must be viewed critically. The standards between railway and road noise were harmonised on the basis of “average and high disturbance” (≥5 on the scale).

Another singular factor is that the threshold definition derives from the concept of a five frame[16]. It was doubtless correct in 1959 to highlight the uncertainty of these provisional values with a numbered diagram in steps of five. The data has become more reliable over time and yet this practice continued for air traffic with one exception (planning value Lr_n ESII).

What is hardest to understand from today’s perspective is the fact that so few resources were provided for the empirical study of the exposure-effect relationships. All the surveys after 1974 had to struggle with massive budget cuts. On the acoustic side in particular (noise exposure), it was necessary to resort to rough estimates or model calculations instead of taking measurements at the respondents’ locations. Various models subsequently proved to be far from exact. Particularly worrying is the lack of an adequate empirical basis for the thresholds for railway noise. Its noise nuisance scale is linked to the road noise scale which was investigated in the same study. It was not possible to measure the noise exposure due to road traffic. Instead, this was obtained by averaging the estimates provided by four acoustic engineers, because that was all the financial and personnel resources would allow. Ultimately these results significantly influenced the thresholds for railway noise, for the reduction of which some CHF 2.8 billion has been allocated in the FinöV bill!

[16] Cf. Annexes in the Noise Abatement Ordinance (NAO, SR 814.41) of 15 December 1986.

2.4 Legal requirements for impact thresholds for noise[17]

The requirements under environmental law for definition of impact thresholds represent – in addition to knowledge of their history – the second central focus for the following review of the need for action. The following two key questions are relevant:

What are the **legal bases** for definition of noise impact thresholds?

How must the **terms** "considerable disturbance", "state of knowledge" and "state of experience" be defined? Is there a need for action due to any change of meaning of the terms?

a) Relevant standards under the Federal Constitution and Environmental Protection Act (EPA)

The Federal Constitution (FC) obliges and authorises the legislators in Art. 74 para.1 to enact regulations on **protection of the population and its natural environment** against damage or nuisance. Under para.2 of the provision, the legislator must ensure that such effects are prevented. "Damage" and "nuisance" effects are to be understood as follows:

Damage effects affect human physical or psychological health or cause damage to the natural environment.

Nuisance effects impair human existence without causing health damage. Nuisance of this kind can lead to impairment of human efficiency and vitality, enjoyment of nature, quietness and private life generally.

Under the terms of the FC, the Federal Council is instructed in Art. 13 para.1 EPA to define impact thresholds for rating of damaging and nuisance effects.

The impact thresholds are intended to be used for clear demarcation between damaging and nuisance and harmless or non-annoying effects and must therefore be quantifiable factors.

The **impact thresholds for noise** required by the EPA relate to the rating of external noise and only cover noise which is generated by the construction and operation of installations. Impact thresholds are to be defined primarily for noise from fixed installations such as buildings, transport infrastructure and other fixed facilities. Impact thresholds are less suitable for noise from mobile installations which change location. The criteria for definition of impact thresholds for noise are given in Art.15 and 13 para.2 EPA.

[17] The information is based on Zäch C. (2009), Review of the Impact Thresholds for Noise, Input Paper 1: Law.

b) Criteria for definition of impact thresholds for noise

In accordance with Art. 15 EPA, the impact thresholds for noise must be defined so that **on the basis of scientific knowledge or experience, noise exposure below these values does not significantly disturb the well-being of the population**. With regard to the impact of the exposure, the Federal Council must take into account **high-sensitivity population groups** such as children, the sick, the elderly and pregnant women (Art. 13 para.2 EPA). The main criteria for this definition are to be interpreted as follows:

- When defining the impact thresholds, the current **state of scientific knowledge or experience is critical**. This requires a periodic review and possible adaptation of the thresholds if there are genuine reasons why they no longer conform to the current state of scientific knowledge or experience.
- The **well-being of the population** covers the person's psychological, physical and social well-being forming the basis for his undisturbed development, productivity and vitality. Well-being does not just mean an absence of illness or infirmity.
- The term **disturbance** covers both harmful effects (hearing damage, sleep disturbance, impact on the cardiovascular system) and annoying effects (disturbance of peace and recreation, leisure activity, speech intelligibility, concentration).
- (Only) **considerable** disturbance to the well-being of the population is significant. The Act recognises that human activities – private, economic and social – are generally associated with noise emissions which can impact on other people.
- The extent of noise disturbance and therefore the rating of how substantial it is are determined by various **interference factors** of an acoustic, physiological and psychological nature:
  - Acoustic factors: level, frequency, characteristics of the noise; occurrence and duration of the noise events.
  - Physiological factors: Different activities of the noise sufferer such as working, resting, sleeping, but also his constitution.
  - Psychological factors: Personal attitude to and experience of noise sources.

c) Procedure for definition of the impact thresholds for noise

On the basis of the criteria described above, the following points must be considered when defining the impact thresholds for noise:

- **Differentiation** of the impact thresholds by:
  - Type of noise: The definition of the impact thresholds must allow for the fact that different types of noise at the same level can give rise to different levels of disturbance, because of their different characteristics (frequency, time sequence and predictability of occurrence of the noise events).
  - Day/night: Consideration must be given to the fact that the noise sensitivity of the population differs between daytime and night-time.
  - Type of use and previous noise exposure at the noise emission point.
- Acquisition of the **noise exposure** by means of a noise exposure scale which appropriately accounts for acoustic disturbance factors (sound pressure level, frequency of occurrence and duration of the noise event, frequency range and characteristics of the noise) and by which the noise impact at a specific location can be fully described over a longer period.
- Recording of the **noise disturbance** by means of sociological surveys on how those affected experience the noise.
- **Correlation** of objective noise exposure with surveyed noise nuisance.

These minimal requirements raise the question of whether the basis for the impact thresholds still corresponds to the present state of knowledge or experience. This question is discussed in the next chapter through an analysis of the development of the noise environment in the Technology & Operations, Acoustics and Noise Impact dimensions.

3 Need for action

The main results of the analysis of the need for action in the Technology & Operations, Acoustics and Noise Impact dimensions are summarised in this chapter. The presentation for each key question follows a standard pattern which is divided into the following three parts:

- Brief discussion of the key question with an outline of the problem.
- Exposition of the information from the detailed analysis of the key question. Normally only the most important results are presented, without discussing individual studies or sources in detail.
- At the end of each key question there is an evaluation of the need for action based on a standard assessment (no action needed, or a low, medium or high need for action).

3.1 Technology & Operations[18]

In the Technology & Operations dimension, it is generally a matter of whether the change in the traffic volume, specific vehicle emissions or distribution throughout the day indicates any consequences which have or could have an influence on definition of the impact thresholds. It is important to consider both the influence on the impact threshold levels and the question of the day-night limit and changes in the frequency of occurrence of noise events, for example.

An important factor in the analysis is that an immediate need for action does not result merely from changes in traffic volumes, their composition or their day/night distribution. A need for action to review the impact thresholds or in the way the rating levels are determined can be justified only if it has to be assumed that these changes were neither known nor properly addressed by the noise rating level when the impact thresholds were set.

Starting from this distinction, the need for action on the 9 key questions in the Technology & Operations dimension is examined below. To streamline and simplify the presentation, key questions 1-3 on road traffic, 4-6 on railway traffic and 7-9 on air traffic are each combined in the same section specific to the method of transport.

3.1.1 T&O 1-3: How have road traffic volumes, noise emissions and distribution throughout the day changed and is a need for action indicated?

a) Traffic volumes

Motorised passenger traffic increased by 55% between 1980 and 2005 (measured in vehicle kilometres). In freight transport the rise was 84% for light freight vehicles (up to 3t) and 51% for heavy vehicles (> 3t). The development of average daily traffic (ADT) show that traffic on

[18] The information is based on Höin R., Buchmann B., (2009), Review of the Impact Thresholds for Noise, Input Paper 2: Technology & Operations.

the motorways in particular has seen the largest increase over the last 25 years with a growth rate of 76% compared with rural roads (18%) and urban roads (6%). On very busy roads there is actually continuous 24-hour traffic almost with quiet periods almost totally absent and with no peace at night, unlike other roads. The lack of quiet and the high exposure during the night are the main cause of the increased nuisance, which is probably not adequately reflected in the increase in the Leq. These considerations mean that the **need for action** to review the scientific basis of the impact thresholds is considered to be **high**. The main question raised is whether a separate disturbance correction should be introduced for the very busy roads due to their permanent traffic.

b) Emissions

Noise emissions from motor vehicles in road traffic must be divided into propulsion noise[19] and rolling noise[20]. Due to the different speeds, it can be stated in simplified terms that propulsion noise dominates in town and rolling noise out of town. Various developments (speed limits, speed governors) have reduced the specific emissions per vehicle. Too little is known about the development of other parameters (tyre characteristics, vehicle weights) for a reliable conclusion to be drawn. The relevant documentation would need to be processed in detail. With this in mind the **need for action is low**.

c) Distribution throughout the day

The proportion of night traffic in the total traffic mix (all vehicles) rose slightly between 1991 and 2002. The increase is more pronounced for lorries (vehicles longer than 12.5m). These generally start their journeys at exactly 5 a.m. (end of night driving ban). But under the Noise Abatement Ordinance the noise energy generated by lorries during the last night hour (5-6 a.m.) is averaged out over the full 8-hour night-time period.

In recent years there has been a marked trend in inner city areas, particularly at night, towards more aggressive driving behaviour with very noisy individual events causing disturbance which is not (or inadequately) covered by the Leq.

Both developments generate a medium need for action, particularly to examine whether calculation of the Leq over the full night-time period remains the most suitable rating level or whether separate rating of individual night hours, as is the case for air traffic, might need to be implemented.

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[19] This results from the noise emissions from the engine, gearbox and exhaust and extraction systems. The engine noise depends largely on the engine type, condition and rpm.

[20] Rolling noise includes noise generated by the rolling action of the tyre on the road surface, the aerodynamic noise and any rattles. Rolling noise is the more important. With relation to the vehicle, the noise depends on the tyre tread and width and the vehicle weight. With relation to the road surface, the porosity of the pavement, its surface roughness and the spatial configuration of the infrastructure are important.

3.1.2 T&O 4-6: How have railway traffic volumes, noise emissions and distribution throughout the day changed and is a need for action indicated?

a) Traffic volumes

Passenger traffic rose sharply between 1980 and 2005 with a growth rate of 66% (measured in train kilometres). An increase has also been recorded in freight traffic but is much lower at 9%. In parallel with this growth, the average train density per line per day (24 hours) also rose by 22% from 90 to 110 trains. On some sections – particularly along the Gotthard axis – the increase is even greater. Train lengths have also tended to increase.

Although the increase in traffic is accommodated in full by the Leq noise scale, it is debatable whether the general railway bonus of -5 dB(A) is still appropriate given the higher train density. Compared with the threshold defined in the NAO (>79 trains per day or night) above which only a minimum bonus of -5 dB applies, train frequencies have increased considerably both during the day and at night, particularly on the Gotthard line. The quiet phases between the individual noise events that are typical of the railways are now greatly reduced on these sections. Given these high train frequencies, it is questionable whether railway traffic at the same Leq as road traffic is still perceived by the population as less annoying and still merits a bonus of -5 dB(A). Due to these considerations, the **need for action is high** to check the level correction.

b) Emissions

The noise from passing trains is generated mainly by the contact between wheel and rail. The decisive factor is the surface roughness of the two contact surfaces. The resultant noise emissions are determined by the volume of traffic (number of day/night trains), the infrastructure (speed regulations, track profile, substructure and superstructure) and the quality of the rolling stock and track materials.

Significant improvements have been achieved in rolling stock in recent years by replacing shoe brakes with disc or drum brakes. This is a very positive development because it considerably reduces the total emissions at equivalent train frequencies. This situation could influence the relationship between the three types of noise (railway, road, and aircraft) in the perception of the population. On this basis the **need for action** to review the impact thresholds is assessed as **medium**. The main question to be considered is the specific modal rating level (Lr) at which equal noise nuisance can be assumed, for example whether it is still true – as assumed in the NAO – that road and railway noise are perceived as equally disturbing at an Lr of 60 dB(A).

c) Distribution throughout the day[21]

Along with the general increase in train density, the proportion of loud freight trains during the night is rising rapidly, particularly on the Gotthard line. Because the freight trains at night are reliant on the gaps between passenger trains and operate according to need rather than to a timetable, their (unexpected) arrival in the night must be considered very disturbing. It is also known that the noise or disturbance pattern of a loud freight train is very different from that of a passenger train. Freight trains normally have different types of goods wagon each with widely varying noise levels. Long freight trains also have long passing times, which can increase the likelihood of waking the people affected.

In general, these developments have led to a redistribution of the noisy phases in the night-time period, at least on very busy freight lines. The calculation of the level correction K1 (according to Annex 4 NAO) requires particular scrutiny because it actually rewards trains at night with a bonus of -3 dB(A) compared to daytime trains (if their numbers per day and night are below 79 and over 7.9).[22] Overall the **need for action** on the time of day distribution and its share of the rating measure Lr is assessed as **high**.

3.1.3 T&O 7-9: How has the volume of air traffic, noise emissions and distribution throughout the day changed and is a need for action indicated?

a) Traffic volumes

Between 1980 and 2005 aircraft movements increased markedly at all the national airports (Basel-Mulhouse: 142%, Geneva: 68%, Zurich 94%). As detailed in section 3.1, the increase in traffic volumes does not in itself indicate an immediate need for action to review the impact thresholds. In addition, the impact thresholds for civil aviation were not defined until 2000, which means that a significant proportion of the increase in traffic since 1980 has already been taken into account. On this basis, the **need for action** is assessed as **low**.

b) Emissions

The emissions from aircraft noise depend on the sound radiated from each type of aircraft, the landing and take-off behaviour and the emission regulations at the airport concerned. Great advances have been made regarding engine noise over the last 25 years. These positive developments have led to a massive reduction in noise emissions per aircraft movement and have always been taken into account when the airport operating regulations have been

[21] In addition to the distribution throughout the day, the changes in spatial distribution were also studied for all three modes of transport (rail, road, aircraft). It was found that even if some of these changes have occurred, this does not indicate a need for action to review the scientific basis. Therefore spatial distribution is not discussed in detail in this summary.

[22] Sample calculation:

- 4 trains per hour daytime = Total 64 trains; K1 = 10*log(64/250) = -5.9
- 4 trains per hour night-time = Total 32 trains; K1 = 10*log(32/250) = -8.9

redefined. The example of Zurich Kloten Airport shows that the noise reduction developments on aircraft and in the operating regulations since 1987 have led to a significant reduction in the areas exposed to noise above the impact threshold. At the same time, however, in the communities exposed to aircraft noise there has been a large increase in population.

The general significant reduction in emissions is counteracted by the massive increase in the number of aircraft movements in total and in the daily pattern. This is perceived as hugely disturbing by local residents irrespective of the noise level of the individual flights. The impact of the disproportionate increase in flights accompanied by the disproportionate reduction in source noise level cannot be modelled to the necessary degree by the rating level in its current form.

Overall this development indicates a **low need for action** to review the scientific basis.

c) Distribution throughout the day

As with the other modes of transport, with air traffic the distribution of noise events throughout the day is also very relevant to the noise nuisance perceived by the population.

Developments in Zurich show that aircraft movements in the first two night hours (10-11 p.m. and 11 p.m. - midnight) increased by over 190% in the period from 1980 to 2005. In contrast, a fall of 98% was recorded during the last night hour (5-6 a.m.) as a result of the 213th German Implementation Ordinance on the Aircraft Noise Ordinance and the resultant need for landing aircraft to approach from the south. A huge increase of plus 41% also occurred between 1996 and 2005 during the marginal hour in the evening (9-10 p.m.). Due to the shift in incoming traffic, which had previously landed before 6 am, into the period after 6 am, there is also a large rise in aircraft movements in the first hour of the day (6-7 a.m.). These increases are averaged out over the whole daytime period of 16 hours when the rating level is calculated.

At the other airports (particularly Geneva and Basel) movements are consistently low during the last night hour but an increase was recorded in the second night hour (11 p.m. - midnight).

It is known from the noise impact research (see section 3.3.4) that disturbance from noise events is particularly high during sleep and that the marginal daytime hours from 9-10 p.m. and 6-7 a.m. form part of the night for many population groups. Therefore it must be assumed that the method of determining the rating levels explained above underestimates the actual noise nuisance experienced during these marginal hours. Therefore the need for action from a Technology & Operations perspective is considered to be medium.

3.1.4 Overall assessment for Technology & Operations

Table 3-1 gives a final summary of the need for action on Technology & Operations.

Table 3-1: Summary of the need for action on Technology & Operations

Technology & Operations	Key question	Need for action
T&O 1	How have road traffic volumes changed over the last 25 years, particularly on the motorways, and what are the forecasts?	High
T&O 2	How have road traffic emissions changed over the last 25 years and what are the forecasts?	Low
T&O 3	How has the distribution of road traffic throughout the day changed over the last 25 years and what are the forecasts?	Medium
T&O 4	How have rail traffic volumes changed over the last 25 years, particularly on the main lines, and what are the forecasts?	High
T&O 5	How have rolling stock emissions from rail traffic changed over the last 25 years and what are the forecasts?	Medium
T&0 6	How has the distribution of rail traffic throughout the day changed over the last 25 years and what are the forecasts?	High
T&O 7	How have aircraft movements around airports changed over the last 25 years and what are the forecasts?	Low
T&O 8	How have emissions from air traffic changed over the last 25 years and what are the forecasts?	Low
T&O 9	How has the distribution of air traffic throughout the day changed over the last 25 years?	Low

In general, the need for action is assessed as high on three key questions (1, 4 and 6). One of these relates to road traffic and two to railway traffic:

- With regard to **road traffic**, the huge increase in traffic on very busy roads is causing continuous noise pollution which hardly abates even at night. It is suspected that the resultant nuisance to the population is not adequately addressed by merely increasing the rating level. This means that a separate disturbance correction may be required for roads that are continually very busy.
- With regard to **railway traffic**, the huge increase in train density raises the question of whether the bonus over road traffic is still justified. The high percentage of freight traffic during the night and the increasing train lengths make it questionable whether the calculation of the level correction is still justified, giving trains at night an advantage over those in the daytime provided there are less than 79 each night.

On three questions (3, 5 and 9) there is a **medium** need for action, and for the remaining three questions (2, 7 and 8) the need is low.

3.2 Acoustics[23]

The main focus in the Acoustics dimension is on the following questions:

- What definition factors exist for recording noise?
- What developments and approaches have evolved for acoustic measurement and calculation?
- How significant are the measurement and calculation uncertainties and how are they handled?

The focus in answering these questions is on the relevance relative to the need for action. It is necessary to clarify whether any development or information has emerged in any of the areas which are reason in themselves for a review of basis for the impact thresholds. As with the Technology & Operations section, it is important to note that a change does not directly indicate a need for action. A need for action arises only if it is assumed that the current basis for the impact thresholds and associated methods for determination of the rating level no longer guarantee protection of the population from damaging or annoying effects.

3.2.1 A 1: Is the concept of the rating sound level, which is the sum of an average level and one or more corrections, suitable to reflect the noise impact (nuisance, sleep disturbance, health risk)?

There are various physical factors in a noise which can be used to express an acoustic noise impact at a specific point. In general, analysis of the noise situation by recording the course of the sound pressure over time is sufficient. Various signal characteristics of the noise can be deduced from this, such as maximum level L_{max}, average level L_{eqT} (= equivalent continuous sound pressure level) over a period T or event level L_E. The peak level L_{peak} is also used for discrete noise pulses, particularly for rating of hearing damage.

The purely physical definition is not sufficient to reflect hearing sensitivity. Measurement of the volume of a noise must take particular account of the hearing sensitivity which varies according to frequency (pitch). This is achieved using the so-called A-rating. The A-rated sound pressure level L_{AF} and the factors derived from it such as the average level L_{Aeq} and the maximum level L_{AFmax} or L_{ASmax} are mainly used for measurements and calculations in noise abatement.[24]

For rating of the noise, these technical signal characteristics must be transformed into noise rating levels Lr. They are normally based on the average level L_{Aeq} with corrections applied. This method is used in the NAO. In recent decades other noise rating scales have been developed such as the NNI (Noise and Number Index) or Leq(4).

[23] The information is based on Bütikofer R., Eggenschwiler K., Heutschi K., Thomann G. and Wunderli, J.M. (2009), Review of the Impact Thresholds for Noise, Input Paper 3: Acoustics.

[24] F stands for the time constant FAST in the sliding average of the original signal, S for SLOW.

Overall it is noted that the noise rating scales all reflect the noise nuisance experienced by the population assessed in the noise impact research more or less equally well or equally badly. None of the new noise rating scales developed over recent years has proved to be markedly superior. From this perspective the rating levels used in the Noise Abatement Ordinance continue to represent current technology and know-how. From an acoustic standpoint, there is **no need for action** on key question A 1. This does not mean that the noise impact research does not give pointers for refinement or redesign of the rating scales to improve the correlation between exposure and nuisance or define sleep disturbance more accurately.

3.2.2 A 2: Is the point of application for the impact thresholds in the NAO appropriate in acoustic terms for recording the disturbance experienced by the noise sufferer?

The acoustic impacts must be determined so as to offer a logical basis for rating of the noise. Measurement of the road and railway noise exposure at an open window continues to be suitable in acoustic terms. Reliable results can be obtained using the dynamic pressure method, even if the windows cannot be kept permanently open during a long measuring campaign. Acoustically, there is **no need for action** on this question.

3.2.3 A 3: Since entry into force of the NAO, have the technical facilities for acoustic measurement changed or improved to the extent that this would possibly affect definition of the noise impact thresholds?

There have been no fundamental changes over the past 50 years in the way sound pressure level is determined using microphones, though the metrological facilities for recording and processing sound pressure have changed radically. The development of integrated circuits and processors means that parameters for almost any problem of frequency rating, volume, disturbance pattern (sequence of quiet times and disturbance), and level increase (rate of change)[25] can be recorded and analysed. Monitoring of noise exposure over many years (e.g. near a motorway) with storage of all the key data on the acoustics, weather and traffic is also possible. Furthermore, the evaluable dynamic range (minimum and maximum volume of a noise) has dramatically increased from the previous limits of 50 dB(A) or less to over 100 dB(A).

In general it is also clear that modern measuring methods allow much more comprehensive data capture and analysis than was possible in the 1980s. Yet the basic measuring system which was used in the previous studies for definition of the limits in the Noise Abatement Ordinance is still suitable by today's standards to determine the noise exposure. The previous results on noise exposure and nuisance are not distorted by the "old" measuring system. In this sense the previous factors L_{Aeq} and L_{AFmax} retain their validity for rating of traffic noise (see also the discussion on key question A1).

[25] The rate of change measures how rapidly the noise level increases. A train passing quickly produces a faster increase in the level than one passing slowly.

However, if new empirical studies are carried out on noise exposure and the associated nuisance to the population – e.g. to specify new limits and methods to determine the rating sound levels – the current measuring systems offer an u ntapped potential for new approaches to noise definition factors. From this perspective the **need for action** can be rated as **medium**.

3.2.4 A 4: Since entry into force of the NAO, have the methodology approaches and the acoustic simulation technologies (calculation of noise exposure) changed or improved to the extent that this would possibly affect definition of the noise impact thresholds?

Although the calculation models used in the 1980s to estimate noise exposure were based on a broad spectrum of measured data, the modelling technology was not well advanced by today's standards. The description of the noise source was generally limited to a few parameters such as route of the road, railway line or flight path and number of vehicles per unit of time. The sound propagation calculation generally consisted of a term to reflect the distance relationship between the source and the modelled impact location plus corrections usually obtained empirically. The models were unable to account for different types of ground (grassland or paved surfaces) or weather conditions (wind direction, temperature) despite the fact that measurements show that these can generate level differences of several decibels. This had consequences for modelling of the impact from noise at night in particular: There are more frequent temperature inversions at night, which means that the sound can propagate without attenuation, e.g. over low obstacles. Because the measured data for calibration of the models was derived largely from daytime and, as mentioned, was unable to reflect the difference in temperature stratification between day and night, this led to systematic underestimation of the modelled noise exposure at night.

Equally as important as the deficiencies in the noise propagation modelling was the simplification of the noise sources. For instance, the importance of the type of superstructure and the wheel and rail roughness was not - or not fully – addresses by the railway noise calculation model SEMIBEL. As a result the variations in sound pressure due to the superstructure, wheel and rail could only be accommodated my means of the speed parameter. This resulted in quite different speed characteristics for different types of vehicle which cannot be explained physically. If the scope of application of the model is extended beyond the speed range covered by measured data, significant differences between measurement and calculation can be expected.

Great strides have been made in modelling technology since its infancy in the 1980s. The models continue to be based on calculation of the average weighted sound level L_{Aeq}. What is new is that the models are based on a systematic separation of sound generation or radiation and sound propagation. The advantage is that much more complex sound propagation calculation methods can be developed and employed for all types of noise. In particular, empirical corrections, i.e. those based only on measured data, are avoided as far as possible. Instead the aim is to mirror the physical phenomena as directly as possible. The physical

characteristics of the ground, meteorological influences and reflections are appropriately taken into account.

The trend towards greater orientation towards the physics is also apparent in the source description. Nowadays this is not just limited to identifying the critical variables influencing the sound emissions and correlating them with the measured levels. Attempts are now made to mirror the actual sound generation using complex source models.

This new modelling technology know-how is quite important in relation to the need for action. It must be assumed that the results of national and international studies on the relationship between noise exposure and effect (nuisance or disturbance) are subject to systematic errors if the noise exposure was calculated using older models (as was the case with some Swiss studies). Since the exposure-effect relationships obtained were used for definition of the limits, this also has repercussions for the quality and reliability of the current limits. The new modelling technology know-how generates a **high need for action** to review the exposure-effect relationships.

3.2.5 A 5: Measurements and calculations are affected by quantifiable uncertainties. What significance do these uncertainties have in the definition of impact thresholds?

Measurement and calculation uncertainties are not unusual. In acoustics a much greater awareness of this has developed over the past decade. The current situation can be summarised as follows:[26]

- The measurement uncertainty is dependent on the measuring devices used, their settings, extraneous noise and possibly the local measurement environment. For attended measurements with associated monitoring of extraneous noise, the uncertainty is about 0.5 dB. For automatic (unattended) measurements, it can be well over 1 dB.
  Although in some cases this uncertainty is lower than for calculations, measurements are not always more accurate. For example: When annual mean values are determined over longer sound propagation distances, the measurement uncertainty can be very high if the duration or choice of periods is inappropriate.
- As regards calculation and modelling uncertainties, it is important to distinguish between uncertainty in the source description and in the modelling of the sound propagation processes:
  – The uncertainty in the source description is approximately 1-2 dB.
  – The sound propagation calculation uncertainty is of great importance. It increases with distance. A rough estimate for near ground propagation is approximately 1 dB per 100m propagation distance. The standard uncertainty for aircraft noise is lower than for other types of noise because the propagation is not near ground. It is likely to be around 1 to 2 dB at a distance of one kilometre, increasing at about 0.5 dB per kilometre.

The figures given apply to current calculation models. They refer to the level of individual events. The standard uncertainty of the weighted average level should be lower for current models. Uncertainty levels which are twice as high must be assumed for older models, mainly because the meteorological effects were not taken into account.

This situation affects the need for action because the definition of impact thresholds and stipulation of the calculation and measurement methods to obtain the rating level belong together. This coincidence no longer applies to road and railway traffic because the models and methods used to calculate the rating sound level now differ from those used to define the impact thresholds, at least in some cases. This results in at least a **medium need for action** to review scientific basis of the impact thresholds.

[26] See also Thomann G. (2007), Measurement and Calculation Uncertainty of Aircraft Noise Exposure and its Consequences.

3.2.6 Overall assessment for Acoustics

The need for action on the Acoustics dimension is shown in Table 3-2.

The need for action is high due to the know-how on noise exposure modelling (key question A4). It has to be assumed that the previous calculation models systematically underestimated the noise exposure, particularly at night. This means that the quality and reliability of various national studies on the relationship between noise exposure and nuisance are also called into question, since in some studies the impact was not measured at the location of the respondents but was calculated by “older” models, due to budgetary constraints.

The need for action was assessed as medium on key questions A3 and A5. A need for action is not identified on the other two questions (A1 and A2).

Table 3-2: Summary of need for action on Acoustics

Acoustics	Key Question	Need for action
A 1	Is the concept of the rating sound level, which is the sum of an average level and one or more corrections, appropriate to describe the noise impact (nuisance, sleep disturbance, health risk?)	None
A 2	Is the point of application for the impact thresholds in the NAO appropriate in acoustic terms for recording the disturbance experienced by the noise sufferer?	None
A 3	Since entry into force of the NAO, have the technical facilities for acoustic measurement changed or improved to the extent that that this would possibly affect definition of the noise impact thresholds?	Medium
A 4	Since entry into force of the NAO, have the methodology approaches and the acoustic simulation technologies (calculation of noise exposure) changed or improved to the extent that this would possibly affect definition of the noise impact thresholds?	High
A 5	Measurements and calculations are affected by quantifiable uncertainties. What significance do these uncertainties have in the definition of impact thresholds?	Medium

3.3 Noise Impact[27]

The impact of the noise exposure examined in this section forms the central link in the exposure-effect chain (see Figure 1-1), because the impact thresholds have to be defined ultimately on the basis of the "tolerable" impact. This does not mean that a specific impact threshold can be deduced directly from the socio-psychological or medical noise impact research studies. The research can indicate the nuisance and therefore disturbing and damaging effects that can result from specific noise exposure, but does not as a rule answer the question of whether that level of nuisance is still tolerable within the meaning of the Act or whether the limit of what is reasonable have already been exceeded. Actual definition of the limits remains largely reserved for a political value judgement.[28]

In this regard it is also clear that the analysis of the need for action is largely focussed on confirming or revising the exposure-effect relationships which were decisive for determining the previous impact thresholds. Two aspects are particularly important:

- Has the "composition" of the acoustic energy of a source changed since entry into force of the Noise Abatement Ordinance to such an extent that even at the same average exposure level an effect or nuisance different from the previous one can be determined? This question includes any systematic errors in the previous measurement or calculation of the noise exposure which when corrected now give a different exposure-effect relationship (even if the "composition" of the acoustic energy has not changed in the interim).
- Since entry into force of the Noise Abatement Ordinance, has a collective change in the rating of the tolerability of noise pollution occurred?

In this regard there are two possible main reasons which may lead to a change in exposure-effect correlations, namely acoustic/operational and social/psychological. Both are relevant to the analysis of the need for action and must be included in the answers to the key questions in the noise impact research section.

[27] The information is based on Brink M. (2009), Review of the Impact Thresholds for Noise, Input Paper 4: Noise Impact.

[28] As detailed in section 2.3e), when originally specifying the impact thresholds the Expert Commission agreed that the limits had to be defined so that no more than a significant minority of the population (25%) felt seriously disturbed.

3.3.1 NI 1: What changes in exposure-effect relationships have occurred over time and do they indicate a need for action?

This review of the exposure-effect relationships is limited to the "nuisance" dimension – in the knowledge that other relevant dimensions exist to define noise impact and could also be used to define the thresholds (e.g. waking responses, medical/physiological health indicators etc.). These dimensions are discussed in key question NI 6.

As already stated in section 2.3, the commonest approach in noise effect research is to determine the noise nuisance through a questionnaire. The percentage of the population who report the upper levels of a nuisance scale are reported as HA – "highly annoyed". Road, railway and aircraft noise are known to cause varying degrees of nuisance to the population, even when the average acoustic energy exposure is similar. The evolution of the exposure-effect relationships is therefore discussed below separately for each mode of transport.

a) Road traffic

Comparatively little work has been done over the past 10 to 15 years to enlarge the empirical database on the road noise exposure-effect relationship.

More recent studies carried out after the turn of the century in Sweden[29], Norway[30] and Serbia[31] seem to indicate that compared to studies from earlier research periods, people are more sensitive: the same impact is produced with less noise and the exposure-effect relationship has moved several decibels in the direction of a lower exposure.

The HYENA study[32] carried out only a few years ago on aircraft and road noise nuisance in the vicinity of major European airports (Amsterdam, Athens, Berlin, London, Milan and Stockholm) did not detect a trend towards greater nuisance than in earlier studies. But it did show that the specific national results sometimes deviated considerably from the European average. The results of the ALPNAP study[33] along the Brenner Transalpine in Tyrol also show that the sampled population consistently reported a higher nuisance than would be predicted on the basis of European averages.

[29] Ohrstrom E., Barregard L., Andersson E., Skanberg A., Svensson H. and Angerheim P. (2007), Annoyance due to single and combined sound exposure from railway and road traffic.

[30] Klaeboe R., Amundsen A.H., Fyhri A. and Solberg S. (2004), Road traffic noise - the relationship between noise exposure and noise annoyance in Norway.

[31] Jakovljevic B., Paunovic K. and Belojevic G. (2008), Road-traffic noise and factors influencing noise annoyance in an urban population.

[32] Babisch W., Houthuijs D., Pershagen G., Cadum E., Velonakis M., Katsouyanni K. et al. (2007), Associations between road traffic noise, aircraft noise and noise annoyance. Preliminary results of the HYENA study.

[33] Lercher P., de Greve B., Botteldooren D. and Rüdisser J. (2008), A comparison of regional noise-annoyance-curves in alpine areas with the European standard curves.

In general, these research results show that there is at least a **medium need for action to** update the Swiss exposure-effect relationship. New empirical studies should survey both the noise-related waking responses and the nuisance. The impact on known health consequences such as cardiovascular disease must also be studied.

b) Railway traffic

As already demonstrated for key questions T&O 1-3, railway traffic has undergone major changes since entry into force of the Noise Abatement Ordinance in terms of frequency of trains passing, length of trains and their distribution throughout the day. As a result in particular of the much higher frequency of trains passing, the question is whether the disturbance effect of the railways really deserves a bonus over road traffic. In Europe there are studies which endorse the railway bonus[34] whereas others find its existence dubious[35] or even find reasons for a penalty for railway noise[36]. This situation makes it extremely difficult to achieve a reliable evaluation. The conflicting results are reason enough to see a **high need for action** to update the Swiss study results.

c) Aircraft noise

Aircraft movements at all the national airports rose sharply between 1980 and 2005 (see the details under key question T&O 7). At the same time the level of individual events fell sharply. An annual acoustic average is therefore obtained through many more single events at lower levels. The question is whether equivalent single events are now rated differently from before and whether those affected have noticed (a) the reduction in maximum levels and (b) the increase in the number of events, and if so, how they express these feelings in their rating of nuisance.

[34] Moehler U., Liepert M., Schuemer R. and Griefahn B. (2000), Differences between railway and road traffic noise; Lambert J., Champelovier P. and Vernet, I. (1998), Assessing the railway bonus: The need to examine the "new infrastructure" effect.

[35] Lercher P., Brauchle G. and Widmann U. (1999), The interaction of landscape and soundscape in the Alpine area of the Tyrol: an annoyance perspective.

[36] Ohrstrom E., Barregard L., Andersson E., Skanberg A., Svensson H. and Angerheim P. (2007), Annoyance due to single and combined sound exposure from railway and road traffic.

International studies seem to indicate that there has been a change in nuisance, but this cannot yet be scientifically proven. The comparatively recent surveys from Zurich[37] (2001 and 2003) and Frankfurt[38] (2005) indicate that this trend is continuing. However, the impact thresholds applicable to air traffic are still relatively recent and a review of the scientific basis of the day and night limits is not urgently required. From a noise effect perspective, the lack of a separate rating for the **first hour of the day** (6-7 a.m.) – similar to the separate limits for the first, second and last night hours – is problematic. In terms of sleep psychology, this period must be considered at least as critical as the first or second night hour (see also key question NI 4). The **need for action** is **high** here, either in terms of revising the rating times or by changing the current regulations banning night flights.

d) Conclusion

Due to the importance of the exposure-effect relationships for definition of the impact thresholds and the changes demonstrated or presumed in the nuisance experienced by the population, a **high need for action** exists overall on key question NI 1.

3.3.2 NI 2: Are the previous empirical studies adequate for current threshold definition requirements?

The requirements for the empirical base for threshold definition can be divided into quantitative and qualitative factors. As regards quantity, the general conclusion is that given the importance of threshold definition for spatial planning, the necessary remediation measures on roads and railways and court compensation practice, the empirical database was extremely small in today's terms. In retrospect it is hard to understand - in view of the spatial planning repercussions and the resultant remediation measures costing billions – why the labour and financial resources available for empirical work were so low.

As regards quality, the analysis has to be performed separately for the three noise sources:

a) Road

The empirical database is quite small with four studies between 1972 and 1978. The methods used can be described as quite crude by today's standards. For example, the association between the number of seriously annoyed people and the noise exposure is presented graphically in a study by Wehrli et al. but is not defined by a statistical model. Furthermore, the derivation of the impact threshold from the empirical studies is sketchily presented in the report by the Expert Commission. As mentioned in section 2.3c), the impression given in

[37] Brink M., Wirth K. and Schierz, C. (2007), Swiss Noise Study 2000: Exposure-Effect-Curves of Annoyance 2001 and 2003 (electronic data).

[38] Schreckenberg D. and Meis M. (2006), Aircraft Noise Nuisance around Frankfurt Airport.

retrospect is that experience with the guide limits from 1963 was the decisive factor for determining the thresholds for road noise and the scientific results available afterwards were of lesser importance. As a result of this unsatisfactory empirical and methodological basis, there is a **high need for action** to review the basis for the impact thresholds.

b) Railway

Only one study from the late 1970s was available for railway traffic.[39] The acoustic data collection for this study is open to criticism, since measurements were not taken at the location of the sampled population due to budget constraints and instead the noise exposure was calculated using the EMPA railway model developed at the time, a forerunner of SEMIBEL. As stated in section 3.2.4, with this method the sound propagation and the recording of the source (a single train) could only be modelled using considerable simplification. The calculation model was only verified at a few locations by random sample measurements.

The effect acquisition methodology represented the state of the art at the time. The only rather disturbing factor is that the exposure-effect relationship contained in the report[40] by the Commission does not appear in that form in the final study report.

In general, the database for definition of the impact thresholds is found to be based on a single study and this has many question marks arising out of the acoustic part and the determination of noise exposure. The requirements for definition of impact thresholds are barely met by today's standards and there is a **high need for action** to update and validate the empirical base.

c) Air traffic

The threshold definition for noise from large civil aircraft is based mainly on the Noise Study 90[41]. The design of the study and the methodology meet scientific standards. The only problem is that in the study the people affected by noise were questioned both about disturbance in the home and disturbance in front of the building, but the relevant exposure-effect relationships are normally based on disturbance in the home (as also in the official report by the Commission[42]). In the first instance, this does not conform to current standard practice which asks for a general assessment of the disturbance/nuisance, and in the second instance it leads to some incompatibility within the Noise Abatement Ordinance, because an explicit location was not given for railway traffic, for example. In addition, the exposure-effect rela-

[39] University of Zurich Sociological Institute (1980), Limiting of noise exposure: Socio-psychological investigations on limitation of railway, road and shunting noise.

[40] Federal Commission for Analysis of Noise Impact Thresholds (1982), 4th interim report, Exposure limits for railway noise

[41] Oliva C. (1998), Exposure of the population to aircraft and road noise.

[42] Federal Commission for Analysis of Noise Impact Thresholds (1997), 6th interim report, Exposure limits for noise from national airports.

tionship used, which implicitly propagates the nuisance in the home as the determining factor, probably underestimates the actual noise nuisance experienced by the population. As a result, the dose-response curve in the Noise Study 90 indicates a very low proportion of the population experiencing nuisance in an international comparison. The results from the Noise Study 2000 certainly indicate that people base their assessment of aircraft noise nuisance mainly on their experience outdoors. Given this quite unusual quantification of the relevant noise nuisance, it would be logical also to analyse the nuisance assessments in the Noise Study 90 by reference to outdoor noise exposure. Accordingly a **medium need for action** is assessed.

d) Conclusion

In relation to road and railway noise, the empirical principles have significant defects under the current requirements for threshold definition. Overall there is a **high need for action**.

3.3.3 NI 3: Are the observation periods implemented in the NAO (e.g. averaging over one year) still appropriate in terms of the impact and occurrence of noise?

The basic principle of calculating an average annual exposure is widely accepted. What needs better coverage in future is any periodic exposure patterns which coincide with correspondingly higher levels of sensitivity among the population (e.g. increased noise at the weekend, seasonally operated infrastructure such as mountain pass roads). Overall, the **need for action** on this question can be classified as **low**.

3.3.4 NI 4: Are the time of day analysis periods in the NAO still appropriate for the impact and occurrence of noise?

A distinction is made for definition of the thresholds in the Noise Abatement Ordinance between day (6 a.m. to 10 p.m.) and night (10 p.m. to 6 a.m.). This is intended to take into account the activity pattern of the population and the corresponding noise sensitivity. In retrospect at least, the time division used can hardly be described as empirically based, since it was demonstrated as early as 1978 in the road noise study of that year[43] that only 24% of interviewees were up and about before 6 a.m. or between 5 and 6 a.m.

Since then evidence has accumulated that the day-night division in the Noise Abatement Ordinance does not match the habits of the population. In particular, the “start of the day” at 6 a.m. seems to be too early for the majority of the population. The Noise Study 2000[44] shows that for the people of Zurich the average time to get up is 6:34 a.m. during the week and 8:22 a.m. at the weekend, giving an average over a full week of 7:05 a.m. To qualify this, it should

[43] Wehrli B., Nemecek J., Turrian V., Hofmann R. and Wanner H. U. (1978), Disturbance effects of road traffic noise at night.

[44] Brink M., Wirth K., Rometsch R. and Schierz C. (2005), Noise Study 2000 Conclusion.

be noted that no representative Swiss-wide time-use data exists to date which would conclusively indicate the average getting up time for the whole of Switzerland. The results for the population of Zurich, which show an average time of after 7 a.m., are however a strong indication that starting the day at 6 a.m. – as per the Noise Abatement Ordinance – is much too early.

The marginal daytime hours (6-7 a.m. and 9-10 p.m.) must be looked at very critically because a large proportion of the population is already or still asleep then and people react much more sensitively to disturbance from noise at night than to disturbance or exposure to noise during the day.

Overall there is a **high need for action** to review the day-night times. Representative studies on the activity pattern and time use of the Swiss population throughout the day would be required, together with an investigation as to whether further time differentiation is necessary for threshold definition in addition to the basic day-night distinction. For instance, there are indications that the need for quiet is also very high during the mid-day period (11 a.m. to 2 p.m.).[45]

3.3.5 NI 5: Are all the sources covered in the NAO adequately described in acoustic terms?

In relation to this key question, there is a need to examine whether the rating sound level Lr actually addresses all the relevant acoustic parameters for each type of noise (road, railway, aircraft) which can cause disturbance, nuisance and health related effects among those affected. This analysis must be carried out separately for the three modes of transport:

a) Road traffic

As already explained in the Technology & Operations dimension, motorway traffic in particular has increased significantly. This type of traffic was not covered in the main Swiss analysis studies because they were based largely on surveys of residents on local and main roads. Consequently motorway noise played no part in definition of the thresholds. This is problematic in terms of the noise impact because the level-time curve on motorways is practically constant and therefore differs considerably from local road noise. The spectrum of noise emissions is also shifted on motorways due to the higher vehicle speed where rolling noise and aerodynamic noise predominate. Motorway noise also seems to have a pronounced tonality. If continuous tones or sounds which vary over time are featured in noise immissions, greater subjective annoyance is generally caused. None of these characteristics is covered by the current rating level Lr; nor is it clear precisely how they impact on nuisance.[46]

[45] See Brink M., Wirth K., Rometsch R. and Schierz C. (2005), Noise Study 2000 Conclusion.

[46] For example, noise which is almost constant is generally perceived to be less annoying, though motorway noise is still more disturbing overall because it does not stop at night and has a pronounced tonality.

It is also important in relation to noise emissions from road traffic that today's vehicle mix and engineering are very different from the situation in the 1970s when the critical principles for the Noise Abatement Ordinance were formulated.

Overall, the **need for action** due to this change is assessed as **high**.

b) Railway traffic

It is now debatable whether the **railway bonus** is still valid and continues to be justified due to operational acoustic changes in the "noise environment" of railway traffic (e.g. faster trains). Studies focussing on the night period[47] conclude that there is a high physiological sleep disturbance effect from railway traffic noise. This is because trains passing by quickly have a pronounced surge dynamic in their noise level which is of critical importance for awakening responses.

In addition, railway traffic benefits under the Noise Abatement Ordinance, even at high train frequencies (> 79 movements per rating period), from a "minimum bonus" of -5 dB, even if the number of movements reaches similar levels to road traffic, where a bonus of this kind is hardly justified. Furthermore, consideration is not given to the train lengths in the level correction. Whether and the extent to which the train length is relevant to the disturbance also requires investigation.

Overall, there is at least a **medium need for action** to review the railway bonus.

c) Air traffic

In noise impact research, the rating of single aircraft noise events has proved to be a better measure of noise than the weighted average level Leq in relation to physiological responses during sleep. This is because aircraft noise – like noise from railway traffic – has a pronounced surge dynamic which is particularly relevant to the awakening response, as mentioned above. The main relevant parameters of single events are the event level L_E, the maximum level L_{max}, the rate of change[48] and the number of such events. These considerations raise the question of whether a different rating scale should be used, for the marginal night hours at least. The **need for action** is assessed as **medium**.

[47] Marks A., Griefahn B. and Basner M. (2008), Event-related awakenings caused by nocturnal transportation noise.

[48] For definition of the slew rate, see footnote 25 on page 33.

d) Conclusion

The acoustic characterisation of both road and railway noise is probably inadequate in its current form to address the effects of the whole spectrum of nuisance. This is mainly because both noise sources produce widely varying emissions depending on the composition and spatial environment. In relation to aircraft and railway noise, it would be important to examine whether a rating scale based on single events should be introduced to supplement the average level Leq. In summary, a **medium need for action** is justified as a minimum.

3.3.6 NI 6: What impact dimensions must be considered if a threshold definition is to reflect current knowledge and experience?

In noise impact research, nuisance is the psychological noise reaction most often surveyed and is the only noise effect indicator in the legislation of many countries.

It is then assumed that a threshold which limits the nuisance impact ensures almost automatically that all the medical and physiological effects are limited. This concept now demands scrutiny. A judgement of nuisance cannot be made during sleep because the limited state of consciousness does not allow this. It has to be assumed that noise events at night cause physical reactions that can lead to long-term health consequences even if the exposure is below current limits. It is known from epidemiological studies that a higher incidence of cardiovascular disease such as high blood pressure can occur as a result of chronic noise pollution at night. When a threshold is set, the health impact dimension must be taken into account. Health protection cannot be fully guaranteed by the use of current protection concepts to prevent awakening responses at night because they only limit these responses on average for a population group, not for the individual.

Overall there is a **medium to high need for action** to include other impact dimensions in addition to nuisance when defining the threshold.

3.3.7 NI 7: Does failure to include the combined impact of various noise sources of both similar and different types indicate a need for action?

Under the legal requirements of Art. 8 EPA (assessment of effects), the noise effects at a location have to be rated individually, collectively and according to their actions in combination. The problem here is that no national or international research has as yet offered any widely accepted solutions as to how to handle the combined effect of several noise sources in terms of determination of the exposure and the resultant nuisance. There are various approaches in the literature, e.g. total energy level (the total nuisance is a function of the total individual levels) or nuisance summation (the total nuisance is obtained by adding the individual level-related nuisances). When the research results available are looked at critically, no single model can be found to be fully convincing. To the best of our knowledge, no rating method which allows for the combined noise effect has yet been trialled or adopted in any foreign legal system. Initial pragmatic regulation approaches do exist, however (e.g. in Germany with draft directive E VDI 3722).

From this perspective it is certainly true that noise protection legislation in Switzerland is at least up to the same standard as in other European countries. Nevertheless there remains a **high need for action and/or research** as to how to handle the combined noise effect.

3.3.8 Overall assessment for Noise Impact

Table 3-3 gives an overview of the need for action in the Noise Impact dimension. The noise impact research shows that of all the dimensions studied, the greatest need for action to review the basis for the impact thresholds is here. The need for action is high due to the following factors in particular:

- There are various indications that the exposure-effect relationships have shifted over the past 20-30 years and the same level of noise now causes more nuisance to the population than previously. (→key question NI 1)
- The previous empirical principles which influenced definition of the impact threshold can be considered barely adequate in general, particularly by today's standards. With regard to railway traffic, systematic measurement of the noise exposure at the respondents' location had to be omitted due to budget constraints. Instead the noise exposure was calculated using a model which is outdated by today's standards. With regard to road traffic, the impression is that the good experience with the 1963 guide limits was considered more important for definition of the thresholds than the empirical study results from the 1970s. (→key question NI 2)
- The distinction in the Noise Abatement Ordinance between day (6 a.m. – 10 p.m.) and night (10 p.m. – 6 a.m.) probably does not match the current pattern of activity of the population. Only a small proportion of the population is awake at 6 a.m. and the last marginal daytime hour (9-10 p.m.) is part of the sleeping phase for a (different) proportion of the population. (→ key question NI 4)
- The need for research as to how to handle the combined noise effect is high. It is not known how noise from several sources should be acquired acoustically and the nuisance effect of combined noise is also little known. (→ key question NI 7)

The need for action in relation to the dimensions to be considered in addition to nuisance (key question NI 6) and the acoustic characterisation of noise sources (key question NI 5) is estimated to be medium.

Table 3-3: Summary of the need for action on Noise Impact

Noise effect	Key Question	**Besoin d'intervention**
NI 1	What changes in exposure-effect relationships have taken place over time and do they indicate a need for action?	High
NI 2	Are the previous empirical studies adequate for current threshold definition requirements?	High
NI 3	Are the observation periods implemented in the NAO (e.g. averaging over one year) still appropriate for the impact and occurrence of noise?	Low
NI 4	Are the time of day rating periods in the NAO still appropriate for the impact and occurrence of noise?	High
NI 5	Are all the sources covered in the NAO adequately described in acoustic terms?	Medium
NI 6	What impact dimensions must be considered if a threshold definition is to reflect current knowledge and experience?	Medium
NI 7	Does failure to include the combined impact of various noise sources of both similar and different types indicate a need for action?	High

4 Conclusions and recommendations

4.1 Concluding overview of the need for action

According to the Environmental Protection Act, the impact thresholds for noise should be defined so that on the basis of knowledge or experience, immissions below these levels do not significantly disturb the well-being of the population. As the analysis of the legal requirements for definition of the impact thresholds has shown, the following particular aspects must be guaranteed:

- When defining the impact thresholds, the fact that different types of noise can cause different levels of disturbance due to their varying characteristics must be taken into account.
- Also to be considered is the fact that the noise sensitivity of the population differs between day and night.
- A scale must be used to acquire the noise exposure which reflects all the relevant acoustic parameters (level, frequency of occurrence, time sequence etc.) that can cause disturbance, nuisance or health related effects among noise sufferers.
- The adverse impact on the well-being of the population due to noise and health-related effects needs to be researched by population surveys and/or other investigations. Exposure-effect relationships have to be derived from these.
- Based on these exposure-effect relationships, the thresholds should be defined so that the remaining proportion of the population suffering considerable disturbance is as low as possible.
- Groups with high sensitivity such as children, the sick, the elderly and pregnant women should be given appropriate consideration.

On the basis of these requirements, the Technology & Operations, Acoustics and Noise Impact dimensions were studied by means of 21 key questions to assess whether developments or information have emerged since entry into force of the Noise Abatement Ordinance which trigger a scientifically-based need for action to review the basis for the impact thresholds.

The results of this analysis are summarised in the Table below for all the key questions investigated. As shown, a high need for action was identified by the project team on 8 of the 21 questions. A medium need for action was assessed on 7 questions and a low or non-existent need for action was assessed on 6 questions.

The derivation of these results and the analysis of the need for action were discussed with national and international experts at a full-day workshop. The participating experts also produced their own assessment of the need for action on the basis of the input papers presented. The result of this assessment is also shown in the Table (second column from the right; the far right-hand column gives the number of experts who responded).

Table 4-1: Need for action to review the impact thresholds for noise

Dimension	Key question	Need for action* Project team	Need for action* Expert Ø	No. of expert answers
Technology & Operations			* 0: None; 1: Low; 2: Average; 3: High	
T&O 1	How have road traffic volumes changed over the last 25 years, particularly on the motorways, and what are the forecasts?	3	2.5	(4)
T&O 2	How have road traffic emissions changed over the last 25 years and what are the forecasts?	1	1.6	(5)
T&O 3	How has the distribution of road traffic throughout the day changed over the last 25 years and what are the forecasts?	2	1.8	(5)
T&O 4	How have rail traffic volumes changed over the last 25 years, particularly on the main lines, and what are the forecasts?	3	2.4	(5)
T&O 5	How have rolling stock emissions from rail traffic changed over the last 25 years and what are the forecasts?	2	1.8	(5)
T&0 6	How has the distribution of rail traffic throughout the day changed over the last 25 years and what are the forecasts?	3	2.8	(5)
T&O 7	How have aircraft movements around airports changed over the last 25 years and what are the forecasts?	1	1.2	(6)
T&O 8	How have emissions from air traffic changed over the last 25 years and what are the forecasts?	1	0.7	(6)
T&O 9	How has the distribution of air traffic throughout the day changed over the last 25 years?	1	2.2	(5)
Acoustics			* 0: None; 1: Low; 2: Average; 3: High	
A 1	Is the concept of the rating sound level, which is the sum of an average level and one or more corrections, appropriate to describe the noise impact (nuisance, sleep disturbance, health risk?)	1	1.6	(5)
A 2	Is the point of application for the impact thresholds in the NAO appropriate in acoustic terms for recording the disturbance experienced by the noise sufferer?	1	0.0	(3)
A 3	Since entry into force of the NAO, have the technical facilities for acoustic measurement changed or improved to the extent that that this would possibly affect definition of the noise impact thresholds?	2	1.6	(5)
A 4	Since entry into force of the NAO, have the methodology approaches and the acoustic simulation technologies (calculation of noise exposure) changed or improved to the extent that this would possibly affect definition of the noise impact thresholds?	3	2.8	(5)
A 5	Measurements and calculations are affected by quantifiable uncertainties. What significance do these uncertainties have in the definition of impact thresholds?	2	1.2	(6)
Noise Impact			* 0: None; 1: Low; 2: Average; 3: High	
EB 1	What changes in exposure-effect relationships have taken place over time and do they indicate a need for action?	3	2.9	(8)
EB 2	Are the previous empirical studies adequate for current threshold definition requirements?	3	2.9	(7)
EB 3	Are the observation periods implemented in the NAO (e.g. averaging over one year) still appropriate for the impact and occurrence of noise?	1	1.4	(8)
EB 4	Are the time of day rating periods in the NAO still appropriate for the impact and occurrence of noise?	3	3.0	(8)
EB 5	Are all the sources covered in the NAO adequately described in acoustic terms?	2	2.1	(7)
EB 6	What impact dimensions must be considered if a threshold definition is to reflect current knowledge and experience?	2	2.4	(8)
EB 7	Does failure to include the combined impact of various noise sources of both similar and different types indicate a need for action?	3	2.8	(8)

In general it can be seen that there are no discrepancies between the analysis by the project team and the view of the experts on the key questions with a high need for action – with one exception. On question T&O 4 the experts identify a slightly lower need for action.

It is also interesting that there are questions with a high need for action in all three dimensions, the Noise Impact dimension having the majority. Once again the analysis by the project team coincides with the views of the experts.

The need for action in the **Noise Impact dimension** is high, mainly due to the following factors:

- There are various indications that the exposure-effect relationships on which the threshold definition is based have changed over time and the same level of noise, particularly aircraft noise, causes greater nuisance than previously. (→ key question NI 1)
- The previous empirical principles which were incorporated in the impact threshold definition can be considered barely adequate overall, particularly by today's standards. With regard to railway traffic, for example, systematic measurement of the noise exposure at the respondents' location had to be omitted due to budget constraints. With regard to road traffic, the impression is that the good experience with the 1963 guide limits was considered more important for definition of the thresholds than the empirical study results from the 1970s. (→ key question NI 2)
- The distinction in the Noise Abatement Ordinance between day (6 a.m. – 10 p.m.) and night (10 p.m. – 6 a.m.) does not match the current pattern of activity of the population. Only a small proportion of the population is awake at 6 a.m. and the last marginal daytime hour (9-10 p.m.) is part of the sleeping phase for a (different) proportion of the population. (→ key question NI 4)
- There is a high need for research on how to handle the combined noise effect. It is not known how the noise from several sources should be acquired acoustically and little is known of the nuisance effect of combined noise. (→ key question NI 7)

In the **Technology & Operations dimension**, a high need for action is identified on the key questions (T&O 1, 4 and 6). One of these questions relates to road traffic and two to railway traffic:

- With regard to **road traffic**, it is mainly the huge increase in traffic on very busy roads that causes permanent noise exposure which hardly decreases at night. It can be assumed that a mere increase in the rating sound level does not fully address the associated noise nuisance experienced by the population. It may be necessary to include a separate disturbance correction for roads which are continually very busy.
- With regard to **railway traffic**, the huge increase in train density raises the question of whether the bonus for railway over road traffic is still justified. The high proportion of freight traffic at night also raises doubts about the suitability of the method of calculation of the level correction, because it gives an advantage in its present form to trains at night over those during the day if less than 79 trains run in the relevant period.

In the **Acoustics** dimension the only high need for action is on key question A 4. This is because some previous national surveys to determine exposure-effect relationships calculated the noise exposure rather than measuring it at the locations of the sampled population, due to budgetary constraints. It has now been shown that some of the noise calculation models that were used systematically underestimated the noise exposure, particularly at night, because the modelling technology was not sufficiently advanced - for example in noise propagation – to allow for temperature inversions which frequently occur at night. This may have led to distortion of the impact thresholds because the exposure-effect relationships obtained with these models were used to determine part of the threshold definition.

In conclusion, it can be said that since the Noise Abatement Ordinance entered into force there have been changes in traffic and new scientific results which cast **justifiable doubt as to whether the scientific basis of the current noise impact thresholds** is still adequate. In this context various factors indicate a **high need for action to update** the relevant scientific basis.

This evaluation of the need for action is not intended to be a fundamental criticism of the system of impact thresholds or to call into question implementation of the noise remediation measures in any way. Nor does it represent an objection to the procedure adopted by the Expert Commission responsible at the time for formulation of the noise limits. The evaluation of the need for action must be seen as the consequence of developments over a period in which the volume and time distribution of traffic and its composition have changed significantly, noise exposure measurement and modelling techniques have seen tremendous advances and understanding of the relationship between noise exposure and nuisance experienced subjectively has improved with every empirical study.

4.2 Weighting of the need for action

In terms of further action, the question is how to prioritise the key questions where the need for action is high. The questions are rated according to their relevance:

- **High** relevance exists if the new information or altered bases can be expected to have a crucial influence on definition of the impact thresholds and a large number of people will be affected by the resultant adaptation.
- The relevance is considered **medium** if the new information can be expected to have an influence on definition of the impact thresholds, but one which is only of medium importance, or if only a limited number of people are affected by the change.
- The relevance is **low** if new information has hardly any influence on definition of the impact thresholds or if few people are affected.

The results of this rating are summarised in Table 4-2. This shows that updating of the exposure-effect relationships (NI 1) and a review of the day-night division in the Noise Abatement Ordinance (NI 4) are considered extremely important, both by the project team and the experts. The project team also assigns high relevance to a review of the railway bonus (T&O 4) because a large number of people could be affected.

It can also be seen from the Table that both the project team and the experts assume that all the key questions with a high need for action have at least medium relevance for definition of the impact thresholds. The only exception is question T&O 1 on t he importance of traffic growth on the motorways. The relevance of the permanent noise exposure along motorways which hardly abates at night is considered less important by the experts than by the project team.

Table 4-2: Relevance of key questions with a high need for action

Dimension	Key question	Relevance*		No. of expert answers
		Project team	Expert Ø	
NI 1	What changes in exposure-effect relationships have taken place over time and do they indicate a need for action?	2.8	2.7	(6)
NI 4	Are the time of day rating periods in the NAO still appropriate for the impact and occurrence of noise?	2.8	2.7	(6)
T&O 4	How have rail traffic volumes changed over the last 25 years, particularly on the main lines, and what are the forecasts?	2.8	2.3	(3)
T&0 6	How has the distribution of rail traffic throughout the day changed over the last 25 years and what are the forecasts?	2.6	2.7	(3)
NI 2	Are the previous empirical studies adequate for current threshold definition requirements?	2.5	2.2	(5)
NI 7	Does failure to include the combined impact of various noise sources of both similar and different types indicate a need for action?	2.4	2.3	(6)
T&O 1	How have road traffic volumes changed over the last 25 years, particularly on the motorways, and what are the forecasts?	2.4	1.3	(3)
A 4	Since entry into force of the NAO, have the methodology approaches and the acoustic simulation technologies (calculation of noise exposure) changed or improved to the extent that this would possibly affect definition of the noise impact thresholds?	2.2	2.3	(3)

* 0: None; 1: Low; 2: Medium; 3: High

4.3 Recommendation for further action

The results of the study indicate that a scientifically based need for action exists to review the basis for the impact thresholds for noise. The project team therefore recommends continuing with the further work of updating the empirical bases as a pre-requisite for the future noise assessment system. The action could be structured as follows:

a) Decision by the FOEN on the need for action

Based on analysis of the results by the FNAC, the FOEN can make a decision in principle on whether the need for action is sufficiently justified and the proposed intermediate phase should be launched (see next section).

b) Intermediate phase for overall project planning

The project planning for the full "Noise Research Concept" project must be clarified in an intermediate phase. The following tasks in particular are required:

- Project organisation
  - Organisation chart with senior project management.
  - What is the division of roles between FOEN and FNAC? How are other Federal agencies involved to be included (ASTRA, FOT, FOCA, FSO etc.)?
  - Is a separate "Future Noise Assessment System" Expert Commission to be set up or will this role be the responsibility of FNAC? What functions does this Expert Commission have ("only" support for the further research work or implementation of the results in a revised/ new noise abatement ordinance)?
- Content
  - What key questions should be included in the review of the impact thresholds (all those with a high need for action or also selected questions with a medium need for action)? Which of the questions included require additional clarification?
  - A specification should be formulated for each question needing clarification, with the problem, the methodology, a description and a rough cost estimate.
- Funding: Based on the specifications, the funding requirement for the project as a whole should be calculated and the matter of funding clarified. The possibility of financing by the Swiss National Fund within the framework of a project grant (non-oriented free fundamental research) may also be considered. Moreover, co-funding by other federal offices which accompany the project must be checked. It is essential to secure the funding for the basic studies so that updating of the empirical bases for the exposure-effect relationships can begin within a reasonable period.
- Programme with milestones.
- Communication concept: Timing and type of information to the Federal Council, Parliament and the public.

c) Procedure for main studies

- Tender for main studies for all key questions needing clarification
- Selection of researchers
- Implementation of studies with support from FNAC or separate Expert Commission.

d) Implementation of the results of the main studies

Evaluation of the study results from the previous phase and answering the question of whether impact thresholds would have to be examined in a further phase.

5 Annex: Participants at the expert workshop

The following participants held a critical discussion on the content of the various input papers at the expert workshop at ETH Zurich on 26 February 2009:

FNAC and FOEN support group

- Peter Ettler, Federal Commission for Noise Abatement FNAC
- Jenni Keel, Federal Office for the Environment FOEN
- Beat Marty, Federal Commission for Noise Abatement FNAC
- Tommaso Meloni, Federal Commission for Noise Abatement FNAC
- Urs Walker, Federal Office for the Environment FOEN (also an FNAC member)

Experts

- Wolfgang Babisch, Federal Environment Agency, Environmental Hygiene Department, Berlin
- Mathias Basner, German Aerospace Center (DLR), Institute of Aerospace Medicine, Cologne
- Barbara Griefahn, Leibniz Research Centre for Working Environment at Dortmund TU
- Rainer Guski, Ruhr-University Bochum, Faculty of Psychology, Environmental and Cognition Psychology Working Group
- Ullrich Isermann, German Aerospace Center (DLR), Institute of Aerodynamics and Flow Technology, Göttingen
- Peter Lercher, Innsbruck Medical University, Department of Hygiene, Microbiology and Social Medicine, Social Medicine Section
- Christian Maschke, Maschke Research and Consultancy Office, Berlin
- Werner Stalder, Canton of Lucerne Transport and Civil Engineering Department
- Robert Wolf, Canton of Zurich Administrative Court

Project team responsible

- Mark Brink, ETH Zurich
- Kurt Eggenschwiler, EMPA, Department of Acoustics & Noise Abatement
- Robert Hofmann
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- Christoph Zäch, Office for Legislation
- Heini Sommer, Ecoplan
- Sarah Werner, Ecoplan

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