Martin v/d Berg

Jacques LAMBERT
Michel VALLET

STUDY RELATED TO THE PREPARATION OF A COMMUNICATION ON A FUTURE EC NOISE POLICY

Final Report

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The authors

Jacques LAMBERT, Economist, Research Director at LEN
Michel VALLET, Psychologist, Research Director at LEN

Research Unit

LEN : Laboratoire Energie Nuisances (Energy and Environment Laboratory), 109 avenue Salvador Allende, Case 24, 69675 BRON Cedex, France

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FOREWORD

This report has been prepared by INRETS (Institut National de Recherche sur les Transports et leur Sécurité - France) for the Commission of the European Communities (Directorate General XI).

Transport Road Laboratory (U.K.), BBM-Garcia (Spain), Kilde Akustikk (Norway), C. Vogiatzis and K. Psichas (Greece) contributed to the drafting of this report which has been overseen by the national experts of the Ad-hoc Group on Noise Policy Issues.

Acknowledge is paid to all people in the EC Member States and elsewhere who have made the information available to carry out this study.

However the views expressed in this report are not necessarily those of all the EC Member States.

The authors

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INTRODUCTION

1. A COMMUNICATION ON A FUTURE EC NOISE POLICY

Europeans care for their health and their environment - significant elements in their heritage. Both need to be protected and it is therefore not surprising that all opinion polls in Europe place noise at the head of the list of environmental pollution concerns.

The Commission of the European Communities, Directorate-General XI endeavours to protect the health of Europeans from environmental aggressions and in particular from noise. To do this it is strengthening regulations, undertaking preventive actions, initiating field controls and introducing a new information policy.

People living in all the industrialised nations of Europe are subjected to noise from many sources - at work, when travelling, during their leisure time and at home. The effects are insidious. Noises can be loud - and sometimes intolerable - and always present. Over time they are often repetitive. Unlike urban atmospheric pollution (such as the smog in Athens) the impact of noise is rarely spectacular, except when somebody goes berserk, picks up a gun and shoots the noise-maker, or when Army recruitment medical visits observe an alarming percentage of hearing loss in young men. There are relatively few complaints registered, but it is generally accepted that complaints are a poor indicator of the acoustic situation because they only arise in atypical situations. Conversely, the results of surveys on general environmental problems based on large sample populations valid on a statistical level in which noise is often the main pollution for which repressive measures are requested are considered to be a good indicator.

The Commission has already considered the problem of noise at work, primarily by the Directive 86/188/EEC. Other Directives concern the emissions from primary noise sources such as the reduction of permissible road vehicle noise levels etc. All address ways and means.

The Commission is now envisaging a new phase, to address **results**. This would be a proposed communication to Council and Parliament on a Community Noise Policy. Regulations concerning source noise levels do not always cover this aspect. For example, efforts undertaken to reduce noise emitted by vehicles are rendered meaningless if road traffic increases. Many national regulations concerning different sources of noise already exist in Europe. Some countries have not yet published texts and are waiting for the work of the European Commission.

2. CONTENTS OF THE INRETS STUDY

To support the preparation of this Communication, the Commission of the European Communities has initiated a study on a "Future Noise Policy". INRETS, with the co-operation of the Transport Research Laboratory (U.K.), Garcia B.B.M. (Spain), Kilde Akustikk (Norway) and Greek consultants, carried out works that describe the noise exposure to man. The study has also provided suggestions for noise abatement policies including costs and benefits of alternative sets of noise quality criteria. Transportation noise sources have been covered in priority. However, data on other sources of noise (industrial-construction) have been also collected.

This study consists of six interconnected parts :

Part 1 Evaluation and proposal for noise indices to describe the exposure of populations to community noise

Effects of noise. Assessment of existing units of noise measurement taking account of the characteristics of the noise sources. Relation with noise effects on man (at home, at school, in hospital). Problem of multiexposure to different sources of noise. Proposals.

Part 2 Noise quality criteria : current regulatory policies

Review and analysis of noise quality criteria from selected countries (EEC - USA - Australia - Japan) - Specific environments and periods covered - Purpose of the noise exposure limits - Identification of the responsible levels of administration.

Part 3 Noise exposure and annoyance

Review of data on noise exposure levels (number of people exposed to different sources of noise) and national social surveys on the perception of noise (number of people annoyed). Identification of the missing data. Future outlook.

Part 4 Noise abatement measures & policy instruments

Identification and analysis of the current noise abatement measures implemented - Classification of the actions implemented : planning, regulation, control, economic and non-economic incentives, investment. Efficiency (reduction in dB) - Implementation conditions - Description of national noise abatement programmes.

Part 5 Alternative sets of EC noise quality standards

Proposal of three alternative sets of noise quality criteria for use in the cost-benefit analysis under Part 6 (Limit critical noise exposure situations - Provide satisfactory protection to people exposed - Promote good quality noise environments).

Part 6 Cost-effectiveness and cost-benefit considerations for alternative sets of EC noise quality criteria

Review of the literature concerning these methods. Pilot cost-effectiveness and cost-benefit evaluation applied to land transportation noise in France (corrective programme). Proposals and recommendations for implementing noise abatement policies.

GLOSSARY

A suitable unit : the dB(A)

Although the level of noise which is assumed to be constant is commonly expressed in decibels (dB), it is important to note that current legislation refers to several types of decibel depending on the sources of noise. Thus, the units for measuring the noise from road and railway vehicles are "A" decibels, written as dB(A). The term "A" indicates that the noise recorded by the microphone has been filtered and adjusted in the same way that the human ear filters and adjusts the noise it receives.

Addition of decibels

The units of noise are more complicated to manipulate than familiar units as units of length, for example. Two lengths can be simply added, but this is not the case with noise levels. The straight forward addition of decibels is impossible because decibels are on a logarithmic rather than a linear scale. Il should be remembered that adding two noises of the same intensity produces a total noise level which is increased by 3 dB(A) : 70 dB(A) + 70 dB(A) = 73 dB(A).

Leq : a noise index for predicting annoyance

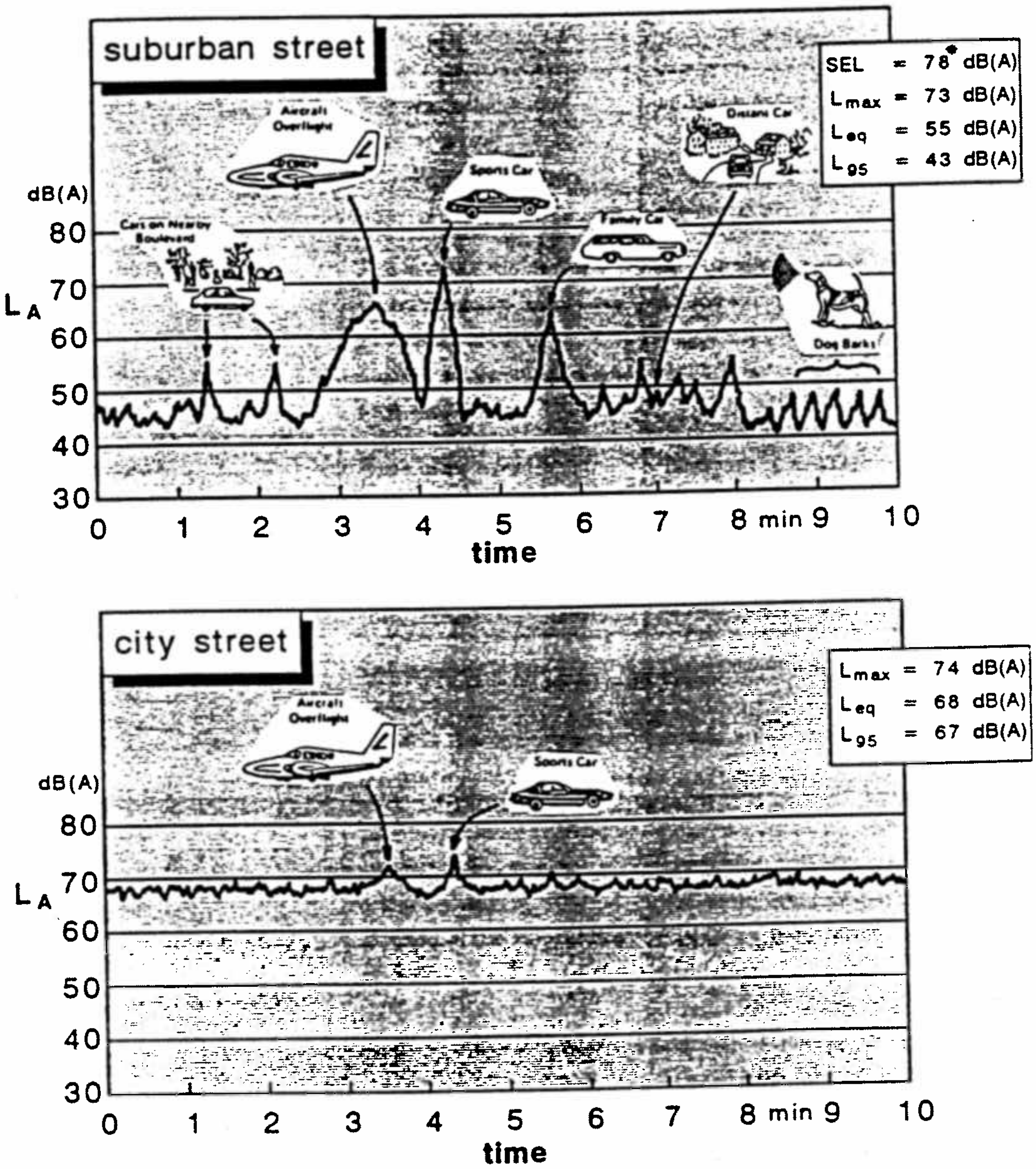
Traffic noise fluctuates a great deal, but it is necessary to characterise it in a simple way so as to predict the annoyance to inhabitants. The equivalent continuous sound level (Leq) is very often uses for this purpose (see annex 1-Part 1 for a more detailed description of the noise units). It represents the acoustic pressure of a noise which is assumed to be constant with the same quantity of acoustic energy over a fixed period as the noise in question. The daytime and night-time Leq is used to characterised annoyance caused by road and railway traffic noise.

The noise scale

The levels of acoustic pressure in the external environment range between 20-25 dB(A) for extremely quiet country nights and 110-120 dB(A), 20 metres away a jet plane at take off. Noise levels usually encountered in urban areas lie between 50 and 78 dB(A) Leq (see two examples next page).

EXAMPLES OF NOISE ENVIRONMENTS

(from ref. 8)



PART 1 : EVALUATION AND PROPOSAL FOR NOISE INDICES TO DESCRIBE THE EXPOSURE OF POPULATIONS TO COMMUNITY NOISE

1. INTRODUCTION

Noise is often described as an unwanted sound or set of sounds and it is difficult to measure the physical and physiological effects of noise on man [1]. Once methods have been established, we then need to determine a dose-effect relationship so as to be able to propose thresholds and define noise indices for regulatory purposes.

Man responds to noise in many ways for example :

- noise impairs the quality of communication when listening to the radio or watching television, classroom intelligibility,
- concentration on intellectual pursuits and manual tasks,
- night and daytime sleep disturbance.

Another complication is that not all people respond to noise in the same way.

The research works available quite clearly demonstrate complexity. It is, however, possible to draw broad general conclusions and thus propose ways in which to consider noise and the most suitable noise indices to describe the effects on man. Experimental results which characterise human response to different levels of noise in laboratories or in the field enable us to suggest noise exposure limits expressed in decibels. Limits can aim to restricting the effects of noise on Public Health or can go further to ensure general comfort for all.

2. THE EFFECTS OF NOISE

2.1. The numerous effects of noise on public health

Due to the wide diversity of situations it is difficult to understand all the effects of noise. Noise stems from a wide range of sources and the effects depend to a large extent on the physiological and psychological attitude of each person subjected to noise [2].

Noise acts on two separate neurophysiological mechanisms. The specific auditory path - i.e. the ear and the auditive nerve connected to those regions of the brain which translate auditive sensations - and by an indirect neurological path which activates the non-auditory nervous structures which play an important part in regulating awareness and in non-auditory responses to noise.

Noises perceived in residential and recreational environments have hardly any effect on the auditory system. High noise levels can accelerate natural hearing loss observed with age and the acute risks of hearing loss are very rare.

For a long time noise was considered to be a physical phenomenon which only affected the auditory system. We now know that this conception is erroneous and that in the same way that food does not only act on the digestive system, noise does not only affect hearing. Reactions to noise affect the whole organism which should be considered as a single unit and not merely as a juxtapositioning of functional systems. Generalised stress response is expressed by activities involving the cardio-vascular, neuro-endocrine and emotive systems [3].

In this document we review the results of research carried out over the last 30 years and present interesting conclusions for the conservation of the Environment and Public Health. The different categories include :

- The physiological effects of noise caused by loss of sleep and physiological - basically cardio-vascular - effects.
- Psychosomatic disturbances such as stress and psychiatric disorders when the individual terrain is favourable. Most commonly, reactions to noise are restricted to a more or less sever disturbance.
- The influence of noise on the intelligibility of communications in recreational activities such as listening to the radio or music, watching television and classroom or work activities.

These primary effects often lead individuals to adopt behaviour patterns to improve their situation. These are secondary indicators of noise. Behavioural changes include closing windows, under-use of some parts of homes or gardens, for example, investments in sound-proofing for the home or quite simply other means of avoiding noise such as leaving home temporarily or permanently, i.e. moving somewhere else.

Noise increases the use of medication, more frequent consultations, absences from work and the use of drugs to calm disorders induced or triggered by environmental noise.

Fortunately perhaps, a given person never responds to noise in all these ways. Reactions appear in a given direction and are rarely combined. This means that to evaluate the scope of the effects of noise it is essential to include the full range of effects by the use of methodologically reliable epidemiological surveys. The reliability of the methods is essential when combining the effects of noise on man with measured or typical noise levels from different environmental situations.

2.2. Sleep disturbance

Sleep restores physical and mental fatigue. Quiet nights are essential to good health. Experience shows that noise disturbs sleep in many ways.

a. Modifications to the structure of sleep linked to different mean noise levels

All the various phases of sleep comprise a relatively constant structure. The most significant effect of night-time noise levels is to disturb the way that sleep is organised. Destructured sleep starts to occur at constant (but not tonal) noise levels of approximately 35 dB(A) Leq throughout the night inside the bedroom. Many studies carried out in laboratories or in peoples' homes in Europe (DG XII Programme) and elsewhere (Sweden, USA) have shown that noise induces :

- difficulties in going to sleep,

- arousal during the night,
- the reduction of some sleep phases,
- degradation of sleep quality by phase changes which the sleeper does not perceive (from deep to lighter sleep).

The dreaming period, considered to be unvaried in sleep organisation, is also affected, more particularly in older subjects. Chronic sleep disturbance by noise has also been observed to occur after several years of exposure. These means that subjects do not develop a completed defence mechanism to noise.

Noise has the effect of reducing the duration of the deep sleep phase, which is vital to physical recovery. Latency in the appearance of the first episode in paradoxical (or dream) sleep is reduced too. These phenomena are observed whether people complain about noise or not.

b. Temporary modifications to sleep related to completely isolated noise events (alarms, aircraft, trucks and trains).

These cause changes in brain wave patterns and pulse rate. Effects appear at approximately peak level 45 dB(A) in children, 50 dB(A) in old people and 55 dB(A) in young adults. However, the peak level of an isolated noise does not completely account for the temporary reactions of sleep patterns. One should also consider the global noise level and the emergence of the peak noise and the number of these events or the time interval between their occurrence.

Results of these different studies show that there is no physiological adaptation to repeated noises during the night, whereas the people concerned believe that they have learned to live with their environment. It also appears to be useful to consider all noises received during a 24 hour period. The duration of the paradoxical sleep phase reduces proportionally to the total amount of noise received during the previous day. Memory of the sound energy received is a good demonstration of the fact that if people manage to adapt to noise during the daytime, it is because their central nervous system accelerates with a consequent impact on subsequent sleep. This means that there is an additive effect between night-time and daytime noises involving specific cardio-vascular functions and that these latter prevent the body from re-setting its regulation points.

Despite of a recent U.K. study [4] which found that at outdoor event levels below 90 dB(A) SEL (80 dB(A) Lmax), average sleep disturbance rates are unlikely to be affected by aircraft noise, it can be said that the recommended noise level inside bedrooms should be approximately 35 dB(A) Leq. The W.H.O. ideal proposal suggests 30 dB(A) at night [5]. For intermittent noises, peaks should not exceed 45 dB(A) inside bedrooms. However, it is also essential to consider the maximum number of events occurring during the night.

Assessing noise to prevent sleep disturbance is a good illustration of the complexity of this problem, i.e. should one consider external or internal noise when dealing with housing ? Is a global noise level indicator sufficient or should one consider both levels and the number of events ? What is the threshold number of events for isolated noise before they become global noise ? Should some periods of the night be weighted to correspond to different sleep phase sensitivity ? Specific researches are needed to answer this question on sleep disturbance as well as subjective daily annoyance.

2.3. The non-auditory physiological effects of noise

In biology as in physics, noise does not act in a vacuum : it interferes with the physiological, psychological and emotional functions of people exposed. What is even more serious is that simply believing one dominates noise modifies physiological responses to the stress it causes.

If it is difficult in practical terms to prove that environmental noise not only has an effect on hearing impairment but also on personal states of mind, it is quite easy to demonstrate experimentally that high noise levels have significant physiological effects. These reactions disappear when the noise source ceases, but repeated exposure to noise can make these states become chronic and thus pathological. This is the case targets like the cardio-vascular or digestive systems.

The notion of noise as a purely physical causal phenomenon - i.e. where it is considered as a stimulus and only the response created is analysed - is no longer current and has been replaced by the more general notion of aggression or stress. Stress amplitude does not only depend on noise loudness. In these conditions, one or several physiological functions can be regulated around new reference points leading to conventional pathological symptoms such as hormonal imbalances, excessive blood pressure, aggressivity and nervous depression appear. We have investigated the sequence of physiological effects and the way that they cause stress and psychosomatic and psychiatric disorders.

In our initial approach, we considered noise to be an alarm signal which induces a "startle" and an orientation reflex.

Some sudden noise sources such as aircraft, fast trains, mopeds and some noises such as clay pigeon shooting and domestic noises (slamming doors, lifts) make muscles contract. Ringing bells can create "startles". If these noises are repeated, reactions are reduced and response disappears, i.e. we become accustomed.

Some hormonal secretions can follow the secretion of adrenaline and noradrenaline which have important cardio-vascular effects including increases in pulse rate and blood pressure. These physiological events occur following high noises but can also be observed when somebody is trying to maintain high levels of performance in a task carried out with high background noise.

Variations in the electrical resistance of the skin linked to sweating can appear at extremely low noise levels of around 35 dB. Pulse changes are observed at over 65 - 70 dB peak values, but could appear for lower noise levels.

Research carried out in Japan suggests that children born to mothers exposed to airport noise have lower weights and heights vs. a noise-free control group. The explanatory mechanism could be due to insufficient production of growth hormone. The secretion of this hormone is related to some sleep phases which are reduced in the presence of noise. Other studies have shown a relationship between noise and the number of premature births but this trend has not however been confirmed by statistical analysis. However, sensitivity to noise does seem to be linked to different periods of pregnancy : if the first months of gestation are lived in a noisy environment, children are less sensitive to noise, whereas if pregnancy is carried to full term in a noiseless environment, infants are extremely sensitive to noise.

2.4. The cardio-vascular effects

Populations exposed to intense noise have high blood pressure. Blood pressure is higher in workers with noise-related hearing impairments than in a control group with no hearing impairments working in extremely noisy workshops. At lower levels, it has been shown that bus drivers' blood pressure rises with age (particularly in subjects whose parents had cardio-vascular problems). No change was observed in bus conductors.

As these two populations are subjected to identical noise levels the results suggest that, heredity aside, a chronic pathology only occurs when driving stress is combined with noise. We should attach more importance to epidemiological research carried out on large samples than to laboratory research which corresponds much more closely to noise levels at work (often as high as 90 dB(A)) than to background noise.

In Holland, observations around an airport show that cardio-vascular illness, medical consultations and the purchase of medication are more frequent in an area with a 67 - 75 dB(A) Leq noise level than in a quieter area (46 - 55 dB Leq).

It has also been observed that low altitude flights of military aircraft induce high increases in blood pressure proportional to the rate at which the noise increases (30 dB in 4 seconds or in 0,4 seconds) in old people and, to a lesser extent, in children. Response increases with the repetition of stimulations which means that sensitivity increases with exposure to noise although it could be expected that subjects become used to noises over time. Despite these instantaneous responses to noise we cannot definitively conclude that long-term effects exist.

The European Community financed two large-scale investigations into cardio-vascular illnesses in Caerphilly and Speedwell to demonstrate a relationship between traffic noise and a table of cardiac disorder appearance risk factors [6]. Samples of 2412 and 3248 men, aged from 45 to 59, were selected in these towns and their risk factors were evaluated by dedicated protocols for 9 years. General background noise was measured for 3 days continuously to enable preparation of noise maps for the 6am-10pm Leq, 10m from the elevations of the residences of each person in the sample. Subjects were classified in 5 dB noise steps from 51 to 70 dBA. The results were not convincing and did not show a direct relationship between exposure to traffic noise and blood pressure or any other known risk factors for cardiac disorders. When the least exposed group of men (under 60 dBA) is compared with the most exposed group (66 to 70 dBA), the relative risk for the appearance of cardiac disorders is only + 110 %. In Caerphilly, the relationship between traffic noise and blood pressure is more acute in people exposed to loud noises at work.

A sample drawn from the population of Berlin was used for control purposes. Exposed to higher noise levels (Leq 60 to 80 dBA) this sample had a higher risk of myocardial infarcts (120 %) after consideration of disturbance factors. This is why it is believed that 66 - 70 dBA in Leq traffic noise is a threshold for risks of cardio-vascular illness.

In a laboratory research programme implemented in the context of the 4th EEC Environmental Research Programme it was found that pulse rates depend on the nature of the noise - the most significant variations were related to traffic noise rather than to the noise to which a construction machine driver was subjected when demolishing steel pilings, or to a shot from a rifle or to intermittent pink noise at 75 dBA Leq.

Some authors believe that for noise to create cardio-vascular disorders, exposure must last 5 to 20 years. Given the most recent research, our conclusion is that even if the results have not yet been confirmed by statistics it seems that the noise from road traffic only has a low impact on blood pressure increase and other cardio-vascular responses. This relationship depends on other noises to which people are subjected, particularly at work, as well as in their personal lives, social life and life styles. The combination of these factors can lead to stress problems.

2.5. Stress

Some of the non-auditive phenomena related to noise and the numerous disorders that noise creates such as vertigo, nausea, gastro-intestinal problems, tunnel vision, over-tiredness and irritability can be explained by analysing stress.

Stress is basically a response by the body to a stimulus which is not necessarily the same for all and which can cause elation (eustress) or depression (distress). It is a non-specific reaction by the body which progresses in three phases : alarm response, resistance phase, collapse.

Noise causes stress but it is obvious that it is difficult to disassociate noise from other environmental factors for each individual. Researchers have developed a "stress scale" comprising 43 events of particularly significant value : loss of a spouse, divorce, family conflicts, money problems and work problems... All these common experiences in life play a part in the appearance of the disorders that we describe above - and can be cumulative. Furthermore, we do not all react in the same way to these aggressions : our responses are modulated by habits and socio-cultural possibilities (leaving home every weekend, for example), by medical characteristics (enhanced sensitivity caused by other problems or by hereditary factors) and by individual biological characteristics (typologies).

In Austria, in 1993, public health doctors demonstrated relationships between some cardio-vascular disorders and the psycho-social characteristics of people subjected to noise. These physio-pathological symptoms are much less evident in people who protect themselves from noise by closing the windows, particularly at night, and by those who participate in general movements of the population to fight noise by signing petitions. In this group the effects of noise are diminished.

Conversely, in some people noise increases stress and leads to a wide range of psychiatric disorders. Analysis of admissions of people living near airports to psychiatric hospitals suggests a relationship with noise level but more particularly in high socio-professional categories with an accentuated sensitivity to noise (i.e. those with high levels of education and income) and in poor people. An indirect indicator of these problems is the consumption of medication for mental disorders which increases overall with noise levels.

In France, the recent creation of a "Psychiatric Epidemiological Observatory" has produced interesting findings over the last year. The network connects 1300 observatories and has shown the continuous nature of anxiety states and the role of noise in their initiation and continuation. In France, 27% of patients consulting doctors discuss anxiety states and 21% of this population is extremely sensitive to noise. Noise is clearly identified as the most common nuisance, of much greater significance than microbial or chemical contamination and smells. 59% of anxious patients talk about noise. Doctors estimate that environmental pollutions play a determining part in 4% of anxio-depressive pathologies and that noise alone can cause initial stress to develop into moderate psychiatric pathologies.

Noise and other nuisances play an important part when associated with other factors in 53% of all cases according to these doctor-observers. These results are extremely significant in that they are not limited to observations in noisy environments (airports, for example) but because they reflect the impact of noise and other forms of disturbance throughout a nation with 58 million inhabitants.

Despite its interest, this category of effects of noise on Public Health does not give any useful indicators as to the noise level that should be recommended as personal factors have too great an incidence in this case.

2.6. The psychological effects of noise

When noise is not excessively loud and does not attain sensitive groups, psychological responses are frequently observed in exposed populations, including difficulties encountered in familiar environments such as inaudible communications and lack of intelligibility as well as effects on awareness and performance.

Psychological disturbance is the subjective perceptive sensation expressed by people hearing noise whereas noise itself is only a perceptive sensation. The psycho-sociological components of this disturbance are complex. Despite this, disturbance is one of the criteria frequently used in research into the effects of noise both in psycho-sociological surveys and in laboratory research. In real situations, disturbance is often a global expression reflecting the situation of people who are responding whereas in laboratories subjects are more or less isolated from their context in which case noise loudness becomes a much more important factor [7]. Disturbance is a strictly psychological and basic response to noise. It can also be a secondary effect of behavioural responses to noise : for example noise can mask sounds from the television. This is a primary effect but often induces a secondary disturbance.

The correlation between the different disturbances expressed by individuals and the physical measurements of noise implemented in that situation is always significant on a statistical level, although, in reality, it is low. Conversely, the comparison of the means for disturbances expressed by groups of subjects placed in situations with different noise exposures reveals significant and coherent differences. The louder the noise the higher the mean of the disturbances expressed. This apparent contradiction is explained by the extremely high variation in disturbances expressed. The consensus is low except in overexposed places and yet even in situations that are apparently insupportable and in which oral communication is impossible, some subjects still claim to have adapted to the background noise.

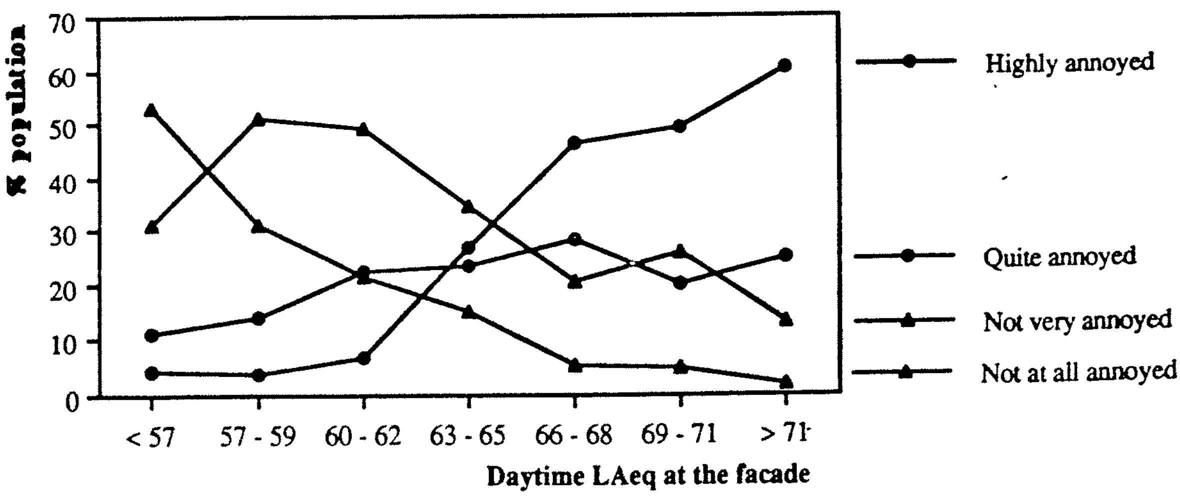
Disturbance can be apparent for extremely low levels of noise. Hence is it not loudness which is the determining element and we have to consider other noise characteristics such as pulsations, repeated noises, the conditions in which noises occur and the impossibility of controlling them. Furthermore, noise is not felt in the same way by everyone.

Over and above its physical characteristics, noise is a psychological event with an emotional and informational content which if it is difficult to quantify nevertheless exists. Reactions to noise are conditioned by individual biological characteristics, habits and social and cultural possibilities. In psychological terms, active ambitious subjects with a sense of responsibility seem less disturbed than people with contrary behaviour patterns. An over-simplification could be that extroverts are less disturbed by noise than introverts.

Furthermore, at home as at work, the disturbance expressed when noise exists will be lower if people are happy and doing the job they want to do. Some groups are more sensitive to noise or become sensitive due to specific factors. These groups include depressives, hypochondriacs and anxious people as well as people who are living difficult personal situations - divorce, unemployment and emotional problems. These make people complain about noise, although the causal relationships with noise are not always easy to determine and complaints in themselves should not be considered a sufficiently good indicator.

Currently, there are over 1000 on-going noise surveys concerning a wide range of different sources. This should lead to an extremely solid basis for conclusions. Statistically valid results combining noise levels and human responses mean we can now devise noise indices and thresholds [8]. Figure 1 below concerns road traffic noise and responses from 1500 people [9].

Figure 1. **Road traffic noise annoyance in France**



On the response curve for "highly annoyed people" the figure climbs steeply above 60 decibels for the 8am - 8pm Leq index with a second point of inflection at 68 dB(A). This would indicate two thresholds : one is the intervention threshold at 68 dB(A) and the other can be taken as an ideal value. In fact, at this level, the percentage of highly annoyed people is under 10% but the sum of highly annoyed and quite annoyed responses is 29%. This percentage is too high to consider the 60 dBA Leq level as a comfort level. For medium and long term planning the threshold should be below 60 dB(A) Leq.

Quite often background noise in a community is generated from several different sources. The ear can identify specific noises within this combination. Several models have been proposed to cumulate this noise and one method has been standardised (ISO 532B) on the basis of the levels in 1/3 octaves of masking noise [10].

This question also arises for the combination of disturbance from a wide range of different sources. It has been observed that disturbance due to a combination of sources is often lower than the maximum of disturbance arising from one specific source.

It can however be concluded that the "dominant source" model is the best of the existing formulae : total disturbance is exactly equal to the maximum disturbance attributed to one of the sources ; furthermore, the noisiest source or the most disturbing source is not necessarily the loudest source.

As the noise environment changes during the 1990s, this problem is actual and additional research is necessary to understand not only global noise perception but total disturbance.

2.7. The effects on communication

Basically the effects concerning intelligibility and masking. When a secondary noise source exists, useful sounds are masked.

The intelligibility of conversation, radio, music, television and other sound signals are an essential element in life. Understanding conditions acoustic comfort in every home as well as safety in industry, transportation, etc. Conversely, privacy is conditioned by not hearing the conversations of the neighbours.

The intelligibility required for intellectual work depends not only on masking noises but on the nature of the messages transmitted and the training of the listener. The "dynamic" of speech levels (i.e. the difference between the lowest and highest levels attained) is great - approximately 30 dB.

Noise levels frequently attained in streets, gardens and on balconies interfere with speech. Noise levels inside buildings usually cause occupiers to close windows if they want to hold a conversation once the external Leq reaches 69 dB(A). When the windows are shut and the difference between external noise and internal noise is considered it is observed that occupiers want to be able to hold a conversation in a normal tone of voice up to 6 metres apart, facing each other and at a much smaller distance if other people participating in the conversation are not necessarily facing the speaker.

Inside homes people want to be able to speak softly, listen to music and watch television. Listening to television implies lower background noises other than conversation : it is difficult to ask speakers to repeat what they have said and television sound levels cannot be turned up too high as they could disturb the neighbours. That is why it is generally accepted that noise levels in homes should not exceed 45 dB(A) during the daytime and evening. This level is often exceeded by traffic noise even with the windows closed.

Most studies define intelligibility and comfort zones for conversations for people with excellent hearing. However, 8 to 10% of the population have a hearing impairment of 20 dB and more due to natural ageing. This figure does not include hearing loss due to illness and this should specifically be included in any recommendations.

One topic on which all researchers agree concerning noise at work is that simple repetitive tasks are not degraded by noise and it has even been observed that performances improve in the presence of significant sounds such as music or speech. Conversely, work requiring concentration is disturbed by noise and it has been observed that when workers have two simple tasks to complete at the same time, the task which they consider to be the most important is not degraded whereas the task considered as secondary is significantly degraded.

On the neurophysiological level, it is obvious that whatever the experimental results, working in noise is always an additional biological load. Either the noise is filtered, which implies an increased work load for some structures, or it is continuously analysed on a cortical level. This latter hypothesis implies a division in time between processing the task-related information and processing the noise-related information.

2.8. Noise and children

Over and above the purely physiological effects on children, noise can have an impact on their intellectual and emotional development.

When noise interferes with speech, children have more difficulties than adults in understanding because they are in a apprenticeship phase. As they have no background knowledge to which to refer, they cannot reconstruct snatches of conversation masked by background noise. For this reason, noise has deleterious effects on the development of language and learning how to read.

Apart from these masking effects, noise also inhibits the development of concentration. Children who live in noisy environments can never sufficiently develop their listening capability and become inattentive to sound signals in general. Research in the USA has demonstrated that children exposed at home to a wide range of different sound sources simultaneously such as the radio, television, miscellaneous domestic appliances - what the authors call "confused noises" - seem to learn to speak more slowly during the first two years of their life.

Other symptoms include aggressiveness, irritability, fatigue and psychomotor agitation. All can deteriorate the social climate.

In canteens in which an effort has been made to reduce noise levels, it has been observed that children behave completely differently, holding extended conversations and take longer over their meals, eating cheese and desserts.

Noise is also a risk factor in the health of children. It should not however be forgotten that children are often the source of noise and this is a salutary reminder that some noise is essential to life.

2.9. Effects of noise on behaviour

a. *Getting away from it all*

If noise does not seem to encourage families to increase their daytime or weekend outings (indicator revealing get-away behaviour), it does seem to intervene quite significantly in intentions to move home, particularly above 68 dB(A) and primarily for tenants.

This behaviour can be understood more objectively through the turn-over rate of homes. A survey carried out in France of 700 homes shows that the mean turn-over rate of homes exposed to loud noise is 7,9% vs. 6,7% for homes in which noise is not a problem. Although it has not been possible to detail this result, it can be deduced that noise in this case has increased the number of removals by 18%.

b. Spontaneous noise insulation

When noise levels are high (Leq > 68 dB(A)) owners tend to insulate their homes.

c. Legal and political recourse

Traffic noise can induce complaints to administrative tribunals when the State, operating companies and motorway operators are responsible for noise pollution (detours of trunk roads, creation of expressways, by-passes and motorways) and collective actions when local residents group together in a Defence Committee.

2.10. The effects of low frequencies and vibrations

Low frequency noises contribute to disturbance in at least 3 different ways :

- low frequencies induce the feeling of static pressure. For example, the ear registers pressure for at least one minute when a car window is opened, effectively creating a Helmholtz resonator ;
- low frequencies contribute to masking medium and high frequencies in conversations. Speech which includes large variations in amplitude remains intelligible but is comprehension is seriously affected ;
- loud low frequency noises produced by aircraft or by large vehicles make doors, windows and buildings tremble which increases disturbance due to noise as it worries local residents.

A type weightings filter many of these low frequencies and the difference between dBC and dBA is used to identify the potential impact of low frequencies [11]. However, the disturbance resulting from the combination of noise and vibrations from trucks, trains and industrial noises is not clear and people exposed to them have a strong tendency to confuse the sources.

3. PHYSICAL ASSESSMENT OF NOISE

3.1. Noise units

From a physical point of view, noise is an acoustic phenomenon. A noisy event can be characterised by three parameters :

- loudness and energy, expressed as sound pressure amplitude ;
- frequency or sonority ;
- variability over time.

We propose a specific vocabulary to express the various concepts used. This is part of ISO standard 1996.

1/ **Level L** is the instantaneous amplitude of the sound expressed in decibels ; decibels follow a logarithmic scale and are expressed as linear or weighted decibels. Human hearing is not equally sensitive at all audible sound frequencies and for this reason measurement instruments are fitted with filters designed to weight noises in the same way as the human ear does. ISO standard 1996 uses weighting A which reduces the sensitivity of the frequencies below 300 Hz and above 8000 Hz. Other weightings are briefly reviewed in the annex 1 to this report.

2/ **Scale** of noise is a combination of physical variables designed to evaluate response to noise. The duration of the measurement is always defined. For example, the level of noise attained or exceeded during 10% of the time will be written $L_{A10,18hr}$.

3/ **Noise indices** are physical descriptions adding other factors to the noise scale over and above strict physical measurement : they can include a correction for the type of land use or for the period of the day, the number of noise events, etc.

4/ **Indicators** of noise are not physical descriptors but sets of variables used to evaluate the impact of noise on a set of individuals, places or activities. For example, the percentage of homes exposed to a certain level of noise in a block of flats is an indicator which characterises the site.

Other frequency weightings are used for aircraft noise (ISO R 3891*) and a scale should also be used to consider perceived noise (PN) when an aircraft flies overhead. The annex 1 summarises the complexities involved in noise evaluation. In the same way, a recent CEC-DGXI report [12] lists a 4 point classification used to rank aircraft noise in European nations. A huge amount of research work has been devoted to this question. The different ways in which noise can be considered correspond correctly to specificities of noisy situations. A strong correlation can be also be observed between the noise scales used and also between noise indices. This means that the different noise scale units used can be considered in an almost identical way.

The examination of the effects of noise on man, the examination of existing standards (ISO 1996) and current practices throughout the world have led to the adoption of the Leq equivalent energy level. This is defined as the level of a continuous stable noise over a given period of time which would be the equivalent of real noise presenting variations in level and measured over the same period.

The equation $L_{Aeq} = 10\log_{10}\left[\frac{1}{T}\int_0^T 10^{\frac{L_A}{10}}\,dt\right]$ is calculated from knowledge about level L at each moment. Instantaneous level L is measured in dBA. The periods for integration purposes, 24 h, or daytime, evening, etc. are defined. The different periods must cover the overall day period. In France, the use of 8 am-8 pm Leq and midnight-5 am Leq leaves uncovered 8 pm - midnight and 5 am-8 am periods ; people don't hesitate to ask why. In England L_{10} is used on the 6 am-24 pm and in Germany the main period is Leq 6 am-10 pm. Following the principle of subsidiarity and effective differences in the way of life between Northern and Southern Europe, each member state could choose between 2 or 3 periods inside 24 hours and fix the limits (see table 1 at the end of this chapter)

3.2. Road traffic

The measurement of the noise emitted by individual road vehicles is subject to regulation in many countries as well as for measuring the noise from a stream of traffic alongside a road. The microphone is set up at a defined height and distance from the road and measurements of individual vehicle passages (in dB(A)) or general traffic noise is sampled over a period (e.g. 18 hours) and estimates of, for example, L_{A10}, L_{A50} or L_{A90} are made.

* this standard is on the revision (Working Group : ISO/TC43/SC1/WG43).

In the UK the procedure used for assessing levels of traffic noise is described in Department of Transports' Technical Memorandum "Calculation of Road Traffic Noise" CRTN. This document describes procedures for both predicting and measuring the noise from road traffic. The noise measure used is $L_{A10,18hr}$ dB where the 18 hour period is from 6 a.m. to midnight.

The levels determined using the prediction method are used primarily to establish entitlement to noise insulation grants [13]. However, it is also used as part of the environmental assessment process described in the UK Department of Transports' Manual of Environmental Appraisal (MEA). The MEA provides the assessment framework used by highway authorities to compare the environmental impact of alternative options for proposed road schemes.

On most roads, particularly motorways and other main roads, there is usually a reasonably predictable flow pattern over the 24 hours with, typically, peak flow periods in the morning and evening followed by a substantial reduction in the flow during the night. It follows that traffic noise also exhibits a similar diurnal variation. Sargent [14], for example, has reported the measurements of traffic noise at several sites over a 24 hour period. The measurements were of (L_{A10}) and were taken in 1990-91.

These results showed that the average difference between the day and night noise levels was 10 dB(A) with the actual differences ranging from 4.2 dB(A) to 17.6 dB(A). Consequently, it would appear that for road traffic, measurements of daytime noise is, to some extent, automatically related to the levels of noise generated at night and it has been argued therefore that daytime measures of traffic noise will also be reasonably correlated with the degree of nuisance caused at night. Indeed, we need a night-time index or evening and night-time indexes to take into account of the differences between the night noise exposure.

This view is supported by the fact that the degree of correlation of noise with nuisance appears to be unaffected when the night time period is included in the noise measure examined. In addition, since the degree of nuisance is normally assessed over the total period of exposure, which includes the night time period, it is reasonable to assume that if a correlation has been established between overall nuisance and a daytime measure of noise then the night-time period can be safely excluded from the physical measure of noise adopted.

However, if situations arise where night-time traffic is unusually high, or if trends in traffic with time tend to reduce the day/night ratio of flows, then this assumption would not necessarily hold. The need for separate day and night time assessments of traffic noise is therefore a subject which needs to be re-assessed from as traffic flow patterns change.

3.3. Railways

For general railway noise the scale of L_{Aeq} is currently generally accepted as the best form of noise descriptor. The Mitchell Report [15] concluded that the scale L_{A10} that is used in the UK for road noise is not suitable for railway noise because on many railways noise from trains is not audible for as much as 10% of the time and under these conditions L_{A10} is measuring background noise rather than train noise. The evidence examined by the Mitchell Committee showed that L_{Aeq} is at least as good a predictor of railway noise annoyance as any available alternate measure and is widely accepted and used for rating many other kinds of environmental noise.

The Mitchell Committee reviewed the noise indices used by different countries for railway noise assessment. It was found that all countries use the L_{Aeq} measure but adopt different averaging times to cover different parts of the day including day, evening and night-time periods. In addition, some countries also stipulate noise limits in terms of a maximum noise level, L_{Amax} particularly for the night-time period for reasons concerned with sleep disturbance. The Mitchell Report states that noise from railways causes less disturbance to sleep than does noise from roads ; the noise differential in favour of rail for equal sleep disturbance is stated to be at least 5 dB(A). However, sleep disturbance by trains may be expected to become significant once the outdoor night-time (2200-0700 hours) L_{Aeq} exceeds 60 dB(A), but it could occur at lower values if there are more than 20 noise events per night for which the L_{Amax} of individual events exceeds 85 dB(A).

In comparing the noise standards that have been introduced for road traffic and railways, it is clear that most authorities favour specifying noise limits for railways for the whole of the 24 hour period whereas this is not necessarily the case for roads as described in the previous section. For railways, it is not possible to rely on the typical diurnal variation in traffic flow to allow the use of noise indices which cover only part of the day since the flow of railway traffic is entirely under the control of the operator. It has been argued therefore that in order to protect the night-time noise environment from railways it is necessary to specify a separate night-time noise limit. This approach has been accepted by the UK Minister of Transport in deciding on noise limits for new railway developments.

In the UK the Mitchell Committee was assigned the task of establishing noise limits for new railways which matched the limits already imposed for new roads in that the values recommended should give rise to similar degrees of disturbance for both transport modes.

The recommendations of the Committee were that those responsible for a new railway should have a duty to offer to insulate residential buildings against noise when the facade noise level from the railway was at least 66 dB $L_{Aeq,24hr}$ or at least 61 dB(A) $L_{Aeq,night}$. In this case night was defined as 2300 to 0700 hours.

The UK Transport Minister accepted the findings of the Mitchell Report but modified the noise levels and time periods to emphasise the separation of the two criteria for day and night time noise. The finally accepted noise criteria were 68 dB $L_{Aeq,18hr}$ for day and 63 dB(A) $L_{Aeq,6hr}$ for night-time. In this case the day time period was from 0600 - 2400 hours and the night-time period was from 2400 - 0600 hours.

Since the publication of the Mitchell Report, Noise Insulation Regulations for new railways have been drafted and a technical committee chaired by the Transport Research Laboratory in the UK has been set up to develop a method of calculating noise from new railways, including ways of improving the forecast of traffic on the line and of the likely day/night distribution of the traffic.

3.4. Aircraft

The ISO method is used for describing aircraft noise as heard on the ground [16]. The standard describes a method of measurement and data reduction. It deals with spectral analysis and temporal variation as well as the simpler weighted metrics. It does not deal with noise rating indices such as NNI or L_{DEN}. It is intended to cover all types of aircraft operation including in-flight and ground running although only where basic source data are to be acquired over an almost ideal hard surface with no intervening obstructions. Hence it is inappropriate for the measurement of ground noise from airports as received in the community.

Jonkhart [12] has compared the existing methodologies for the calculation of aircraft noise used in all member states of the European Union. In all member states calculation methods are used for the assessment of noise caused by aircraft but both the noise indices and calculation methods differ. Jonkhart summarises the noise exposure indices used in the member states of the EC and suggests that these can be divided into four categories based on the measure used to quantify the noise of a single aircraft passage:

- Indices based on the A weighted sound pressure level (SPL) and which do not take into account the duration of the noise events. Such an index is the Kosten index used in the Netherlands ;

- Indices based on SPL and which do take into account the duration of the noise events. Countries which use these indices include Belgium and Spain (day-night level), Denmark (day-evening-night level), Germany and Luxembourg (Stor index), and the UK (16hr L_{Aeq}) method. Belgium and Spain also make use of the indices of group 3.

- Indices based on the Perceived Noise Level which do not take into account duration of noise events. Countries which use such indices are France (Isopsophic index) and Ireland (NNI).

- Indices based on the tone corrected Perceived Noise Level and which do take into account the duration of noise events. These are used by Greece (Noise Exposure Forecast) and Italy (Weighted Equivalent Continuous Perceived Noise Level).

Military aircraft in low-altitude training flights pose different noise impacts to civil aircraft. The noise environment associated with such operations is characterised by infrequent, irregular, sudden, short and loud noise events. The American Air Force supported research to determine whether or not the current methods of annoyance assessment are applicable to noise from low level flight training operations [17]. Preliminary results suggested that in addition to the noise levels of the events, their high onset rate (rate of change of noise with time measured in dB/sec) played a role in determining human annoyance. To account for the estimated effect of onset rate an acoustic metric, L_{dmnr} (onset rate corrected, busiest month, day-night average sound level) was recommended to describe the average noise exposure from low altitude military training flight operations. L_{dmnr} adds onset rate adjustments to the individual aircraft overflight sound exposure levels that are used to compute the busiest month, day-night average sound level (L_{dnm}). Above about 20 dB/sec the onset rate adjustment to the sound exposure level was up to 11 dB. But these results have not yet been incorporated into policy. The current policy of the USAF involves a maximum "adjustment" of 6 dB.

In the U.K., since the 1960's the Civil Aviation authority (CAA) has maintained and developed a computer model to generate contours of aircraft air noise exposure. These are based on annually updated input information describing noise levels, height profiles, flight routings and traffic data . Up to 1989 NNI was used as the UK index of aircraft noise but in 1984 the UK Aircraft Noise Index Study (ANIS) was carried out by the CAA to investigate other measures[18]. It was concluded by ANIS that continued use of NNI might lead to inaccurate assessments because of its particular combination of noise and number terms, and its 80 PN dB cut-off. At first it was considered that $L_{Aeq,24hr}$ gave a good fit to aircraft noise annoyance responses but there was concern that this measure did not allow for night disturbance effects. The CAA had studied aircraft noise and sleep disturbance in 1980 and 1986 on the basis of which it was decided to distinguish between day (0700-2300) and night (2300-0700) in the application of noise indices.

Night contours using $L_{Aeq,8hr}$ have been adopted by the Department of Transport to evaluate the effectiveness of night operations at airports in the UK but are not in regular use in the U.K. The daytime $L_{Aeq,16hr}$ metric correlates as well with aircraft noise disturbance as does $L_{Aeq,24hr}$ and therefore $L_{Aeq,16hr}$ has been used as the daytime metric. L_{Aeq} is calculated for the busiest period i.e. the average summer day, by using input data appropriate to the period mid-June to mid-September. The $L_{Aeq,16hr}$ was introduced as the UK index of aircraft noise exposure in 1990. All major airports in the UK operate noise insulation schemes, most of which are based on the 66 dB $L_{Aeq,16hr}$ noise contour.

3.5. Industrial noise

N. Porter [19] has reviewed the national practices of various countries in the assessment of industrial noise. There was some commonalty in the various practices, for example the choice of L_{Aeq} as a suitable descriptor, but also large differences in some areas such as the rating of noise with specific characteristics. The L_{Aeq} is often calculated from representative sound pressure levels (L_p) of steady noise, short term L_{Aeq}, sound exposure levels (L_{AE}), sound power levels (L_p) etc. Background noise is described by various methods including an energy equivalent level and a statistical distribution of A-weighted sound pressure levels, e.g. L_{A95} and L_{A90}. The adjustment for tonal noise is commonly 2, 3, 5 or 6 dB. Impulsivity adjustments range from 0 to 6 dB.

The relevant standard in the UK for industrial noise is BS 4142:1990 "Method of rating industrial noise affecting mixed residential and industrial areas". This has been recently revised and work is in progress on a long term revision planned to be completed by 1996. Essentially this standard gives a method of determining a noise level (L_{Aeq}) from an industrial source together with a method of rating the noise in order to assess whether the noise is likely to give rise to complaints by residents living nearby. It is used mainly by Environmental Health Officers to deal with complaints from the public. The equivalent ISO standard is ISO 1996, Acoustics - Description and measurement of environmental noise. This standard also uses L_{Aeq} to describe the noise. The BS 4142 rating method applies a 5 dB adjustment to take into account noise that is judged to be tonal or impulsive in nature or irregular enough to attract attention. L_{A90} is used to describe background noise level.

3.6. Neighbourhood noise

In the UK, the Environmental Protection Act, 1990 sections 79-81, as amended by the Noise and Statutory Nuisance Act 1993, empowers local authorities to deal with general noise nuisance from fixed premises, factories, shops, discos and dwellings and also from vehicles, machinery and equipment in the street. However, there are no objective noise measurements required or noise standards applied to these situations except in the case of factories where the relevant standard is BS 4142 as described above. Measurements of general environmental noise in residential areas are made by local authorities and research organisations for purposes other than enforcement. These would probably use L_{Aeq} or some derivatives as to add the number of events or the emergence level of the disturbing noise above the background level. The disturbing noise has to be considered inside the flats and the notion of emergence is applied. The concept of emergence is already applied in Belgium, France and Great-Britain at least.

3.7. Construction site noise

The use of L_{Aeq} is generally recommended and where the noise is from isolated events a short period, e.g. 5 minute, L_{Aeq} is suggested. Where mobile plant is using a regular route at a known rate per hour the L_{Aeq} can be predicted. L_{Aeq} is calculated from the sound power level, L_{WA} of the individual items of plant and the way in which they are operated. Overall site noise is computed from the combination of activities of plant of both a static and mobile nature. Hours of work are an important consideration where residents are concerned. Periods when people are getting to sleep and just before they wake are particularly sensitive times. Site noise expressed as L_{Aeq} over 1 hour at the facade of noise-sensitive premises may need to be as low as 40 dB(A) to 45 dB(A) to avoid sleep disturbance.

4. PROPOSAL FOR THE CHOICE OF NOISE INDICES

4.1. Conclusion on the effects of noise

Noise does not induce illness in the short term. However, scientific experimentation has shown that noise is a major source of disturbance and discontent. Noise is clearly identified as being responsible for physical and psychological disorders throughout the whole of the population and psychosomatic disorders in the most sensitive groups. For some groups, noise accumulates with cultural or personal variables and causes psychiatric disorders.

In Public Health terms the chronic aspect of some physiological responses to noise is a factor in the appearance of pathological disorders in the long term such as modifications to pulse rate and sleep disturbance. It is preferable to act before these pathological symptoms appear because, generally speaking, protective measures taken by Public Health authorities are always introduced sometime after absolute proof has been demonstrated.

It is also the mission of research to track changes in the responses of the population to traffic noise, which has changed over the last 15 years and to examine psychological disturbance and psychosomatic disorders.

Physiological and individual human responses to noise occur simultaneously with changes in social behaviour. Recently incidents and accidents involving violence have increased, particularly in situations in which those involved have the feeling that noise is not inevitable. In more considered approaches, people living close to identifiable noise sources form associations and via special tribunals sue for damages for restrictions to their liberty to use their property and impact on their home life.

4.2. Criteria for a good noise index

Noise indices selected to characterise the exposure of populations to noise must fulfil several conditions. The three major criteria are the following :

- *Correct evaluation of the effects of noise on health* for the degree of severity of these effects on one person or the frequency at which they are observed in the population as a whole. Noise indices showing a good statistical correlation with various effects of noise on health are preferable, even if these later show a high level of interpersonal variability. It is commonly observed that a certain percentage of people state that they are disturbed by low levels of noise. Conversely, some people show unexpected resistance to the deleterious effects of noise at very high levels. The effects of a given noise level on the population and on health can be obtained from this statistical relationship which permits satisfactory forecasting. This enables noise thresholds which protect the health of the majority of the population to be proposed.

- The second criteria concerns *the case of noise measurement and forecasting* in situations in which the noise source does not yet exist. It makes no sense to suggest an index that is difficult to measure or to forecast because we would no longer be able to manipulate simple yet sometimes sensitive parameters to describe situational changes. The use of the decibel logarithmic scale is already sufficiently complicated ! It is always possible to measure noise levels and then calculate complex indices such as those used around airports which combine the average peak level and a logarithm of the number of landing and take-off events but a correction factor is necessary to obtain a condensed, usable and representative scale such as the NNI index which varies between 30 and 80 for most existing situations.

- This leads us to the 3rd criterion which concerns *simple explanations to local inhabitants*, environmental protection associations and elected representatives. Basically, noise problems affect people living close to noisy sites and it is essential that the way in which noise is measured should not be the first cause of misunderstanding and mistrust when they discuss their problems with local authorities and the operators of the noise-generating sites. Good indicators must enable physical measurement using simple methods which associations can afford and which elected representatives - the pivot between local populations and technicians - understand.

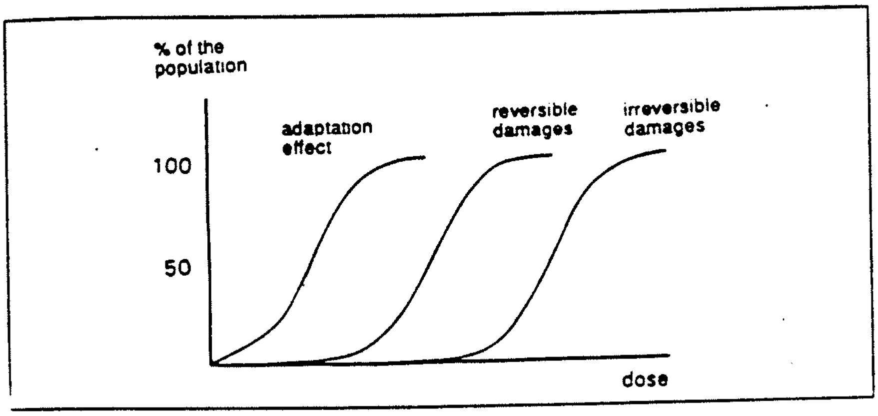
The other criteria concern the accuracy for describing the various noises and the coherence with the regulatory action. The selected index should have to be already used in other countries, for other sources of noise and/or in some EC member states as a standard.

4.3. Proposals

a. Use of Leq as a descriptor for baseline noise levels

The relationship between noise levels and individual or global responses is relatively complex to define because of the difference between the quantity of noise in the environment and the wide range of responses observed [20-21]. This is due to the body's defence mechanisms and ability to adapt. The figure 2 below shows the general relationship between noise levels and effects on a population [22]. For environmental noise, irreversible damage is rare ; irreversible damage is usually due to working conditions or the effect of loud accidental noise on hearing.

Figure 2. **Relationship between noise exposure and effects in a population**



In order to examine thresholds which should not be exceeded, we firstly have to define the noise levels that should be selected in the "Decibel family" and what effect on health we are going to consider. This is a major discussion point and articles in scientific publications contain arguments to support a wide range of propositions. Debates are centred on :

- the choice between a global energy indicator such as the Leq and an index which considers peak levels and number of events ;
- the choice between frequency weighting A, which corresponds to ear sensitivity and which reduces values for frequencies until 500 Hz and a weighting which considers the nature of the noise, for example, weighting C for low frequencies ;
- the consideration, or not, of pulsed noises together with main variations in comparison with an extremely stable noise such as that emitted by air conditioning systems in buildings ;

- the consideration of the different sensitivity of all possible human activities throughout the day, for example night-time sleep, without forgetting that there are probably 10 million people in Europe who work at night and sleep during the daytime ;
- the introduction into the environment of a new noise source such as a motorway. Regulations should take account of the initial noise level ;
- most regulations recommend measuring external noise sources outside homes and totally ignore the insulation provided by windows and lifestyles. We suppose that people have their windows open more often in Seville than in Aberdeen and a regulation considering external noise levels would introduce a much higher distortion than that due to a simplification of the choice of a noise measurement system.

The Leq can lead to a penalty for excessive noise at night as in the USA : the mean day/night (Ldn) level includes a 10 dB penalty for night-time noise levels between 10.00 p.m. and 7.00 a.m. Indices similar to the Ldn weight the evening at 5 dB and the night 10 dB in California, Holland and Germany.

This way of characterising noise does not consider disturbances caused by isolated noises and in this case the sound exposure level (SEL) is sometimes used. This is the mean energy of the duration of the event, calculated for 1 second. It concerns two major noise sources, aircraft and trains. However since 1991 in Great-Britain the regulations covering aircraft noise have selected the Leq index integrating levels and the number of events instead of the NNI. In France, Leq is used for railway noises.

Our proposal is thus to use in general the L_{Aeq} to describe noise and to use additional descriptors in some specific situations depending on sources and the nature of the noise.

Some Leq weighting factors are relatively easy to suggest because scientific results are consistent, others are subject to discussion.

b. Noise impulsiveness

The first ISO 1996 standard proposed a penalty of 5 dB for noise pulsations but this was not included for this standard in 1987. The Community has given a definition for the impulsiveness of a noise (Official Journal of the ECE in 1979).

The 4th environmental research programme (1986-1990) included work on this theme, with in-laboratory experiments, field observations, noise measurements and surveys [23]. The results supplied demonstrate the interest of a weighting for impulsiveness, physical quantification methods and the part played by noise pulsations in disturbance responses. Some noises are considered to be impulse noises (telephone, horn, typewriter, fire siren) and some are judged not to be impulsive (car door slamming, fire arms and tennis balls).

The proposal stemming from this programme is that the penalty scale should vary with the overall noise level, going from 0 dB for an Leq of 80 dBA to 10 dB for an Leq of 50 dB. Our proposal suggests a penalty of 5 dBA for a Leq $\leq$ 60 dB and 3 dBA up to 70 dB. Over 70 dB, a weighting doesnot seem to be necessary.

c. The noise spectrum and the presence of pure tones

Noise frequency weightings based on curve A are close to the sensitivity of the young adult ear. A weighting scale which emphasises deep sounds is useful when the source noise is modified before reaching the ears of the listener (via insulating windows, noise barriers, the distance between the source and the ear etc.) and also in older people whose useful listening frequencies have been off-set towards the bass.

It is essential to consider bass sounds in the 32-250 Hz for traffic noise measured inside buildings and for noises generated by domestic equipment which produced soft hums. Retrofitting older aircraft only transfers energy downwards to the lowest frequencies. This set of observations means that in cities, for example, there is a sort of acoustic low-frequency fog. An effort should be made to understand this problem better and to integrate existing knowledge into the standards [24].

An initial proposal consists in a penalty when the sound spectrum contains a high proportion of low-frequency sounds measured by the difference between dBA and dBC levels. When the difference between dBC - dBA is ≥ 10 dB, a penalty of 5 dB(A) for a Leq < 60 dB (A) and a penalty of 3 dB(A) for a Leq ≥ 60 dB(A) are introduced.

In the same way, if a level peak is present in a pure tone, in low frequency, this contribute to identify the source of noise (electric transformer, fans etc.) and to increase annoyance. Penalties are suggested for the same levels : 5 dB(A) is added to the Leq ≤ 60 dB(A) levels and 3 dB(A) to the Leq dB(A) levels > 60 dB(A). An other type of penalty could be suggested with reference to the ISO 1996 method and similar methods existing in Belgium, French and German standards.

d. Consideration of the initial situation

This is essential in the case of quiet areas in which a new noise-generating infrastructure is going to completely change the noise environment or to a lesser degree when protective actions are taken to reduce the impact of an existing sound source. It is quite easy to understand that acceptance of noise level created by a new motorway in the suburbs of a large city where there is already a background noise will be much easier to attain than in a rural area in which the ambient noise is 40 dB LAeq, for example.

In this latter case, it could be meaningful to set a threshold limited to an increase of 12 dB(A) Leq between the quiet situation and the noisy situation after the motorway opens. To put it another way, a limitation to 60 dB(A) Leq would be extremely acceptable in an area with a initial noise level of 55 dB(A) and not acceptable in an area with a background noise level of 40 dB(A). Few people have published results of research into this phenomenon and we have used Australian regulations as our source material [25]. In the USA some specialists are suggesting a penalty of 5 dB(A) [8].

e. The inclusion of noisy events and their peak level

The problem arises when there are very few events and when it is not relevant an equivalent noise index because the characteristics of the situation are based on infrequent peak noise levels.

When the number of noise events increases, inclusion of the energy for each event leads to a calculation which is similar to the Leq. For road traffic and even for noises around large airports it is possible to assess peak levels from vehicle speeds and the distance from the road to the dwelling.

Following the W.H.O. draft report on Community Noise (1993) : " A large number of field surveys have examined the impact of the number of noise events on annoyance. The survey data do not provide sufficiently accurate results to conclusively prove that Leq is preferable to other competing noise metrics. In an analysis of the data from eight surveys , it was found that the best estimates of the relative effect of noise level and number of events do not reject the trade-off implied by Leq, but are also consistent with a weaker effect for the number of noise events. Further studies are not likely to yield improved estimates unless there are important developments in the annoyance study methodology. Normally, the noise events are added to the prevalence of annoyance according to the principle of equal energy. The influence of the number of noise events (n) on percentage of annoyed subjects (% s) can be expressed by the formula : % s = dB(A) + *k* log (n). When the noise events are added according to the principle of equal energy, the value of k is 10. There are often large variations. Fields has found that the value of k can vary within the interval -3.7 to +23.8 depending on the type of noise event index being used. The concept of evaluating the noise level from the noisiest event and the number of events separately is particularly crucial at airports ".

For annoyance, laboratory research work carried out in Sweden and some European research demonstrates the impact of the number of events on the disturbance induced by an identical Leq level. When the global level is under 60 dB(A) in Leq, the number of events, if low, i.e. between 3 and 10 noise events per hour, decreases disturbance in comparison with 20 or 30 events occurring during the same period. Conversely, during sleep, it has been observed that closely-spaced noise had less impact on the quality of sleep than noises occurring infrequently. The greatest probability for awakening appears when noises are 40 minutes apart.

Quite obviously, these observations are extremely useful for the evaluation of isolated train noises during the night or for infrequent night-time flights. However, in this field there is little reliable data from laboratories or from the field and we cannot suggest a weighting for those situations in which Leq levels are under 60 dB(A) which is quite often the case during the evening and at night. It can be suggested that peak levels of noise events shouldn't exceed of 10 dB(A) the LAeq threshold level.

f. Conclusion

Table 1 summarises the main proposals concerning the units and indices to be applied.

These proposals are not a synthesis of the existing or coming standards, which are often on revision by working groups. There is an evidence for the main ISO 1996 standard : in the first version, there is a penalty for impulsive noise, no weighting in the second version, and now the discussion is going on a new introduction of this penalty. This is a proof of the difficulty to assess noise effects on people. This also demonstrates the interest for some principles for several weighting factors to be added to Leq. In some situations, with special noises or with a mixture of different noises, it would be not very easy to combine the proposed weighting factors. A technical discussion is needed to adopt the physical factors to be taken into account and to weight them, alone and combined.

If this table has to be the basis of a harmonised measuring method, it has to be reconsidered by a technical work group.

Table 1. **Units and indices for noise exposure**

Sources and types of noise	**Units and indices**	
1/ Basic index : - road traffic - main airport and railways - industry	LAeq ISO 1996, preferably defined with a 1 sec. integrating duration. Periods : 2 or 3 (day - night - evening) covering continuously 24 hours. For example : 6am-10pm, 10pm-6am (2 periods) or 6am-6pm, 6pm-10pm, 10pm-6am (3 periods).	
2/ Change in the noise exposure, new source of noise.	Conditions of appliance	If final Leq < noise exposure limit adopted for planning purpose
	Second criteria	Final Leq - Initial Leq ≤ 12 dB(A)
3/ Impulsive noises : mainly construction noise.	Conditions of appliance	Ref. JO EEC 1979 or revised version of ISO 1996
	Penalty	+ 5 dB if LAeq < 60 dB + 3 dB if LAeq ≥ 60 to 70 dB
4/ Spectral components : mainly industrial noise	Conditions of appliance	° If Leq (dBC) - Leq (dBA) > 10 dB ; and/or ° If existing pure tone component (applying ISO 1996 method)
	Penalty	+ 5 dB if LAeq < 60 dB + 3 dB if LAeq ≥ 60 to 70 dB
5/ Single events : light railways and air traffic	Conditions of appliance	° Definition : Sound exposure level Leq 1 sec. (ISO 3891) ° If number of single events per hour < 10
	Penalty	+ 5 dB if LAeq < 60 dB + 3 dB if LAeq > 60 - 70 dB

ANNEX 1 : NOISE UNITS

1. INTRODUCTION

This annex is concerned with the physical measures that are conventionally used to describe noise from different sources.

Sounds are caused by tiny fluctuations in air pressure which propagate through the atmosphere at a speed which is dependent on the local air temperature and atmospheric pressure. The human hearing system cancels out the slowly varying changes that occur in the atmospheric pressure and only responds to the rapid pressure fluctuations which are the characteristic of sound waves.

The range of audible sound pressure fluctuations is very large. The lowest pressure changes that can be detected by the human hearing system occur at about 2×10^{-5} Pascals (Pa). The loudest sounds, i.e. sounds which are painful to the hearer, occur at about 20 Pa.

Although pressure is measured in Pascals it is customary to specify sound level in decibels. This is a logarithmic scale which is well suited to human hearing which is also logarithmic rather than linear in its behaviour. In order to provide a convenient scale the actual rms acoustic pressure is divided by a reference pressure which is normally taken as the threshold of hearing, i.e. 2×10^{-5} Pa, before the logarithm is taken. Consequently taking the audible pressure range given above, to represent the range of sounds normally encountered it can be seen that in terms of decibels the range is from 0 decibels, which is equivalent to 2×10^{-5} Pascals, to 120 decibels, which is equivalent to 20 Pascals.

2. LEVELS, SCALES AND RATINGS

The terms 'level', 'scale', 'index' and 'rating' occur in the literature often without distinction and it is important to adopt a consistent definition. The convention used most generally is described next.

'level' is the instantaneous auditory magnitude of the sound, e.g. the A-weighted sound level L_A. The word 'level' is always included when the decibel scale is used.

'noise scale' refers to a combination of the physical variables which contribute to peoples' overall response to noise, such as sound pressure, time etc, e.g. the noise level exceeded for 10% of the time, L_{A10} dB.

'noise index' or 'noise rating' refers to the numerical description of noise in which other factors are superimposed on the scale numbers describing the physical properties of the noise. These may include corrections for type of neighbourhood, number of noisy events, corrections for time of day or season etc. For example, the noise and number index NNI.

The symbol commonly used to denote 'level' and 'scale' is '*L*' with an appropriate suffix when used in mathematical equations and as an acronym in text. For example, the Perceived Noise Level is written in text as PNL whilst the form L_{PN} is used in mathematical expressions. There are exceptions to the convention where some noise scales are regarded as having a generally accepted form in the literature. For example, the equivalent continuous noise level appears as L_{eq} whether used in text or as part of a mathematical expression.

In addition when sound levels have been weighted (see § III) it is usual to include the weighting scale adopted in the suffix. For example 'A' weighted values of the equivalent continuous noise level would be written as L_{Aeq}.

3. WEIGHTING SCALES

Human hearing is not equally sensitive to all frequencies of sound and for this reason the instrumentation used to measure environmental noise are equipped with electrical filters which 'weight' their response to make them behave in a manner similar to the human ear. A complication is that human hearing sensitivity also varies with the loudness of a sound. The variation in hearing sensitivity is less for louder sounds than for quieter sounds. To account for these differences several weighting curves have been devised which attempt to account for human hearing sensitivity changes over the range of different types of sound commonly experienced. The most frequently used in environmental noise analysis are :

3.1. 'A' weighted sound pressure level, L_A

The characteristic of 'A' weighting is that it corresponds to the reduced sensitivity of the human ear to frequencies above 8 kHz and, more markedly, below around 200Hz at a relatively low loudness level of 30 phon, i.e. where the standard equal loudness contour passes through 1000 Hz at 30 dB. The 'A' weighting has proved to be the most useful of all the weighting curves that have been developed for environmental noise assessment. A measurement made using 'A' weighting is expressed as a noise level in dB(A).

3.2. 'B' weighted sound pressure level, L_B

The 'B' weighting is similar in concept to the 'A' weighting in that it corresponds to the behaviour of the human ear but at a higher loudness level, i.e. corresponding roughly with the 70 phon equal loudness contour. In practice it is seldom used since it offers no positive advantage over the 'A' weighting in terms of the correlation with subjective response to noise. The sound levels obtained with 'B' weighting are quoted as dB(B).

3.3. 'C' weighted sound pressure level, L_C

The 'C' weighting corresponds approximately with the 100 phon equal loudness contour and differs little from a flat frequency response being just a few dB down at either end of the audible range. It may be preferred where the frequency content of the measured noise contains a significant proportion of low frequency sounds, e.g.. noise from heavy lorry exhausts. However research has failed to establish convincing reasons for its general use over 'A' weighting and it is not often used. The use of 'C' weighting is justified as an alternative to unweighted overall sound pressure level as it is defined at the extremes of frequency whereas the latter is undefined and is dependent on the performance of the microphone and associated electronics. The sound levels obtained with 'C' weighting are quoted as dB(C).

3.4. 'D' weighted sound pressure level, L_D

The 'D' weighting was introduced solely for the purpose of measuring aircraft noise and it attributes far more significance to frequencies in the range 1 kHz - 10 kHz than the other weighting curves described above. This is consistent with the equal noisiness contours for aircraft noise which were developed to take into account the high-pitched whine associated with some types of commercial jet engines. 'D' weighted sound levels are quoted as dB(D).

4. INDICES AND RATINGS

4.1. Perceived noise level, PNL (L_{pn})

The concept of perceived noise level was developed in the 1960's specifically to account for the noisiness or annoyance of jet aircraft. This index is based on the equal noisiness contours for aircraft mentioned above. This index is determined in practice by measuring the noise from an overflying aircraft at a ground based receiver. During the fly-over the noise is monitored and the full 1/3 octave band spectrum is determined at intervals of 0.5 s. For each time interval, each frequency band is converted to an annoyance value (known as a noy value) using the data contained in the noise contours. The set of noy values is then summed according to the following formula :

$$N = N_{max} + 0{,}15\left[\sum_{i=1}^{n} N_i - N_{max}\right]$$

where N_i is the noy value in band i and N_{max} is the maximum noy value of any band. The total noy value, N, is changed back to PNL through the relationship :

$$L_{PN} = 40 + 33.3 \log_{10} N \; PNdB$$

A further refinement requires the correction of each value of *PNL* for the presence of tones in the frequency spectrum. This involves analysing the 1/3 octave band spectrum to identify any relatively large peaks and making a correction according to the rules laid down in the standard. The result is known as the tone corrected perceived noise level and is written as *PNLT*.

An alternative and simpler method of determining the PNL is to use either the 'A' or 'D' weighting described above. These give direct readings of level as a function of time and so avoid the computations involved using the above equations. However, there are numerical differences between the 'A' and 'D' weighted levels and the corresponding perceived noise level. The following empirical relationship have been developed to correct the measured L_A and L_D values :

$$L_{PN} = L_A + 13 \text{ PNdB and } L_{PN} = L_D + 7 \text{ PNdB}$$

This method is not suited to calculating the tone corrected perceived noise level, *PNLT*.

4.2. Statistical level, L_N

Any time-varying noise such as road traffic noise can be described in terms of its cumulative sound level distribution. This form of analysis of a time varying sound level has been used to establish different physical descriptors of the sound. For example, for road traffic noise some authorities have adopted the use of L_{A10}, L_{A50} and L_{A90} which are the sound levels in dB(A) exceeded for 10%, 50% and 90% of the measurement period respectively.

For measurements taken near to a busy road the L_{A10} will give an indication of maximum noise levels that occur during the measurement period. However, for situations where the traffic flow is low and there are only intermittent peaks then the L_{A10} level can be substantially less than the peak noise level. In the absence of nearby noise sources L_{A90} will tend to correspond to the background or ambient noise level (i.e. the noise level remaining when the noise from the source being assessed is absent). When used for assessing traffic noise L_{A10} is usually sampled for a period of 5 - 15 minutes in every hour during an agreed measurement period, usually 18 hour (06.00 - 24.00 hrs). In the UK, the Department of Transport has recommended that the minimum hourly sampling time should be :

$$t_{min} = \left(\frac{4000}{q} + \frac{120}{s} \right) \text{min}$$

where q is the vehicle flow rate in vehicles/hour and s is the sampling rate in samples/min. There is a proviso that t_{min} should not be less than 5 or greater than 55 minutes.

4.3. *Equivalent continuous sound level, L_{eq}*

The equivalent continuous sound level is defined as the level of that (hypothetical) steady sound that, over the period of measurement, would deliver the same sound energy as the actual intermittent or time varying sound. The level is invariably 'A' weighted before the averaging process. The general form of the equation for L_{Aeq} is given by :

$$L_{Aeq} = 10 \log_{10} \left[\frac{1}{T} \int_0^T 10^{\frac{L_A}{10}} dt \right] \text{dB(A)}$$

L_{Aeq} is defined over a fixed time period, e.g. 1, 8, 18 or 24 hours and it is important when quoting values that the time period is clearly stipulated. The time period is usually written in the suffix. For example, if the time period was 18 hours, the equivalent continuous sound level would be written as $L_{Aeq,18hr}$.

It is frequently criticised because it de-emphasises occasional noisy events. The energy in a short burst of high-level noise is 'spread' into the quieter parts by the time averaging process. It has also proved to be difficult to measure particularly where the noise source is at a relatively low level and the ambient or background noise is characterised by intermittent high noise levels. Under these circumstances and without strict controls on the noise being measured the L_{Aeq} will tend to overestimate the noise from the source being investigated. Such difficulties occur, for example, when trying to measure the noise from a distant road in an otherwise quiet countryside setting. In such situations the relatively constant level of noise from the distant roadway may well be contaminated by the occasional high levels of noise generated by, for example, an overflying aircraft or a road vehicle running on a local road. Such difficulties would not necessarily occur when using a measure such as L_{A10} since this type of measure is not sensitive to the occasional noisy event provided, of course, that such events do not occur for more than 10% of the measurement time period.

It follows, however, that when assessing a noise source which has an intermittent character such as a railway, or an airport where the noise is characterised by relatively infrequent high levels of noise followed by long periods of quiet, the L_{A10} measure would not be appropriate since it is likely that the railway or airport noise would not occur for 10 % or more of the time. Under these circumstances it is likely that the L_{A10} measure would tend to under-estimate the noise whereas L_{Aeq} would be a much better form of physical descriptor because it takes into account the peak noise levels that are generated.

Despite the above reservations regarding the use of L_{Aeq} for road traffic noise it has become the most widely used form of descriptor for all types of environmental noise including road traffic. The L_{A10} measure, however, continues to be used by some countries for traffic noise assessment including the UK, Australia, New Zealand, Hong Kong and South Africa.

For freely flowing road traffic, an empirical relationship has been established to allow conversion between L_{A10} and L_{Aeq}. The following general relationship applies for moderate and high road traffic flows :

$$L_{10} = L_{eq} + 3 \text{ dB(A)}$$

However, this equation cannot be regarded as rigorous and cannot be applied to all situations and traffic flows, particularly low traffic flows.

4.4. Single event noise exposure level, L_{AX}

The single event noise exposure level is defined as the continuous noise level which, when maintained constant for 1s, contains the same quantity of sound energy as the actual time varying level of one noise event. L_{AX} values for contributing noise sources can be considered as individual building blocks being used in the construction of a calculated value of L_{Aeq} for the total noise. Like L_{Aeq} the level is 'A' weighted prior to integration and is normally written as :

$$L_{AX} = 10 \log_{10} \left[\int_{-\infty}^{+\infty} 10^{\frac{L_A}{10}} dt \right] \text{ dB(A)}$$

In practice integration is limited to the time during which the actual noise level is within 10 dB(A) of the maximum, i.e. :

$$L_{AX} = 10 \log_{10} \left[\int_{t_1}^{t_2} 10^{\frac{L_A}{10}} dt \right] \text{ dB(A)}$$

where t_1 and t_2 denote the beginning and end, respectively, of the single event.

Since most noise events, other than impulses, last for more than 1s, the value of L_{AX} is usually higher than the maximum value of L_A during the event. Consequently the direct quotation of an L_{AX} value is intrinsically misleading unless it is supported by further information or explanation. Its real use is as an aid to calculating L_{eq} over a given time period because L_{AX} defines the energy contribution of the single event. As mentioned above, the value of L_{eq} over the period T from a number of single events is given by the formula :

$$L_{eq} = 10 \log_{10} \left[\frac{1}{T} \sum_{i=1}^{n} 10^{\frac{L_{AXi}}{10}} \right] \text{dB(A)}$$

4.5. Disturbance index, Q

The disturbance index originated in Germany and is another variation on L_{eq}. The general formula is given by :

$$Q = 13.3 \log_{10}\left[\frac{1}{T}\int_0^1 10^{\frac{L}{13.3}}\,dt\right] \text{dB}$$

By choosing 13.3 as the factor outside the logarithm, less significance is attached to high-level short-duration noises than in the formula for L_{eq} which uses the factor 10. This means that the trade-off between level and time is 4 dB per doubling of time in Q compared with 3 dB per doubling in L_{eq}. In Germany the disturbance index was originally derived for assessing aircraft noise. The level used in the formula is the perceived noise level, *PNL* , and the time period is over the six busiest months. Additionally a night-time penalty of 5PN dB is added during the period 2200-0600 hours.

In Austria the index has been used for traffic noise situations. Then the level is the 'A' weighted level, L_A, and the time is appropriate to the situation. Some care must be exercised when applying the index because the value will be of the order of 13 dB less with L_A than with *PNL.*

In general, this particular index has not been used widely and its use appears to be limited currently to research applications.

4.6. Effective perceived noise level, EPNL

The effective perceived noise level, EPNL is also an index which appears to have been replaced recently by the L_{Aeq} measure. It was originally intended for use in assessing the noise from aircraft. It is calculated by integrating the energy over the time period during which the tone corrected perceived noise level is within 10 PN dB of the maximum value. The result is normalised with respect to a reference time of 10s. The EPNL is defined as :

$$L_{EPN} = 10 \log_{10}\left[\frac{1}{10}\int_{t_1}^{t_2} 10^{\frac{L_{PNT}}{10}}\text{dt}\right] \text{PN dB}$$

where L_{PNT} is the tone corrected perceived noise level. In practice, the integration would be carried out as a summation, and if the values of PNLT are available at 0.5 s intervals, the equation becomes :

$$L_{EPN} = 10 \log_{10}\left[\frac{0.5}{10}\sum_{i=1}^{n} 10^{\frac{L_{PNLT}}{10}}\right] = 10 \log_{10}\left[\sum_{i=1}^{n} 10^{\frac{L_{PNLT}}{10}}\right] - 13 \text{ PN dB}$$

The idea of normalising to 10 s is to penalise aircraft that generate high noise levels over a relatively long period. The period of 10s was chosen to be representative of a typical fly past. (NB. PNL_{max} and PN_{max} may also be written as *PNLM* and *PNM* in the text).

4.7. Day/Night equivalent sound level, DNL

This is a noise rating based on the equivalent continuous sound level which originated in the USA (Office of noise abatement and control, Washington, DC, 1974). The noise energy is averaged over 24 hours but the noise level during the night-time period, 2200 to 0700 hours, is penalised by the addition of 10 dB(A), i.e.:

$$L_{DN} = 10 \log_{10}\left[\frac{1}{24}\int_{7}^{22} 10^{\frac{L_A}{10}} dt + \int_{22}^{7} 10^{\frac{L_A+10}{10}}\right] dB(A)$$

DNL has found widespread acceptance in the USA for community noise assessment including the impact of aircraft and traffic noise. It can be criticised for not making any allowance for either tonal or impulsive content of noises but the same is true also of the majority of scales and ratings reviewed above.

4.8. Community noise equivalent level, CNEL

This index is similar to the day/night level described in the previous paragraph. Again the index was first suggested for use for community noise assessment in the USA (California Department of Aeronautics, 1970) and subsequently adopted by Denmark. It was intended for use in assessing aircraft noise, but, like DNL, makes use of the 'A' weighted sound level uncorrected for tonal content. It differs from DNL in that it also includes an evening period, from 1900 to 2200 hours, in which all noise levels are penalised by the addition of 5 dB(A) to the measured levels, i.e.:

$$L_{CNE} = 10 \log_{10}\left[\frac{1}{24}\left\{\int_{7}^{19} 10^{\frac{L_A}{10}} dt + \int_{19}^{22} 10^{\frac{L_A+5}{10}} dt + \int_{22}^{7} 10^{\frac{L_A+10}{10}} dt\right\}\right] dB(A)$$

The numerical difference between *DNL* and *CNEL* is usually very small. (NB. also referred to as the day, evening, night level *DENL* and symbolised as L_{DEN}.).

4.9. Total noise load, B (Kosten unit)

This rating was developed in the Netherlands for assessing aircraft noise. The formula is written as a summation rather than an integral because the maximum 'A' weighted level, L_{Amax}, of each event is used, no account being taken of its duration. The formula is :

$$B = 20 \log_{10}\left[\sum_{i=1}^{n} w_i \, 10^{\frac{L_{Amaxi}}{15}}\right] - C \, dB(A)$$

where the constant C is 157 for a time period of one year or 106 for one day, L_{maxi} is the maximum 'A' weighted level of event *i*, *n* is the number of events and w_i is a weighting factor depending on the time of day (eg. the weighting factor is 10 when the averaging period is from 2300 to 0600 hours, 8 from 0600 to 0700 hours, 4 from 0700 to 0800 hours, 1 from 0800 to 1800 hours, 2 from 1800 to 1900 hours, 3 from 1900 to 2000 hours, 4 from 2000 to 2100 hours, 6 from 2100 to 2200 hours, and 8 from 2200 to 2300 hours).

4.10. *Noise exposure forecast, NEF*

The noise exposure forecast was developed in the USA for assessing the effect of noise from civil aircraft. It is based on the effective perceived noise level, *EPNL* and the number of events. For one particular class of aircraft *i* on flight path *j* producing $EPNL_{ij}$, the contribution to the *NEF* is :

$$NEF_{ij} = L_{EPN_i} + 10\log_{10}\left[n_{Dij} + 16.67 n_{Nij}\right] - 88$$

where n_{Dij} is the number of daytime flights (0700 - 2200 hours) and n_{Nij} is the number of night-time flights (2200 - 0700 hours). The total *NEF* is then given by :

$$NEF = 10\log_{10}\left[\sum_i \sum_j 10^{\frac{NEF_{ij}}{10}}\right] \text{PN dB}$$

The weighting against night flights as compared with day flights is 16.67, which is quite a severe penalty. The constant 88 is arbitrary and serves to confine *NEF* values to a range similar to other ratings.

4.11. *Weighted equivalent continuous perceived noise level, WECPNL(2)*

This may be regarded as an international hybrid of the *EPNL* which is tone and duration corrected, and a day/night energy average together with a seasonal correction based on temperature.

The equivalent continuous perceived noise level, *ECPNL*, is calculated for each separate time period, i.e.:

$$L_{ECPN} = 10\log_{10}\left[\frac{10}{T}\sum_{i=1}^{n} 10^{\frac{L_{EPN_i}}{10}}\right] \text{PN dB}$$

where *n* represents the number of aircraft movements in time T and the coefficient (10) adjusts to the actual time from each 10s EPNL. The weighted *ECPNL* is then obtained from the appropriate day and night values of *ECPNL* according to the expression :

$$L_{WECPN} = 10\log_{10}\left[\frac{15}{24}10^{\frac{L_{ECPND}}{10}} + \frac{9}{24}10^{\frac{L_{ECPNN}+10}{10}}\right] + S \text{ PN dB}$$

where L_{ECPND} is the daytime value from 0700 to 2200 hours and L_{ECPNN} is the night-time value from 2200 to 0700 hours. S depends on the outdoor temperature (-5 when < 100 hours per month above 20 degrees C, 5 when >100 hours per month above 25.6 degrees C, 0 otherwise). The seasonal correction reflects the likelihood of windows being open.

In Italy the 24 hours are divided into three periods (day, evening and night)(*WECPNL*(3)) . Day is 0700 to 1900 hours, evening is 1900 to 2200 hours and night is 2200 to 0700 hours.

4.12. Noise and number index, NNI

The noise and number index, for aircraft noise, is of British origin and is relatively unsophisticated. It combines the maximum perceived noise level of each aircraft, not corrected for tone or duration, with the number of aircraft movements according to the formula :

$$NNI = 10\log_{10}\left[\frac{1}{n}\sum_{i=1}^{n} 10^{\frac{L_{PN(maxi)}}{10}}\right] + 15\log_{10} n - 80 \text{ PN dB}$$

An event is only included if it creates a maximum level of 80 PN dB or more and the period to be taken is from 0600 to 1800 hours GMT. In principle the *NNI* could also be evaluated for the night-time period and a more stringent criterion set. The constant is subtracted because when the index was established at Heathrow, measurement of aircraft peak noise levels of less than 80 PNdB proved difficult because the background noise was of a similar level during the passage of an aircraft.

In the UK, in 1990 the NNI measure for aircraft noise was replaced by an equivalent continuous noise level measure, $L_{Aeq,16hr}$.

4.13. Isopsophic index, I

This is an index developed originally in France which is similar in concept to the *NNI*. It began as two separate expressions, one for day and the other for night, but has now evolved into a single expression for the 24 hours with night-time events weighted by 10 dB. It is used specifically for assessing aircraft noise. The index is defined as :

$$I = 10\log_{10}\left[\sum_{i=1}^{n_D} 10^{\frac{L_{PN(maxi)}}{10}} + \sum_{j=1}^{n_N} 10^{\frac{L_{PN(maxi)}+10}{10}}\right] - 32 \text{ PN dB}$$

where n_D is the number of daytime events (0600 - 2200 hours) and n_N is the number of night-time events (2200 - 0600 hours).

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PART 2 : NOISE QUALITY CRITERIA
Current regulatory policies

One of the main objectives of noise abatement legislation is to define and ensure application and respect of noise exposure limits. Most European countries have prepared a legal framework for noise limits either by national laws, ordinances or municipal by-laws [1-2-3]. Other countries only have recommendations or guidelines.

A large number of European countries have adopted the L_{Aeq} index for the main sources of noise (road-rail-industry). The exception is aircraft noise for which regulatory practice is highly disparate. These differences in the indices adopted, the periods and areas to which regulations apply, definitions of measurement conditions and the ways in which noise levels are calculated make it difficult to compare current European standards.

1. EEC MEMBER STATES

1.1. BELGIUM

Environmental protection in Belgium is a matter treated by regional authorities. As a result laws and regulations can differ between the 3 regions.

1.1.1. Flemish region

The Flemish regulation VLAREM II, in force since the beginning of 1993, concerns different establishments such as factories, storage depots etc, but also discotheques, shooting ranges and motor sport-activities.

The VLAREM-regulations give $L_{A95,1h}$ guidevalues for the ambient noise level. These values differ with time of day and with type of area as defined by land-use regulations (table 2).

The regulations are such that higher demands are made on new plants than on existing plants and that requirements are more severe in quiet areas than elsewhere.

The noise levels of new projects is limited to the guidevalue - 5 dB(A) and, in some areas, to the pre-existing $L_{A95,1h}$ level. In cases where the ambient noise level is already higher than the guide value, the level is limited to this guidevalue and to the pre-existing $L_{A95,1h}$ - 5 dB(A).

For existing plants, the absolute limit for noise immission is the guidevalue +10 dB(A). The immission noise level produced by the establishment is measured for at least one whole working period during a day and can be evaluated with L_{Aeq}, or with statistical noise levels suited for the situation. The expert in charge justifies the chosen noise descriptors.

In the case of discotheques, indoor limit values are foreseen for the neighbouring dwellings. These limits depend on the pre-existing background level indoors.

Table 2. **Guidevalues for the ambient noise level in the Flemish region**

Area	Guidevalues in dB(A)		
	Day	Evening	Night
1° Rural areas etc.	40	35	30
2° Residential and rural areas within 500m from industrial zones	50	45	45
3° Residential and rural areas within 500m from artisanal and commercial zones	50	45	40
4° Residential areas other than 2. and 3. above	45	40	35
5° Industrial and commercial zones	60	55	55
6° Recreational areas	50	45	40
7° Most other areas	45	40	35
8° Buffer zones	55	50	50

The noise of motorsport-activities is fought by keeping this activities at sufficient distances from quiet areas, residential zones etc. The emission level of the vehicles is limited to 106 dB(A) (measured at 0.5m from the exhaust).

A revision of the VLAREM II regulations is prepared and will probably be published in 1995. For road traffic, railway and aircraft noise, no legal regulations exist at the moment.

1.1.2. Brussels Region

A new legislation is currently being prepared. It will cover the field of regulations, as well as the field of policies, programming and planning [4].

At the time being present, a specific regulation covers the field of community and industrial noise [5]. His first originality is to be aimed at specifically protecting the people in their own living and sleeping rooms against external noise. Measures are thus made in those rooms, with the windows closed, instead of being taken near the source. The second specificity is to use the "emergence" unit as a mean to determine unacceptable noise hinderness from external sources. This unit means the difference between the noise measurements, when registered with (max. levels) and without (L_{A90} background levels) the contribution of the suspected noise source.

Noise is considered as non acceptable if the "emergence" exceeds 6 dB in the living room and 3 dB in the bedroom. If the total noise does not exceed 30 dB(A), the "emergence" is not taken into consideration, whatever his value can be. Penalties of 5 dB can be added to the measured values in case of "pure sound" or "impact" noises. This regulation finds its roots in considerations and units in ISO - R - 1996 and ISO 1996 parts 1 and 2.

A slightly different rule is used to measure music from discotheque etc. Roughly, it uses Leq values instead of sound pressure values $L_{(A)}$. It takes the prevailing background noise into consideration. If the background noise is less than 30 dB(A), the emergence is limited to 5 dB(A). If the background noise is more than 30 dB(A), but less than 35 dB(A); the total noise cannot exceed 35 dB(A). If the background noise is more than 35 dB(A), the total noise cannot exceed the background noise level.

There are yet no regulations covering the field of road traffic, tramways, railways and aircraft noises.

1.2. DENMARK

Danish regulation concerning road noise and railway noise are mainly concentrated on the planning situation for either construction of new roads and railways or building of new houses near the road or railway.

1.2.1. Road traffic noise

The planning guidelines for road traffic noise are shown in table 3.

Table 3. **Road traffic noise guideline limits in Denmark (free field values)**

Area	LAeq, 24h
Summer residential - Camping	50
Hospital - School	55
Residential	55
Hotel - Office	60

1.2.2. Railway noise

The planning guidelines for railway noise are shown in table 4. The limit for L_{Amax} from the most noisy train normally used on the railway line is 85 dB(A).

Table 4. **Railway noise guideline limits in Denmark (free field values)**

Area	LAeq, 24h
Summer residential - Camping	55
Hospital* - School	60
Residential*	60
Hotel - Office	65

** To avoid vibration nuisances and to reduce LAmax, a minimum distance between the nearest rail and the houses must be respected. This minimum distance is 50 meter for railway lines with more than 10 trains per day and 25 meter for other railway line.*

For all residential areas with more than 65 dB(A), the Danish States Railways build noise screens and subsidy noise insulation for homes exposed. This is done in the period 1987-2005 relating to a plan for all the country financed by using 1% of the yearly construction budget for the Danish States Railways for this purpose.

1.2.3. Aircraft noise

All airports and airfields will relating to a statutory order be regulated in the period 1995-1999 to meet the noise levels set up in table 5. Noise zones will be calculated for these noise limits to ensure that new houses are not build inside the noise zone.

Around Copenhagen airport, the Danish Government has subsidised noise insulation for dwellings exposed to LAeq > 65 dB(A).

Table 5. Aircraft noise guideline limits in Denmark (DEN Level*, free-field values)

Area	Smaller airfield	Airport or military airfield
Summer residential - Camping	45	50
Hospital* - School	45-50	55
Residential*	45-50	55
Hotel - Office	60	60
Rural	50	60

** The Day-Evening-Night level is based on LAeq calculated for an average of the 3 months of a year with the highest number of operations, and with specific weighting for operations in the evening and in the night and special activities in the weekend.*

The limit for LAmax during night is 70 dB(A) for smaller airfields and 80 dB(A) for airports and military airfields.

1.2.4. Industrial noise

The most noisy factory will relating to a statuary order be environmentally regulated in the period 1994-2000 to meet the noise levels (corrected for clearly impulse noise and tones) set up in table 6.

Table 6. Industrial noise guideline limits in Denmark [6] (LAeq, free-field values)

Area	Mon/Fri (7am-6pm) Sat (7am-2pm)	Mon/Fri (6pm-10pm) Sat (2pm-10pm) Sun (7am-10pm)	All days (10pm-7am)
Commercial/ Industrial	70	70	70
Commercial/ Industrial (ban on noisy activities)	60	60	60
Mixed (resident. and commercial)	55	45	40
High rise resident.	50	45	40
Low rise resident	45	40	35
Recreational areas	40	35	35
Allotment gardens	*	*	*
Rural	**	**	**

** levels vary depending on location and planning purpose of area*
*** levels to be low as background noise levels.*

For existing factories the noise limits, if necessary according to a technical and economic evaluation , can be exceeded up to 10 dB(A). The limit for LAmax all days (10pm-7am) is 15 dB(A) higher than the limits for LAeq for the same period mentioned in table 6.

1.3. FRANCE

French regulations concerning transportation noise are covered by a set of texts which largely concern situations encountered in the field. These regulations, which aim to protect people living along new roads or in new buildings erected close to existing roads are primarily based on research carried out since the mid 60s and more particularly in the 1970s. They are designed to evaluate the impact of noise.

1.3.1. Road traffic noise

In the case of new roads to be built close to existing buildings, the legal basis is the July 1976 law on impact studies. The first application texts for this law were published in March 1978 as a circular from the Ministry of Transport. This text stated that the contribution to noise arising from the new roads (or extensions) should not exceed 65 dB(A) (plus or minus 5 dB(A)) evaluated in LAeq (8.00 a.m. - 8.00 p.m.) two metres from the front of the facades of buildings ("Guide du bruit des transports terrestres") which existed before the road was declared to be a public necessity (the principle of precedence).

Leq (8.00 a.m. - 8.00 p.m.) was selected as it gives a good representation of the overall annoyance felt by local residents over 24 hours as demonstrated in psycho-sociological surveys implemented during the 1970s. Given the correlations between daytime and night-time traffic, this index enables 90% of all cases to be handled correctly and addresses both daytime and night-time noise problems. On average, daytime noise is 10 dB(A) higher than night-time noise. However, an additional Leq index (0.00 a.m. - 5.00 a.m.) to consider night-time annoyance (the impact of noise on conditions of sleep) can be added but only for exceptional cases, particularly close to roads with very heavy night-time goods vehicle traffic when the difference between Leq day and Leq night is low (under 6 dB(A)).

The initial 1978 text was modified in March 1983 by a circular concerning protection from noise close to national network roads infrastructures [7]. The aim was to contain the Leq (8.00 a.m. - 8.00 p.m.) level produced by the road within the 60 to 65 dB(A) range. This text also specifies that comfort levels of approximately 60 dB(A) should be attained if housing is located in quiet residential areas or if the nature of the equipment justifies it or if the additional cost involved is not excessive. If the pre-existing noise level is higher than 65 dB(A), the objective is to limit the contribution of the new road to 65 dB(A) so as to modify the final noise value only slightly.

A text published by the General Office of the Local Authorities recommends the use of these rules for local roads.

When existing roads are modified, virtually the same rules apply as for the creation of new roads if the initial noise level generated by the road (prior to modification) is under 65 dB(A). If the initial level is between 65 and 70 dB(A), the objective is the ensure that this level is not increased by the new development. If the initial level is greater than 70 dB(A), it is recommended to reduce the noise level to 70 dB(A) maximum after modifications to the road.

The case of buildings to be erected close to transportation infrastructures is covered both by the town planning code and the construction code. The operational text is based on the inter-ministerial decision dated the 6th of October 1978 [8]. This decision makes mandatory a general census of all noisy roads - or roads likely to become noisy - in cities (in which case it is included in the urban zoning plans) or in intercity environments (extremely annoying roads are classified as type I, and annoying roads type II).

This survey provides details about the exposure of buildings to be erected in a 200 m strip to each side of the roadway and then selects 30, 35, 40 or 45 dB(A) minimum sound-proofing levels depending on the case ; the objective is to attain an indoor noise level which does not exceed 35 dB(A) in Leq 8.00 a.m. - 8.00 p.m..

The noise law adopted on the 31st of December 1992 [9] substantially modifies texts which are currently in force. One main difference is that it distinguishes between building usage and time of day for new infrastructures which brings French legislation closer to that of other European nations such as Germany and Switzerland. Noise limits will thus, in all probability, be modulated to take account of both these criteria and unlikely to attain the following values [table 7]. The by-laws and the decrees of application of the law have not yet been published.

Table 7. Road traffic noise immission limits (proposals)
New road (LAeq - facade)

Area	Day (6am - 10 pm)	Night (10pm - 6am)
Hospital	57 dB(A)	52 dB(A)
School	57 dB(A)	-
Dwelling in low noise exposure area (Leq < 60 dB(A))	60 dB(A)	55 dB(A)
Other dwelling	65 dB(A)	57 dB(A)
Industrial/Commercial	65 dB(A)	60 dB(A)

In the case of modifications to existing road, i.e. if the pre-existing noise level is likely to increase by more than 2 dB(A), total noise after modifications of the road must be reduced to a maximum 65 dB(A) if the pre-existing level was greater than 65 dB(A). If the pre-existing level was lower than 65 dB(A) the objective is to maintain the pre-existing level.

1.3.2. Railway noise

Application of the law on environmental impact studies (EIE) imposes the protection of buildings close to new infrastructures such as high-speed train lines. As for road traffic noise, the first recommendation was contained in the "Guide du bruit des transports terrestres" ($65 < L_{Aeq} < 75$ dB(A)). In practice, the first application of these principles concerned the new TGV Atlantique line and noise protections have been installed when noise exceeds 65 dB(A) measured in Leq 8.00 a.m. - 8.00 p.m. (when pre-existing ambient noise is less than this value).

The application of the noise law dated the 31st of December 1992 should lead to a further reduction of this limit to 62 dB(A) for daytime periods when new high speed train are to be built ; this level will be even further reduced to 60 dB(A) when the quieter, third generation TGVs start to operate.

1.3.3. Aircraft noise

France uses the psophic index (Ip). In addition to the number of aircraft movements this index includes a maximum permitted noise level for over flights during the 16-hour period between 6.00 a.m. and 10.00 p.m. (daytime) and a maximum permitted noise level for over flights during the 8-hour period from 10.00 p.m. to 6.00 a.m. (night-time). Night-time traffic is considered to be more disturbing than daytime traffic and it is thus weighted with a factor of 10. Residential or other types of construction work are determined per zone :

- Zone A : $Ip \geq 96$;
- Zone B : $89 \leq Ip < 96$;
- Zone C : $84 \leq Ip < 89$;
- Zone D : $Ip < 84$.

Regulatory and legislative texts have imposed land planning restrictions on zones exposed to aircraft noise, particularly concerning building insulation (table 8).

Only residences and buildings required for aeronautical activities and public amenities vital for existing populations are permitted in isopsophic zone 96. Residences required for individual, commercial and agricultural activities are permitted in zone B and in the already-developed sectors of zone A (between 96 and 89). Individual non-estate housing is permitted in zone C (under 89) located in already-developed sectors as are all refurbishing operations for districts and existing homes providing that they do not significantly increase the population of the area exposed to noise.

Table 8. **Minimum noise insulation values**

Area	A	B	C	Near zone C
BUILDINGS used for airline and airport activities	42 dB(A) (1)	35 dB(A) (1)	35 dB(A) (2)	30 dB(A) (2)
RESIDENTIAL	excluded	excluded	35 dB(A) dwellings only	30 dB(A) (2)
SCHOOL and health-care facilities, company housing for employees	(3) 47 dB(A) (1)	(4) 40 dB(A) (1)	35 dB(A)	30 dB(A)
OFFICES and other buildings open to the public	42 dB(A) (1)	35 dB(A) (2)	30 dB(A) (2)	-
BUILDINGS open to the public that are essential to aviation activities at the airport. Industrial and commercial warehouse and workshops	special study required	special study required	-	-

(1) unless a special study has been done (2) a special study required in the case of high buildings
(3) permitted in special case except for company housing (4) permitted in special case

1.3.4. Industrial noise

Authorised noise levels in the immediate environment of industrial installations are defined by a French by-law dated 20th of August 1985. These levels consider the type of housing exposed and the period - day (7.00 a.m. - 8.00 p.m.), night (10.00 p.m. - 6.00 a.m.). Noise limits for new installations to be erected close to existing homes are as follows (table 9).

Table 9. **Noise immission limits (LAeq - facade)**

Area	Day	Night
Hospital, health care building etc.	45	35
Residential (rural)	50	40
Residential in urban area	55	45
Residential/ commercial	60	50
Commercial / industrial	65	55
Industrial	70	60

1.4. GERMANY [10-11-12-13]

1.4.1 Road traffic noise

It was not until 1974 that the Federal Immission Safeguards Act (march 1974) and the Federal highway act (October 1974) obliged road makers to protect dwellings located along the federal road network. Subsequently other texts addressed road noise problems, particularly the Road traffic Code which contains several regulations designed to reduce disturbance from road noise.

These regulations cover :

- noise limits for vehicles (application of EEC standards)
- the definition of the silent vehicle concept
- the ban of heavy goods vehicle traffic in specific circumstances
- the possibility of limiting road traffic so as to protect the population from noise and more generally to develop traffic plans designed to protect the environment.

In 1983, the Ministry of Transport published a full text defining the noise immission limits that should not be exceeded along the Federal road network. Amended in 1986 and then again in 1990 this text is currently in force. In fact, in practice, the values used are often below official values.

There are three categories of roads in Germany : Federal roads (including the motorways), roads built by the Länders and local roads. The responsible level for building the road is also responsible for protection from noise.

There are two basic categories for Federal network roads for which the Ministry of Transport is responsible :

- new roads (and major changes to road) : noise should not exceed 59 dB(A) (free-field) in residential areas during the daytime (Leq 6.00 a.m. - 10.00 p.m.) and 49 dB(A) at night (Leq 10.00 p.m.- 6.00 a.m.). In practice, a high number of sites are protected to a noise limit which does not exceed 57 dB(A) in the daytime and 47 dB(A) at night (table 10). These limits also apply in the case of roadway extensions if road noise increases by more than 2 - 3 dB(A) or if the daytime level exceeds 70 dB(A) or 60 dB(A) at night. If noise limits are exceeded, either the road route is modified, noise barriers are erected or exposed homes are insulated.

- existing roads : the protection of local residents (essentially by insulation) is only implemented if daytime levels exceed 70 dB(A) or night-time levels exceed 60 dB(A) in sensitive or residential areas.

Table 10. **Guidelines on noise abatement on federal roads (Immission limits - LAeq, free-field)**

Area	New and significantly modified road		Improvement (existing road)	
	Day	Night	Day	Night
Hospital - School	57	47	70	60
Residential area	59	49	70	60
Mixed business and residential area	64	54	72	62
Area with light industry	69	59	75	65

The same limits apply to <u>new Länder road</u>.

There are no regulations for <u>local roads</u>. Municipalities act according to their own sensitivity and social pressure (particularly the number of complaints received). It should be noted that towns with over 80 000 inhabitants are also responsible for erecting noise barriers on Federal roads running through their territory. The Ministry of Transport is responsible for regulating noise problems in smaller towns.

1.4.2. Railway noise

The ordinance dated June 1990 [14] sets the same noise immission limits for new lines as for roadways (see table 10). As it is assumed that noise from railways is less disturbing, a bonus of 5 dB(A) is subtracted to calculated noise levels prior to comparison with these noise limits. If the noise levels calculated in this way are exceeded, homes must be protected.

In the case of extensions to existing lines, sound-proofing measures must be adopted if noise levels increase by at least 3 dB(A) or if they exceed 70 dB(A) during the day or 60 dB(A) at night.

There is no current noise level legislation for existing lines.

1.4.3. Aircraft noise

In the act relating to aircraft noise [15] two noise protection zones are defined by noise levels expressed in Leq : Zone 1 : Leq > 75 dB(A) ; Zone 2 : 67 < Leq < 75 dB(A). These limits apply to the daytime period (6.00 a.m. - 10.00 p.m.) and the noisiest hour during the night-time period (10.00 p.m. - 6.00 a.m.). It is forbidden to build convalescent and retirement homes and schools in these two zones.

In zone 1, no residential construction is permitted and owners of existing buildings (flats, houses, schools, hospitals) can request reimbursement of expenses incurred for insulation. In zone 2, the construction of dwellings is authorised provided that they are insulated. In addition to establishment of the noise protection zones, a third boundary is calculated on the basis of 62 dB(A) noise limit for various planning purposes.

1.4.4. Construction noise

The first text of a general law concerning construction noise was published in August 1970. It defines the noise limits which must not be exceeded by type of zone and daytime/night-time periods (table 11).

Noise levels must be reduced when the levels measured exceed recommended limits by more than 5 dB(A) or if day-time peak levels exceed exposure recommendations by over 30 dB(A) (respectively 20 dB(A) at night-time and 10 dB(A) inside home).

1.4.5. Industrial noise

Immission limits included in regulations dated July 1968 [16] (TA Lärm) are identical to those relating to construction site noise but the periods are different : daytime (6.00 a.m. - 10.00 p.m.), night-time (10.00 p.m. - 6.00 a.m.). The TA Lärm covers indoor noise when the housing is directly linked to the industrial installations.

Table 11. Construction noise immission limits

Area	Time of day	
	Daytime LAeq (7am - 8pm)	Night-time LAeq (8pm - 7am)
Hospital	45	35
Exclusively residential area	50	35
Mainly residential area	55	40
Mixed area (residential + commercial)	60	45
Commercial and industrial area	65	50
Industrial area	70	70
Indoor	40	30

1.5. GREECE

Ambient noise standards were developed in 1981 for industrial plants. The general limit is 50 dB(A) Leq inside residential zones, 55 to 65 dB(A) in mixed zones (residential/industrial), and 70 dB(A) in industrial zones. For installations which are in structural contact with houses or flats, the maximum permissible limit of noise is 45 dB(A), irrespectively of the category of the area. Noise is measured inside the house with the doors and windows open.

For road traffic noise, the limit not be exceeded is 67 dB(A) Leq or 70 dB(A) L_{10} [17]. When new buildings are erected the regulation concerning authorised indoor noise levels includes a 30 to 35 dB(A) limit. This regulation concerns all noise sources. In the case of specific buildings such as : schools, hospitals etc, the above maximum permissible values can be reduced by 5-10 dB(A).

Concerning aircraft noise, the law classifies 14 different land use areas and examines the approval of planning permissions for future development for three noise exposure bands around the airports - via Noise Exposure Forecast curves through the well established Equivalent Perceived Noise Level, as follows : NEF > 40 EPNDB, 30 < NEF < 40, NEF < 30. NEF curves exist for all the major Greek airports and it is the duty of the Greek Civil Aviation Authority (Environmental Division) to update the curves and also provide information to potential developers.

The existing and recently proposed, but not yet legislated, Greek environmental noise limits are as follows. Maximum day/night permissible noise levels in the property boundaries of the area that the relevant noise source is located :

	Existing Day & / or night	Proposed Day / Night
1. Industrial area	70 dB(A)	65 / 65 dB(A)
2. Mixed area (main use : Industrial)	65 dB(A)	- -
3. Mixed area (main use : Residential)	55 dB(A)	50 / 45 dB(A)
4. Urban (strictly residential) & Rural areas	50 dB(A)	45 / 40 dB(A)

In the proposed legislation, in the case of a structural continuity between source and receiver, the maximum noise level in the receiver is limited to 35 dB(A) for residences and 40 dB(A) for offices or commercial use. The relevant existing limit of 45 dB(A) applies only to residences.

1.6. ITALY

Up until 1991, there was no national environmental noise law. There was, however, a circular from the Health Ministry (September 1971) which set limit values for exposure to industrial noise at 60 dB(A) during the day and 40 dB(A) at night. There are also local and regional laws which set limit values for all noise sources except traffic noise (e.g. Lombardy). Apparently only Bolzano has introduced noise limits for road traffic (table 12).

Table 12. Road traffic noise immission limits in Bolzano (LAeq, 25 meters from the middle of the road)

Area	Day	Night
Urban residential (local street)	55 dB(A)	45 dB(A)
Urban residential (distribution street)	60 dB(A)	50 dB(A)
Urban residential (arterial road)	65 dB(A)	55 dB(A)

Subsequent to the recommendations in Italian law dated 23rd of December 1978 concerning the revision of noise limit values and the law dated the 8th of July 1986, a decree defining the objectives and the applicability of protection from environmental noise was promulgated in arch 1991 [18 and 19]. This decree fixes noise limit values for day and night depending on urban zoning (table 13).

One of the current difficulties of the applicability of the law is that it considers the noise from road traffic as a specific noise source and not as an element of background noise. For this reason, the law is often only applied to new factories with noise levels likely to exceed 70 dB(A), the level which often corresponds to the background noise from road traffic.

Table 13. **Environmental noise limit in Italy (LAeq, free-field values)**

Area	Day 6 am - 10 pm	Night 10 pm - 6 am
Sensitive : hospital, school etc	50	40
Residential (primarily)	55	45
Mixed : residential / commercial	60	50
Commercial	65	55
Industrial (primarily)	70	60
Industrial	70	70

To these limits should be added a second criterion which is the difference between background noise and residual noise measured inside homes. This difference should not exceed 5 dB(A) during the day and 3 dB(A) at night. If background noise is under 40 dB(A) in daytime and 30 dB(A) at night, the noise is considered to be tolerable. If the background noise is higher than 60 dB(A) by day and 50 dB(A) by night, this differential criterion does not apply. Given that in a large number of cities noise levels often exceed 70 dB(A), this differential criterion is hardly ever applied.

1.7. NETHERLANDS [20-21]

1.7.1. Legislative and regulatory framework

The law designed to fight noise was adopted in 1979 [22]. It was applied in several phases. At the end of 1987, all sections of this law became mandatory, in particular those concerning :

- zoning around airports (1982)
- zoning close to new roads and industrial areas (1982)
- insulation of homes (1983)
- treatment of the noise around existing roadways (1986)
- zoning around railway lines (1987)

The law aimed to :

- eliminate new noise problems (preventive actions) ;
- find solutions for existing problems (black spot corrective actions).

The main institutions involved in the fight against noise are the national government (and more particularly the Ministry for the Environment and the Ministry of Transport and Public Works) which is responsible for the law and multi-year programme to fight noise. These plans also involve the regions and particularly the townships who have the task of making a census of all homes exposed to noise particularly when urban zoning is revised and to prepare action plans to enable the law to be applied.