is not the sum of the acute effects, such as frequently being awoken by noise, sleep disturbance and self-reported sleep quality, the Committee considers it plausible that a series consisting of numerous relatively low-intensity noise events has a greater effect than a series with the same overall *Lnight* value, consisting of a smaller number of higher-intensity noise events.

4.1.3 Consequences for regulation

The 1997 Health Council report *Assessing Noise Exposure for Public Health Purposes* proposes the use of *Lnight* for the regulation of exposure to night-time environmental noise. Of course, the extent to which controls based on *Lnight* can protect against the effects of exposure to night-time noise when sleeping depends on the level at which the limit is set. However, it follows from the considerations set out above that various situations might arise in which, although the prescribed *Lnight* value was not exceeded, the exposure levels were undesirable from a health and well-being perspective, due to the occurrence of relatively frequent low-intensity noise events.

If one concludes that exposure should be limited further, but that that cannot be achieved by applying stricter *Lnight* exposure limits, the best way forward would be to place a limit on the number of noise events. The reason being that setting *SEL* or *LAmax* exposure limits for noise events would allow for less favourable situations, unless the exposure limits were set at impracticably low levels. Hence limitation of the number of events is preferable.

There is another reason for specifying a maximum permissible number of noise events. The *greater the nightly number* of noise events (above the observation threshold), the greater the chance is that one will coincidentally hear such a noise after 'spontaneously' waking up in the night, possibly leading to annoyance and problems going back to sleep. As indicated in section 3.2, if all intervals of 'spontaneous' wakefulness were to coincide with a noise event audible in the bedroom, a person might under extreme circumstances hear a noise that had not woken him or her up approximately ten times in the course of a night.

4.1.4 Conclusion

At a given *Lnight,* (or *Lnight_i*) an acute effect of exposure to night-time noise is most influential if the *LAmax_i* or *SEL_i* values of the separate noise events are approximately 5 dB(A) above the observation threshold for the effect in question. In order to prevent the occurrence of the worst-case scenario associable with a given *Lnight* value, consideration should be given to regulating not only *Lnight*, but also the number of noise events. One consequence of setting a ceiling on the number of noise events would be that one was less likely to hear a noise event after 'spontaneously' waking in the night, and therefore less likely to suffer sleep disturbance.

Whether it is necessary or desirable to set an exposure limit on the number of noise events, in addition to limiting *Lnight* values, depends on the level of the *Lnight* limit and the level of protection one wishes to provide. The relationships between acute effects and *SEL_i* values defined in this report, make this method of regulation a viable option.

4.2 Noise characteristics

The Committee has identified a number of forms of noise that may have a particularly pronounced effect on people exposed to them:

- Noise characterised by low-pitch components (buzzing)
- Noise consisting entirely of one or more low buzzing sounds (low-frequency noise)
- Tonal noise
- Noise events characterised by a rapid increase in intensity at the beginning (impulse noise)
- Industrial noise
- Noise characterised by sporadic high *LAmax* or *SEL* values.

4.2.1 Noise characterised by low-pitch components

As indicated in chapter 2, noise exposure is generally measured using a so-called A-weighting, which takes account of the frequency sensitivity of the human ear. However, there is evidence to suggest that this method may place insufficient emphasis on low-frequency noise components in particular. This possible drawback does not apply if use is made of the so-called C-weighting, which affords nearly as much weight to low-pitch components as to high-pitch components.

In the Netherlands, a study is in progress aimed at determining the differences between outdoor A-weighted and C-weighted equivalent sound pressure levels measured in situations that frequently arise in practice[107]. The measured average differences so far determined for aircraft, lorries, freight trains, shipping and industrial activities are, respectively, 9, 7, 5, 14, and 13 dB and the ranges of the measured differences are, respectively, 2-13, 2-15, 1-15, 9-21, and 6-24 dB. From these figures, it is apparent that noise from shipping and from industrial activities contains more low-frequency components than noise from road, rail or air traffic. The researchers believe that the differences are much greater indoors than out, because the fabric of residential buildings attenuates some frequencies more than others.

The extent to which the presence of lower-frequency components increases noise-related annoyance or sleep disturbance is still under investigation. The Committee anticipates that the results of the research currently in progress will enhance understanding of the contribution that lower-frequency noise components make to annoyance and sleep disturbance, but does not expect that it will be necessary to revise the exposure-response relationships that have so far been defined, since these definitions already take account of any extra influence of lower-frequency components. However, the tendency to use higher powered equipment may mean that in the future the noise from certain sources will contain much more low-frequency noise components, possibly necessitating modification of the exposure-effect relationships as presently defined.

4.2.2 *Low-frequency noise*

After considerable deliberation, the authors of the 1997 Health Council report decided that low-frequency noise should not be incorporated into the assessment framework, since there was no reliable means of defining the necessary low-frequency noise adjustment factor. The present Committee sees no reason to revise this view, as no relevant new data has become available since. However, it does follow that the conclusions set out in this advisory report do not necessarily apply to low-frequency night-time noise. It should nevertheless be pointed out that low-frequency noise is relatively unusual in the domestic environment; at least, the Committee is unaware of any commonplace sources of such noise. Where sources of low-frequency noise are present, however, annoyance is most likely to occur at night, when such noise is not masked by higher-frequency noises in the domestic environment.

4.2.3 *Tonal noise*

Nor has any new data relating to tonal noise become available since 1997. The Committee accordingly endorses the recommendation contained in the earlier Health Council report, namely that the equivalent sound pressure level should be increased by between 0 and 5 dB(A) in cases that involve exposure to tonal noise when sleeping (see Annex F). It is worth noting that, like low-frequency noise, tonal noise is rare in the domestic environment.

4.2.4 *Impulse noise*

An impulse noise is a noise that increases very quickly, so that, as far as the listener is concerned, it seems to reach its maximum intensity almost immediately. Examples include gunshots and low-flying military jets. The international standard ISO1996/01[108], published in 2002, sets out a method for the assessment of impulse noises that is consistent with the thinking of the Health Council's 1997 report. This system indicates that adjustment factors of 5 and 12 dB(A), respectively, should be used for certain specified impulse noises (low-flying military jets, car doors slamming, church bells chiming) and certain specified very impulse-like noises (gunshots, metal beating, pneumatic hammering, shunting of rail rolling stock). ISO 1996/01[108] lists the impulse noises and very impulse-like noises in respect of which adjustment factors should be applied, because, according to the working group that developed the standard, ISO 1996/01 there was too little readily interpretable research data available to enable quantification of the adjustment factors in audiological, physical or acoustic terms. The ISO standard did not adopt the assessment method prescribed in the 1996 US standard ANSI S12.9[109], which was based on the speed with which the sound pressure level rose at the beginning of an impulse noise. In the Netherlands, however, a provisional assessment method was introduced for railway yards, which followed the US method in working on the basis of the speed with which the sound pressure level rises at the beginning of a noise event[110].The maximal adjustment factor that can be used is the 12 dB(A) applicable in relation to very impulse-like noise.

The adjustment factors of 5 and 12 dB(A) are derived from research into noise-related annoyance. People probably find impulse noises more annoying because of the startle responses they tend to induce[105]. Research by Griefahn[65] (into the effects of gunshot noise in the laboratory), Vos[111] (into the effects of gunshot noise in the field, see Figure 24 in Annex D) and Fidell[49] (the effects of noise from military jets in the field, as analysed by Passchier-Vermeer[52], see Figure 22 in Annex D) have all shown that noise events characterised by a rapid initial rise in sound pressure level also cause considerably more sleep disturbance than ‘ordinary’ environmental noises.

4.2.5 *Industrial noise*

While attaching certain caveats, the 1997 Health Council report suggests that, in situations characterised by lower noise exposures, the equivalent sound pressure levels associated with industrial noise should be corrected by between 0 and 10 dB(A). This proposal was based on considerations regarding noise-related annoyance relative to noise exposure over the full twenty-four-hour period. Recent research has since shown that there is no scientific basis for making such an adjustment[112].

Figure 14 illustrates the relationships between industrial noise and annoyance, as defined using data from recent research by Miedema *et al*[112], and the relationships between road traffic noise and annoyance[113]. The figure shows the percentages of people experiencing high annoyance attributable to road traffic noise and industrial noise, the percentages of people experiencing at least moderate annoyance, and the percentages of people experiencing at least slight annoyance, as functions of *Lden*. It will be seen that the curves for industrial and road traffic noise are almost identical, and certainly do no

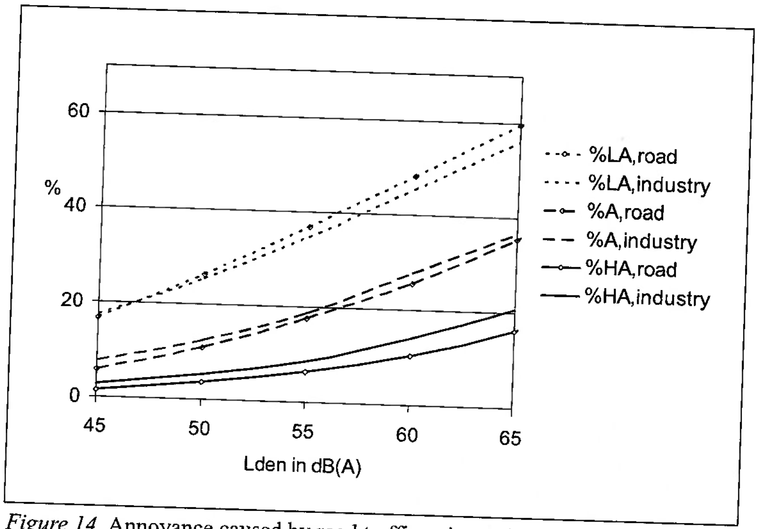


Figure 14 Annoyance caused by road traffic noise and industrial noise as a function of *Lden*[112,113]. %HA is the percentage of people experiencing high annoyance, %A is the percentage of people experiencing at least moderate annoyance, and %LA is the percentage of people experiencing at least slight annoyance.

justify the conclusion that, at *Lden* values of between 40 and 60 dB(A), industrial noise causes more annoyance than road traffic noise. The Committee consequently believes that there is no longer any justification for correcting the equivalent sound pressure levels associated with *night-time* industrial noise either.

4.2.6 Sporadic high LAmax or SEL values

The exposure-response relationships described above have been defined on the basis of data from situations where night-time noise events occurred regularly. It is therefore pertinent to ask whether these relationships remain valid in situations characterised by sporadic noise events with comparatively high *SEL* and *LAmax* values. The Committee anticipates that, in such a situation, the probability of an *acute* effect (of whatever kind) will be greater than the defined relationships suggest, since the hearer will necessarily be unused to noise events of the kind involved, and anxiety is very likely to play a role. Anxiety is particularly likely to play a role where the hearer associates a noise with a previously experienced threat to him/herself or others. A single event of this kind can also have consequences for the hearer's quality of sleep for the rest of the night and on subsequent nights. However, the Committee does not have sufficient research data at its disposal to develop these assumptions more fully.

In questionnaire-based studies of self-reported long-term effects (such as diminished sleep quality and night-time noise-related annoyance), a one-year assessment period is typically used. The Committee is not aware of any research that has looked at the specific effects that noise events with relatively very high *SEL* or *LAmax* values have on such self-reported parameters. The Committee cannot therefore make any scientifically justified statement about such effects.

4.2.7 *Conclusion*

Although little is known about how sleep is affected by exposure to noises with unusual characteristics, the Committee believes that it is reasonable to assume that the effects of exposure to some 'special' types of noise are greater than the effects of exposure to 'ordinary' traffic noise. The Committee is of the opinion that the conclusions of the 1997 Health Council report *Assessing Noise Exposure for Public Health Purposes* remain valid in relation to noise with low-frequency components, low-frequency noise, tonal noise and impulse noise. The adjustment factors that need to be applied to the exposure indexes are given in Annex F. However, where noise from industrial activities is concerned, data published since 1997 indicates that the application of an adjustment factor is no longer justified. The Committee is unable to make any definitive statement regarding the possibility that occasional, very loud noise events may have more far-reaching consequences.

4.3 Efficiency and effectiveness of the acoustic insulation of homes

4.3.1 *Data*

In the Netherlands, there have only been a number of isolated studies into the efficiency and effectiveness of acoustic insulation in the reduction of perceived road and aviation noise levels, or into people's views regarding such insulation[114-119].

Bitter *et al* looked at the effects of fitting additional acoustic insulation to flats beside busy motorways in Dordrecht[114] and Amsterdam[115]. A survey of residents 2.5 years after the modifications were made revealed that half the people living in the flats were no longer annoyed by night-time road traffic noise.

Van Dongen *et al*[116] carried out an exploratory study into sleep quality in homes fitted with additional acoustic insulation in the vicinity of Amsterdam's Schiphol Airport. Comparative analysis revealed that self-reported sleep disturbance and self-reported high sleep disturbance were slightly lower in the better-insulated dwellings than in 'ordinary' dwellings. However, the design of the study precluded the drawing of definitive conclusions.

Three reports were published between 1994 and 1999[117-119] regarding people's general views concerning modifications made to homes near Schiphol with a view to reducing aircraft noise-related problems. Some 85 per cent of subjects reported that the insulation had reduced noise-related annoyance indoors. Nevertheless, people in more than 55 per cent of the homes continued to experience at least slight noise-related annoyance, and people in 15 per cent of the homes reported experiencing high annoyance since the modifications were made. The distribution patterns of both overall and night-time levels of aircraft noise-related annoyance were clearly seasonal: on (cold) winter nights, 10 per cent of subjects often or always experienced annoyance during the sleep period, compared with 40 per cent on (warm) summer nights. The differences were closely related to the use of windows: only 25 per cent of respondents said they slept with the bedroom window at least slightly ajar in the winter, whereas 70 per cent did so in the summer.

Almost no research into the efficiency of domestic acoustic insulation has been done in other countries either, the exceptions being studies by Fidell and Silvati[120], Utley[121] and Minoura[122].

Fidell and Silvati[120] investigated what effect the fitting of insulation to attenuate aviation noise had on levels of annoyance. However, they did not look specifically at annoyance during the sleep period.

In the UK, an extensive study was done to establish how effective extra acoustic insulation was in reducing exposure to road traffic noise[121]. In the specially insulated homes, approximately a quarter of subjects whose bedrooms faced the street reported being very highly or highly annoyed by night-time road traffic noise; a similar number had difficulty getting to sleep because of the noise, and more than a quarter of respondents said they were woken up at night by road traffic noise. The results proved to be influenced to a considerable extent by whether the subject felt that, without the window open, his or her bedroom was too hot in the summer: 37 per cent of those who felt unable to sleep with the window closed in warm weather were very highly or highly annoyed by night-time road traffic noise, whereas only 15 per cent of those who didn't mind having the window closed experienced similar problems.

Minouri investigated the situation in the vicinity of a US air base on a Japanese island, with a view to determining how effective additional acoustic insulation was in an area with a very high aircraft noise exposure. Because the circumstances on the island are quite unlike any in the Netherlands, the findings – which indicated that the insulation was disappointingly ineffective – are not transferable to the Dutch situation.

In an interview-based study of 1242 households in the Netherlands, Leidelmeijer and Marsman[99] investigated the audibility of and annoyance associated with noise from neighbours during the day and at night. The researchers distinguished between five types of noise: noise from sanitary fittings, contact noise, noise from audio equipment, do-it-yourself (DIY) noise and noise from pets. Further distinctions were made according to the part of the house where the noise was audible or caused annoyance, and the time of the day or night. Subjects proved least tolerant of noise from their neighbours that was audible in the master bedroom. Where each of the five investigated types of noise were concerned, roughly 10 to 15 per cent of subjects indicated that they felt it was unacceptable for the noise to be audible during the day. In each case, a higher percentage said the noise should not be audible in the evening, and a still higher percentage did not want to hear the noise at night (between 11pm and 7am). Overall, nearly 30 per cent of subjects said that sanitary fittings should not be audible at night, while approximately 50 per cent felt each of the other four types of noise were unacceptable by night.

Subjects were also asked whether they could hear voices from neighbouring homes. While the percentage of affirmative answers varied according to the type of dwelling, ordinary speech was to some extent audible in an average of 35 per cent of dwellings, and partially or readily comprehensible in approximately 8 per cent of dwellings. Raised voices could be heard, at least some to extent, in approximately 65 per cent of dwellings; they were at least partially comprehensible in 27 per cent of homes and readily comprehensible in approximately 10 per cent.

In 1993, Kranendonk *et al* produced a synthesis of the research conducted up to that point in time into the annoyance associated with noise from neighbours[100]. TNO later produced a report[101] on neighbour-noise and acoustic insulation based on the findings of a questionnaire-based survey of the residents of six hundred homes. They established that nearly half of the respondents heard at least some noise from neighbouring dwellings every day. Approximately 10 per cent of subjects found their neighbours' noise highly annoying. The chief causes of annoyance were loud radios, hi-fis and TVs, the slamming of doors and footsteps on floors and staircases.

The authors of both studies concluded that, given the minimum level of acoustic insulation required in new dwellings under the Building Decree[14] (an *Ilu,k* value of 0 dB(A)), noise from neighbours caused high annoyance for 10 per cent of subjects and at least moderate annoyance for 25 per cent.

4.3.2 Conclusion

From the little data available, the Committee concludes that fitting additional acoustic insulation to homes can reduce the annoyance associated with night-time traffic noise to some extent. It is not presently possible to quantify the benefit, however. One thing that is clear, is that if steps are not also taken to enable householders to keep their bedrooms cool in hot weather, the benefit of additional acoustic insulation is liable to be offset in the summer by people opening their windows.

In addition, the Committee considers the following points to be important for assessment of the effectiveness and efficiency of domestic acoustic insulation and therefore important in the context of research in this field:

- There is a danger that fitting high-grade acoustic insulation to exterior walls in an effort to deal with a form of noise that is much louder than other noises in the environment will have the effect of cutting out all noises except the one that is causing problems.
- High-grade acoustic insulation against noises from external sources has implications for inter-dwelling acoustic insulation. If the latter is only of a moderate standard, as is frequently the case in the Netherlands, noises from neighbouring dwellings (sanitary facilities, TV, radio, kitchen noises, people going up and down stairs, parties, rows, voices) becomes much more apparent, potentially leading to social tensions.
- Many people like to sleep with their windows at least partially open, which negates the effect of acoustic insulation on the exterior walls to some extent. Although there are technical solutions for this problem, such as variable ventilation systems, that adjust the ventilation opening in line with rising or approaching noises from outside, they are not in widespread use.
- Very high levels of insulation can cause 'acoustic isolation': cutting the householder off from 'pleasant' outside noises, such as birdsong and children at play. However, the Committee anticipates that acoustic isolation is less likely to be a problem at night than during the day.

The Committee believes that the standard of inter-dwelling acoustic insulation presently required is not sufficient to provide protection against annoyance attributable to noise from neighbours. Since people are a lot less tolerant of the noise their neighbours make at night-time than of their neighbours' evening or daytime noise, it may be assumed that much of the annoyance associated with noise from neighbours relates to the influence of such noise on sleep.

Chapter 5

Answers to the State Secretary's questions

In this chapter, the Committee presents its answers to the specific questions posed by the State Secretary and summarises its conclusions. The answers to the State Secretary's questions are based upon the information provided in chapters 3 and 4. First, however, the Committee explains how the answers fit into the environment and health context described in section 2.4.

5.1 General principles

5.1.1 Effects of exposure to noise when sleeping

In its evaluation of the consequences of exposure to noise when sleeping, the Committee has applied the model illustrated in Figure 3. In this model, biological phenomena occur in response to environmental noise because, even when sleeping, an individual still needs to assess and process 'stimuli' from the environment. The biological responses that are liable to occur include waking up, difficulties getting off to sleep and increased average motility while sleeping. To some extent, these responses involve acute changes during exposure to a noise, and to some extent they involve changes that manifest themselves over the course of a night (before, while and after sleeping). Such effects can be predictors of long-term decline in health and well-being, which may or may not depend upon the nature and duration of the exposure. It is not therefore possible to say in advance whether a biological response to night-time noise will lead to a decline in health or well-being.

5.1.2 *Strength of the evidence*

In order to define the degree of certainty concerning the relationship between exposure to night-time noise and a particular effect, the Committee has defined three categories of evidence: sufficient, limited and insufficient evidence; see Table 2. The category 'limited evidence' is subdivided into two forms:

- A causal relationship is plausible, and has been observed to a limited extent in epidemiological research.
- No direct link has been epidemiologically established between exposure and effect, but there is good quality indirect empirical evidence for such a link, and the presence of a link is plausible. Indirect evidence may be said to exist if it has been observed that exposure has an intermediary effect, which is known from other research to lead to the ultimate effect under consideration.

5.2 Effects of noise when sleeping

Question 1: What are the effects (expressed in quantitative terms as far as possible) of exposure to noise when sleeping?

Environmental noise can be divided into noise from traffic (such as air, road and rail traffic), noise from stationary sources (such as factories and shunting yards), neighbourhood noise (noise from, for example, sports stadiums, racing circuit or open air events) and noise from neighbours (contact noise, noise of audio equipment, voices). Research into the relationship between, on the one hand, sleep characteristics and health and, on the other, exposure to night-time noise has tended to focus mainly on road and air traffic noise. In the following subsections, the Committee accordingly first addresses noise from these sources, before moving on to consider noise from rail traffic and stationary environmental sources, the neighbourhood noise and noise from neighbours.

The Committee distinguishes between biological effects and the accumulated effects on health and well-being of exposure resulting from sleeping in an environment affected by night-time noise. The Committee has divided effects of the latter kind into five categories: diminished sleep quality, diminished general well-being, impaired social contacts and concentration, medical conditions and reduction in life expectancy.

5.2.1 *Biological effects of road traffic noise and aviation noise*

Biological effects can be divided into acute (immediate) effects and effects that occur over the course of a night (before, while and after sleeping).

Acute biological effects

Noise during the sleep period induces an immediate response from the body. The effects that have been observed to take place in direct response on noise events that occur while the subject is sleeping are listed in Table 9. There is sufficient evidence for a causal relationship between each of these effects and night-time noise events.

Table 9 Acute biological effects for which there is sufficient evidence of a causal relationship with night-time noise (see Table 1 for terminological definitions).

Effect
Cardiovascular change[a]
Sleep stage change, from deeper to less deep sleep
EEG awakening
Motility
Onset of motility
Subject-registered awakening

[a] The advisory report focuses mainly on heart rate acceleration, but there is also sufficient evidence of the induction of vasoconstriction and acute blood pressure rises.

Most of these effects have been sufficiently well studied to enable exposure-effect relationships to be defined. Hence, it appears that effects such as EEG awakening and increased motility first manifest themselves at indoor *SEL* values of approximately 40 dB(A). Noise-related subject-registered awakening is liable to occur at *SEL* values of 55 dB(A) and above. These values are valid for adults; insufficient data is available to enable the definition of relationships for children. It is assumed that night-time noises can induce acute changes in the (stress) hormone concentrations in a sleeping subject's blood, but this has not been proven. Such changes cannot easily be studied in a field situation, because it would involve the use of invasive test techniques.

Effects before, while and after sleeping

Numerous biological effects over a night (before, while and after sleeping) have been observed in epidemiological research. Some of these relate directly to the acute responses: raised average heart rate, increased motility, more frequent subject-registered awakening, and longer waking intervals (as registered on a sleep EEG). The level of average motility observed in people who are exposed to night-time road and air traffic noise appears to be greater than might be expected on the basis of the acute responses alone. Average motility is closely related to waking up more frequently, diminished perceived sleep quality and increased drowsiness during the day. Furthermore, people who when trying to get to sleep are exposed to road or air traffic noise, or are worried about the possibility of being disturbed by noise in the night ahead, have more difficulty getting to sleep. The effects that manifest themselves after a sleep period are reduced perceived sleep quality, increased irritability and rise of drowsiness and tiredness during the day. There is therefore sufficient evidence of a causal relationship between noise and all these effects.

There is limited direct evidence that under certain circumstances exposure to night-time noise can influence (stress) hormones levels in sleeping subjects: this effect was observed in women who were troubled by noise in the night and unable to take corrective action. However, more definitive conclusions regarding the influence of noise on (stress) hormone levels must await the availability of further research data.

The exposure-related biological effects over the course of a night are listed in Table 10. For each effect, the table indicates the strength of the evidence for the existence of a causal relationship between exposure and effect, and the plausibility of the effect being indicative of a negative influence on health and well-being.

Table 10 Biological (physiological and psycho-physiological) effects observed after chronic exposure over numerous nights, indicating the strength of the evidence for a causal relationship with exposure to road and air traffic noise and the plausibility of the effect being indicative of an influence on health and well-being.

Variable	Strength of the evidence	Plausibility of influence on health and well-being
Change in cardiovascular activity	Sufficient evidence	Plausible
Increased average motility (motility)	Sufficient evidence	Plausible
Changes in duration of various stages of sleep, in sleep structure, fragmentation of sleep	Sufficient evidence	Empirical data
Prolongation of the sleep inception period, difficulty getting to sleep	Sufficient evidence	Plausible
Changes in (stress) hormone levels	Limited evidence, plausible	Plausible
Immune functions	Insufficient evidence	-
Waking up in the night and/or too early in the morning	Sufficient evidence	Empirical data
Drowsiness/Tiredness during the day and evening	Sufficient evidence	Empirical data
Impaired cognitive performance	Limited evidence, plausible	Plausible
Increased irritability	Limited evidence, plausible	Plausible
Annoyance	Limited evidence, plausible	Plausible

5.2.2 *Consequences for health and well-being*

Road and air traffic noise

The Committee's conclusions regarding the relationships between exposure to night-time road and air traffic noise when sleeping and changes in health and well-being are summarised in Table 11. The effect parameters which the Committee has grouped under the five categories listed in the first column are specified individually and in each case an indication is given of the strength of the evidence for a causal relationship between the effect parameter in question and night-time exposure to noise when sleeping.

Table 11 Effects on health and well-being of prolonged exposure to noise during the sleep period.

	Effect parameter	Evidence
Sleep quality	Reduced perceived sleep quality	Sufficient evidence
	Difficulty getting to sleep, difficulty staying asleep	Sufficient evidence
	Sleep fragmentation, reduced sleeping time	Sufficient evidence
	Increased average motility when sleeping	Sufficient evidence
Well-being	Sleep disturbance	Sufficient evidence
	Health problems	Sufficient evidence
	Use of somnifacient drugs and sedatives	Sufficient evidence
	Increased daytime irritability	Limited evidence, plausible
Social contacts and concentration	Impaired social contacts	Limited evidence, plausible
	Impaired cognitive performance	Limited evidence, plausible
Medical conditions	Insomnia	Sufficient evidence
	Hypertension	Limited, indirect evidence, plausible
	Depression (in women)	Limited, indirect evidence, plausible
	Cardiovascular disease	Limited, indirect evidence, plausible
Reduction in life expectancy (premature mortality)[a]	Occupational accidents	Limited, indirect evidence, plausible

[a] Cardiovascular disease also involves the loss of healthy life expectancy. However, no account has been taken here of the lost life-years, since there is only limited evidence for a causal association between cardiovascular disease and exposure to night-time noise.

With regard to the long-term health and well-being implications of exposure to night-time noise during the sleep period, the Committee's overall conclusion is that there is sufficient evidence that such exposure leads to reduced sleep quality and reduced general well-being, and limited evidence that it leads to impaired social contacts and concentration, increased probability of developing medical conditions and reduced life expectancy due to fatal occupational accidents.

Rail traffic and stationary environmental sources

Epidemiological research into the effects of rail traffic noise has been confined to self-reported sleep disturbance, changes in sleep EEG and motility. At a given noise exposure, rail traffic noise is slightly less likely to induce these effects than road traffic noise or aviation noise. Although there is no direct evidence that rail traffic noise has any other effects, the Committee considers it plausible that other effects can occur, although the relationship between noise exposure and observation thresholds may not be the same as where road or air traffic noise are concerned.

No epidemiological research has been carried out into the consequences of exposure to night-time noise from stationary environmental sources. However, laboratory research has indicated that the effects of individual noise events associated with stationary environmental sources are essentially similar to the effects of events associated with road and air traffic noise. Lack of epidemiological research data prevents the Committee from drawing any definitive conclusions regarding the effects of continuous noise from stationary environmental sources.

Neighbourhood noise and noise from neighbours

Inventory research in the Netherlands indicates that sleep disturbance attributable to the most annoying forms of neighbourhood noise and noise from neighbours (contact noise and human noises in the environment) is on a similar scale to disturbance attributable to the most annoying sources of road traffic noise (mopeds and passenger cars). It is reasonable to assume that chronic sleep disturbance is in the long term liable to have consequences for health and well-being. The sound pressure level and other noise characteristics are liable to determine the nature of the influence to some extent, but certain other factors play a more prominent role than is the case with traffic noise. These factors include appreciation of the noise and of the party responsible for the noise, as well as the hearer's personal circumstances. However, scientific understanding of the relative importance of and interaction between acoustic and non-acoustic factors is not sufficient for the Committee to draw any definitive conclusions regarding the relationship between, on the one hand, exposure to night-time neighbourhood noise and noise from neighbours and, on the other, health and well-being.

5.3 Public health perspective

Question 2: How do such effects compare with other effects on health, in terms of seriousness and magnitude?

The Committee assumes that what the State Secretary is interested in is the magnitude of the effects within the Dutch population. The Committee has estimated the consequences of exposure to night-time traffic noise on the health and well-being of the Dutch population in terms of self-reported high sleep disturbance and insomnia. The Committee's estimates are based on the cumulative noise exposure associated with road, rail and air traffic in 2003 (Annex G). Because the calculations inevitably involve considerable uncertainty, the results should be regarded as merely indicative.

The number of adults in the Netherlands experiencing high sleep disturbance due to traffic noise in 2003 has been estimated at between a hundred thousand and a million. The increase in the number of adults suffering from insomnia attributable to exposure to night-time traffic noise is put at between ten thousand and a hundred thousand. The number of people suffering from insomnia caused by traffic noise is 2 per cent of the people with high sleep disturbance.

For the year 2000, the RIVM has estimated separate *Lnight* values for the noise exposures attributable to road traffic, rail traffic and air traffic[15]. On the basis of this data, the Committee has calculated that the number of adults in the Netherlands experiencing self-reported high sleep disturbance due to noise from each of these three types of traffic in that year was between a hundred thousand and one million. The increase in the number of people suffering insomnia attributable to road traffic noise and rail traffic noise is in each case estimated at between one thousand and ten thousand, while the corresponding figure for aviation noise in the general vicinity of Schiphol Airport is between a hundred and a thousand people.

In recent years, there has been considerable focus on quantifying the collective disease burden attributable to environmental factors. One initiative in this area has been the introduction of the DALY as a unit of measurement. In response to questions posed by the State Secretary for Housing, Spatial Planning and the Environment, the Health Council is to prepare a separate advisory report on the issues associated with the use of DALYs. On the basis of information from a thesis by De Hollander and noise data provided by the RIVM (see Annex G), the Committee concludes that the disease burden associated with high sleep disturbance by night-time traffic noise in the Netherlands is several tens of thousands of DALYs. The corresponding figure for insomnia is certainly considerably lower. Although these estimates involve considerable uncertainty, they would appear to indicate that, through its influence on sleep, night-time traffic noise accounts for an important part of the overall effect that the physical environment has on public health.

By quantifying effects in DALYs, the effects of night-time traffic noise on health and well-being can be compared with the effects of other physical environmental factors. However, the Committee wishes to emphasise that a cautious approach should be taken, since there is considerable uncertainly about many of the estimates.

5.4 Risk groups

Question 3: Is it necessary to take special account of any population groups that are at particular risk?

As indicated in Chapter 3, the consequences of a given level of exposure to night-time noise when sleeping vary from person to person. The question therefore arises, is it possible to identify certain groups that are at increased risk? The Committee believes that there are some population groups whose health and well-being are more likely to be affected than others. This belief is based on extrapolations from what is known about sleep disorders and sleeping problems as they generally occur in the population at large, since very little of the research that has been done into the effects of night-time noise exposure has shed light on the risk factors affecting particular groups.

Although the strength of the evidence found by the Committee is limited, it does appear that people with cardiovascular problems, people who regard themselves as particularly sensitive to noise, and children may all be particularly sensitive to the acute cardiovascular effects of exposure to night-time noise. Because of the shortage of research data on children, it is not possible to say with confidence whether children are more sensitive than adults to other acute biological effects.

Where effects over the course of a night are concerned, people who suffer from insomnia constitute a risk group. People who during the sleep latency period worry about environmental noise need longer to get to sleep and perceive the quality of their sleep to be diminished.

Although there is no direct evidence, the Committee believes that adults who suffer from insomnia or another sleep disorder or who have another sleeping problem that causes them to wake up frequently in the night are more likely than 'sound sleepers' to suffer annoyance due to night-time noise reaching their bedrooms. The Committee also considers it plausible that there is an increased risk that the health and well-being of the following groups of adults will be adversely affected by exposure to night-time noise: older people; pregnant women and women who were pregnant within roughly the last year; people who work night shifts; people affected by physical pain, dementia, depression, hypertension, cardiovascular disease or respiratory illness. No research has been carried out into the relative risk of exposure to night-time noise having adverse consequences for the health and well-being of children.

5.5 Protection against night-time noise

Question 4: In view of the effects referred to, would it be advisable to introduce special rules, similar to those contained in Directive 2002/49 and the Aviation Act, for night-time noise from sources other than air traffic?

The Committee has been able, in its answers questions 1 to 3 (concerning the influence of noise on health), to comment regarding the influence of road and air traffic noise, and to a very limited extent regarding the influence of rail traffic noise and industrial noise, but has not been able to comment regarding the influence of noise from stationary sources, neighbourhood noise or noise from neighbours. Nothing can be said regarding noise from the latter group of sources in answer to question 4 either.

5.5.1 *Two noise indexes*

There is no decisive medical reason why road traffic, rail traffic or industrial activities should be treated differently to air traffic in the context of night-time noise regulation. In its 1997 advisory report *Assessing Noise Exposure for Public Health Purposes*, the Health Council put forward a system of two noise indexes for use in protection of the general public against traffic noise and industrial noise in the domestic environment[8]. The Committee sees no reason to depart from its predecessor's recommendations. As indicated in the 1997 report, an index of exposure to noise over a twenty-four-hour period needs to reflect general noise-related annoyance, while an index of exposure to night-time noise should be related to sleep disturbance. The desirability of a two-index system is emphasised by the summary given in Chapter 3: the effect mechanisms of and consequences of exposure to night-time noise differ at least in part from those associated with general noise-related annoyance.

The approach currently recommended by the European Union involves the application of the noise indexes *Lden* and *Lnight* (see section 2.2). In essence, this approach closely matches that put forward by the Health Council's 1997 report[8]. Again, one might ask whether it would not be sufficient to work with a single index, *Lden*, for all sources of noise. After all, *Lden* does make allowance for night-time noise, even attaching an additional weighting factor to nocturnal values. Furthermore, the regulation of sound pressure levels on the basis of *Lden* would imply limiting *Lnight* to a value 5 dB(A) or more lower than *Lden**. However, by using a two-index system, one can apply separate criteria to general noise-related annoyance and sleep disturbance, each tailored to the effects in question. This makes for more transparent regulation and, particularly in situations where high values of *Lden* are permitted, to more effective protection**.

5.5.2 Shortcomings of the index for night-time noise

Although, as indicated above, the Committee favours *Lnight* as the index for night-time noise, this expression does have certain shortcomings.

If exposure to noise is the decisive factor influencing sleep, then the noise exposure in a person's bedroom is the variable that is most closely related to the effects of exposure. A number of examples are given in Chapter 3 to illustrate this point. Although the Building Decree[14] makes certain requirements regarding the noise-attenuating properties of the walls of new dwellings, and thus makes indirect requirements regarding the indoor noise exposure, the rules do not apply to existing homes. Consequently, at a given outdoor noise exposure, there is considerable variation in the noise exposures that people actually experience in their bedrooms. The picture is further complicated by differences in people's attitude to bedroom ventilation. Hence, the actual noise exposure and the magnitude and seriousness of the associated effects can vary substantially at a given *Lnight* value.

It is also important to recognise that the nation's sleeping times vary sharply, and that most people – especially younger people – have a different sleeping pattern at the weekend from the one they follow during the week. It is estimated that approximately 15 per cent of adults in the Netherlands go to sleep before 11pm, and 50 per cent sleep beyond 7am. Therefore, because *Lnight* relates to the period from 11pm to 7am, it by no means covers the sleeping times of the entire population. Hence, no requirement based on *Lnight* can ever provide full protection against sleep disturbance.

Despite the shortcomings highlighted here, the Committee does not advocate the use of an alternative index, because it is unrealistic to suppose that any regulatory method could address every conceivable factor. Furthermore, it is the Committee's view that a regulatory system based on the use of *Lnight* (in addition to *Lden*) can provide considerable protection against exposure to noise when sleeping. Just how effective such a regulatory system actually is will obviously depend on the *Lnight*-based standards and limits that are defined.

* In the most extreme case, where all noise occurs between 11pm and 7am, *Lden* would be 5 dB(A) higher than *Lnight*. (*Lnight* = x, *Lden* = 10*lg[8/24*10**((x+10)/10)] = x + 5 (dB(A)). Under all other circumstances, *Lnight* would be more than 5 dB(A) lower than *Lden*.

** Such as additional acoustic insulation for bedrooms.

5.6 Indexes for night-time noise

Question 5: If so, is it sufficient for such rules to be based on *Lnight*, or are additional indexes of exposure required, with a view to regulating impulse-like noises and situations involving relatively infrequent but high-intensity noise events?

This question may be divided into the following two elements:

- Is *Lnight* an adequate sole exposure index for noise with no special characteristics?
- Should any additional indexes be used for the regulation of noise with special characteristics or in special situations?

The Committee's answers are based upon the deliberations set out in, respectively, section 4.1 and section 4.2.

5.6.1 *Lnight as an index of exposure*

The question is, would protection be enhanced by regulating not only *Lnight* values, but also individual noise events? One might, for example, impose a *maximum sound pressure level* for a noise event or limit the *number of* noise events per night. As indicated in section 4.1, the Committee considers it inappropriate to impose a maximum sound pressure level. The reason being that, for a given *Lnight* value, situations characterised by numerous events with relatively low *SEL* or *LAmax* values are generally more likely to be problematic than situations involving smaller numbers of events with higher *SEL* or *LAmax* values.

The *more* noise events a person is exposed to per night, the greater the chance is that he or she will happen to hear one of the noises after waking up 'spontaneously', and then have trouble getting back to sleep. This may help to explain the prevalence of sleep disturbance, and could justify limiting the number of noise events per night. As indicated in subsection 3.2.4, in an extreme case it is theoretically possible that someone could hear a passing car, plane or train car ten times in the night without the associated noise being the cause of the person waking up. The Committee believes that calculations could theoretically be made regarding these matters, but does not believe that there is presently enough detailed data available for anything better than rough estimates.

5.6.2 *Adjustment of Lnight for special noises*

As indicated in section 4.2, the Committee considers the following 'special' noises to be of particular relevance for the night-time domestic environment:

- Noise with lower-frequency components (such as engine noises with deep components)
- Low-frequency noise (such as noise from transformers)
- Tonal noise (such as sirens)
- Impulse noise (such as the noise from low-flying military jets or gunshot noises)
- Industrial noise
- Noise involving sporadic high *LAmax* or *SEL* values.

Little information is available regarding the influence on sleep of exposure to noise with special characteristics. Nevertheless, the Committee believes that in some cases the effects of exposure to such noise are greater than the effects of exposure to 'ordinary' traffic noise. With regard to noise with low-frequency components, low-frequency noise, tonal noise, and impulse noise, the Committee endorses the conclusions set out in the Health Council's 1997 report *Assessing Noise Exposure for Public Health Purposes*. Hence, adjustment factors are proposed for use in the regulation of noise with low-frequency components, tonal noise and impulse noise, but it has not been possible to define an *Lnight* adjustment factor for low-frequency noise. The values of the proposed factors are given in Annex F. Where noise from industrial activities is concerned, the Committee takes the view that research published since 1997 has demonstrated that no adjustment factors other than those referred to above are required.

It is not clear whether very loud sporadic noise events have any special implications for sleep. The Committee anticipates that the probability of such events having an *acute* effect (of whatever kind) is greater than the defined relationships might suggest, since the hearer will necessarily be unused to noise events of the kind involved, and anxiety is very likely to play a role. A single event of this kind can also have consequences for the hearer's quality of sleep for the rest of the night and on subsequent nights. However, the Committee does not have sufficient research data at its disposal to develop these assumptions more fully. In questionnaire-based studies of self-reported long-term effects (such as awakening, diminished sleep quality and night-time noise-related annoyance), a one-year assessment period is typically used. The Committee is not aware of any research that has looked at the specific effects that noise events with relatively very high *SEL* or *LAmax* values have on such self-reported parameters. The Committee cannot therefore make any scientifically justified statement about such effects.

5.7 Protection measures

Question 6: Could the public be protected by the use of a. performance-related or design requirements for residential buildings, b. personal protective gear, c. rules regarding sound pressure levels outside buildings, d. rules relating to vehicles and machinery, or e. a combination of these measures?

The Committee notes that the State Secretary does not mention publicity and dialogue as means of achieving protection. The Committee has nevertheless included publicity and dialogue in the response below, along with the measures that are referred to in the question. In its response, the Committee adheres to the standard strategy used in environmental management and occupational health and safety. This strategy involves first seeking to address a problem at source (which may entail reducing the number of sources), then exploring ways of intervening in the transfer from source to 'recipient', and considering recipient-oriented measures only as a final resort.

5.7.1 *Source-oriented measures*

The regulation of noise emissions from transport and industrial sources is a matter that has received increasing international attention. The ICAO* convention, for example, makes various provisions regarding noise production by aircraft[123,124]. Newer aircraft that meet the requirements of Chapter 3 are significantly quieter than those that merely comply with Chapter 2**. Measures designed to reduce noise from cars and aircraft can sometimes be undesirable in the context of reducing exhaust-related atmospheric pollution[38]. Furthermore, it is not sufficient to merely impose design requirements on vehicles and other machinery: maintenance and monitoring are also necessary in order to ensure that noise emissions are kept down in practice (buses are liable to become noisy with age, for example, while mopeds and scooters are sometimes 'hotted up' by their owners). In some cases, much more is technically possible than the regulations require, and social preferences (such as 4-wheel drive vehicles and wide tyres) often negate the 'gains' achievable through technological advancement.

5.7.2 *Intervention in the transfer from source to recipient*

Possible ways of controlling the transfer of noise from source to sleeper come under a number of headings: town planning measures (orientation of buildings and bedrooms, separation distances between noise sources and dwellings), acoustic screens and embankments, covers (tunnels) and domestic acoustic insulation. The Committee has restricted its detailed response to consideration of the last option.

An overview of published research into the effectiveness of domestic acoustic insulation as a means of controlling the influence of night-time noise is presented in section 4.3. Considering the large sums spent on fitting extra acoustic insulation to homes, the Committee finds it surprising that so little research has been done into the

* ICAO stands for International Civil Aviation Organization.

** Chapters 2 and 3 of Annex 16, Volume I of the ICAO convention.

effectiveness and efficiency of such modifications. As things stand, it is not possible to say more than that fitting acoustic insulation reduces sleep disturbance by night-time noise. It is clear that if steps are not also taken to enable householders to keep their bedrooms cool in hot weather, the benefit of acoustically efficient glazing is liable to be offset in the summer by people opening their windows.

Inventory research has revealed that many Dutch people are bothered by noise from their neighbours. The Committee regards this as indicative of shortcomings in the existing standards of inter-dwelling acoustic insulation. Since people are less tolerant of the noise their neighbours make at night-time than of their neighbours' evening or daytime noise, it may be assumed that much of the annoyance associated with noise from neighbours relates to the influence of such noise on sleep.

5.7.3 *Recipient-oriented measures*

It is possible for people to protect themselves against the effects of night-time noise by inserting ear plugs* of various kinds (plastic foam, moulded plugs, preformed and pre-sized plugs and mouldable plugs) into the auditory duct. Properly fitted, ear plugs can reduce lower-frequency traffic noises by 15 dB(A) or more. Some types of plug are soft and therefore not at all uncomfortable to use while sleeping.

Personal hearing protection can provide a solution only in specific cases. The Committee does not consider hearing protection appropriate for the general prevention of noise-related problems in the population at large. Not only would it be impossible to make sure that people actually used their ear plugs in the privacy of their own homes, but wearers would in many cases be unable or less readily able to hear important sounds, such their partners, children, alarm clocks, intruders or sirens.

5.7.4 *Publicity and dialogue*

Where environmental factors that have a demonstrable adverse effect on the quality of the human environment are concerned, it is certainly the case that publicity and dialogue are necessary to ensure that effective and efficient action is taken to keep such effects within acceptable bounds. Publicity involves the unilateral provision of information to the private citizen by the government or the party responsible for the environmental factor concerned. Dialogue is a bilateral communication process that often begins with listening to the private citizen[38,125,126].

In relation to the effects of noise on sleep, publicity and dialogue have two important aspects: the provision of information about the consequences of exposure to noise

* Headphone-style hearing protectors are not practical for use at night, and ordinary cotton wool offer no protection[123].

and the two-way exchange of information aimed at the reconciliation of scientific data with the experiences of the private citizen, as well as information about the advantages and disadvantages of source-oriented, transfer-oriented and recipient-oriented measures.

5.7.5 *The combination of various types of measures*

From what has been said in the preceding subsections, it will be clear that there is very little research data available on the effectiveness and efficiency of protection measures. It is not therefore possible to give evidence-based guidance on the form that any protection regime should take. Nevertheless, the Committee considers it inevitable that the control of noise-related problems will necessitate the combination of source-oriented, transfer-oriented and in some cases recipient-oriented measures. This is because measures of all types are difficult to realise, irrespective of how effective or efficient they may be. In practice, cost issues come into play as well ('Who pays?' and 'Who is best able to afford the cost?'), as do questions regarding the quality of the planning of the human environment. Also of relevance in this context is increasing mobility, which tends to negate the benefits of technological advancement to some extent.

Finally, the Committee wishes to highlight the fact that noise-related sleep disturbance is not an isolated issue. Night-time noise almost always occurs in tandem with daytime noise. Not only do some people sleep during the day (by choice or out of necessity), but also exposure to noise has health implications at any time. The environmental noise issue is part of the wider debate on the quality of the human environment. The quality of the human environment and its (positive and negative) influences on health and well-being are determined by numerous factors (see Chapter 2), some being characteristics of the physical environment and some being of a social or behavioural nature. However complicated it may be to do so, this wider context should be taken into account. This underlines once more the importance of dialogue.

5.8 Recommendations for further research

In his letter, the State Secretary did not enquire regarding problems relating to research into sleep, health and noise. While the Committee does not therefore see the definition of a research programme as part of its remit, it is felt appropriate that this advisory report should be concluded with a summary of the most important gaps in knowledge previously highlighted.

The *2002 Actieprogramma gezondheid en milieu, uitwerking van een beleidsversterking* (Environment and Health Action Programme, the Practical Reinforcement of Policy) concluded that, in the Netherlands as elsewhere, research into the relationship between environment and health needed fresh impetus. The Action Programme identified a number of themes concerning which more scientific knowledge was required, and placed the themes in a general order of priority. In this context, the Health Council was asked to advise on an environment and health research programme[38]. In the resulting advisory report, the Council highlighted the main gaps in knowledge regarding the influence that environmental factors have on health, and made recommendations regarding the research and reporting activities necessary to close those gaps. One of the themes addressed was exposure to noise. The report concluded that, in terms of their health implications, the themes exterior atmosphere, noise and indoor environment were of particular importance. The gaps identified in knowledge regarding the consequences of exposure to night-time noise were the effect that the level of insulation and the position of a person's bedroom have on the relationship between night-time noise exposure and consequences for health and well-being, the effectiveness of acoustic insulation on noise exposure and sleep disturbance, and the relationship between night-time road traffic noise exposure and effects on sleep and health. The present Committee feels it appropriate to elaborate on the research requirements referred to in the earlier report by highlighting the need for the following:

- Research into the long-term consequences of exposure for health and well-being, distinguishing between the effects associated with the noise exposure when sleeping, and those associated with the noise exposure during the daytime and evening. Most studies into effects such as hypertension, ischemic cardiovascular disease in adults and reduced cognitive performance by children have concentrated on relationships with daytime (and evening) noise exposure. However, recent research suggests that night-time noise and its effects on sleep and when sleeping play a much more significant role[82,95,128]. Knowledge regarding such matters is particularly important for the formulation of intervention policies.
- Research into the effects of night-time noise on children. Almost nothing is known about this subject. In the near future (summer 2004), the findings of the European research project *Road traffic and Aircraft Noise exposure and children's Cognition and Health* (RANCH) are to be published. RANCH is a field study looking at the relationship between, on the one hand, exposure to road and air traffic noise in the domestic environment and at school and, on the other, cognitive performance, blood pressure, general health, annoyance and sleep disturbance. It is not designed to shed light on the biological consequences in children of exposure to noise when sleeping. It is, however, expected to yield information about children's self-reported responses to night-time exposure to noise.
- Questionnaire-based or field research into insomnia caused by exposure to night-time noise, making use of clinical concepts. Such research would serve to bring together medical and environmental health expertise relating to insomnia.

- Research into the efficiency and effectiveness of acoustic insulation between dwellings and on or in exterior walls. Also of importance in this context is the position of the bedroom relative to the noise source and the influence of people's behaviour on the efficiency and effectiveness of insulation.
- Research into the effects of neighbourhood noise and noise from neighbours. Such research should be placed within the wider setting of research into the quality of the human environment.

Where the initiation of research is concerned, it is desirable to seek international alignment, as recommended by the Health Council in its report *Environmental Health: Research for Policy*.

References

1 Gezondheidsraad. Grote luchthavens en Gezondheid. Den Haag: Gezondheidsraad; 1999; Rapport 1999/14.

2 Gezondheidsraad Commissie Noise and Health. Geluid en Gezondheid. Rijswijk: Gezondheidsraad; 1994; Rapport 1994/15.

3 EU. Directive of the European Parliament and of the Council relating to the assessment and management of environmental noise. Joint text approved by the Conciliation Committee provided for in Article 251(4) of the EC Treaty. Brussel: The European Parliament, The Council; 8-4-2002; Document 2000/0194 (COD), PE-CONS 3611/02.

4 EU WG2. Position Paper on dose response relationships between transportation noise and annoyance. 20-2-2002. Internet: www.europe.eu.int/com/environment/noise/noise expert network.pdf.

5 Europese Commissie. Advies van de Commissie overeenkomstig artikel 251, lid 2, derde alinea, onder c) van het EG-Verdrag, over de amendementen van het Europees Parlement op het gemeenschappelijke standpunt van de Raad inzake het voorstel voor een Richtlijn van het Europees Parlement en de Raad inzake de evaluatie en de beheersing van omgevingslawaai, houdende Wijziging van het Voorstel van de Commissie, overeenkomstig artikel 250, lid 2, van het EG-Verdrag. Brussel: Europese Commissie; 24-10-2001; Document COM(2001) 621 definitief. Internet: http://europa.eu.int/eur-lex/nl/com/pdf/2001/nl_501PC0621.pdf.

6 Gezondheidsraad: Commissie Vliegtuiglawaai en slaap. Vliegtuiglawaai en slaap. Den Haag: Gezondheidsraad; 1991; Rapport 1991/05.

7 Gezondheidsraad: Geluidhinder. Rapport Gezondheidsraad Commissie Geluidhinder en Lawaaaibestrijding. Den Haag: Gezondheidsraad; 1971; Rapport 1971/24.

8 Gezondheidsraad: Uniforme geluiddosismaat. Omgevingslawaai beoordelen. Rijswijk: Gezondheidsraad; 1997; Rapport 1997/23.

9 Jong de RG, Steenbekkers JHM, Vos H. Hinder en andere zelf-gerapporteerde effecten van milieuverontreiniging in Nederland. Inventarisatie verstoringen 1998. Leiden: TNO-PG; 2000; Rapport PG/VGZ/2000.012.

10 Matser JJ, Eisses AR, Minnen E. Akoestisch onderzoek vrachtwagenbewegingen. Delft: TNO TPD, TU Delft; 1995; TPD-HAG-RPT-950085.

11 Jong RGd. Beoordeling van piekniveaus met betrekking tot vrachtverkeer. Leiden: TNO Preventie en Gezondheid; 1996.

12 Passchier-Vermeer W, Vos H, Steenbekkers JHM, van der Ploeg FD, Groothuis-Oudshoorn K. Sleep disturbance and aircraft noise. Exposure-effect relationships. Leiden: TNO-PG; 2002; Report nr 2002.027.

13 Passchier-Vermeer W, Miedema HME, Vos H, Steenbekkers JHM, Houthuijs D, Reijneveld SA. Slaapverstoring door vliegtuiggeluid. Delft: TNO-Inro; 2002; TNO Report nr 2002.028, RIVM report nr 441520019, 2002.

14 Ministerie van VROM. Bouwbesluit. 2004; http://www.vrom.nl/Docs/wonen/bouwbesluitSTB.pdf.; geraadpleegd 04-01-2004.

15 Rijksinstituut voor Volksgezondheid en Milieu. Ontwikkelingen Nachtelijke Geluidsbelastingen in Nederland, herziene versie 24-05-2004. Bilthoven: RIVM; 8-4-2002; RIVM briefrapport M/715120/01/BB-3 van 8 April 2002.

16 Goossen CM, Langers F. Alterra, eds. Geluidbelasting in het Centraal Veluws Natuurgebied; Een quick scan van de geluidbelasting in het Centraal Veluws Natuurgebied in zijn geheel en in afzonderlijke delen die belangrijk zijn voor recreatie. Wageningen: 2003; 798/JATW/08-2003. Internet: http://www.alterra.nl.

17 Hofman WF. Vliegtuiglawaai, slaap en gezondheid. Achtergrondstudie in opdracht van de Gezondheidsraad. Den Haag: Gezondheidsraad; 1991; Report A91/1.

18 Principles and Practise of Sleep Medicine. Kryger M, Roth T, Dement WC, editors, eds. Principles and Practise of Sleep Medicine. Philadelphia: W.B.SaundersCO, 2000.

19 Visser P, Hofman WF. Slapen en dromen, theorie en klinische praktijk. Alphen aan den Rijn: Samson Stafleu, 1986.

20 Hennevin E, Hars B, Maho C, Bloch V. Processing of lerarned information in paradoxical sleep: relevance for memory. Behavioural Brain Research 1995; 96:125-135.

21 Karni A, Sagi D. The time course of learning a visual skill. Nature 1993; 365: 250-252.

22 Karni A, Tanne D, Rubenstein BS, Askenasy JJM, Sagi D. Dependence on REM-sleep of overnight improvement of a perceptual skill. Science 1994; 265: 679-682.

23 Stickgold R, James L, Hobson JA. Visual discrimination learning requires sleep after training. Nat Neurosci 2000; 3(12):1237-1238.

24 Stickgold R, Whidbee D, Schirmer B, Patel V, Hobson JA. Visual discrimination task improvement: A multi-step process occurring during sleep. J Cogn Neurosci 2000; 12(2): 246-254.

25 Stickgold R. Watching the sleeping brain watch us - sensory processing during sleep. Trends Neurosci 2001; 24(6): 307-309.

26 Stickgold R, Malia A, Fosse R, Propper R, Hobson JA. Brain-mind states: I. Longitudinal field study of sleep/wake factors influencing mentation report length. Sleep 2001; 24(2): 171-179.

27 Stickgold R, Hobson JA, Fosse R, Fosse M. Sleep, learning, and dreams: off-line memory reprocessing. Science 2001; 294(5544): 1052-1057.

28 Stickgold R. Finding the Stuff that Dreams are Made Of. ScientificWorldJournal 2001; 1(5): 211-212.

29 Stickgold R. Toward a cognitive neuroscience of sleep. Sleep Med Rev 2001; 5(6): 417-421.

30 Stickgold R, Fosse R, Walker MP. Linking brain and behavior in sleep-dependent learning and memory consolidation. Proc Natl Acad Sci U S A 2002; 99(26): 16519-16521.

31 Stickgold R. EMDR: a putative neurobiological mechanism of action. J Clin Psychol 2002; 58(1): 61-75.

32 Hollander de AEM. Assessing and evaluating the health impact of environmental exposures. Deaths, DALY's or Dollars. Universiteit van Utrecht, 2004.

33 Rijksinstituut voor Volksgezondheid en Milieu. van Oers JAM, eds. Gezondheid op koers? Volksgezondheid Toekomst Verkenning 2002. Bilthoven: Rijksinstituut voor Volksgezondheid en Milieu; 2002; RIVM-rapportnummer 270551001. Internet: http://www.rivm.nl/bibliotheek/rapporten/270551001.pdf , geraadpleegd op 19-6-2003.

34 Rijksinstituut voor Volksgezondheid en Milieu. Milieubalans 2003. Het Nederlandse milieu verklaard. Alphen aan de Rijn: Samson H.D. Tjeenk Willink bv; 2003., geraadpleegd op 18-4-2003.

35 Rijksinstituut voor Volksgezondheid en Milieu. Milieubalans 2004. Alphen aan de Rijn: Samson H.D. Tjeenk Willink bv; 2004.

36 Murray JC. Quantifying the burden of desease: the technical basis for disability-adjusted life years. Bull World Health Organ 1994; 72(3): 429-445.

37 Stolk E, Poley M, Brouwer W, van Busschbach J. Proeftoetsing van het iMTA-model. Identificatie van aandoeningen met minimale ziektelast en proeftoetsing van de voor ziektelast gecorrigeerde doelmatigheidstoets. In: Toenders WGM, editor. Vervolgonderzoek breedte geneesmiddelenpakket. Amstelveen: College voor zorgverzekeringen, 2002.

38 Gezondheidsraad. Gezondheid en milieu: Kennis voor beleid. Den Haag: Gezondheidsraad; 14-10-2003; Publicatie nr 2003/20.

39 Campen van C, Hessing-Wagner J. Gezondheid en zorg. In: Roes T, editor. De sociale staat van Nederland 2003. Den Haag: Sociaal en Cultureel Planbureau, 2003: 107-128.

40 Gezondheidsraad: Commissie Risicomaten en risicobeoordeling. Niet alle risico's zijn gelijk. Den Haag: Gezondheidsraad; 1995; Rapport 1995/06.

41 IARC IAfRoC, 12-6-1997. Preamble to the IARC Monographs. Internet: http://193 51 164 11/monoeval/preamble html, geraadpleegd op 1-11-2003 2004.

42 Wiedemann PM, Mertens J, Schütz H, Hennings W, Kallfass M. Risikopotenziale elektromagnetischer Felder: Bewertungsansätze und Vorsorgeoptionen. Band 1. Endbericht für das Bayerische Staatsministerium für Landesentwicklung und Umweltfragen. Jülich: Forschungszentrum Jülich GmbH Programmgruppe Mensch, Umwelt, Technik; 2001; D 52425 2001-5. Internet: Internet: http://www.emf-risiko.de/pdf/heft_81.pdf, geraadpleegd op 3-3-2004.

43 Hill AB. The environment and disease: association or causation? Proceedings R Soc Med 1965; 58: 295-300.

44 Weed DL. Interpreting epidemiological evidence: how meta-analysis and causal inference methods are related. Int J Epidemiol 2000; 29(3): 387-390.

45 Weed DL. Underdetermination and Incommensurability in Contemporary Epidemiology. Kennedy Institute of Ethics Journal 2004; 7(2): 107-127.

46 Thiessen GJ. Habituation of behavioural awakening and EEG measures of response to noise. In: Proceedings ICBEN 1980. 10. Rockville, Maryland: 1980: 397-400.

47 Maschke C, Harder J, Ising H, Hecht K, Thierfelder W. Stress hormone changes in persons exposed to simulated night noise. Noise & Health 2002; 5(17): 35-45.

48 Pearsons KS, Barber DS, Tabachnick BG, Fidell S. Predicting noise-induced sleep disturbance. J Acoust Soc Am 1995; 97:331-338.

49 Fidell S, Pearsons K, Tabachnick B, Howe R, Silvati L, Barber DS. Field study of noise-induced sleep disturbance. J Acoust Soc Am 1995; 98(2 Pt 1): 1025-1033.

50 Fidell S, Pearsons K, Tabachnick BG, Hower R. Effects of sleep disturbance of changes in aircraft noise near three airports. J Acoust Soc Am 2000; 107(5:1): 2535-2547.

51 Ollerhead JB, Jones CJ, Cadoux RE. Report of field study on aircraft noise and sleep disturbance. London: Civil Aviation Authority; 1992.

52 Passchier-Vermeer W. Night-time noise events and awakening. Delft: TNO Inro; 2003; 2003.023.

53 Carter NL, Job RFS, editors. Awakening and motility effects of aircraft noise. Proceedings of the 7th International Congress on Noise as a Public Health Problem; Sydney: University of Sydney, 1998.

54 Horne JA, Pankhurst FL, Reyner LA, Hume KI, Diamond ID. A field of sleep disturbance: effects of aircraft noise and other factors on 5.742 nights of actimetrically monitored sleep in a large subject sample. Sleep 1994; 17: 146-159.

55 Busby K, Pivik RT. Auditory arousal thresholds during sleep in hyperkinetic children. Sleep 1985; 8(4): 332-341.

56 Eberhardt JL. Berglund B, Lindvall L, eds. The disturbance by road traffic noise on the sleep of prepubertal children as studied in the home. Stockholm: Building Research Sweden; 1988; Proceedings of Noise as a public health problem.

57 Lukas JS. Effects of aircraft noise on human sleep. Am Ind Hyg Assoc J 1972; 33(5):298-303.

58 Hofman WF, Kumar A, Tulen JHM. Cardiac reactivity to traffic noise during sleep in man. J Sound Vib 1995; 179(4): 577-589.

59 Griefahn B, Gros E. Noise and sleep at home, a field study on primary and after-effects. J Sound Vib 1986; 105(3): 373-383.

60 Griefahn B, Schuemer-Kohrs A, Schuemer R, Moehler U, Mehnert P. Physiological, subjective, and behavioural responses during sleep to noise from rail and road traffic. Noise Health 2000; 3(9): 59-71.

61 Relationship between subjective and physiological assessments of noise-disturbed sleep.: 1973.

62 Muzet A. Habituation and age differences of cariovascular responses to noise during sleep. Sleep 1981; 212-215.

63 Spreng M. Central nervous system activation by noise. Noise & Health 2000; 49-57.

64 Di Nisi J, Muzet A, Ehrhart J, Libert JP. Comparison of cardiovascular responses to noise during waking and sleeping in humans. Sleep 1990; 13(2): 108-120.

65 Griefahn B. Die Wirkung von Schiessgeräuschen auf die Herzfrequenz im Schlaf. Z Lärmbekämpfung 1989; 36: 61-65.

66 Öhrström E, Rylander R, Björkman M. Effects of night time road traffic noise - An overview of laboratory and field studies on noise dose and subjective sensitivity. J Sound Vib 1988; 127(3): 441-448.

67 Carter NL, Henderson R, Lal S, Hart M, Booth S, Hunyor S. Cardiovascular and Autonomic responses to environmental noise during sleep in night shift workers. Sleep 2002; 25(4): 457-464.

68 Smezcuk B. Studies on the influence of acoustic stimuli on respiratory movements. Polish Med J 1967; 7: 1090-1100.

69 Franssen EAM, Kwekkeboom JMI. Effecten van geluid door wegverkeer op de slaap. Een systematisch review van studies in de woonomgeving. Bilthoven: RIVM; 2003; Report 715120010/2003.

70 Jurriëns AA, Griefahn B, Kumar A, Vallet M, Wilkinson RT. An essay in european research collaboration: common results from the project on traffic noise and sleep in the home. In: Proceedings of the 4th International Congress on Noise as a Public Health Problem. Torino: 1983: 929-937.

71 Kumar A, Tulen JHM, Hofman WF, van Diest R, Jurriëns AA. Does double-glazing reduce sleep disturbance during sleep? In: Proceedings of the 4th International Congress on Noise as a Public Health Problem. Torino: 1983: 939-949.

72 Vallet M, Gagneux JM, Blanchet V. Long term sleep disturbance due to traffic noise. J Sound Vib 1983; 90: 173-191.

73 Wilkinson RT, Campbell KT. Effects of traffic noise on quality of sleep: assessment by EEG, subjective report, or performance next day. J Acoust Soc Am 1983; 75(2): 468-475.

74 Öhrström E. Sleep disturbance, psycho-social and medical symptoms - a pilot survey among persons exposed to high levels of road traffic noise. J Sound Vib 1989; 133(1): 117-128.

75 Öhrström E, Agge A, Björkman M. Sleep disturbances before and after reduction of road traffic noise. In: Carter NL, Job RFS, editors. Proceedings of the 7th International Congress on Noise as a Public Health Problem. Sydney: University of Sydney, 1998: 451-454.

76 Öhrström E, Svensson H. Effects of road traffic noise on sleep. In: Proceedings of the 8th International Congress on the Biological Effects of Noise ICBEN2003, 2003.

77 Griefahn B, Möhler U, Schümer R.(Hrsg). Vergleichende Untersuchung über die Lärmwirkung bei Strassen- und Schienenverkehr (Hauptbericht-Textteil, Kurzfassung, Abbildungen und Tabellen,Dokumentationsanhang). München: SGS; 1999.

78 Moehler U, Liepert M, Schümer R.(Hrsg), Griefahn B. Differences between Railway and Road Traffic Noise. J Sound Vib 2000; 231(3): 853-864.

79 Passchier-Vermeer W, Vos H, Griefahn B, Moehler U. Motility and road and rail traffic noise. Delft: TNO-Inro; 2004; TNO Report nr 2004.xxx.

80 Smith AP, Nutt D, Wilson S. Noise and insomnia: a study of community noise, sleep disturbance, noise sensitivity and subjective reports of health. Cardiff: Centre for Occupational and Health Psychology, Cardiff University; 2001. Internet: http://www.doh.gov.uk/hef/airpol/insomnia.pdf (217 pag).

81 Babisch W. Stress Hormones in the Research on Cardiovascular Effects of Noise. Noise Health 2003; 5(18): 1-11.

82 Babisch W, Fromme H, Beyer A, Ising H. Increased catecholamine levels in urine in subjects exposed to road traffic noise: the role of stress hormones in noise research. Environ Int 2001; 26(7-8): 475-481.

83 Ising H, Braun C. Acute and chronic endocrine effects of noise: Reviw of the research conducted at the Institute for Water, Soil, and Air Hygiene. Noise & Health 2000; 7: 7-24.

84 Osada Y. Tsunashima S, Yoshida K, Asano M, Ogawa S, *et al.* Experimental study on the influence of noise on sleep. Bull Inst Public Health (Tokyo) 1968; 17(3): 208-217.

85 Osada Y, Tsunashima S, Yoshida K, Asano M, Ogawa S, et al. Sleep impairment caused by short time exposure to continuous and intermittent noise. Bull Inst Public Health (Tokyo) 1969; 18: 1-9.

86 Osada Y, Tsunashima S, Yoshida K, Asano M, Ohokubo C. Effects of train and jet aircraft noise on sleep. Bull Inst Public Health (Tokyo) 1972; 21(3): 133-138.

87 Osada Y, Ogawa S, Ohokubo C, Mizunami S. Experimental study on the sleep interference by train noise. Bull Inst Public Health (Tokyo) 1974; 23(3): 171-177.

88 Born J, Fehm HL. The Neuroendocrine Recovery Function of Sleep. Noise & Health 2000; 7: 25-37.

89 Kageyama T, Kabuto M, Nitta H, Kurokawa Y, Taira K, Suzuki S *et al.* A population study on risk factors for insomnia among adult Japanese women: a possible effect of road traffic volume. Sleep 1997; 20(11): 963-971.

90 WHO. The ICD-10 classification of mental and behavioral disorders: clinical description and diagnostic guidelines. Geneva: World Healt Organization; 1992.

91 Stolk EA, Poley M, Brouwer W, Busschbach JJV. WGM.Toenders, eds. Proeftoetsing van het iMTA-model. Identificatie van aandoeningen met minimale ziektelast en proeftoetsing van de voor ziektelast gecorrigeerde doelmatigheidstoets. In Vervolgonderzoek breedte geneesmiddelenpakket. Amstelveen: College voor Zorgverzekeringen; 2002.

92 Stolk EA, Busschbach JJV. Economics and ethics in health care. Where can they meet?. In: C.Gastmans, editor. Between Technology and Humanity. Leuven: University Press, 2002: 49-66.

93 Langdon FJ, Buller IB. Road traffic noise and disturbance to sleep. J Sound Vib 1977; 50(1): 13-28.

94 Belojevic G, Jakov, Jakovljevic B. Traffic noise and sleep disturbances with regard to age. In: Carter NL, Job RFS, editors. Proceedings of the 7th International Congress on Noise as a Public Health Problem. Sydney: University of Sydney, 1998: 451-454.

95 Maschke C, Wolf U, Leitmann T. Epidemiologische Untersuchungen zum Einfluss von Lärmstress auf das Immunsystem und die Entstehung von Arteriosklerose. Berlin: Umweltbundesambt; 2003; Forschungsbericht 298 62 515 UBA-FB 000387.

96 Horne JA, Reyner LA, Pankhurst FL, Hume KI. Patterns of spontaneous and evoked body movements during sleep. Sleep 1995; 18(3): 209-211.

97 Miedema HME, Passchier-Vermeer W, Vos H. Elements for a position paper on night-time transportation noise and sleep disturbance. Delft: TNO Inro; 2003; 2002.59.

98 Miedema HME. Self-reported sleep disturbance caused by aircraft noise. Delft: TNO Inro; 2004; 2004-15.

99 Leidelmeijer K, Marsman G. Geluid van buren. Horen, hinder en sociale normen. Amsterdam: RIGO; 1997; 97/65.

100 Kranendonk F, Gerretsen E, Luxemburg van LCJ. Akoestische kwaliteit van woningen versus de beleving van burengeluid. TNO-BOUW, TUE-Bouwkunde; 1993; 93-CBO-R3185.

101 Dongen JEFv, Vos H, Luxemburg LCJv, Raijmakers TMJ. TNO PG, eds. Dosis-effect relaties voor geluid van buren. Leiden: 3-1998; 98.002.

102 Rijksinstituut voor Volksgezondheid en Milieu. Nationale Milieuverkenning 5: 2000 - 2030. Alphen aan de Rijn: Samson H.D. Tjeenk Willink bv; 2000. Internet: http://www.rivm.nl/milieu/milieubalans_verkenning/milieuverkenning/ , geraadpleegd op 18-4-2003.

103 Kageyama T, Nishikido N, Kobayashi T, Oga J, Kawashima M. Cross-sectional survey on risk factors for insomnia in Japanese female hospital nurses working rapidly rotating shift systems. J Hum Ergol (Tokyo) 2001; 30(1-2): 149-154.

104 Hollander de AEM, Melse JM, Lebret E, Kramers PG. An aggregate public health indicator to represent the impact of multiple environmental exposures. Epidemiology 1999; 10(5): 606-617.

105 Miedema HME, Passchier-Vermeer W. Beoordeling van geluidpieken in de woonomgeving. Leiden: TNO-PG; 1999; Report PG/VGZ/99.023.

106 Passchier-Vermeer W. Sleep disturbance due to nighttime aircraft noise. Leiden: 1994; Report nr 94.077.

107 Peutz & Associes. Eerste fase Inventarisatie Correctiefactor laagfrequent geluid. 2003; R 842-1.

108 ISO. Acoustics - Description, measurement and assessment of environmental noise - Part 1: Basic quantities and assessment. Geneva: International Standards Organization; 2002; ISO/FDIS 1996-1.

109 ANSI. Quantities and procedures for the description and measurement of environmental sound - Part 4: Noise assessment and prediction of long-term community response. Washington: ANSI; 1996; Draft 6b ANSI S12.9-1996-Part 4.

110 V&W en VROM. Aanpak geluid spooremplacementen. Den Haag: V&W en VROM; 22-12-2003.

111 Vos J. On the relevance of shooting-noise-induced sleep disturbance to noise zoning. In: Proceedings of the 8th International Congress on the Biological Effects of Noise ICBEN2003, 2003.

112 Miedema HME, Jong de RG, CLeij J, Steenbekkers JHM, Vos H, Oudshoorn CG. Relaties tussen geluidbelasting en hinder voor industrie- en rangeerterreinen. Delft: TNO Inro; 2002; 2002.53.

113 Miedema HME, Oudshoorn GCM. Annoyance from Transportation Noise: Relationships with Exposure Metrics DNL and DENL and Their Confidence Intervals. J Acoust Soc Am 2001; 109(4): 409-416.

114 Bitter C, Kaper JP, Pinkse WAH. Beleving geluidwerende voorzieningen in de woonsituatie langs Rijksweg 16 in Dordrecht. Leidschendam: Ministerie van Volksgezonheid en Milieuhygiëne; 1978; VL-DR-14-01.

115 Bitter C, Holst JHK, Kandelaar HAC, Schoonderbeek W. Beleving geluidwerende voorzieningen in de woonsituatie langs Rijksweg 10 in Amsterdam. Leidschendam: Ministerie van Volksgezonheid en Milieuhygiëne; 1982; VL-DR-14-02.

116 Dongen van JEF, Vos H, Miedema HME. De zelf-gerapporteerde slaapkwaliteit in geluid-geïsoleerde woningen rond Schiphol. Leiden: TNO-PG; 1995; Report PG/VGZ/95.018.

117 Dongen van JEF, Steenbekkers JHM, Miedema HME. Waardering van geluidwerende voorzieningen in woningen rond Schiphol. Evaluatie door bewoners van voorzieningen in de eerste fase van het isolatieplan voor Schiphol. Leiden: TNO-PG; 1994; Report PG/VGZ/94.084.

118 Dongen van JEF, Miedema HME. De beleving van geluidwerende voorzieningen aan woningen rond Schiphol vóór en na een beleidswijziging. Leiden: TNO-PG; 1996; Report PG/VGZ/96.026.

119 Luxemburg van LCJ. Geluidisolatie woningen nabij Amsterdam Airport Schiphol, fase 3 een "satisfier for all" benadering. Eindhoven: TNO Bouw; 1999; 99-CBO-R037 LGL/DNA.

120 Fidell S, Silvati L. An assessment of the effect of residential acoustic insulation on prevalence of annoyance in an airport community. J Acoust Soc Am 1991; 89(1): 244-247.

121 Utley WA, Buller IB, Keighley EC, Sargent JW. The effectiveness and acceptibility of measures for insulating dwellings against traffic noise. J Sound Vib 1986; 109(1): 1-18.

122 Carter NL, Job RFS, editors. Sleep disturbance reported around Kaneda U.S. airfield in the Ryukyus. Proceedings of the 7th International Congress on Noise as a Public Health Problem; Sydney: University of Sydney, 1998.

123 ICAO. Convention on International Civil Aviation, signed at Chicago, on 7 December 1944 (Chicago Convention). Montreal, Canada_: International Civial Aviation Organization; 7-12-1944. Internet: http:// www.iasl.mcgill.ca/airlaw/public.htm#chicago , geraadpleegd op 29-2-2004.

124 ICAO. Convention on International Civil Aviation, signed at Chicago, on 7 December 1944 (Chicago Convention), Annex 16, volumes I and II, Environmental Protection. Montreal, Canada_: International Civial Aviation Organization; 1971., geraadpleegd op 29-2-2004.

125 Gezondheidsraad. Ongerustheid over lokale milieufactoren; risicocommunicatie, blootstellingsbeoordeling en clusteronderzoek. Den Haag: Gezondheidsraad; 3-4-2001; Publicatie nr 2001/10.

126 Minister van Volkshuisvesting Ruimtelijke Ordening en Milieubeheer. Gezondheid en milieu (Actieprogramma gezondheid en milieu. Uitwerking van een beleidsversterking). Den Haag: SDU Uitgevers; 25-4-2002; Tweede Kamer, Vergaderjaar 2001-2002, 28 089, nr. 2.

127 Minister van Volkshuisvesting ROeM. Gezondheid en Milieu (Actieprogramma gezondheid en milieu. Uitwerking van een beleidsversterking). Den Haag: SDU Uitgevers; 2002; Tweede Kamer, Vergaderjaar 2001-2002, 28 089, nr. 2.

128 Babisch W. The Noise/stress concept, risk assessment and research needs. Noise Health 2002; 4(16): 1-11.

129 Carter NL, Inham P, Tran K, Hunyor S. A field study of the effects of traffic noise on heart rate and cardiac arrhythmia during sleep. J Sound Vib 1994; 169: 211-227.

130 Pearsons K, Bennett R, Fidell S. Effects of cessation of late-night landings on behavioral awakening. Canoga Park: BNN Systems and Technologies Corporation; 1973; Report nr 2439.

131 Vallet M, Gagneux JM, Simonnet F. Effects of aircraft noise on sleep: an in situ experience. 1983; ASHA Reports (no 10).

132 Vernet M. Effects of train noise on sleep for people living in houses bordering the railway line. J Sound Vib 1979; 66(3): 483-492.

133 Fidell S, Howe R, Tabachnick B, Silvati L, Sneddon M, Fletcher E. Field studies of habituation to change in nighttime aircraft noise and of sleep motility measurement methods. California: BBN Technologies; 1998; report no. 8195.

134 Fidell S, Howe R, Tabachnick BG, Pearsons K, Silvati L, Sneddon M, *et al.* Field studies of habituation to change in nighttime aircraft noise and of sleep motility measurement methods. Canoga Park California: BBN; 1998; 8195.

135 Finegold LS, Elias B. A predictive model of noise induced awakenings from transportation noise sources. Dearborn (MI): 2002.

136 Thiessen GJ. Disturbance of sleep by noise. J Acoust Soc Am 1978; 64(1): 216-222.

137 Thiessen GJ. Effect of traffic noise on the cyclical nature of sleep. J Acoust Soc Am 1988; 84(5): 1741-1743.

138 Griefahn B, Jansen G. Disturbance of sleep by sonic booms. Sci Total Environ 1975; 4(1): 107-112.

139 Griefahn B, Jansen G. EEG-responses caused by environmental noise during sleep their relationships to exogenic and endogenic influences. Sci Total Environ 1978; 10(2): 187-199.

140 Carter NL, Inham P. A laboratory study of the effects of background noise level and number of truck noise events on sleep. Sydney National Acoustic Laboratories; 1995; Report 124.

141 Basner M, Buess H, Luks N, Maass H, Mawet L, *et al.* Nachtfluglärmwirkungen - eine Teilauswirkung von 64 Versuchspersonen in 832 Schlaflabornächten. Köln: Deutsches Zentrum für Luft- und Raumfahrt e.v.; 2001; Forschungsbericht 2001-26.

142 Bonnet MH. Differentiating sleep continuity effects from sleep stage effects (Letter to the editor). J Sleep Res 2001; 9: 403-406.

143 Kawada T, Kiryu Y, Aoki S, Suzuki S. [Changes in the hypnograms of subjects exposed to repeated truck-passing sounds of 45, 50 and 55 dB (A)]. Nippon Eiseigaku Zasshi 1993; 48(5): 932-938.

144 Kawada T, Suzuki S. Transient and all-night effects of passing truck noise on the number of sleep spindle. Jpn J Psychiatry Neurol 1994; 48(3): 629-634.

145 Kawada T, Suzuki S. Instantaneous change in sleep stage with noise of a passing truck. Percept Mot Skills 1995; 80(3 Pt 1): 1031-1040.

146 Kawada T, Suzuki S. Change in rapid eye movement (REM) sleep in response to exposure to all-night noise and transient noise. Arch Environ Health 1999; 54(5): 336-340.

147 Ising H. Stressreactionen und Gesundheitsrisiko bei Verkehrslärmbelastung. Berlin: Institut für Wasser-, Boden- und Lufthygiene des Bundesgesundheitsamtes; 1983.

148 Born J, Kern W, Bieber K, Fehm-Wolfsdorf G, Schiebe M, Fehm HL. Night time plasma cortisol secretion is associated with specific sleep stages. Biol Psychiatry 1986; 1415-1424.

149 Carter NL. Some issues in noise-induced sleept disturbance. Acoustics Australia 1998; 26(2): 49-52.

150 Harder J, Maschke C, Ising H. Längsschnittstudie zum Verlauf von Stressreaktionen unter Einfluss von nächtlichem Fluglärm. Berlin: Umweltbundesambt; 1999.

151 Carter NL, Hunyor S, Crawford G, Kelly D, Smith AJM. Environmental noise and sleep - a study of arousals, cardiac arrhythmia and urinary catecholamines. Sleep 1994; 17(4): 298-307.

152 Babisch W, Ising H. Längschnittstudie zu gesundheitlichen Auswirkungen des Lärms, Caerphilly (Wales)Traffic noise as a risk factor for myocardial infarction. Berlin: Umweltbundesambt; 1986.

153 Evans GW, Lercher P, Meis M, Ising H, Kofler WW. Community noise exposure and stress in children. J Acoust Soc Am 2001; 109(3): 1023-1027.

154 Ising H, Ising M. Chronic cortisol increase in the first half of the night caused by road traffic noise. Noise Health 2002; 4(16): 13-21.

155 Lercher P, Evans GW, Meis M, Kofler WW. Ambient neighbourhood noise and children's mental health. Occup Environ Med 2002; 59(6): 380-386.

156 Evans A, Hygge S, Bullinger M. Chronic noise exposure and physiological stress. Psychological Science 1995; 6: 333-338.

157 Evans GW, Bullinger M, Hygge S. Chronic noise exposure and physiological response: a prospective study of children living under environmental stress. Psychological Science 1998; 9: 75-77.

158 Haines MM, Stansfeld SA, Head J, Berglund B, Job RF. A follow-up study of effects of chronic aircraft noise exposure on child stress responses and cognition. Int Epidemiological Association 2001; 30: 839-845.

159 Haines MM, Stansfeld SA, Brentnall S, Head J, Berry B, Jiggins M, *et al.* The West London School Study: the effects of chronic aircraft noise exposure on child health. Psychological Medicine 2001; 31: 1385-1396.

160 Kastka J, Faust M, Weber K, Losberg S, Borsch-Galetke E. Cortisolausscheidung als Nachweis einer Stressreaktion von Anwohnern eines Grossflughafens. In: Rettenmeier AW, Feldhaua C, editors. Rindt, Fulda, 1999: 655-657.

161 Schulte W, Otten H. Ergebnisse einer Tieffluglärmstudie in der Bundesrepublik Deutschland: Extraaurale Langzeitwirkungen. In: Ising H, Kruppa B, editors. Proceedings of the International Symposium Berlin. Stuttgart: Gustav Fisher Verlag, 1993.

162 Stansfeld SA, Brentnall S, Haines MM. Investigating the effects of noise exposure on stress hormone responses in children. In: Boone R.editor. Proceedings Internoise 2001. The Hague: NAG, 2001.

163 Ising H, Peines F. Meis M. Beeinflussung der Lebensqualität von Kindern durch militärischen Fluglärm. Berlin: Umweltbundesambt; 2002.

164 Eberhart JL, Akselsson KR. The disturbance by road traffic noise on the sleep of young male adults as recorded in the home. J Sound Vib 1987; 114(3): 417-434.

165 Öhrström E, Björkman M. Sleep disturbance before and after traffic noise attenuation in an apartment building. J Acoust Soc Am 1983; 73(3): 877-879.

166 Labiale G, Vallet M. Comparatative study of effeccts of noise on sleep in the laboratory and at home. Travail Humaine 1984; 47(2): 143-154.

167 Schnelle JF, Alessi CA, Nahla R, Al-Samarrai MA, Frickler RD, Ouslander JG. The Nursing Home at Night: Effects of an Intervention on Noise, Light, and Sleep. J Am Geriatrics Soc 1999; 47: 430-438.

168 Reyner LA. Sleep disturbance and daytime sleepiness in normal subjects. Loughborough: Loughborough University of Technology; 1995.

169 Reyner LA, Horne JA. Gender- and age-related differences in sleep determined by home-recorded sleep logs and actimetry from 400 adults. Sleep 1995; 18(2): 127-134.

170 Maschke C, Wolf U, Leitmann T. Epidemiological examinations to the influence of noise stress on the immune system and the emergence of arteriosclerosis. Berlin: Robert Koch-Institut; 2002.

171 Carter NL, Job RFS, editors. Cardiovascular response to environmental noise during sleep. Proceedings of the 7th International Congress on Noise as a Public Health Problem; Sydney: University of Sydney, 1998.

172 Rylander R, Berglund K, Sorensen S. [Human reactions after sonic boom exposure--experience from Swedish field studies]. Nord Hyg Tidskr 1973; 54(1): 1-5.

173 Flindell IH, Bullmore AJ, Robertson KA. Aircraft Noise and Sleep. 1999 UK Trial Methodology Study. Southampton: ISVR; 2000; Report 6131 R01.

174 Passchier-Vermeer W. Aricraft noise and sleep: study in the Netherlands. In: Proceedings of the 8th International Congress on the Biological Effects of Noise ICBEN2003, 2003.

175 Bullen R, Hede A, Williams T. Sleep disturbance due to environmental noise: a proposed assessment index. Acoustics Australia 1996; 24(3): 91-96.

176 Carter NL, Job RFS, editors. A practical index for assessment of sleep disturbance. Proceedings of the 7th International Congress on Noise as a Public Health Problem; Sydney: University of Sydney, 1998.

177 Fican. Effects of Aviation Noise on Awakenings from Sleep. 6-1997. Internet: http://www.fican.org/pages/sleepdst.html.

178 Finegold LS, Harris S, von Gierke HE. Community Annoyance and Sleep Disturbance: Updated Criteria for Assessing the Impacts of General Transportation Noise on People. Noise Control Eng J 1994; 42(1): 25-30.

179 Finegold LS. Sleep disturbance due to transportation noise. In: Proceedings of the 8th International Congress on the Biological Effects of Noise ICBEN2003, 2003.

180 Wiechen CMAGv, Franssen EAM, Jong RGd, Lebret E. Aircraft noise exposure from Schiphol Airport: A relation with complaints. Noise & Health 2002; 5(17): 23-34.

181 Wiechen CMAGv. Complaining about aircraft noise. State-of-the-art around Amsterdam Airport Schiphol. In: Proceedings of the 8th International Congress on the Biological Effects of Noise ICBEN2003, 2003.

182 TNO-PG en RIVM. Hinder.slaapverstoring,gezondheids- en belevingsaspecten in de regio Schiphol, resultaten van een vragenlijstonderzoek (Annoyance, sleep disturbance, health and experience aspects in the Schiphol region: results of a survey). Leiden/Bilthoven: 10-1998; TNO:98.039 RIVM: 441520010., geraadpleegd op .

183 DGL Milieu. Nachtvluchten en Schiphol. Den Haag: DGL; 2004; www.luchtvaartbeleid.nl/dgl/milieu/bkginfo/nachtvluchten1.asp.

184 DCMR Milieudienst Rijnmond. Geluidklachten Rijnmond. 2004.

185 Miedema HME. Geluidmaten voor vliegverkeer. Leiden: NIPG TNO; 1993; 93.085.

186 Kok Md. GGD Noord-Kennemerland, eds. Geluidhinder en slaapverstoring in Noord-Kennemerland; Omnibusonderzoek 2000. Alkmaar: 10-2000; 2000. Internet: http://www.ggd-alkmaar.nl.

187 American Psychiatric Association. Quick reference to the diagnostic criteria from DSM-IV. Washington D.C.: American Psychiatric Association; 1994.

188 Nederlandse Vereniging voor Psychiatrie. Beknopte handleiding bij de Diagnostische Criteria van de DSM-IV. Lisse: Swets & Zeitlinger; 2004.

189 Monroe LJ. Psychological and physiological differences between good and poor sleepers. J Abnormal Psychology 1967; 72(255): 264.
190 Spielman AJ. Assessment of insomnia. Clinical Psychology Review 1986; 6:11-26.
191 Vgontzas AN, Bixler EO, Lin HM, Prolo P, Mastorakos G, Vela B, *et al*. Chronic insomnia is associated with nyctohemeral activation of the hypothalamic-pituitary-adrenal axis: clinical implications. J Clin Endocrinol Metab 2001; 86(8): 3787-3794.
192 Ohayon MM. Epidemiology of insomnia: what we know and what we still need to learn. Sleep Med Rev 2002; 6(2): 97-111.
193 Léger D. Public Health and Insomnia: Economic Impact. Sleep 2000; 23(supplement 3): S69-S76.
194 Hajak G. Epidemiology of severe insomnia and its consequences in Germany. Eur Arch Psychiatry Clin Neurosci 2001; 251(2): 49-56.
195 Kim K, Uchiyama M, Okawa M, Liu X, Ogihara R. An epidemiological study of insomnia among the Japanese general population. Sleep 2000; 23(1): 41-47.
196 Wilson KG, Eriksson MY, D'Eon JL, Mikail SF, Emery PC. Major depression and insomnia in chronic pain. Clin J Pain 2002; 18(2): 77-83.
197 Tachibana H, Izumi T, Honda S, Takemoto TI. The prevalence and pattern of insomnia in Japanese industrial workers: relationship between psychosocial stress and type of insomnia. Psychiatry Clin Neurosci 1998; 52(4): 397-402.
198 Sukying C, Bhokakul V, Udomsubpayakul U. An epidemiological study on insomnia in an elderly Thai population. J Med Assoc Thai 2003; 86(4): 316-324.
199 Simon GE, VonKorff M. Prevalence, burden, and treatment of insomnia in primary care. Am J Psychiatry 1997; 154(10): 1417-1423.
200 Shochat T, Umphress J, Israel AG, Ancoli-Israel S. Insomnia in primary care patients. Sleep 1999; 22 Suppl 2:S359-S365.
201 Shaver JL, Johnston SK, Lentz MJ, Landis CA. Stress exposure, psychological distress, and physiological stress activation in midlife women with insomnia. Psychosom Med 2002; 64(5): 793-802.
202 Seppala M, Hyyppa MT, Impivaara O, Knuts LR, Sourander L. Subjective quality of sleep and use of hypnotics in an elderly urban population. Aging (Milano) 1997; 9(5): 327-334.
203 Schubert CR, Cruickshanks KJ, Dalton DS, Klein BE, Klein R, Nondahl DM. Prevalence of sleep problems and quality of life in an older population. Sleep 2002; 25(8): 889-893.
204 Savard J, Simard S, Blanchet J, Ivers H, Morin CM. Prevalence, clinical characteristics, and risk factors for insomnia in the context of breast cancer. Sleep 2001; 24(5): 583-590.
205 Sangi-Haghpeykar H, Poindexter AN, III. Epidemiology of endometriosis among parous women. Obstet Gynecol 1995; 85(6): 983-992.
206 Sales EC, Santana VS. Depressive and anxiety symptoms among housemaids. Am J Ind Med 2003; 44(6): 85-691.
207 Rubinstein ML, Selwyn PA. High prevalence of insomnia in an outpatient population with HIV infection. J Acquir Immune Defic Syndr Hum Retrovirol 1998; 19(3): 260-265.

208 Rocha FL, Uchoa E, Guerra HL, Firmo JO, Vidigal PG, Lima-Costa MF. Prevalence of sleep complaints and associated factors in community-dwelling older people in Brazil: the Bambui Health and Ageing Study (BHAS). Sleep Med 2002; 3(3): 231-238.

209 Roberts RE, Shema SJ, Kaplan GA. Prospective data on sleep complaints and associated risk factors in an older cohort. Psychosom Med 1999; 61(2): 188-196.

210 Redondo-Martinez MP, Salcedo-Aguilar F, Garcia-Jimenez MA, Monterde-Aznar ML, Rodriguez-Almonacid FM, Marcos-Navarro AI. [Prevalence of insomnia and use of psychodrugs among elderly in a basic health area in Cuenca]. Aten Primaria 2000; 25(6): 400-404.

211 Redeker NS, Lev EL, Ruggiero J. Insomnia, fatigue, anxiety, depression, and quality of life of cancer patients undergoing chemotherapy. Sch Inq Nurs Pract 2000; 14(4): 275-290.

212 Paivarinta A, Verkkoniemi A, Niinisto L, Kivela SL, Sulkava R. The prevalence and associates of depressive disorders in the oldest-old Finns. Soc Psychiatry Psychiatr Epidemiol 1999; 34(7): 352-359.

213 Ohayon MM, Zulley J. Correlates of global sleep dissatisfaction in the German population. Sleep 2001; 24(7): 780-787.

214 Ohayon MM, Morselli PL, Guilleminault C. Prevalence of nightmares and their relationship to psychopathology and daytime functioning in insomnia subjects. Sleep 1997; 20(5): 340-348.

215 Nakata A, Haratani T, Takahashi M, Kawakami N, Arito H, Fujioka Y, *et al.* Job stress, social support at work, and insomnia in Japanese shift workers. J Hum Ergol (Tokyo) 2001; 30(1-2): 203-209.

216 Muscatello DJ, Rissel C, Szonyi G. Urinary symptoms and incontinence in an urban community: prevalence and associated factors in older men and women. Intern Med J 2001; 31(3): 151-160.

217 Menezes AM, Victora CG, Rigatto M. Prevalence and risk factors for chronic bronchitis in Pelotas, RS, Brazil: a population-based study. Thorax 1994; 49(12): 1217-1221.

218 McCall WV, Reboussin BA, Cohen W. Subjective measurement of insomnia and quality of life in depressed inpatients. J Sleep Res 2000; 9(1): 43-48.

219 Martikainen K, Partinen M, Hasan J, Laippala P, Urponen H, Vuori I. The impact of somatic health problems on insomnia in middle age. Sleep Med 2003; 4(3): 201-206.

220 Mallon L, Broman JE, Hetta J. Relationship between insomnia, depression, and mortality: a 12-year follow-up of older adults in the community. Int Psychogeriatr 2000; 12(3): 295-306.

221 Chiu HF, Leung T, Lam LC, Wing YK, Chung DW, Li SW, *et al.* Sleep problems in Chinese elderly in Hong Kong. Sleep 1999; 22(6): 717-726.

222 Moline ML, Broch L, Zak R, Gross V. Sleep in women across the life cycle from adulthood through menopaus. Clinical Review. Sleep Medicine Reviews 2003; 7(155): 177.

223 Chevalier H, Los F, Boichut D, Bianchi M, Nutt DJ, Hajak G, *et al.* Evaluation of severe insomnia in the general population: results of a European multinational survey. J Psychopharmacol 1999; 13(4 Suppl 1):S21-S24.

224 Hatoum HT, Kong SX, Kania CM, Wong JM, Mendelson WB. Insomnia, health-related quality of life and healthcare resource consumption. A study of managed-care organisation enrollees. Pharmacoeconomics 1998; 14(6): 629-637.

225 Katz DA, McHorney CA. The relationship between insomnia and health-related quality of life in patients with chronic illness. J Fam Pract 2002; 51(3): 229-235.

226 Zammit GK, Weiner J, Damato N, Sillup GP, McMillan CA. Quality of life in people with insomnia. Sleep 1999; 22 Suppl 2: S379-S385.

227 Gallup Organization. Sleep in America. Princeton NJ: The Gallup Organization; 1991.

228 Schwartz S, McDowell Anderson W, Cole SR, Cornoni-Huntley J, Hays JC, Blazer D. Insomnia and heart disease: A review of epidemiologic studies. Journal of Psychosomatic Research 1999; 47 (4): 313-333.

229 Janson C, Lindberg E, Gislason T, Elmasry A, Boman G. Insomnia in men-a 10-year prospective population based study. Sleep 2001; 24(4): 425-430.

230 Kales A, Bixler EO, Soltados CR, Vela-Bueno A, *et al.* Biopsychobehavioral correlates of insomnia. Part 1: Role of sleep apnea and nocturnal myoclonus. Psychosomatics 1982; 23(589): 600.

231 Ohayon MM, Zulley J, Guilleminault C, Smirne S, Priest RG. How age and daytime activities are related to insomnia in the general population: consequences for older people. J Am Geriatr Soc 2001; 49(4): 360-366.

232 Suka M, Yoshida K, Sugimori H. Persistent insomnia is a predictor of hypertension in Japanese male workers. J Occup Health 2003; 45(6): 344-350.

233 Barbar SI, Enright PL, Boyle P, Foley D, Sharp DS, Petrovitch H, *et al.* Sleep disturbances and their correlates in elderly Japanese American men residing in Hawaii. J Gerontol A Biol Sci Med Sci 2000; 55(7): M406-M411.

234 Bardage C, Isacson DG. Self-reported side-effects of antihypertensive drugs: an epidemiological study on prevalence and impact on health-state utility. Blood Press 2000; 9(6): 328-334.

235 Bixler EO, Vgontzas AN, Lin HM, Vela-Bueno A, Kales A. Insomnia in central Pennsylvania. J Psychosom Res 2002; 53(1): 589-592.

236 Blais FC, Morin CM, Boisclair A, Grenier V, Guay B. [Insomnia. Prevalence and treatment of patients in general practice]. Can Fam Physician 2001; 47: 759-767.

237 Brower KJ, Aldrich MS, Robinson EA, Zucker RA, Greden JF. Insomnia, self-medication, and relapse to alcoholism. Am J Psychiatry 2001; 158(3): 399-404.

238 Cricco M, Simonsick EM, Foley DJ. The impact of insomnia on cognitive functioning in older adults. J Am Geriatr Soc 2001; 49(9): 1185-1189.

239 Fichten CS, Creti L, Amsel R, Brender W, Weinstein N, Libman E. Poor sleepers who do not complain of insomnia: myths and realities about psychological and lifestyle characteristics of older good and poor sleepers. J Behav Med 1995; 18(2): 189-223.

240 Foley DJ, Monjan AA, Izmirlian G, Hays JC, Blazer DG. Incidence and remission of insomnia among elderly adults in a biracial cohort. Sleep 1999; 22 Suppl 2: S373-S378.

241 Han SY, Yoon JW, Jo SK, Shin JH, Shin C, Lee JB, *et al.* Insomnia in diabetic hemodialysis patients. Prevalence and risk factors by a multicenter study. Nephron 2002; 92(1): 127-132.

242 Maggi S, Langlois JA, Minicuci N, Grigoletto F, Pavan M, Foley D,J *et al.* Sleep complaints in community-dwelling older persons: prevalence, associated factors, and reported causes. J Am Geriatr Soc 1998; 46(2): 161-168.

243 Morin CM, Rodrigue S, Ivers H. Role of stress, arousal, and coping skills in primary insomnia. Psychosom Med 2003; 65(2): 259-267.

244 Ohayon MM, Schatzberg AF. Prevalence of depressive episodes with psychotic features in the general population. Am J Psychiatry 2002; 159(11): 1855-1861.

245 Whooley MA, Grady D, Cauley JA. Postmenopausal estrogen therapy and depressive symptoms in older women. J Gen Intern Med 2000; 15(8): 535-541.

246 Ohayon MM, Hong SC. Prevalence of insomnia and associated factors in South Korea. J Psychosom Res 2002; 53(1): 593-600.

247 Ohayon MM, Caulet M, Priest RG, Guilleminault C. DSM-IV and ICSD-90 insomnia symptoms and sleep dissatisfaction. Br J Psychiatry 1997; 171: 382-388.

248 Ohayon MM, Roth T. What are the contributing factors for insomnia in the general population? J Psychosom Res 2001; 51(6): 745-755.

249 Ohayon MM, Priest RG, Zulley J, Smirne S, Paiva T. Prevalence of narcolepsy symptomatology and diagnosis in the European general population. Neurology 2002; 58(12): 1826-1833.

250 Ohayon MM, Hong SC. Prevalence of insomnia and associated factors in South Korea. J Psychosom Res 2002; 53(1): 593-600.

251 Ohayon MM, Lemoine P. [A connection between insomnia and psychiatric disorders in the French general population]. Encephale 2002; 28(5 Pt 1): 420-428.

252 Ohayon MM, Roth T. Prevalence of restless legs syndrome and periodic limb movement disorder in the general population. J Psychosom Res 2002; 53(1): 547-554.

253 Ohayon MM, Smirne S. Prevalence and consequences of insomnia disorders in the general population of Italy. Sleep Med 2002; 3(2): 115-120.

254 Ohayon MM, Partinen M. Insomnia and global sleep dissatisfaction in Finland. J Sleep Res 2002; 11(4): 339-346.

255 Ohayon MM, Roth T. Place of chronic insomnia in the course of depressive and anxiety disorders. J Psychiatr Res 2003; 37(1): 9-15.

256 Webb WB. The cost of sleep-related accidients: A reanalysis. Sleep: J of Sleep Research and Sleep Medicine 1995; 18(4): 276-280.

257 Connor J, Whitlock G, Norton R, Jackson R. The role of driver sleepiness in car crashes: a systematic review of epidemiological studies. Accid Anal Prev 2001; 33(1): 31-41.

258 Lloberes P, Levy G, Descals C, Sampol G, Roca A, Sagales T, *et al.* Self-reported sleepiness while driving as a risk factor for traffic accidents in patients with obstructive sleep apnoea syndrome and in non-apnoeic snorers. Respir Med 2000; 94(10): 971-976.

259 Akerstedt T, Fredlund P. A prospective study of fatal occupational accidents - relationship to sleeping difficulties and occupational factors. J Sleep Res 2002; 11(1): 69-71.

260 Chau N, Gauchard GC. Relationships of job, age, and life conditions with the causes and severity of occupational injuries in construction workers. Int Arch Occup Environ Health 2004; 77(1): 60-66.

261 Gauchard GC, Chau N. Individual characteristics in occupational accidents due to imbalance: a case-control study of the employees of a railway company. Occup Environ Med 2003; 60(5): 330-335.

262 Lindberg E, Carter N. Role of snoring and daytime sleepiness in occupational accidents. Am J Respir Crit Care Med 2001; 164(11): 2031-2035.

263 Melamed S, Oksenberg A. Excessive daytime sleepiness and risk of occupational injuries in non-shift daytime workers. Sleep 2002; 25(3): 315-322.

Annexes

Annex **A**

The State Secretary's letter

The President of the Health Council received the following request from the State Secretary for Housing, Spatial Planning and the Environment in a letter dated 3 February 2003, reference no. LMV 2003003076.

I am writing to ask the Health Council to prepare an advisory report on exposure to night-time noise. The background to this request is outlined below. Following the outline, you will find a list of the specific questions that I would like the Council's advisory report to address.

Background

In several earlier reports, the Council has directly or indirectly addressed the issue of night-time noise. To a certain extent, therefore, this request is prompted by the possibility that new information may have become available, which can confirm or shed new light on advice given in the past.

In its first report on this topic in 1972, the Council unequivocally stated that 'Sufficient undisturbed sleep is extremely important to health.' In 1991, the Council turned its focus specifically to the question of aircraft noise in a report that was prompted by the heated debate then in progress concerning the proposed expansion of Maastricht Airport (*Airplane noise and sleep. Sleep disturbance by airplane noise at night*). The conclusion of the latter report was that 'Although not all the results lend themselves to clear interpretation, the indications are that the regular disturbance of sleep by noise has an adverse effect on health and well-being.'

The very thorough advisory report *Noise and Health* (1994) stated that there was sufficient evidence to attribute a number of phenomena to exposure to noise when sleeping. The phenomena in question were changes in heart rate, changes in sleeping pattern, awakening, sleep stage changes and changes in the subjective quality of sleep. In relation to each of these effects, 'observed effects levels' – exposure levels at and above which effects were demonstrable – were calculated from the published data. Where other phenomena were concerned, the evidence for a causal relationship was less convincing, or an observation threshold could not be calculated.

The advisory report *Assessing Noise Exposure for Public Health Purposes* (1997) recommended that the index *LAeq* (covering an eight-hour overnight period) should be used when assessing (the seriousness of) night-time exposure to noise. However, the exposure-response relationships presented in the report for sleep disturbance and awakening attributable to traffic noise and noise from stationary sources were qualified as 'provisional'.

Finally, the advisory report entitled *Public Health Impact of Large Airports* (1999) devoted considerable attention to the question of sleep disturbance. Although on the basis of recent research the Council described the evidence for a causal relationship between exposure to night-time noise and changes in stress hormone levels as limited, it was felt that there was sufficient reason to view sleep disturbance as a 'moderately serious' effect on health, similar to increasing respiratory illness. It was estimated that 'a considerable proportion of exposed individuals' were affected.

Recent developments

This request leads on directly or indirectly from a number of recent developments.

- The European Directive 2002/49 relating to the assessment and management of environmental noise (2002)* has been published, defining a separate index of night-time exposure to noise: the *LAeq* for an eight-hour period (*Lnight*). This index should at least be used for the compulsory strategic noise maps.
- The European Commission has completed a study of dose-effect relationships for the *Lnight*.
- The question of how best to quantify night-time exposure has also become topical in the context of the modernisation of the noise regulation policy tool set.
- In November 2002, the results of the field study of aviation noise-related sleep disturbance in the vicinity of Schiphol Airport** was published; a number of relevant studies have been reported by researchers in other countries***,****.

* Position paper on dose response relationships between transportation noise and annoyance, Luxembourg: Office for Official Publications of the European Communities, 2002, ISBN 92-894-3894-0, European Communities, 2002

** Sleep disturbance by aviation noise, TNO/RIVM, 2002

*** Epidemiological research on stress caused by road traffic noise and its effects on health 1 - Results for hypertension, Maschke, UBA, 2002

**** Nachffluglarmwirkungen, Forschungsbericht 26, DLR, Grezner, 2001

Specific questions

In view of the matters outlined above, I would like the Council to respond to the following questions in its advisory report:

1. What are the effects (expressed in quantitative terms as far as possible) of exposure to noise when sleeping?
2. How do such effects compare with other effects on health, in terms of seriousness and magnitude?
3. Is it necessary to take special account of any population groups that are at particular risk?
4. In view of the effects referred to, would it be advisable to introduce special rules, similar to those contained in Directive 2002/49 and the Aviation Act, for night-time noise from sources other than air traffic?
5. If so, is it sufficient for such rules to be based on *Lnight*, or are additional indexes of exposure required, with a view to regulating impulse-like noises and situations involving relatively infrequent but high-intensity noise events.
6. Could the public be protected by the use of a. performance-related or design requirements for residential buildings, b. personal protective gear, c. rules regarding sound pressure levels outside buildings, d. rules relating to vehicles and machinery, or e. a combination of these measures?

Timetable

I would be very grateful if the Council could present its advisory report in autumn 2003 or thereabouts.

Yours sincerely,

(signed)
PLBA van Geel,
State Secretary for Housing, Spatial Planning and the Environment

Annex **B**

The Committee

- Professor JJ Heimans, *Chairman*
  Department of Neurology, VU University Medical Center, Amsterdam
- M van den Berg, *consultant*
  Ministry of Housing, Spatial Planning and the Environment, Directorate General for Environmental Management, The Hague
- Dr JJ van Busschbach
  Erasmus Medical Centre, Institute for Medical Psychology and Psychotherapy, Rotterdam
- JH Granneman
  Peutz bv, Zoetermeer
- Dr HME Miedema
  TNO Inro, Department of Environment and Health, Delft
- Professor FJN Nijhuis
  Occupational Perspective Centre, Hoensbroek
- Professor WF Passchier, *consultant*
  Health Council, The Hague
- Dr H Tiemeier
  Erasmus Medical Centre, Institute for Epidemiology and Biostatistics, Rotterdam
- Professor AJJM Vingerhoets
  University of Tilburg, Psychology and Health, Tilburg

- Dr AW de Weerd
  Haaglanden Medical Centre, Westeinde Hospital Site, Centre for Sleep and Waking Disorders, The Hague
- W Passchier-Vermeer, *Secretary*
  TNO Inro, Department of Environment and Health, Delft, and Health Council, The Hague

Administrative support: M Bakker, Health Council, The Hague.
Layout: M Javarmardi/J van Kan, Health Council, The Hague.

Annex **C**

Individuals and bodies who responded to the request for information

A letter was sent to more than fifty bodies with an interest in the subject matter concerning which the State Secretary had asked for advice. In addition, an advertisement was placed in the Government Gazette of 22 July 2003, inviting interested parties to submit any information that might be of value in the compilation of the advisory report.

Written responses were received from the following individuals and bodies:

- Greater Rotterdam Regional Health Service, General Healthcare Sector, Environment & Hygiene Department, R van Doorn
- Achterhoek Regional Health Service, CH Capel
- JJM Veraart, in a private capacity
- Kop van Noord-Holland Regional Health Service, JE de Leeuw den Bouter
- Noord-Kennemerland Regional Health Service, J Paulisse, enclosing a report entitled *Geluidhinder en slaapverstoring in Noord-Kennemerland* (*Noise-Related Annoyance and Sleep Disturbance in Noord-Kennemerland*); OMNIBUSONDERZOEK 2000
- Amsterdam Airport Schiphol, Business Unit Airlines, M Bouwmeester, enclosing a final draft report entitled *Non-auditory Health Effects of Aircraft Noise With Special Reference to Sleep Disturbance.*

E-mail responses were received from the following bodies:

- Northern South Holland Regional Health Service, M Mooij
- IPO BOAG, J Witteman

- Groningen Municipal Health Service, M Denekamp
- DCMR Rijnmond Environmental Service, Noise Bureau, RG de Jong
- ANWB, Department for Members' General Interests, P Clausing, enclosing a report entitled *Geluidbelasting in het Centraal Veluws gebied* (*Noise Exposure in the Central Veluwe Area*)

Annex **D**

Research into the consequences of night-time exposure to environmental noise when sleeping

D.1 Introduction

This annex contains a more in-depth review of studies that have been conducted into the effects of night-time noise. The annex's division into sections reflects the structure of the main body of the report. Thus, the annex deals in turn with research into the acute biological effects of exposure to noise when sleeping, research into biological effects over the course of a night (before, while and after sleeping) and research into the consequences for health and well-being of chronic exposure to night-time noise.

Tables 12 to 14 list the effect parameters, the technique used to measure them and a selection of references to research reports. Where biological effects are concerned, distinction is made in the references between field research and laboratory research.

Table 12 Acute biological effect parameters, the technique used to measure them and a selection of references to field and laboratory research.

Variable	Measurement technique	Field research references	Laboratory research references (selection)
Probability of acute cardiovascular changes	ECG, plethysmography	58,129	64-67
Probability of acute changes in stress hormone concentrations in the blood	Immediate blood sampling		
Probability of sleep stage change, from deeper to less deep sleep, including EEG awakening	Polygraphy (EEG, EMG, EOG)	48,130-132	48
Probability of motility (onset)	Actimetry	12,50,51,77-79,96,133	
Probability of subject-registered awakening	Pressing a button	12,49,50,52,134,135	

Table 13 Biological effect parameters relating to the course of a night (before, while and after sleeping), the technique used to measure them and a selection of references to field and laboratory research.

Variable	Measurement technique	Field research references	Laboratory research references (selection)
Prolongation of the sleep inception period, difficulty getting to sleep	Polygraphy (EEG, EMG, EOG), actimetry, journal	12,75	136,137
Changes in cardiovascular activity	ECG, plethysmography	70,131,132,138-140	141-146
Change in average motility during the sleep period	Actimetry	12,66,75,79	
Changes in the duration of the various stages of sleep, in sleep structure, fragmentation of sleep	Polygraphy (EEG, EMG, EOG), actimetry	59,70-73	136,137,140,141
Changes in (stress) hormone concentrations	Blood, saliva and urine sampling	82,82,140,147-154 153, 155-163	
Changes in immunological parameters			84-87
Recalled frequency of awakening and premature awakening by noise	Journal and actimetry	12,51,66,75,96	74,129,164-166,75,76,167, 47,150
Self-reported sleep quality, self-reported sleep disturbance	Journal	12,17,147,168,169	
Drowsiness/tiredness during the day and evening	Test, journal	12,17,147	
Cognitive performance	Test	12,17,147,70	
Irritability	Test, journal	17,147	
Annoyance	Journal	12,17,147	

Table 14 Parameters studied in field and questionnaire-based research into the influence of chronic exposure to night-time noise on health and well-being.

Variable	Measurement technique	Field research references
Sleep quality: reduced perceived sleep quality, difficulty getting to sleep, difficulty staying asleep, sleep fragmentation, reduced sleeping time, increased motility when sleeping	Questionnaire, journals, actimetry	12,12,17,51,66,75,79,80,96,96,147, 168,169
Well-being: self-reported sleep disturbance, self-reported health problems, use of somnifacient drugs and sedatives, daytime irritability	Questionnaire, test	12,51,66,75,97,168,169
Social contacts and concentration: impaired social contacts, impaired cognitive performance	Questionnaire, test	12,17,66,70,147
Medical conditions: insomnia, other investigated illnesses and medical conditions	Medical examination, questionnaire	12,89,170

D.2 Acute biological effects

D.2.1 Autonomous cardiovascular responses to noise events

Acute cardiovascular responses include raised (systolic) blood pressure, constriction of the blood vessels in the limbs and elsewhere, and accelerated heart rate. In this review, the Committee has restricted itself to acute heart rate accelerations in response to noise. The Committee is aware of only two field studies, both relating to road traffic noise[58,129]. Laboratory research has been taken into consideration because it sheds light on:

- Possible differences between the effects of exposure to road traffic noise and the effects of exposure to noise from other sources
- Possible differences between the effects of exposure when sleeping and exposure during the day
- Personal characteristics that influence the effects

Field research

The Dutch researchers Hofman *et al* carried out a field study with twelve subjects who lived beside a motorway[58]. They studied each subject in two situations, each for ten nights. The two situations differed in terms of the acoustic insulation provided by the fabric of the building, relating to the presence of double glazing, which provided an average attenuation of 9 dB(A). On each of the twenty nights that each subject was monitored, an EEG, two EOGs and an ECG were made and respiration was monitored. The noise situation was described by the researchers as a gradually varying background level with superimposed noise peaks (when particularly noisy vehicles passed). A noise peak was defined as a noise event with an *LAmax_i* of at least 10 dB(A) above the prevailing background level over a ten-minute interval (*L90*). In each of the two study situations, there were approximately ninety-three noise peaks per night. *LAmax_i* was generally between 30 and 65 dB(A). The variation in ECG-determined heart rate over time was compared with the distribution of noise peaks over time. For each noise peak, the maximum change in the heart rate (ECR: Event-related Cardiac Response) was determined from eight heart rate figures (four before and four after occurrence of the noise peak). For the purposes of comparison, a 'pseudo-ECR' was calculated for a peak-free interval immediately prior to the noise peak. In 80 per cent of cases, the ECR was greater than the pseudo-ECR. Analysis revealed that the ECR was not dependent on *LAmax_i*, on the subject's sleep stage at the time of the noise peak, or on whether the bedroom had double glazing. However, the speed at which the noise increased in intensity did influence the ECR: faster rises in intensity were associated with higher ECRs. Figure 15 shows the results relating to noise peaks occurring while the subject was in sleep stage 3 or 4 (SWS). If it is assumed that, of the 80 per cent of ECRs that exceeded the associated pseudo-ECR, 20 per cent were higher purely by chance, just as 20 per cent of all ECRs were lower purely by chance, it follows that subjects' heart rates rose in response to 60 per cent of noise peaks, irrespective of sleep stage or *LAmax_i* value.

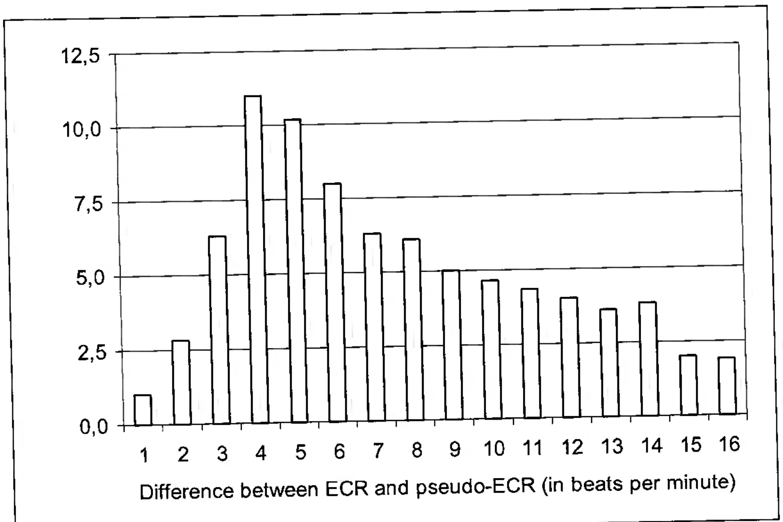


Figure 15 Percentage of cases in which the ECR (ECR: Event-related Cardiac Response) was higher than the pseudo-ECR, as a function of heart rate change involved in the ECR and pseudo-ECR. The various columns add up to a total of 80 per cent; in 20 per cent of cases, the difference between the ECR and pseudo-ECR was zero or negative.

A team led by Carter, a leading researcher in the field of the effects of noise on sleep, studied the effect of road traffic noise on seven older men, four of whom suffered from slight arrhythmia (simple premature ventricular contractions)[129]. They observed that in two of the four men with arrhythmia, noise peaks (*LAmax_i* of more than 70 dB(A) associated with lorries) induced a premature contraction 20 to 40 seconds later, especially if the men were in sleep stage 4 at the time. However, the researchers were unable to replicate this effect in a laboratory study involving road traffic noise[151]. In this context, Carter recounted an incident in which the sound of an alarm clock consistently induced ventricular fibrillation in a patient with a heart condition[171]. Carter argued that it was important that more research was done into the effects of noise on people with heart problems, since he anticipated that they were likely to be more than averagely sensitive to noise.

Laboratory research

Öhrström *et al* studied the acute effects of road traffic noise on heart rate in twenty-four subjects. Fifty-seven times a night for nine nights, subjects were exposed to the noise of a passing car or lorry with an *LAmax_i* of between 58 and 60 dB(A)[66]. The average increase in heart rate during the noise events was 1.5 beats per minute; among subjects who considered themselves sensitive to noise, the average increase was 1.8 beats per minute, while among subjects with no such self-perception, the increase was 1.1 beats per minute.

A French research team led by Muzet carried out a study in which twenty subjects were monitored for three nights, on one of which they were exposed to aircraft, lorry, moped and train noises[64]. The *LAmax_i* and noise event duration values were, for aircraft, 71 dB(A) and 21 seconds; for lorries, 66 dB(A) and 20 seconds; for mopeds, 56 dB(A) and 10 seconds; and, for trains, 62 dB(A) and 17 seconds. Over the course of the night, the noises were introduced randomly eight times per hour. In addition, subjects were exposed to similar noises of 15 dB(A) louder during the day. The results are presented in Figure 16. The increase in heart rate was not calculated in the same way as in the other publications referred to in this annex. Di Nisi *et al* worked on the basis of the difference between the highest heart rate and the slowest subsequent heart rate during a noise event (the latter rate generally being much lower than the average rate over an interval before or after the noise event).

The conclusion drawn by the researchers, which is illustrated by Figure 16, was that the response at night was much greater than that during the day. Furthermore, the daytime effects barely differed from one source to another. In addition to monitoring heart rate, the French team also used a finger plethysmograph to measure blood flow through subjects' finger tips. The plethysmography data also indicated that the most common

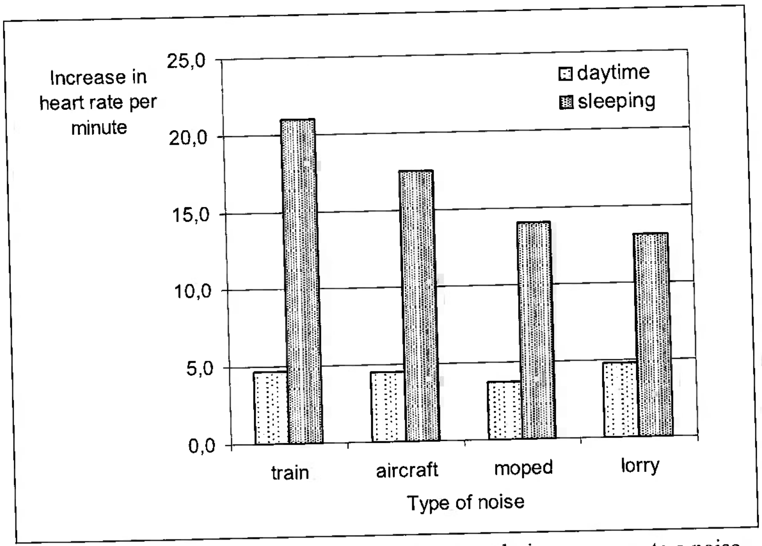


Figure 16 Comparison of the increase in heart rate during exposure to a noise event during the daytime and when sleeping. The daytime noises were 15 dB(A) louder than the noises subjects were exposed to when sleeping. From laboratory research by a French team[64].

response to the noise events, namely vasoconstriction, was also much more pronounced when sleeping than during the day. The subjects' score on a noise sensitivity scale did not appear to influence the magnitude of the heart rate response either during the day or at night, but was related to the degree of vasoconstriction during the day.

According to the data presented in Figure 16, aviation noise and lorry noise had a broadly similar effect on the sleeping heart rate. Because the train noise quickly rose to a maximum and remained at this level for almost the entire time until the train had passed, the *SEL_i* of the train noise was probably about the same as that of the aircraft and lorry noises. It is therefore plausible that, at a given *SEL_i*, the effect of train noise characterised by a rapid initial increase in intensity is slightly greater than the effect of noise from a passing aircraft or lorry. Comparing the data for the different sources, it is striking that mopeds – with a maximal level 10 to 15 dB(A) lower than the maximums of the other noise sources, and with the shortest duration – register quite high scores. The researchers did not investigate whether this was due, for example, to the faster rise in the intensity of moped noise or to aversion to the noise on the part of the subjects.

In view of the much greater heart rate responses observed in subjects exposed to noise when sleeping than in the same subjects during the day, the researchers suggested that more attention should be paid to protecting the general public against higher night-time noise exposures.

An Australian research team exposed nine subjects over three sleep periods to various types of noise: low-flying military jets, lorries, landing civil aircraft, and a five-second 1000-Hz sound[67]. Each type of noise event was generated at *LAmax_i* values of 55, 65 and 75 dB(A). The time taken to reach maximum intensity (build-up period) and the overall duration of the noise event varied with the *LAmax_i* value; the values are given in Table 15.

Table 15 Details of the noise events featured in the research by Carter *et al*[67].

Noise event	Build-up period (seconds)			Overall duration (seconds)		
LAmax_i (dB(A))	55	65	75	55	65	75
Low-flying military jet	1	1	1	1	2	6
Civil aircraft	13	14	16	8	18	25
Lorry	10	19	20	10	20	27
1000-Hz sound	0	0	0	5	5	5

Subjects were exposed to a total of approximately 1300 noise events. The increase in heart rate during the noise events did not appear to be related to the type of noise involved. At *LAmax_i* values of 55 and 65 dB(A), the increase in heart rate averaged 1.5 beats per minute, while at 75 dB(A) it was approximately three beats per minute. Expressed in the form of *SEL_i* values, the civil aircraft and lorry noise events were very similar at each of the three exposure levels. At the lowest exposure, the *SEL_i* value of the 1000 Hz sound was approximately the same as those of the lorry and civil aircraft noises, while at the higher exposures it was roughly 3 to 5 dB(A) lower. Because of its short duration, the military jet noise had an *SEL_i* value approximately 10 dB(A) lower than those of the lorry and civil aircraft noises at the two lower exposures, and about 5 dB(A) lower at the highest exposure. It follows that, at a given *SEL_i*, the increase in heart rate induced by the 1000 Hz sound and the military jet noise is greater than that induced by the lorry and civil aircraft noises.

In Germany, Griefahn carried out an experiment in which twenty subjects were exposed in their sleep to a reproduction of the noise of shots from a tank, with an *LAmax_i* value of between 78 and 82 dB(A)[65]. A total of 1209 impulses were distributed over sixty-eight person-nights. On average, subjects' heart rates rose from 66 to 77 beats per minute, measured three seconds after the 'shot'. This increase by an average of eleven beats per minute was greater than the increase induced by road traffic noise under similar circumstances, albeit at lower *LAmax_i* values.

In 1967, Semczuk investigated the effects of exposure to noise when sleeping, by using thoraxgraphy to monitor breathing in a study group of fifty children (five to seven years old) and a hundred adults[68]. The trigger level for respiratory changes associated with an aural stimulus (sound of a particular pitch) was 10 to 15 dB(A) lower in children than in adults. The researcher accordingly concluded that a child's autonomous nervous system is more readily activated by noise when sleeping than an adult's, and that children are therefore physiologically more sensitive to night-time noise than adults.

D.2.2 *Acute changes in hormone levels*

The lower four graphs in Figure 17 show how the concentrations in the blood of the stress hormones cortisol, adrenaline and noradrenaline and of the growth hormone (GH)[88] normally change in the course of a night.

The Committee is not aware of any field or laboratory research into acute changes in hormone concentrations in response to exposure to noise.

D.2.3 *Sleep stage change, including EEG awakening*

Reference has already been made in the main body of the report to the meta-analysis performed by Pearsons *et al*[48]; see Figure 7. The relationships between exposure and the probability of EEG awakening and the probability of sleep stage change were presented by Pearsons, using both *LAmax_i* and *SEL_i* as indexes of exposure. Only three of the five field studies reviewed by Pearsons involved EEG scans[130-132]; one other was a questionnaire-based study[66] and another involved monitoring movements of the bed in which subjects slept[172]. The latter two studies entailed very few observations, so their results had only a marginal influence on the outcome of Pearsons' meta-analysis. The relationships defined from the field study data were based on a total of 213 subject-nights with EEG scans and 2770 noise events. The noise sources in the three studies were civil air traffic and rail traffic.

The Committee traced only three reported studies that had looked at the effect of night-time noise on children's sleep EEG[55-57]. Lukas exposed twenty-two people, six of them children (five to seven years old) to aviation noise and sonic booms once they had entered stage 3 or 4, as registered on an EEG. He observed that the children's EEGs showed less response to noise while in deep sleep than the adults' EEGs. Eberhardt[56] reported the effects of exposure to road traffic noise on thirteen children. Eight of the children lived on a quiet street, but on several nights during the study period were exposed to recorded lorry noise (sixty-eight times per night); the other five children slept beside a busy road. EEG awakening occurred in the first group of eight children in response to 0.2, 0.8 and 2.1 per cent of noises with *LAmax_i* values of, respectively, 45, 55 and 65 dB(A). The only other statistically significant difference revealed by the EEG analysis was a six-minute increase in the time spent in a waking state (W) on the nights with the higher noise exposures. The children also reported that, on the nights when they were exposed to road traffic noise, they found it harder to go to sleep, found that they woke up more often, recalled being awoken more often by road traffic noise, felt less

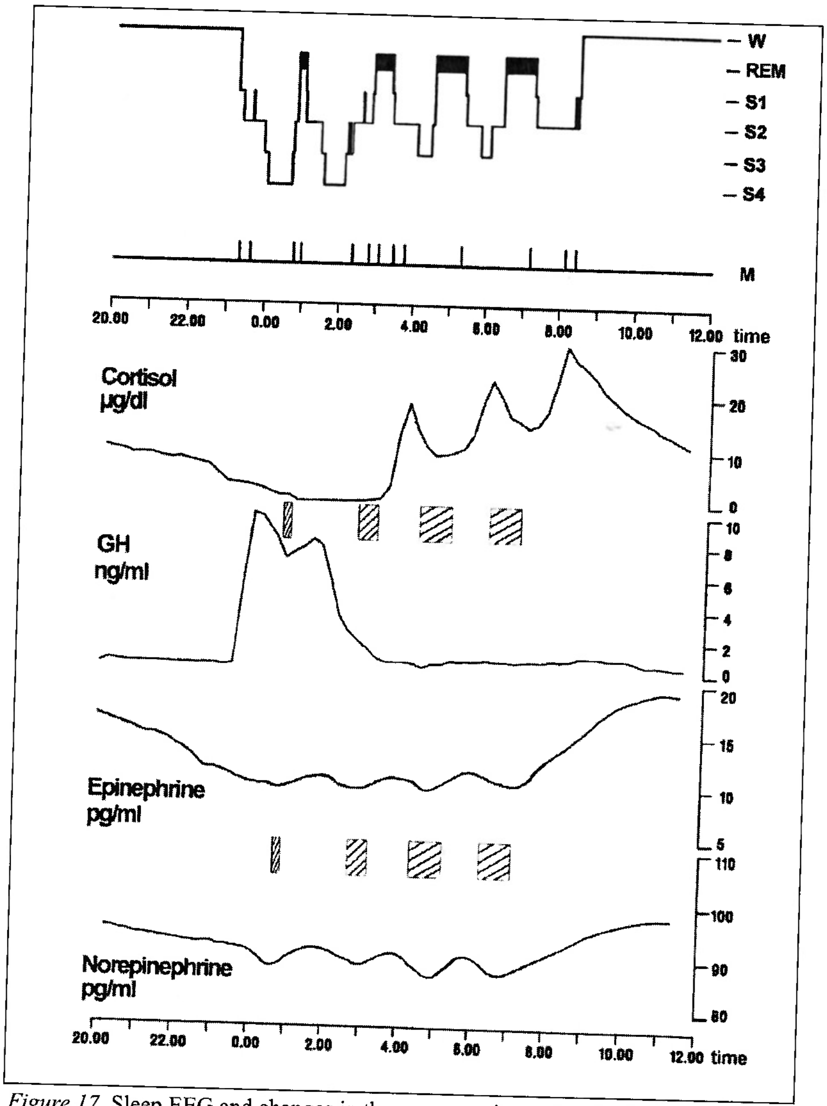


Figure 17 Sleep EEG and changes in the concentrations of cortisol, growth hormone (GH), epinephrine (adrenaline), and norepinephrine (noradrenaline) in the blood, as a function of the time from 8pm to 12 noon; typical patterns for healthy young adults[88].

well rested the following day and perceived the quality of their sleep to have been diminished.

Double glazing was fitted to the bedroom windows of the second group of just five children, thus attenuating the noise by an average of 10 dB(A). The only statistically significant effect of this intervention observed in the very small study group was a seven-minute reduction in sleep inception period. Eberhardt concluded that children exhibited less strong responses to noise when sleeping than adults; he estimated that a noise needed to be about 10 dB(A) louder to induce a given EEG response in a child than was necessary to induce the same response in an adult.

In a laboratory study, Busby exposed twenty-four boys (eight to eleven years old) to three-second bursts of sound of successively increased volume (each sound being 2 to 5 dB(A) louder than the last), until EEG awakening occurred. It was possible to reproduce the sound at up to approximately 95 dB(A) above the perception threshold. The percentages of EEG awakenings from SWS, stage 2 and REM sleep were, respectively, 4.5, 34 and 50 per cent. When the night was divided into three phases, the percentages of awakenings and arousals in the first phase (characterised mainly by SWS) were 12 and 14 per cent, respectively; the corresponding figures in the second phase of the night were 30 and 20 per cent, respectively, and in the third phase (mainly REM sleep) 50 and 8 per cent, respectively. Comparing responses to noise in hyperactive children, hyperactive children on medication and non-hyperactive children, Busby observed no differences. From the findings, Busby concluded that, in the latter phase of the sleep period, children were very sensitive to noise, and that much more research was needed to build up a full picture of how children responded to noise when sleeping.

D.2.4 *Motility*

Over the last ten years, various large-scale field studies have been carried out, in which subjects wore actimeters when sleeping in order to record motility. In the USA, there have been two studies focusing on aviation noise[49,50,134], in Germany there has been one study concerned with road and rail traffic noise[60,77,78], in the UK there have been a further three studies on aviation noise[51,54,80,173], and finally one study into aviation noise has taken place in the Netherlands[12,13,174]. In several studies, noise events were linked over time with motility, as indicated by the actimeter data, in order to shed light on the acute motility responses. In four of the studies, it was thus possible to define the relationship between *LAmax_i* or *SEL_i* and acute motility during and attributable to aircraft noise events[12,49,51,134]. In the other studies, the researchers focused on average motility during the sleep period.

Figure 18 shows the increase in the probability of acute motility attributable to aviation noise in the fifteen-second interval with *LAmax_i* as deduced from the Dutch research. Acute motility was induced by the noise of a passing aeroplane from an

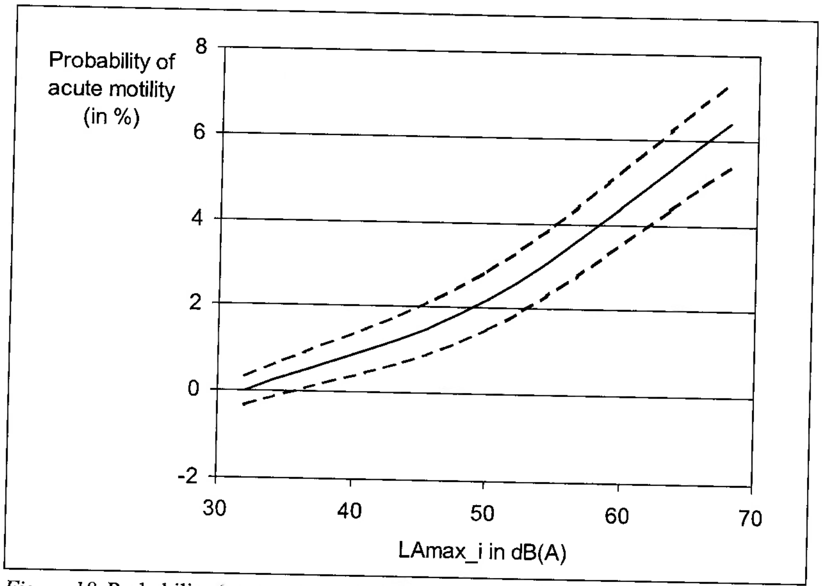


Figure 18 Probability (as a percentage) of acute motility being induced by an aircraft passage, as function a of the *LAmax_i* of the noise event, in the fifteen-second interval with *LAmax_i*. The figure also shows the so-called '95 per cent prediction-intervals'[12,13].

LAmax_i of 32 dB(A)*; an *LAmax_i* of 32 dB(A) is therefore the observation threshold for motility.

The curve shown in Figure 18 represents the average effect. The effect is strongly dependent on *Li*; as *Li* increases, so the probability of acute motility being induced by aviation noise decreases. In other words, people who are exposed to the sound of a passing aircraft numerous times while sleeping respond less to a single passage than people who are exposed to the sound only occasionally. The relationship between the probability of aviation noise-induced motility and exposure to aviation noise was not found to be gender-dependent and was barely age-dependent. The study findings also indicated that, at a given *LAmax_i* value, the type of aircraft manoeuvre (landing or taking off) did not affect the probability of aviation noise-induced motility. The researchers also asked subjects about their attitude to air traffic and to the expansion of Schiphol Airport. Attitude was found to have no influence on the probability of acute motility induced by aviation noise.

* In the Dutch study, *LAmax_i* was not measured in fast mode; rather *LAmax_i* was the maximum indoor equivalent sound pressure level measured over a one-second interval during an aircraft passage. Theory suggests that *LAmax_i* measured in fast mode should be 0.2 to 1 dB(A) higher than the maximum indoor equivalent sound pressure level measured over a one-second interval. The observation threshold for acute motility is therefore an *LAmax_i* in fast mode of 33 dB(A)

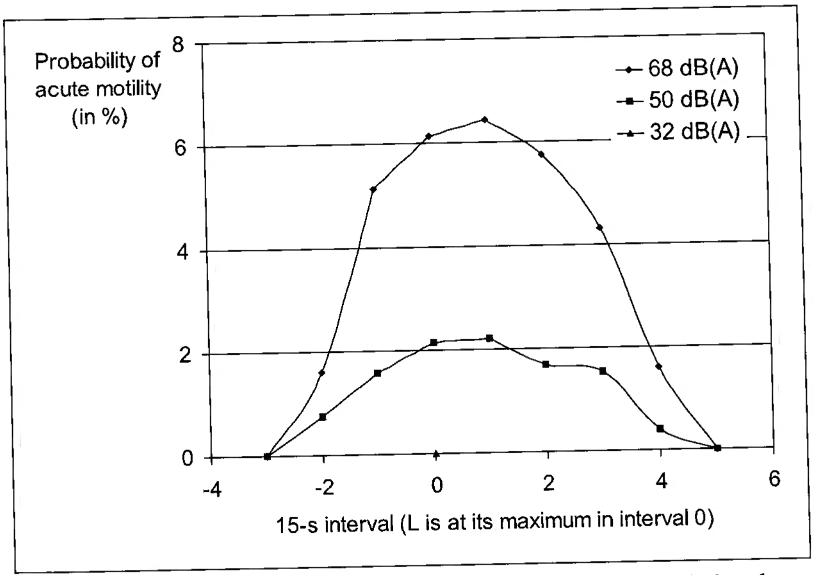


Figure 19 Probability of acute motility in three fifteen-second intervals before the interval in which the *LAmax_i* of an aircraft noise event occurred, in the interval of occurrence, and in five fifteen-second intervals after the interval of occurrence, for three flight passages with *LAmax_i* values of 68, 50, and 32 dB(A).

The Dutch researchers additionally calculated the probability of motility onset by aviation noise in the fifteen-second interval with *LAmax_i*. The observation threshold for motility onset also worked out at an *LAmax_i* for the aircraft passage of 32 dB(A).

Increased probability of acute aircraft noise-induced motility was sometimes observed both before and after the fifteen-second interval in which the *LAmax_i* occurred. This phenomenon is illustrated in Figure 19. Overall, the probability of motility being induced by aviation noise in any fifteen-second interval was more than four times that probability in the fifteen-second interval in which *LAmax_i* occurred.

The Dutch study's findings are consistent with those of the first US study, by Fidell *et al*[49]. This study focused exclusively on people exposed to (very) high night-time aircraft noise exposures. The researchers established that the observation threshold for motility was 45 dB(A). This figure is broadly in line with the 42 dB(A) calculated by the Dutch research team for subjects with an *Li* of 40 dB(A). In the second US study, which was much smaller-scale than the one just referred to, no statistically significant relationship could be demonstrated[134].

The relationship established in the British study between motility onset in a thirty-second interval and the *LAmax* of an aircraft passage differed considerably from the pattern illustrated in Figure 18, even allowing for the facts that the British researchers looked at the probability of motility in thirty-second intervals and that the relationship

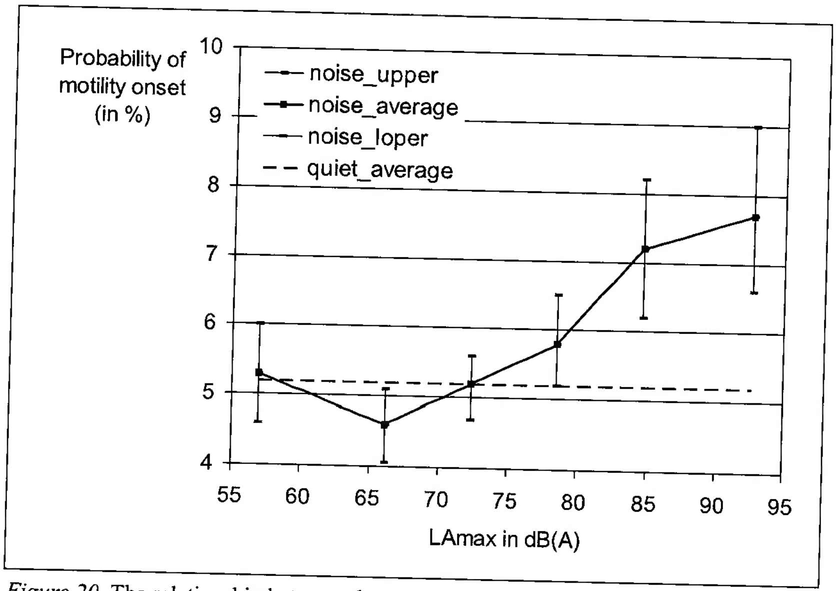


Figure 20 The relationship between the average probability of motility onset in the thirty-second interval in which *LAmax* occurs during an aircraft passage (noise_average) and *LAmax* of the passage, with the probability of motility onset outside these intervals also illustrated (quiet_average), based on research by Ollerhead[51]. The 95 per cent prediction interval (from noise_lower to noise_upper) is also given for each value.

between the probability of motility onset and the *LAmax* of an aircraft noise event is based on outdoor *LAmax* values. Various TNO reports have looked at this point[12,13,79,97]. Some of the findings of the British study are illustrated in Figure 20.

The British researchers came to the conclusion that the probability of motility onset by an aircraft passage began to increase from an *LAmax* of 82 dB(A)[51]. Even when this outdoor value is reduced by 25 dB(A) (the figure quoted by the researchers[54] as the difference between outdoor and indoor levels), the observation threshold works out at an *LAmax_i* of 57 dB(A). This is 25 dB(A) higher than the corresponding figure established by the Dutch team for the probability of aircraft noise-induced motility or motility onset. The Committee believes that the main reasons for the differences in the findings of the British and Dutch studies are as follows:

- In the British study, aviation noise levels were established on the basis of *outdoor* measurements only. The instruments used by the researchers were positioned so as to be directly exposed to the noise. The outdoor sound pressure levels on subjects' bedroom walls will in some cases have been (much) lower, particularly where there was screening in the form of objects such as other buildings and trees. The outdoor measurements therefore represent the upper values in a wide range of outdoor sound pressure levels on subjects' bedroom walls. The distribution of indoor values will have been even greater, since the sound attenuating characteristics of each room will have differed, and the window aperture status will have varied from subject to subject and from night to night. In the Dutch research, where the average difference between the outdoor and indoor *LAmax* values of more than 63,000 aircraft passages during subjects' sleep periods was 21 dB(A), outdoor values as high as 82 dB(A) were sometimes associated with indoor values as low as 32 dB(A). These considerations suggest that, at a measured outdoor noise exposure of 82 dB(A), the actual exposure inside the subject's bedroom may well have been much lower. The Dutch study, by contrast, made use of measured indoor values.

- The British researchers considered whether there had been an aircraft passage only if their instruments registered a noise event with a sound pressure level of more than 60 dB(A) lasting for at least two seconds. If the timing of such a noise event coincided with the timing of a registered aircraft passage, the event was 'recognised' as an aircraft passage. Furthermore, any aircraft passage occurring within five minutes of the previous passage was excluded from the analyses. Then 'noise' was defined as any thirty-second interval in which the *LAmax* of a recognised aircraft passage occurred, and 'quiet' as all other thirty-second intervals. In other words, quiet included all intervals in which relatively quiet aircraft passages occurred, all intervals in which there were aircraft passages within five minutes of a previous passage, and all intervals during an aircraft passage before and after the interval of *LAmax* occurrence. The researchers then worked out the average probability of motility onset during 'quiet' periods (see Figure 20). However, this average will have been higher than a typical value for a genuinely quiet thirty-second interval, since all non-aircraft noises, all aviation noise outside the thirty-second intervals of *LAmax* occurrence and all 'quieter' and 'non-recognised' passages, plus the associated motility, were ignored. In consequence, the probability of motility onset *by aviation noise* (*noise – quiet*) was underestimated. In the Dutch study, an aircraft passage was included if its *LAmax* was 40 dB(A) or higher. Furthermore, distinction was made in the analyses between intervals characterised by the background sound pressure level only and intervals characterised by the presence of the background sound pressure level plus a non-aviation noise. Hence, the model takes account of the additional chance of motility or motility onset attributable to non-aviation noise, so that only the probability of extra motility caused by aviation noise is attributed to this source.
- The British study focused exclusively on *motility onset*, whereas monitoring *motility* would also have taken account of the duration of the effect. Furthermore, the Dutch researchers found that the probability of motility was more closely related to the *LAmax_i* (and *SEL_i*) than the probability of motility onset was.
- The British study looked only at *the thirty-second intervals of LAmax occurrence*. However, it was found in the Dutch study that, overall, motility onset was more

likely *in the intervals before and after the interval of LAmax occurrence* than in the interval of occurrence itself.

- The scope for performing calculations was more limited in 1992, with the result that not all the British team's data could be analysed. Hence, the relationship between the probability of motility onset and exposure to aviation noise was defined on the basis of data concerning the period 11.30pm to 5.30am only. However, it is apparent from both the Dutch study and the British study that aircraft passages became more likely to be associated with motility or motility onset as the subject's sleeping time progressed and the absolute time got later. Furthermore, limited calculation capacity obliged the British team to group aircraft passages into noise categories (see Figure 20). For each category, the average probability of motility onset was then calculated and a check made to establish whether there was a statistically significant difference between the calculated value and the average probability of motility onset during quiet. An analysis method involving the processing of all the data at once would undoubtedly have led to the definition of a much lower threshold value.

The original purpose of the German study was not to establish acute-level exposure-effect relationships, so the data from the study has recently been re-analysed with a view to defining such relationships for road and rail traffic noise[79]. Where rail traffic noise is concerned, the relationship has been defined between the probability of acute concurrent motility or motility onset and the *SEL* of a rail traffic noise event lasting up to two minutes. From these calculations, it appears that exposure to rail traffic noise does not increase the probability of acute motility or motility onset as much as exposure to aviation noise. After conversion of the German data to fifteen-second interval values, a 40 dB(A) *SEL* increase, from 60 to 100 dB(A), was estimated to be associated with roughly a 2.5 per cent increase in the probability of motility or motility onset. The corresponding figure for aviation noise is approximately 7 per cent.

In the German study, the exposure patterns for road traffic noise proved to be very different from the patterns for rail and aviation noise. Rail and aviation noise both involve distinct noise events, with an aircraft passage rarely lasting more than one minute and a train passage rarely longer than three minutes. (In the German study, 2,6 per cent of the nearly 69,000 train passages lasted longer than three minutes.) In total, nearly 17 per cent of thirty-second intervals included train noise. By contrast, nearly 53 per cent of thirty-second intervals involved road traffic noise in excess of the background level (i.e. three times the percentage for rail traffic noise).

In addition, a relationship has been established between acute motility during a thirty-second interval featuring road traffic noise and the equivalent sound pressure level during the interval[79]. The probability of acute motility during a given thirty-second interval featuring road traffic noise was found to rise to a small but statistically significant extent as noise exposure increased: a rise in the equivalent sound pressure level over a thirty-second interval from 40 to 70 dB(A) was associated with a 0.3 per cent increase in the probability of motility. However, in the first thirty-second interval of a period featuring road traffic noise, the probability of acute motility was on average 3.4 per cent higher than in a given thirty-second interval without road traffic noise or in another thirty-second interval during a period featuring road traffic noise. In other words, the effect at the start of a period featuring road traffic noise is quite strong.

D.2.5 *Subject-registered awakening*

Over the last ten years, various meta-analyses have been performed on data from eight or nine field studies, with a view to establishing the relationship between the probability of noise-induced subject-registered awakening (awakening recorded by the subject during his/her sleep period, by pressing a button) and a noise index (*SEL_i*) for the event[52,134,135,175-179]. Two of the analyses – those by Finegold and Elias[135] in 2002 and Passchier-Vermeer[52] in 2003 – used the same database, previously assembled by Fidell[134]. Passchier-Vermeer additionally included in her analysis data from the Dutch study into sleep disturbance caused by aviation noise. In contrast to Finegold's meta-analysis, the secondary analysis performed by Passchier-Vermeer took account of the following:

- The type of noise source: civil aircraft, military jets, trains, other environmental noise events
- Differences in the probability of subject-registered awakening, EEG awakening and motility onset associated with a noise event of a given intensity (see Figure 8)
- The number of observations per subgroup (with subgroups formed on the basis of the *SEL_i* of the noise event, with the result thatthe number of observations per subgroup varied by a factor of 100)
- Differences in the time windows around a noise event within which the different researchers looked for evidence of awakening or arousal
- The probability of waking up in a period without noise events.

From the analyses, it was apparent that a statistically significant relationship was demonstrable between civil and military aircraft noise and subject-registered awakening, but not between rail traffic noise or 'other environmental noise events' and such awakening[52]. Since the relationship between the noise of military jets and subject-registered awakening is based purely on data relating to people living near to a single military air base, the findings should be verified by further research.

The database used by Passchier-Vermeer for her analyses included data on noise levels in the bedrooms of more than a thousand subjects in seven studies into the effects of civil air traffic noise, involving more than 170,000 aircraft passages. In these seven field studies, the data on the aircraft passages was aggregated to seventy-eight points on the basis of *SEL_i*. This data was cross-referenced to the data on subject-registered awakenings to determine whether subjects recorded waking up within a five-minute window around an aircraft passage (from one minute before to four minutes after the *LAmax_i* of the passage).

The frequency of subject-registered awakening was also established for five-minute time windows in which no aircraft noise events occurred. The probability of *subject-registered awakening attributable to a noise event* was then calculated by subtracting the probability of *awakening in time windows without noise events* from the probability of *awakening in time windows with noise events*.

The average probability of subject-registered awakening in a five-minute interval without aviation noise was 1.73 per cent. Figure 21 shows the probability (as a percentage) of subject-registered awakening *attributable to aviation noise* during a five-minute interval, as well as the probability of *awakening for any reason during* a five-minute interval in which an aviation noise event occurred. The observation threshold for aviation noise-induced subject-registered awakening is an *SEL_i* of 54 dB(A). This is estimated to correspond with an *LAmax_i* (measured in fast mode) of 42 dB(A).

In principle, a noise with a very low sound pressure level can be audible in a very quiet environment. In young people, the binaural perception threshold (the threshold for the perception of a sound using both ears) is close to 0 dB(A). Although the threshold

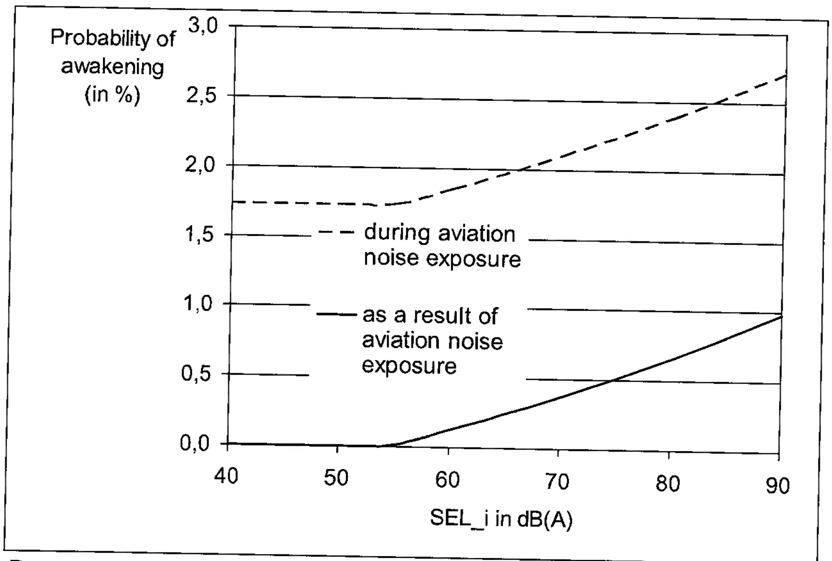


Figure 21 Percentage of subject-registered awakenings during a five-minute interval in which aviation noise occurs and percentage of subject-registered awakenings due to aviation noise as a function of indoor measured *SEL* (in dB(A))[52].

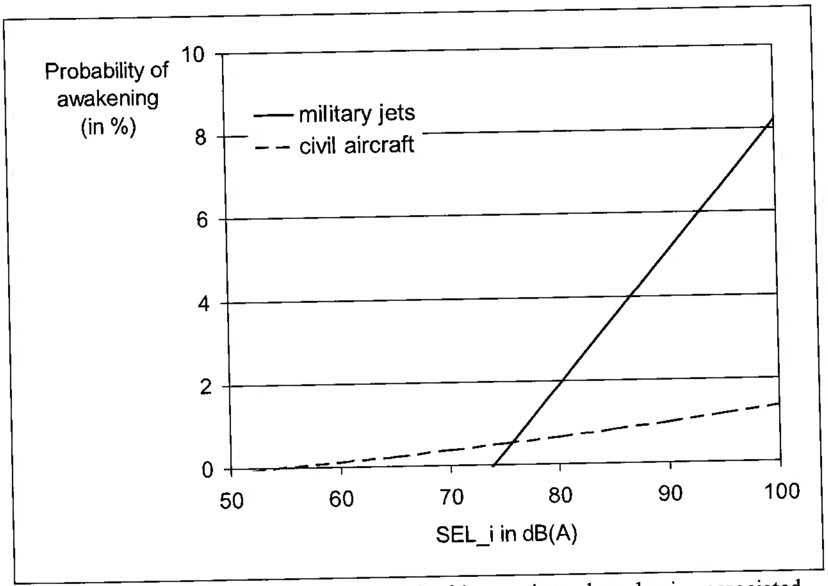


Figure 22 The probability of noise-induced subject-registered awakening associated with civil aircraft and military jets, as a function of indoor measured *SEL* (in dB(A))[52].

for the perception of higher frequencies (above about 2000 Hz) increases as a result of normal age-related loss of acuity, the ability to hear lower-frequency noises, such as aircraft noise, does not decline nearly as much. Not many people's bedrooms are so quiet that special sounds of close to 0 dB(A) can be heard, since such sounds are liable to be masked by normal background noise. Generally speaking, aviation noise can be heard in an otherwise quite bedroom when the level is more than about 15 to 20 dB(A). This implies that, when a person is awake, the noise of a distant aircraft can be heard if it is more than about 15 to 20 dB(A), provided that the bedroom is otherwise sufficiently quiet.

Figure 22 shows the probability of noise-induced subject-registered awakening associated with civil aircraft and military jets[52]. Although the data relating to military jets requires further verification, the Committee considers it appropriate to highlight the data, as it illustrates the effect of exposure to noise events characterised by a rapid initial rise in intensity.

D.2.6 Acute annoyance and inconvenience

The Committee is not aware of any field or laboratory research into acute annoyance or other acute problems due to night-time noise.

D.2.7 Summary

The results of the research into the acute biological effects of exposure to night-time noise described in this section can be summarised as follows:

Acute heart rate change

- In people who had been exposed to road traffic noise for years, heart rate accelerations occurred in response to road traffic noise peaks with *LAmax_i* values typically in excess of 30 dB(A). The observation threshold for heart rate acceleration is therefore likely to be below an *LAmax_i* of 30 dB(A).
- Noise is much more likely to induce heart rate acceleration at night than during the day.
- People with cardiovascular problems and people who consider themselves to be particularly sensitive to noise may well be more liable to experience noise-induced heart rate accelerations.
- The field research carried out by Hofman indicates that there is a cardiac response to roughly 60 per cent of motorway traffic noise peaks, irrespective of the hearer's sleep stage or the *LAmax_i* value of the noise peak (lorry).
- From laboratory research data, one can deduce that lorry passages and aircraft passages with similar *SEL_i* values have approximately the same effect on the heart rate.
- The results of the various laboratory studies referred to all indicate that, at a given *SEL_i*, a noise event characterised by a (very) rapid initial rise in intensity is more likely to affect the heart rate than a noise event that rises in intensity more gradually at the beginning. It is not possible to quantify this effect, however.
- Data from the only study involving children (five to seven years old) suggests that children's physiological responses to noise events during sleep are indicative of a 10 dB(A) higher sensitivity to noise.

Acute changes in hormone levels

Not investigated.

Sleep stage change, including EEG awakening

- Among people who are accustomed to exposure to night-time aviation noise, the observation threshold for EEG awakening is an *SEL_i* of 40 dB(A); the observation threshold for sleep stage change is probably slightly lower.

- The effect of night-time noise on children has been studied in the context of laboratory studies with just twenty-four, eight and six children, and in one field study of five children in a domestic setting. One of the researchers indicated that children were less sensitive than adults to the onset of acute EEG-registered changes by night-time noise. Another researcher who studied children observed that, in the last phase of the sleep period, noise peaks of up to 95 dB(A) induced EEG awakenings (excluding EEG arousals) 50 per cent of the time and EEG arousals 8 per cent of the time.

Motility, motility onset

- Among people who are accustomed to exposure to night-time aviation noise, the average observation threshold is an *LAmax_i* of 32 dB(A) both for acute motility and for acute motility onset (with *SEL_i* values of 38 and 40 dB(A)). The observation threshold for acute motility is comparatively high among people who have been habitually exposed to higher levels of night-time aviation noise, and comparatively low among people who are only occasionally exposed to the sound of night-time aircraft passages. People in the latter group consequently respond more to a single aircraft passage.
- Among people who are accustomed to exposure to night-time rail traffic noise, the observation threshold for motility is estimated to be an *LAmax_i* of about 30 to 35 dB(A).
- Among people who are accustomed to exposure to night-time road traffic noise, the probability of acute motility during a given thirty-second interval featuring road traffic noise barely increases at higher noise exposures. However, in the first thirty-second interval of a period featuring road traffic noise, the probability of acute motility is higher than in a given thirty-second interval without road traffic noise or in another thirty-second interval during a period featuring road traffic noise.

Subject-registered awakening

- Among people who are accustomed to exposure to night-time aviation noise, the average observation threshold for subject-registered awakening is an *SEL_i* of 54 dB(A), which corresponds to an *LAmax_i* of 42 dB(A).
- The one study into the relationship between noise from military jets and subject-registered awakening indicated that, at higher exposures, military jets are much more likely to induce subject-registered awakening than civil aircraft.

Acute annoyance and other acute problems

Not investigated.

D.3 Biological effects over the course of a night (before, while and after sleeping)

D.3.1 Introduction

Very few field studies have looked specifically at the relationship between an effect measured over the course of or following a sleep period and the noise exposure during sleep. Furthermore, data from the studies of acute noise-induced changes described in D.2 has not in most cases been aggregated to provide full-night figures.

In 2003, the RIVM performed a review of field studies that had specifically sought to shed light on the effects of night-time road traffic noise on sleep[69]. For this review, the researchers collated literature published since 1970. The reviewers found thirty-four field studies, of which twenty-three focused entirely on self-reported effects over an extended assessment period (e.g. a year). The results of these twenty-three studies are considered in the section of this annex devoted to the chronic consequences of exposure to (road traffic) noise. Ten of the other eleven studies used EEG, ECG or actimetry monitoring of sleeping subjects, sometimes supported by journal entries, to investigate effects over the course of a single night. In most cases, noise levels were also measured (in subjects' bedrooms) during the study nights. The eleventh study monitored effects on the basis of journal entries only. These eleven studies are considered in D.3.2.

In an article published in 2003, Babisch[81] provided an overview of research into stress hormone levels associated with exposure to noise, both in a domestic setting and in an occupational setting. He referred to approximately a hundred studies, twenty-three of them epidemiological. Eleven of these twenty-three studies were concerned with the effects of occupational exposure to noise, while twelve studies looked at the effects of exposure to noise in the domestic environment. In eight of these studies (three of which focused on exposure to road traffic noise and five on exposure to aviation noise), stress hormone levels were determined by analysing urine samples collected during and after sleep, or saliva samples collected after the subjects had waken up. These eight studies are considered below.

The eleven field studies mentioned in the RIVM report[69] and the eight field studies referred to in Babisch's article[81] were concerned almost exclusively with road and air traffic noise; just one of the studies looked at both road and rail traffic. No similar studies into the effects of stationary noise sources were traced. In the following subsections, first the results of the field studies of road traffic noise are dealt with, then the field studies of aviation noise, and finally the one field study of rail traffic noise. The subsection on aviation noise field studies also takes account of data from one quasi-field study.

This section concludes with an inventory of (laboratory) studies into the influence of night-time noise on the immunological properties of blood cells.

D.3.2 *Road traffic noise*

The eleven field studies referred to in the RIVM report[69] were as follows:

1 Four very small studies. These studies involved very small numbers of subjects and subject-nights (three, six, seven, and twelve people) and do not lend themselves to generalisation. They are not therefore considered further here[129,164-166].
2 Research from the USA[49]. This research into the effects of aviation noise included only a control group that was exposed to road traffic noise. The report does not include any aggregated single-night data relating to this group.
3 Four European studies conducted around 1980 in the Netherlands, Germany, France and the UK on behalf of the European Commission[58,59,70-73].
4 Research carried out in Germany[77,78]. This is the same research referred to in D.2.4, into the differences between the effects of night-time exposure to road traffic noise and rail traffic noise.
5 Research undertaken in Sweden by Öhrström[74], which monitored effects purely on the basis of journal entries.

The four European studies mentioned in list item 3 were intervention studies, in which road traffic-related noise exposure was reduced by approximately 10 dB(A) by various means: double glazing of bedroom windows, gap sealing, use of personal hearing protection, and temporary bedroom relocation to the quiet side of the house[58,59,70-73]. The four studies involved a total of seventy subjects and 922 subject-nights. Jurriëns drew the following conclusions regarding the effects observed in relatively noisy situations (compared with quieter situations):

- The average duration of REM sleep is 6.5 minutes shorter
- In reaction time tests, the average reaction time is twelve milliseconds (12 ms) longer than the overall average reaction time of 350 ms, and more mistakes are made (8 per cent)
- Self-reported quality of sleep is less (7 per cent)
- The W (waking) time recorded by EEG is 7 minutes longer (determined in two of the four studies)
- The average heart rate when sleeping is higher. In the Dutch research, the rate was 3.2 beats per minute higher (71.5 bpm, compared with 68.3 bpm)[58].

In the German research referred to in list item 4[77,78], 188 subjects were exposed mainly to road traffic noise and a similar number mainly to noise from passing trains. The number of subject-nights with usable data on motility was 1710 in the road traffic group. A recent analysis[79] of the data indicated that, among people exposed to road traffic noise, average motility for a single sleep period increased as the equivalent indoor or outdoor traffic sound pressure level was higher during the period in question.

The research by Öhrström referred to in list item 5[74] involved 106 subjects. Analysis of their journal entries revealed the following: 37 per cent of subjects in noisy environments had difficulty getting to sleep, compared with 8 per cent in quiet environments; the percentages of subjects in the two types of environment who were woken in the night by road traffic noise were 57 per cent and 4 per cent; average sleep quality, as rated on an eleven-point scale (where 0 equals very poor and 10 equals very good) was 6.2 for the noisy environments and 8.2 for the quiet ones; morning fatigue/alertness scores, as rated on an eleven-point scale (where 0 equals very tired and 10 equals not at all tired) were 5.0 and 7.0; the average scores for morning irritability, as rated on an eleven-point scale (where 0 equals very irritable and 10 equals not at all irritable) were 6.5 and 7.8. In other words, all parameters values were less favourable in the noisy situation.

Swedish researcher Öhrström recently made a longitudinal study of the change in noise-induced effects on sleep following realisation of a scheme designed to reduce road traffic noise by the enclosure of a road in a tunnel. The report on elements of the study[75] will shortly be followed by two publications in *J Sound Vib*[**]. The forthcoming data will show that the study was modest in scale: at each of two locations (one noisy, one quieter), thirteen subjects were monitored on each of three occasions, once before and twice after completion of the tunnel, which has reduced indoor noise by 10 dB(A) at the noisy location. Within the exposed group, no statistically significant change was detected in various parameters monitored before and after completion of the tunnel, the parameters in question being average motility, minutes spent in bed, sleep inception period, sleep duration, number of 'awakenings', and number of waking intervals of more than five minutes. Not surprisingly, in view of the small number of subjects, there is considerable variation in the average values; notably, there was an increase in the values of various parameters – i.e. a deterioration – in the third monitoring round, a year after completion of the tunnel, relative to the values measured in the second phase.

At the ICBEN2003 Congress, Öhrström presented a provisional report on those results from the international RANCH study that related to night-time noise. The subjects were seventy-nine children between the ages of nine and twelve, plus one parent of each child[76]. The equivalent sound pressure level of the road traffic over a twenty-four-hour period, as determined on the outside of the most heavily exposed wall , varied from less than 55 to more than 64 dB(A). The sleep parameters monitored were sleep quality

* Öhrström, personal communication.

(overall quality, as established by questionnaire, and nightly quality, as recorded in a journal), sleep inception period and average motility. Although marked differences were observed between the parameter changes in children and those in their parents, the changes did not appear to be dependent on the noise exposure.

Table 16 summarises data from the three field studies[82,152-154] referred to by Babisch[81], which sought to establish the effects of noise on hormone concentrations, as determined from urine samples collected over the course of a night or blood samples collected after awakening. Strictly speaking, the results do not show whether the observed changes are the result of exposure to road traffic noise during the night in question, or (at least partly) the result of exposure the previous day, or the result of chronic daytime or night-time exposure.

Table 16 Summary of data from the three field studies referred to by Babisch[81], which sought to establish the effects of noise on hormone concentrations[a].

Publication	Outdoor noise exposure (*LAeq* in dB(A))	Subjects	Adrenaline	Noradrenaline	Cortisol	Monitoring method
Babisch, 2001[82]	45-75, during the night	234 women	=	+	x	Urine collection during the night
Evans, 2001[153]	Less than 50 or more than 60 over the twenty-four-hour period	115 children	=	=	+	Urine collection during the night
Ising, 2002[154]	Lmax= 40 or Lmax= 66 dB(C) over the twenty-four-hour period	56 children	x	x	+	Urine collection during the night

a Relative effect at higher noise exposure: + statistically significant change in the anticipated direction, = no significant change in the anticipated direction, x not monitored.

Working at the Berlin Environmental Department, Babisch *et al* studied the effect of road traffic noise on the excretion of adrenaline and noradrenaline in the night-time urine of 234 women (thirty to forty-five years old)[82], some of whom lived in homes with the bedroom on the street side, and some in homes with the living room on the street side. The volume of passing road traffic varied considerably from dwelling to dwelling. The analyses took account of numerous distorting variables. Among the women with bedrooms on the street side, a statistically significant increase was observed in noradrenaline levels as the logarithm of the traffic volume rose. (The logarithm of the traffic volume is approximately proportional to the equivalent sound pressure level.) Changes in adrenaline level were not associated with changes in traffic volume, however. Among women with the living room on the street side, no effect was observed on either adrenaline or noradrenaline levels. The fact that it was mainly noradrenaline concentrations that were raised is consistent with Ising's model, which predicts that the noradrenaline concentration is particularly likely to increase in response to noises to which a person is exposed for a long time[83]. The effect of road traffic noise on noradrenaline concentration was particularly pronounced in women who indicated that they slept with the bedroom window closed to prevent their sleep being disturbed by road traffic noise, and nevertheless experienced noise-related annoyance. Among women who experienced no noise-related annoyance when their windows were closed, no statistically significant increase in noradrenaline concentrations was observed. The researchers explain these findings as the result of a coping mechanism: among women who are able to prevent noise-related sleep disturbance by closing their windows, noradrenaline levels are not affected, but among women who are not able to cope in this way, they rise. If a raised noradrenaline level may be regarded as predictive of cardiovascular problems, the authors argue that only those people who are highly sleep disturbed due to environmental noise and are not able to take corrective action are at increased risk of developing cardiovascular problems. However, the research results do not exclude the possibility that the observed effect is a reversible change.

Evans and Lercher studied 115 children around the age of seven who were exposed to road and rail traffic in Austria[153,155]. Half of the children lived in an environment with relatively little road and rail traffic noise *(Lden* less than 50 dB(A), average 46 dB(A)), while the other half lived in an environment where noise levels were typically more than 60 dB(A) (average 62 dB(A)). The researchers compared various endocrine and cardiovascular functions: daytime diastolic and systolic blood pressure and heart rate, plus adrenaline, noradrenaline, cortisol and 20A-dihydrocortisol levels, as determined from urine samples collected in the course of the night. A statistically significant difference of more than 25 per cent was observed between the cortisol and 20A-dihydrocortisol concentrations of the two groups. In a test that involved asking the children to solve impossible puzzles, girls exposed to higher noise exposures performed less well than girls in the low-exposure group.

D.3.3 *Aviation noise*

D.3.3.1 Field research

Table 17 summarises the findings of Babisch's review[81] of research into aviation noise-related changes in hormone levels over the course of a night.

Table 17 The findings of research[156-159,162,163] into changes and differences[a] in stress hormone levels, as reviewed by Babisch[81].

Publication	Noise exposure (*LAeq* in dB(A))	Subjects	Adrenaline	Noradrenaline	Cortisol	Monitoring technique
Evans, 1995[156]	59-65 24 hours	135 children	+	+	=	Urine collection during the night
Evans, 1998[157]	53-62 24 hours	217 children	+	+	=	Urine collection during the night
Ising, 1999[163]	56-70 over the day	40 children	=	=	=	Urine collection during the night
Haines, 2001[158,159]	53-62 24 hours	204 children	=	=	=	Urine collection during the night
Stansfeld, 2001[162]	<57->66 over the day	238 children	x	x	=	Saliva collected in the morning

a Relative effect at higher noise exposure: + statistically significant increase, = no significant change, x not monitored.

The Bristol-based team of Smith *et al*[80] made a phased investigation of the interrelationships between aviation noise, sleep disturbance and health.

In the final phase, the motility of ninety people (forty-five couples) was monitored using actimeters for three nights, during which sound pressure levels were measured in the subjects' bedrooms. The sources of the noises audible in the subjects' bedrooms were not determined using an external identification system, nor were any outdoor sound pressure levels measured. Noise events were divided into two groups: prolonged noise events (more than one minute above the background level) and brief noise events (less than one minute above the background level, with an equivalent sound pressure level of more than 50 dB(A) over at least one five-second interval). The number of brief noise events averaged 8.2 per night (with an average *SEL_i* of 59 dB(A)), and the number of prolonged noise events averaged 6.4 per night (with an average *SEL_i* of 65 dB(A)). No association was found between noise exposure and actimetric activity. The researchers suggested that this was due to the low noise exposures that subjects were exposed to, even though there was considerable inter-individual variation in exposure values. The team reported having nevertheless observed statistically significant associations between noise exposure and motility among subjects on board a ship. The observed associations were:

- between the *number of* noise events and an index of sleep disturbance derived from several variables;
- between higher sound pressure levels during the sleep latency period and difficulty getting to sleep; and
- between higher sound pressure levels towards the end of a subject's sleeping time and premature awakening.

However, because the sources of the noises were not identified, the researchers could not exclude the possibility that the increased disturbance levels were related to the subjects' waking activities and were not therefore the effects of noise on sleeping patterns.

Passchier-Vermeer[12] identified four functions that she considered indicative of the effect of aviation noise over the course of a sleep period. The functions in question (see Figure 23) were:

- High average motility during sleep. This was quantified as follows. The data was analysed to calculate a level of motility as a function of age, which was exceeded by 5 per cent of subjects when not exposed to aviation noise when sleeping. A figure was then worked out for the percentage of subjects who on a given research night exhibited higher average motility than the 'normal' value for their age; the percentage of people who would exceed the normal motility value in the absence of aviation noise (approximately 5 per cent) was then deducted from the percentage for the night. The analysis revealed that average motility increased with rising night-time noise exposure, but this is not illustrated in Figure 23.
- Recalled awakening. In the journal that they were asked to write each morning, subjects indicated whether they had been woken by aviation noise in the night.
- Subject-registered awakening at least three times a night. Awakenings were recorded by the subject pressing a button on his or her actimeter.
- Use of somnifacient drugs. In their journals, subjects indicated each morning whether they had taken any sleeping pills the night before. The use of somnifacient drugs proved to be strongly age-related. Up to the age of about sixty, the use of somnifacient drugs was quite modest; above that age, use increased sharply with rising exposure to aviation noise.

Figure 23 shows night-time noise exposures in the form of *Lnight* values. The noise exposure was originally expressed as the equivalent sound pressure level during the sleep period. However, the equivalent sound pressure level data was converted to *Lnight* values on the basis of what is known about the relationship between equivalent sound pressure and *Lnight*. Because some effects are age-related, Figure 23 is based on the age profile of the adult Dutch population.

D.3.3.2 Quasi-field research

A research team at Berlin's Robert Koch Institute performed a quasi-field study with sixteen subjects living in the vicinity of Fuhlsbüttel Airport near Hamburg. The study involved observation of the effects induced by aviation noise reproduced in subjects' bedrooms using loudspeakers[47,150]. There were almost no night flights into or out of the

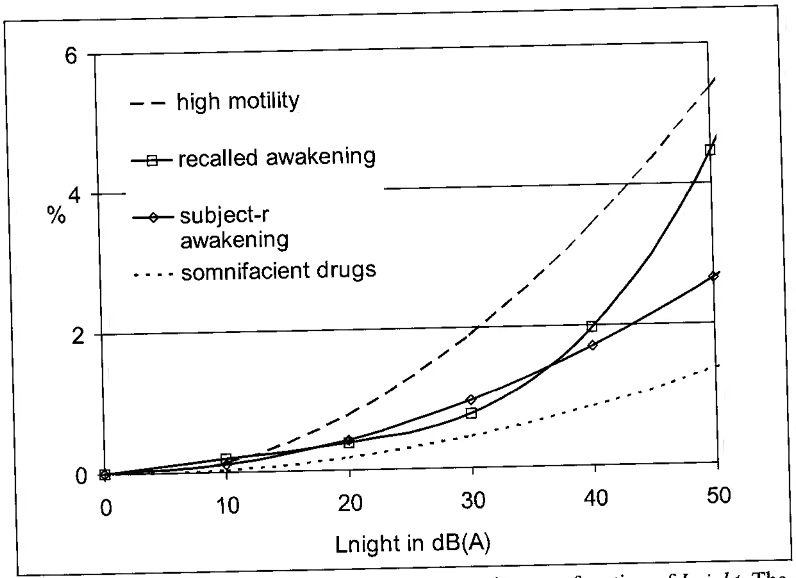


Figure 23 Prevalence of four effects of aviation noise, as a function of *Lnight*. The prevalence values express the following percentages, as attributable to exposure to aviation noise: percentage of people exhibiting high motility levels for their age, percentage of people who recalled being awoken by aviation noise, percentage of people who registered awakening at least three times in a night, and percentage of people who recorded using somnifacient drugs[12].

airport, so at the start of the study the subjects were unused to night-time aviation noise. After two nights without the introduction of any artificial noise, the subjects were exposed to recorded aviation noise with an *LAmax_i* of 65 dB(A) thirty-two times a night for thirty-eight nights. During and immediately after each sleep period, urine samples were collected and the total amount of cortisol present was determined. The researchers distinguished three adaptation patterns over the thirty-eight nights: total cortisol almost stable (observed mainly in female subjects); a large initial rise in total cortisol to a peak on the third night of exposure, followed by a gradual decline for the remainder of the study period; an initial decline in total cortisol, followed by a large peak on the third night of exposure, followed by a gradual increase for the remainder of the study period. With all three patterns, there were fluctuations in the course of the week, which were more pronounced in men than in women.

It is particularly interesting to note how the well-being scores recorded each day using a questionnaire changed over the study period. The scores were given using a scale, designed so that the average for the general population is zero, and 95 per cent of recorded values are between –3 and +3. Before the recorded aviation noise was introduced, in each of the three subsequent adaptation pattern groups the average well-being score was approximately 0.5 (i.e. a little better than normal for the population as a whole). In the stable cortisol group, well-being during the first fourteen days of the study fell from 0.5 to zero, where it remained. In both the other groups, well-being scores continued to fall, from 0.5 to –1 in the increasing cortisol group and from 0.5 to –2.5 in the declining cortisol group.

D.3.4 *Field research rail traffic noise*

In the above-mentioned German research[77,78] 188 subjects were exposed mainly to noise from passing trains. The number of subject-nights characterised by motility was 1581. A recent analysis[79] of the data indicated that, among people exposed to *rail traffic noise*, average motility for a single sleep period was unrelated to the equivalent indoor or outdoor traffic sound pressure level during the period in question.

Evans[153] reported that the noise measurements included not only the road traffic noise exposure experienced by children, but also the train noise exposure. Although the article does not indicate the breakdown between road and rail traffic noise, it seems reasonable to assume that road traffic noise was predominant.

D.3.5 *Laboratory research into changes in immunological parameters*

Between 1968 and 1974, Osada *et al*[84-87] investigated the relationship between exposure to noise and changes in the *number* of cells in the blood with roles in the body's immune functions. They performed four laboratory experiments with twenty-one subjects, in which they monitored changes in leukocyte and (eosinophilic and basophilic) granulocyte levels in the blood associated with exposure to various types of noise (road, air and rail traffic noise, industrial noise, white noise and pink noise). When data from noise exposure nights was compared with data from non-exposure nights, major differences were observed in the average values and wide distributions around the average changes. However, shortcomings have subsequently been highlighted in the study design**, which almost certainly explains the observed changes.

In their survey article *The Neuroendocrine Recovery Function of Sleep*, Born and Fehm devoted a section to the possibility that night-time exposure to noise might affect the immune system[88]. In two experiments, subjects were either deprived of sleep or allowed to sleep 'normally', then certain blood cells (monocytes) were examined to determine whether they exhibited an immune response to a particular stimulus (production of interleukin-1 and TNF-α (tumour necrosis factor α), which affect the production of T-cells, which in turn are important for the production of interleukin-2). Contrary to what had been expected, the immune response of the monocytes was much stronger

* Marth, personal communication.

after a sleepless night than after an ordinary night. On the other hand, there were far fewer monocytes present in the blood after a sleepless night, and production of interleukin-2 by T-cells was much more vigorous after a normal night than after a night of sleep deprivation. On the basis of their findings, the two authors postulate that night-time noise exposure may have a negative influence on the immune system. They add, however, that a great deal more research would be necessary to confirm such a hypothesis.

D.4 Effects on health and well-being

The first two subsections below (D.4.1 and D.4.2) deal with research into the association between chronic exposure to *traffic noise* and medical conditions, sleep quality and well-being. Subsection D.4.3 is concerned with data on (the effects of) *noise from neighbours* and the associated topic of acoustic insulation between dwellings. Finally, subsection D.4.4 described a Dutch inventory study of traffic noise, industrial noise, neighbourhood noise and noise from neighbours.

D.4.1 Medical conditions

D.4.1.1 Insomnia

A group of Japanese researchers carried out a questionnaire-based survey of 3600 adult Japanese women (aged between twenty and eighty) living on eight study sites to gather information about the factors that contribute to insomnia[89]. Some 11 per cent of subjects were found to be affected by insomnia. (The researchers adopted a definition of insomnia based on the *ICD-10 classification of mental and behavioral disorders: clinical description and diagnostic guidelines* [90].) One of the factors whose relationship with insomnia was investigated was the volume of traffic on the road where the subject lived. It was found that a high traffic volume (a nightly average of more than two thousand vehicles per hour, with a lorry counting as ten vehicles) was an insomnia risk factor. Women living on busy roads were considerably more likely to suffer from insomnia than the other women. Analysis of the survey data took account of various distorting variables, such as age, number of (small) children in the family, social status, receipt of medical treatment, regularity of bedtimes, apnoea-like problems and serious unpleasant experiences in the six months prior to completing the questionnaire. When the percentage of insomniacs in each of the three areas with the highest exposures was compared with the percentage in the low-exposure areas, the ratios worked out at, respectively, 1.4 (2100 vehicles per hour, *Lnight* of around 65 dB(A)), 2.1 (2400 vehicles per hour, *Lnight* of around 67 dB(A)) and 2.8 (6000 vehicles per hour, *Lnight* of around 70 dB(A)). The most frequently reported problem was difficulty getting to sleep.

D.4.1.2 Health diminution

A research team at Berlin's Robert-Koch Institute produced a 400-page report on the findings of the Spandauer Gesundheits Survey[95]: a longitudinal study, in the context of which the health of adults in Berlin's Spandau district has been surveyed every two years since 1982. The ninth survey round involved 2015 subjects, of whom 1714 were participating for at least the fifth time. In addition to going through the usual tests and questionnaires, these subjects were asked about noise-related annoyance from road, rail and air traffic, as well as from industrial sources. Noise maps were also produced showing the road traffic-related noise exposure on the homes of the 1718 people subjects who chose to complete the questionnaire on noise-related annoyance. The research into the effects of traffic noise was therefore essentially a cross-sectional cohort study. Furthermore, outdoor sound pressure levels were measured in front of ninety-six homes. However, it was not possible to take recent aircraft noise exposures into account. Most aircraft flying over the area were going to or from Tegel Airfield, which is closed at night (from 10pm for takeoffs and 11pm for landings, to 5am for both takeoffs and landings).

The analyses took account of twelve variables with the potential to distort the results. The presence and treatment of illnesses and medical conditions in the two years since the previous survey round (period prevalence), and in the research period as a whole (total prevalence) were investigated. The probability of a subject receiving medical treatment for a given illness or condition was determined for subjects whose road traffic-related *Lnight* was less than 50 dB(A) and expressed as an odds ratio (OR); in addition, 95 per cent confidence intervals (CIs) were stated in the report. The statistically significant results for subjects with a road traffic-related *Lnight* of more than 55 dB(A) were as follows:

- *Treatment for hypertension*: OR = 1.9 (CI = 1.1 – 3.2) (period prevalence)
- Treatment for hypertension if bedroom window was normally open: OR = 6.1 (CI = 1.3 – 29.2) (period prevalence)
- *Treatment for hypertension*: OR = 1.8 (CI = 1.1 – 2.9) (total prevalence)
- *Asthmatic bronchitis*: OR = 1.5 (CI = 0.9 – 2.5) (total prevalence)

With regard to people who were annoyed by road traffic noise, the following statistically significant association was found with daytime road traffic noise:

- *Treatment for psychological problems*: OR = 2.7 (CI = 1.3 – 5.6) (period prevalence)

Comparison of people exposed to a high exposure of aviation noise over a twenty-four-hour period with people exposed to a lower exposure revealed the following statistically significant association:

- *Treatment for thyroid problems*: OR = 3.8 (CI = 1.3 – 11.3) (period prevalence)

The researchers warn that their findings regarding non-cardiovascular illnesses and medical conditions (asthmatic bronchitis, thyroid problems) are potentially liable to distortion by variables other than the twelve that have been taken into account. Hence, the only conclusion that may be drawn regarding medical conditions is that, within the studied population, night-time exposure to road traffic noise is associated with treatment for hypertension.

The researchers also point out that the study population was made up largely of people who were very conscious of their health. If this population was more or less than averagely prone to hypertension, or inclined towards a lifestyle that increased or decreased the probability of hypertension, the association between hypertension and night-time noise exposure might not be reflective of the population at large.

Where the above-mentioned findings regarding hypertension and night-time road traffic noise were concerned, the OR for people exposed to a noise exposure of between 50 and 55 dB(A) was calculated to be between 1.0 and the PR given in the summary for road traffic noise exposures of more than 55 dB(A).

The researchers were not surprised to find that hypertension was demonstrably associated with night-time noise, but not with daytime noise, partly because people are often elsewhere during the day and partly because people are more sensitive to noise at night than during the day.

A methodological assessment of the research is made in the main body of this report.

D.4.2 *Sleep quality and well-being*

D.4.2.1 Increased motility

The British field study into the effect of aviation noise on sleep found that, over a sleep period, average motility and motility onset increased with rising exposure to aviation noise[96]. Horne reported that there was a strong inverse relationship between average motility and perceived quality of sleep. The Dutch field study into the effect of aviation noise on sleep and the German study regarding the effect of road traffic noise also found that average motility increased with noise exposure when sleeping[12,13]. The researchers found that average motility over the course of a night was strongly associated with the number of times that a subject recalled waking during his/her sleeping time, with the number of times that a subject registered awakening during his/her sleeping time, and with the following variables regarding which subjects provided information by completing a questionnaire at the beginning of the study: number of medicines used, sleep quality, number of sleeping problems, frequency of aviation noise-induced awakening, weekly frequency of aviation noise-induced averse effects on sleep, and number of health problems. The secondary analysis of the German research into road and rail traffic noise (involving 1710 subject-nights characterised by motility in the road traffic subject group and 1581 such subject-nights in the rail traffic group) also indicated that average motility increased with rising road traffic noise exposure[79]. Exposure to rail traffic noise had no demonstrable effect on average motility. Where both aviation noise and road traffic noise were concerned, the increase in motility with *Li* (the equivalent sound pressure level during sleeping time over an extended period) was much greater than would have been expected solely on the basis of the increase in the probability of noise-induced acute motility. The average increase in motility per dB(A) increase in noise exposure appeared to be between 1.3 and 1.5 times greater for road traffic noise than for aviation noise[79].

In the first main phase of a British study of aviation noise, sleep disturbance and health conducted by Smith *et al*[80], 543 subjects from Bristol were asked to answer a questionnaire. Due to lack of information about the noise exposure experienced by respondents, their subjective perceptions of the problems they had experienced getting to sleep were used to estimate levels of exposure to aviation noise when sleeping. Questions were posed regarding health (based on the abbreviated version of the General Health Questionnaire), self-reported health, sensitivity to noise, sleep disturbance and negative affectivity (utilising the Neuroticism Scale in Eysenck's Personality Inventory). Significant health differences and differences in sleep disturbance experience were detected between the subjectively defined high-exposure and low-exposure groups. However, once adjustment was made for the influence of age and degree of neuroticism on health and sleep disturbance, no statistically significant difference was found to exist between the two groups.

In a follow-up survey, some of the respondents from the first main phase completed a further questionnaire. When the findings from the second questionnaire were compared with information regarding the same subjects gathered from the first questionnaire, it was found that diminished health, increased sleep disturbance and increased sensitivity to noise were all associated with an increase between the survey dates in the noise exposure perceived by the respondents. However, no link was found between change in sleep disturbance and change in health. The researchers explained the findings of the follow-up study as follows. If the original effect measured during the first main phase is eliminated (by concentrating on the differences) and there is little situational change between the time of the first survey and the time of the second, (minor) changes will not be correlated.

A further survey with an improved design was subsequently carried out. For this survey, a number of locations in the vicinity of four airports were selected, some with a relatively high aviation noise exposure, and some with a lower exposure. A total of 1121 subjects were questioned orally and a further 658 subjects completed a written postal questionnaire. Differences between the higher exposure and lower-exposure subjects were detected in relation to the following parameters: perceived level of aviation noise when trying to get to sleep, sleep disturbance, physical health and well-being, particularly in terms of irritability, anxiety, depression and sadness. Even after making allowance for other variables, sleep disturbance and health remained closely related. From their findings, the researchers concluded that they were unable to demonstrate a causal relationship between sleep disturbance and health. They added that it was also possible that sleep disturbance was symptomatic of poor health.

D.4.2.2 Self-reported sleep disturbance, self-reported sleep quality diminution, and other self-reported effects of exposure to noise

On the basis of TNO's Disturbance Knowledge Base, exposure-response relationships have been defined for self-reported sleep disturbance by road, rail and air traffic[97,98] for use in an EU position paper. The main body of this report gives details of the relationships involving self-reported high sleep disturbance and includes a discussion of the findings.

The RIVM produced a report[69] which considered the question of whether a quantitative meta-analysis could be made of the results of research into the influence of road traffic noise on perceived sleep quality and difficulty staying asleep. Although the RIVM described several studies as being good quality, the researchers decided that it was not possible to perform a meta-analysis because of discrepancies in the studies' nomenclature, methods, exposure determination techniques and approaches to adjustment for distorting variables. Nevertheless, the Dutch researchers were of the opinion that there were qualitative indications that road traffic noise was associated with diminished perceived sleep quality and more difficulty staying asleep.

At the ICBEN2003 congress, the Dutch researcher Vos presented data from a questionnaire-based study of effects of gunshot noise on sleep[111]. Some of the findings are illustrated in Figure 24. The graph shows the percentage of people who indicated they were woken by gunshot noise (as established in Germany by Buchta) as a function of the average *SEL* (in dB(C)) of the noise discernible in the domestic environment. Informa-

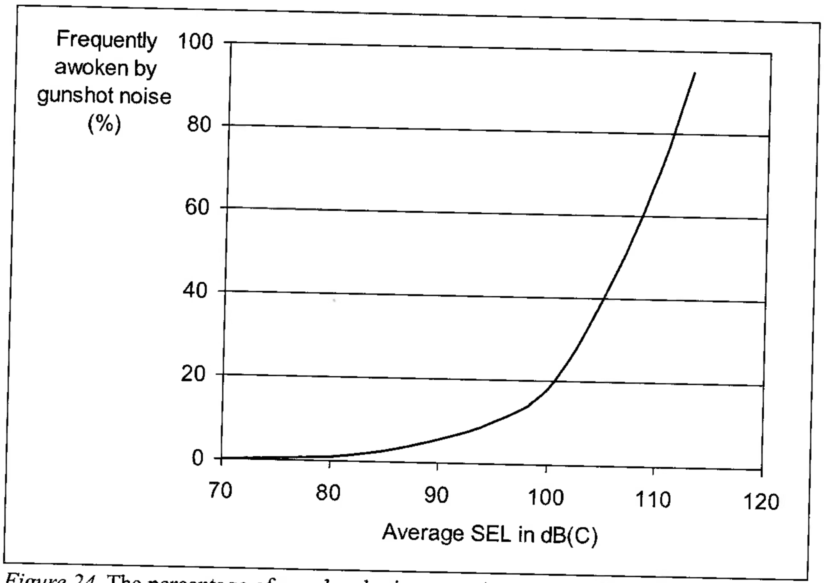


Figure 24 The percentage of people who in a questionnaire-based study indicated being frequently awoken by gunshot noise, as a function of the average *SEL* (in dB(C)) of the noise events[111].

tion about the number of noise events per night was not given, so it has not been possible to convert the data to *Lnight* values to enable comparison with the dose-response relationships for other noise sources. Vos was not (yet) able to make dose-response data other than that illustrated in Figure 24 available*.

D.4.2.3 Health problems

The Dutch field research into the effects of aviation noise on sleep established a relationship between personal noise exposure when sleeping (*Li*) and the frequency of health problems included on the abbreviated Health Perceptions Questionnaire[12,13]. Compiled on the basis of stress research, the Health Perceptions Questionnaire identifies thirteen health-related problems, such as headache, stomach-ache, tiredness and digestive problems. It will be apparent that these are not life-threatening conditions. A rise in aviation noise-related *Li* from 0 to 35 dB(A) is associated with a two-fold increase in the frequency of problems. The researchers considered whether a causal relationship existed, or merely a relationship. The latter might be the case if, for example, people with health problems were liable to get up later and were therefore exposed to the higher high aircraft noise exposures that occur in the morning, resulting in relatively high *Li*

* Vos, personal communication.

values. However, analysis revealed that neither the moment of awakening nor any of the other possible sources of bias investigated by the team had any influence on the relationship between the frequency of health problems and *Li*.

D.4.2.4 Making official complaints about noise

The submission of a complaint about noise may be regarded as symptomatic of reduced well-being. Numerous factors influence a person's inclination in a given situation to make an 'official' complaint about a noise-related problem. These factors include not only the level of annoyance or inconvenience experienced, but also to some extent whether the person knows who to complain to, how easy it is to make a complaint, whether the person believes his/her complaint is likely to be acted upon, and if it is known or suspected that other people are also making complaints. In the Netherlands, people who have experienced problems caused by the noise from aircraft on their way to or from Amsterdam's Schiphol Airport used to be able to complain to the Problem Desk at the Schiphol Airport Committee on Noise-Related Annoyance (now superseded by the Problem Desk at Cros, the Schiphol Airport Liaison Body). The RIVM performed an analysis of complaints to the Problem Desk[180,181] and linked the data to the findings of a questionnaire-based study[182]. Figure 25 illustrates the position between 1986 and 2001, showing the number of problems, the number of complainants and the number of aircraft movements. Approximately 15 per cent of problems were found to relate to noise during the night (11pm to 7am). From the data in Figure 25, it is also apparent that some people complain repeatedly in the course of a year; in 2001, for example, the average number of problems per complainant was thirty-seven.

The number of problems per thousand aircraft movements was 680 in 1997 and 410 in 2001. In 2003, the so-called 'Polder Runway' came into use, despite considerable opposition from people living near the airport. Provisional figures indicate that the number of problems in 2003 was double the number reported the previous year.

Approximately 15 per cent of all problems involved noise during the night (11pm to 7am). Night flights (11pm to 6am) accounted for 4 per cent of the total number of flights, and it is estimated that the number of aircraft movements occurring between 11pm and 7am was 8 per cent of the total[183]. It follows that night flights were linked to approximately twice as many problems as flights during the day and evening, even though the noisiest aircraft are not allowed to take off at night, so that night flights should on average be a little quieter than flights during the day and evening.

In Figure 26, the prevalence of problems is shown as a function of *Lden*. Notably, problems are less prevalent at the highest noise exposure than at a noise exposure of 61 to 62 dB(A). The researchers attribute this to the extra acoustic insulation fitted to homes in the most heavily exposed areas. Below an *Lden* of 50 dB(A), hardly any

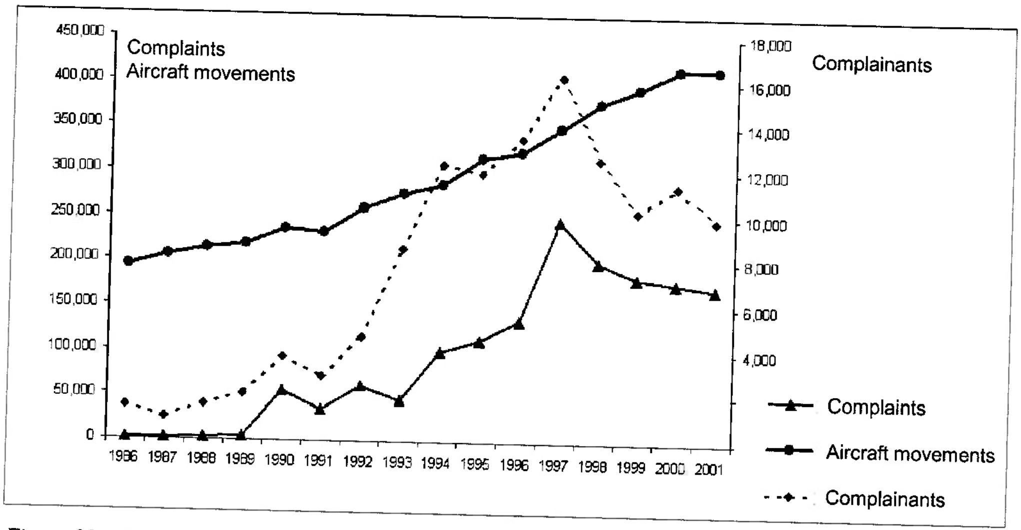


Figure 25 The number of people complaining about flights into and out of Schiphol Airport and the number of problems complained about, together with the number of aircraft movements between 1986 and 2001[180,181].

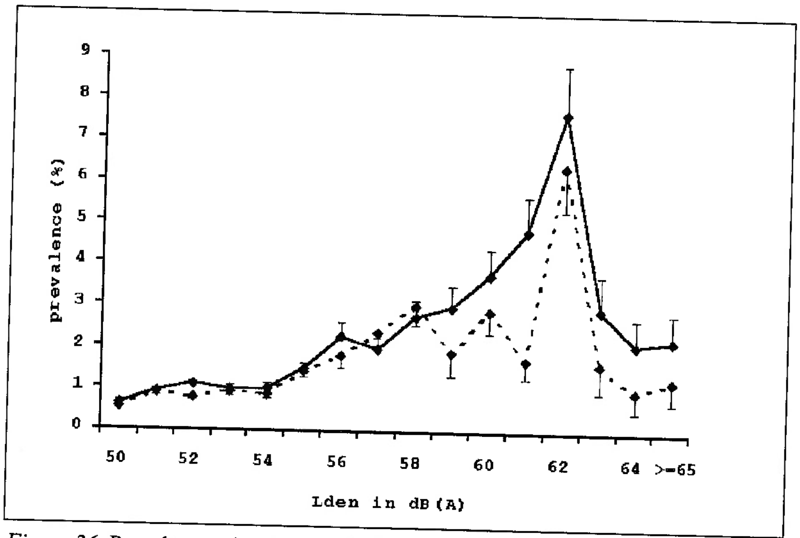


Figure 26 Prevalence of problems relating to particular flights into and out of Schiphol Airport in 1998 (solid line) and 1999 (dotted line), with an estimate of the uncertainty regarding the measurement points (half 95% prediction intervals), as a function of *Lden*[180,181].

h

omes have extra insulation; at an exposure of less than 60 dB(A), 20 per cent of homes have better insulation; at 61 and 62 dB(A), the figure rises to approximately 55 and 70 per cent, and from 63 dB(A), approximately 90 per cent of homes are well insulated.

A questionnaire-based study[182] has shown that the inclination to complain about aviation noise is linked to levels of annoyance, sleep disturbance, health worries and worry about air crashes.

DCMR runs a problem desk for people in the Rijnmond area who are experiencing problems due to environmental noise associated with industrial activities, road, rail and air traffic, etc[184]. Data on the complaints received in 2003 is presented in Table 18.

A total of 8303 problems were reported, of which 1265 (15 per cent) related to noise during the night (midnight to 7am). The heading 'Other noise' covers low and high-frequency machinery noise from unknown sources. Air traffic was the biggest cause of problems during the day and over a twenty-four-hour period. Although there were no regular scheduled night flights into or out of Rotterdam Airport, night-time aviation noise accounted for 25 per cent of all problems during the night. Industrial noise caused the fewest problems. It is interesting to note that relatively few complainants were concerned about (road and rail) traffic, but a lot of people complained about noise from events and bars, clubs and the like.

Table 18 Inventory of noise-related problems in the Rijnmond area reported to the DCMR Problem Desk in 2003[184].

	Number of problems per year			Percentage of problems		
	Day and evening: 7am to midnight	Night: midnight to 7am	Twenty-four-hour period	Day and evening: 7am to midnight	Night: midnight to 7am	Twenty-four-hour period
Traffic & transport	539	144	683	7,7	11,4	8,2
Air traffic	3423	316	3739	48,6	25,0	45,0
Industrial activities, etc	310	78	388	4,4	6,2	4,7
Bars, clubs, events, etc	892	342	1234	12,7	27,0	14,9
Other noise	1874	385	2259	26,6	30,4	27,2
Total	7038	1265	8303	100	100	100

D.4.3 *Domestic acoustic insulation and influence on the effects of traffic noise*

D.4.3.1 Domestic acoustic insulation

The Building Decree makes requirements regarding the sound attenuating characteristics of new homes and other noise-sensitive buildings[14]. For protection against industrial, road and rail traffic noise, each type of noise has to be limited to a twenty-four-hour value of 55 dB(A). This implies an outdoor night-time equivalent sound pressure level of no more than 45 dB(A). If the characteristic attenuation provided by the building's outside wall is 20 dB(A), in relation to the spectrum of the noise source in question, this equates to an *Lnight_i* value of no more than 25 dB(A). If the outdoor twenty-four-hour value is higher than 55 dB(A), more stringent requirements apply. For protection against air traffic noise, requirements are made regarding the sound attenuating characteristics of new homes and other noise-sensitive buildings exposed to aviation noise exposures of more than 35 Ke*. The characteristic attenuation required depends on the 'sensitivity class' of the building and on the noise exposure in Ke, but is always at least 27 dB(A)**.

D.4.3.2 The influence of additional acoustic insulation on the effects of traffic noise

In the Netherlands, there have only been a small number of isolated studies into the efficiency and effectiveness of acoustic insulation in the reduction of perceived road and aviation noise levels, or into people's views regarding such insulation[114-119]. Bitter *et al* looked at the effects of fitting additional acoustic insulation to flats beside busy motorways carrying 70,000 vehicles per twenty-four-hours in Dordrecht[114] and Amsterdam[115]. In the Amsterdam study, 347 people completed an extensive questionnaire 2.5 years after extra insulation had been fitted to their homes to protect against road traffic noise (average additional attenuation 9 dB(A)). The questionnaire addressed matters such as the levels of noise-related annoyance being experienced at the time and previously experienced before the extra insulation was fitted. The findings confirmed that the insulation did reduce annoyance. Feedback regarding non-acoustic matters (humidity, ventilation and ease of cleaning) indicated dissatisfaction with the new insulation, however. Respondents were also asked about annoyance at different times during the twenty-four-hour period. The findings are illustrated in Figure 27. *

From Figure 27, it is clear that, while night-time noise-related annoyance was reduced by the fitting of extra acoustic insulation, the final outcome is less than ideal. A similar picture emerged from the Dordrecht study[114].

Van Dongen *et al*[116] carried out an exploratory study into sleep quality in homes fitted with additional acoustic insulation in the vicinity of Amsterdam's Schiphol Airport. The team determined the relationships between the percentages of people 'sleep disturbed' and 'highly sleep disturbed' and the outdoor noise exposure; the data was then compared with the provisional relationships[185] at the time for homes without special

* Ke stands for 'Kosteneenheid' (Kosten Unit, named after the Committee with professor Kosten as president), the standard unit of air traffic noise exposure in the Netherlands until recently.

** The Building Decree also makes requirements regarding acoustic insulation to protect against noise from installations in the same or adjoining premises, regarding resonant sounds, and regarding inter-dwellings sound attenuation, expressed in terms of *Ilu;k*, *Ilu*, and *Ico*.

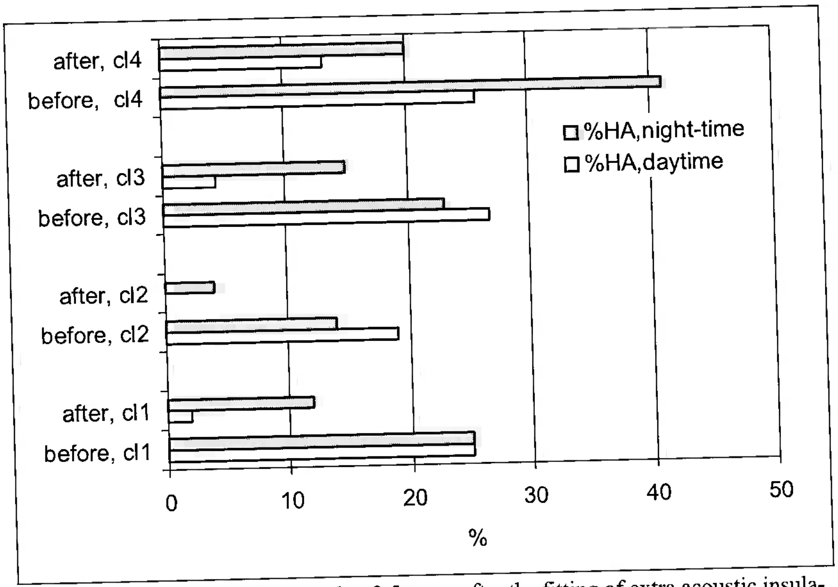


Figure 27 Percentage of people who, 2.5 years after the fitting of extra acoustic insulation to their homes, were highly annoyed by daytime and night-time noise at the time of questioning ('after') and prior to the fitting of extra acoustic insulation ('before'), attributable to four classes of noise (cl4 being the highest road traffic noise exposure, and cl1 the lowest).

insulation. From this comparison, it emerged that percentages sleep disturbed and highly sleep disturbed were slightly lower in the better-insulated dwellings than in 'ordinary' dwellings. However, the design of the study precluded the drawing of definitive conclusions.

Three reports were published between 1994 and 1999[117-119] regarding people's general views concerning modifications made to homes near Schiphol with a view to reducing aircraft noise-related problems. In 1994, opinion was gauged regarding the additional insulation fitted in the first phase of the Schiphol Insulation Plan. The modifications were made before introduction of the Building Decree of 01-10-1992[117]. In 1996, a comparison was made between satisfaction with the insulation packages installed before the Building Decree, and satisfaction with the 'scaled down' packages installed since the Building Decree[118]. The third report recounted the proceedings of an experts' workshop at which the problems associated with the insulation plan were addressed with a view to framing more flexible rules regarding acoustic insulation options[119]. General feelings about acoustic insulation fitted before and after implementation of the 1992 Building Decree were broadly similar: 75 per cent of subjects felt the insulation was good, 20 per cent rated it moderate, and 5 per cent thought it was poor. Some 85 per cent of subjects reported that the insulation had reduced noise-related annoyance indoors. Nevertheless, people in more than 55 per cent of the homes continued to experience at least slight noise-related annoyance, and people in 15 per cent of the homes reported to be highly annoyed since the modifications were made. The distribution patterns of both overall and night-time levels of aircraft noise-related annoyance were clearly seasonal: on (cold) winter nights, 10 per cent of subjects often or always experienced annoyance during the sleep period, compared with 40 per cent on (warm) summer nights. The differences were closely related to the use of windows: only 25 per cent of respondents said they slept with the bedroom window at least slightly ajar in the winter, whereas 70 per cent did so in the summer.

Fidell and Silvati[120] investigated what effect the fitting of insulation to attenuate aviation noise had on levels of being annoyed and being highly annoyed. However, they did not look specifically at annoyance during the sleep period.

In the UK, an extensive study was done to establish how effective extra acoustic insulation was in reducing exposure to road traffic noise[121]. The average sound attenuation achieved was 34 dB(A). Subjects whose bedrooms were adjacent to busy roads experienced night-time noise exposures with an *Lnight* value of between 57 and 77 dB(A). In the specially insulated homes, 23 per cent of subjects whose bedrooms faced the street reported being very highly or highly annoyed by night-time road traffic noise; 25 per cent had difficulty getting to sleep because of the noise, and 30 per cent said they were woken up at night by road traffic noise. The results proved to be influenced to a considerable extent by whether the subject felt that, without the window open, his or her bedroom was too hot in the summer: 37 per cent of those who felt unable to sleep with the window closed in warm weather were very highly or highly annoyed by night-time road traffic noise, whereas only 15 per cent of those who didn't mind having the window closed experienced similar problems. Some 85 per cent of subjects who said their bedrooms were too hot in the summer felt it necessary to sleep with the window open.

In Japan[122], people living in the vicinity of Kaneda Air Base and consequently exposed to very high night-time noise exposures caused by military jets were asked about the effectiveness of the additional acoustic insulation fitted to approximately 60 per cent of homes in the area, and about their satisfaction with the insulation. Scores for both effectiveness and satisfaction declined as noise exposures rose, from 80 and 60 per cent at a noise exposure with an estimated *Lden* of 65 dB(A), to 30 and 13 per cent at an estimated *Lden* of 85 dB(A). The seven investigated aspects of sleep disturbance (difficulty getting to sleep, waking up, difficulty getting to sleep after waking up, inconvenience caused by being woken too early in the morning, sense of having slept badly, and doubt about the prospects for a good following night's sleep) all proved to be related to outdoor noise exposure, but no difference was found between people living in specially insulated homes and people living in 'ordinary' homes. The researchers took the view that other forms of intervention, such as reducing night flying and switching to alternative flight paths, were necessary to reduce the impact of noise on the sleep of people living in highly affected areas near the base.

D.4.4 *Inter-dwelling acoustic insulation and noise from neighbours*

D.4.4.1 Inter-dwelling acoustic insulation

The Building Decree makes requirements regarding the ability of new homes to attenuate sound from adjoining dwellings[14]. Sound attenuation between dwellings can be expressed using an index for the attenuation of airborne noise (I_{lu}); where account is taken of the volume of the reception room and the area of the common screening structure, it can be expressed using an index of characteristic sound attenuation ($I_{lu;k}$). The attenuation of contact noise between two dwellings is expressed using the contact noise index (I_{co}). For new homes, an airborne sound attenuation requirement ($I_{lu;k}$) of at least 0 dB applies. At an $I_{lu;k}$ of 0 dB, ordinary conversation in an adjoining home is audible, but incomprehensible. The quality of airborne sound attenuation is rated on a three-level scale:

- Minimum: $I_{lu;k}$ of 0 to +5 dB (normal conversation in an adjoining home is audible, but not comprehensible)
- Good: $I_{lu;k}$ of +5 to + 10 dB(A) (normal conversation in an adjoining home is not audible, the footsteps of a person in hard-soled shoes on a hard floor are readily audible and sometimes annoying)
- Very good: $I_{lu;k}$ greater than + 10 dB(A) (musical instruments, parties and the footsteps of a person in hard-soled shoes on a hard floor may be audible but are not annoying).

D.4.4.2 Noise from neighbours

Leidelmeijer and Marsman[99] published a report entitled *Geluid van buren: horen, hinder en sociale normen* (*Noise from Neighbours: Audibility, Annoyance and Social Norms*) regarding the findings of an interview-based study of 1242 households in the Netherlands, designed to shed light on the audibility of and annoyance associated with noise from neighbours during the day and at night. As a follow-up to the questionnaire, noise measurements were made in fifty homes. The researchers distinguished between five types of noise:

- Noise from sanitary and heating systems
- Contact noise
- Noise from audio equipment
- DIY (Do-It-Yourself) noise

• Noise from pets.

Distinction was also made according to the part of the house where the noise was audible or caused annoyance. The results are summarised in Table 19. 'Percentage for whom audible' is the percentage of respondents who reported hearing the type of noise in question. 'Percentage tolerant' is the percentage of the respondents for whom the given noise was audible who did not report being annoyed by it.

Table 19 Percentage of survey respondents able to hear and tolerant of each of five types of noise (where 'tolerant of' means able to hear but not annoyed by, i.e. 100 - percentage of hearers reporting annoyance)[99].

Part of house	Sanitary and central heating systems		Contact noise		Noise from audio equipment		DIY noise		Pets	
	% for whom audible	% tolerant	% for whom audible	% tolerant	% for whom audible	% tolerant	% for whom audible	% tolerant	% for whom audible	% tolerant
Living room	18	80	37	86	35	85	15	67	12	88
Kitchen	12	93	16	87	12	91	8	80	5	88
Master bedroom	19	76	22	73	12	74	8	65	6	76
Other bedrooms	5	88	8	75	3	57	2	75	2	70
Bathroom	13	97	6	83	3	100	2	89	1	100
Other rooms	4	95	3	87	1	80	1	100	0	100
Landing/hall/stairs	9	80	8	100	5	100	2	100	2	100
Throughout house	10	91	14	71	5	73	28	89	8	86

Clearly, respondents were least tolerant of noise from their neighbours that was audible in the master bedroom. Subjects were also asked whether they considered it acceptable for the various noises to be audible by day, by evening or by night. Where each of the five investigated types of noise were concerned, roughly 10 to 15 per cent of subjects indicated that they felt it was unacceptable for the noise to be audible during the day (for pets, the figure was 20 per cent; DIY noise was rated unacceptable on weekdays by 5 per cent of respondents and on Sundays by 17 per cent; for noise from audio equipment, the figure was 15 per cent). In each case, a higher percentage said the noise should not be audible in the evening, and a still higher percentage did not want to hear the noise at night (between 11pm and 7am). Overall, nearly 30 per cent of subjects said that sanitary fittings should not be audible at night, while approximately 50 per cent felt each of the other four types of noise was unacceptable by night.

The researchers concluded that audible noise from neighbours was by no means always perceived to be annoying. Whether annoyance is caused depends on the timing, the part of the house where the noise is audible, the volume, whether the noise is expected, how often the noise is audible, the duration of the noise, whether the noise is considered avoidable, and the number of sources.

Subjects were also asked whether they could hear voices in neighbouring homes. While the percentage of affirmative answers varied according to the type of dwelling, ordinary speech was to some extent audible in an average of 35 per cent of dwellings, and partially or readily comprehensible in approximately 8 per cent of dwellings. Raised voices could be heard, at least some to extent, in approximately 65 per cent of dwellings; they were at least partially comprehensible in 27 per cent of homes and readily comprehensible in approximately 10 per cent.

The results of the acoustic insulation tests in fifty homes indicated no statistically significant relationship between the airborne and contact sound attenuation indexes and the audibility of (airborne) noise from neighbouring dwellings.

In 1993, Kranendonk *et al* produced a synthesis of the research conducted up to that point in time into the annoyance associated with noise from neighbours[100]. Their synthesis covered four Dutch, one Swedish, one British and one French study. The various studies used a variety of effect indexes (annoyance scoring systems) and a variety of means of determining airborne and contact sound attenuation. Although it was, the researchers reported, difficult to assess all the data on the same basis, they were able to produce a table of synthesised findings (see Table 20). The average annoyance score was determined on a seven-point scale, where 7 equated to not annoyed and 1 to highly annoyed. As will be apparent from Table 20, an I_{lu} of zero corresponds to an average annoyance score of 5, to 10 per cent of people experiencing to be highly annoyed and to 25 per cent of people experiencing some annoyance.

Table 20 Acoustic performance of a dwelling (in terms of I_{lu} and *Ico*) and the corresponding average annoyance scores and percentages of people experiencing to be annoyed or highly annoyed[100].

I_{lu}	I_{co}	Average annoyance score	% people highly annoyed	% people annoyed (including highly annoyed)
-13	-5	3	50	75
-7	0	4	25	50
0	+6	5	10	25
+7	+11	6	2,5	10
+13	+17	7	0,5	2,5

TNO produced a report[101] on the relationship between noise from neighbouring dwellings and the airborne and contact noise attenuating indices I_{lu}, $I_{lu;k}$, and I_{co}, drawing on data from a questionnaire-based survey of the residents of six hundred dwellings, whose acoustic quality was determined in 202 cases. It was established that nearly half of the respondents heard at least some noise from neighbouring dwellings every day. Approximately 10 per cent of subjects found their neighbours' noise highly annoying.

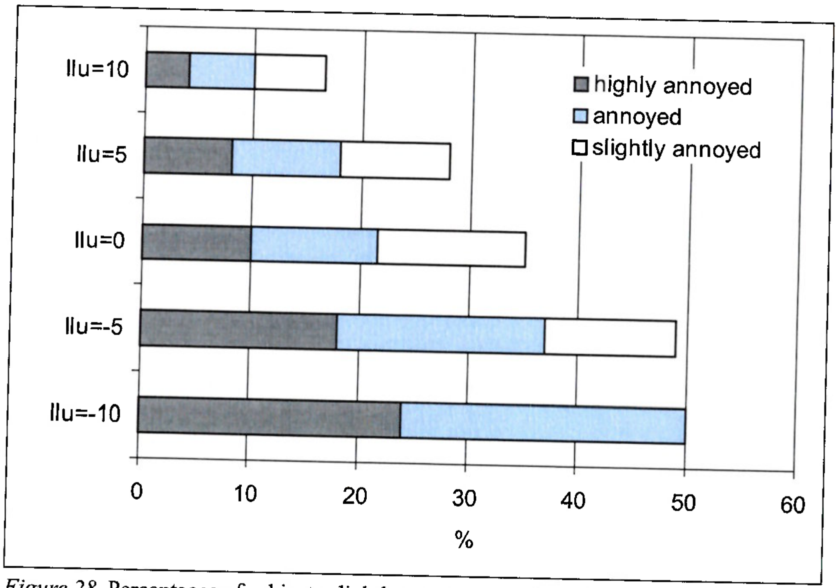


Figure 28 Percentages of subjects slightly annoyed, moderately annoyed and highly annoyed by noise from neighbouring dwellings[101].

The chief causes of annoyance were loud radios, hi-fis and TVs, the slamming of doors and footsteps on floors and staircases. Nearly all respondents said that in their own behaviour they were considerate of their neighbours and 80 per cent regarded themselves very tolerant of noise from their neighbours.

No relationship was established between contact noise-related annoyance and I_{co} value. This was not considered surprising by the researchers, because there was not a great deal of spread in the contact noise index values of the dwellings.

The correlation between the percentages of people experiencing annoyance and I_{lu} value is illustrated in Figure 28.

The percentages of people identified by the team as experiencing being annoyed and highly annoyed at a given I_{lu} value are broadly in line with the findings of Kranendonk *et al*[100]. At an I_{lu} of zero, the percentages are identical, while at higher and lower I_{lu} values there is a small difference.

D.4.5 *Data from inventory studies*

The national inventory study[9] carried out in 1998 asked respondents to indicate the extent to which their sleep was disturbed by noise from various sources, by giving a number between 0 and 10, where 0 = not disturbed at all and 10 = very highly disturbed. A standardised method was then used to calculate the percentage of respondents reporting sleep disturbance and high sleep disturbance. This involved transforming the eleven-point scale into a continuous scale from 0 to 100. Respondents who scored 50 or more on this scale were deemed to suffer from self-reported sleep disturbance, and those who scored 72 or more to suffer from high self-reported sleep disturbance. This implies that the number of respondents affected by sleep disturbance includes the number affected by high sleep disturbance.

Table 21 gives the percentage of respondents reporting sleep disturbance and high sleep disturbance due to each noise source. It is not possible to make comparisons between source groups by simply aggregating the source group percentages, because it is not reasonable to assume that the percentage of people affected by (high) sleep disturbance due to a particular group of sources is the sum of the percentages for the individual sources within that group. Where road, rail and air traffic is concerned, passenger cars, lorries and mopeds are the sources to which most sleep disturbance is attributable (affecting, respectively, 7, 6, and 10 per cent of respondents). Where neighbour noise and neighbourhood noise are concerned, the predominant sources are contact noise (footsteps on stairs, slamming of doors), radio, hi-fi & TV, and the noise from other human activities, which were referred to by, respectively, 8, 6, and 8 per cent of respondents. Sleep disturbance due to noise from air or rail traffic, or to industrial noise is (much) less common than sleep disturbance due to the above-mentioned sources.

Table 21 Noise-related sleep disturbance associated with sources of various types[9].

Source group	Noise source	Percentage of respondents reporting sleep disturbance	Percentage of respondents reporting to be highly sleep disturbed
Road traffic	Passenger cars and taxis	7	2
	Delivery vans	3	1
	Lorries	6	3
	Buses	2	1
	Motor cycles and motocross cycles	5	2
	Mopeds	10	4
	Motor-assisted bicycles	4	2
	Military vehicles	0	0
Air traffic	Passenger and cargo aircraft	4	2
	Recreational, executive and advertising aircraft	0	0
	Military aircraft (other than helicopters)	2	1
	Helicopters	1	0
Rail traffic	Trains	2	1
	Trams	0	0
	Light rail vehicles	0	0

Shipping	Commercial shipping	0	0
	Pleasure craft	0	0
Commercial, industrial and professional activities	Retail areas	0	0
	Factories and business premises	1	0
	Loading/unloading sites, etc	1	1
	Lorry parks	1	0
	Shunting yards and rail yards	1	0
	Building and demolition sites	1	0
	Road building	1	0
	Agricultural tractors	1	0
	Civilian shooting ranges	0	0
	Military exercise areas, shooting ranges, etc	0	0
Recreational activities	Fairs, circuses, amusement parks, etc	3	1
	Discos, dance halls, etc	2	1
	Musical practice facilities	0	0
	Sports fields, stadiums, sports halls, swimming baths, tennis courts	1	0
	Racing, motocross and carting circuits	0	0
	Ultra-light aircraft	0	0
	Model aircraft	0	0
	Mass-participation open-air events	2	1
Noises from neighbouring dwellings	Noises from sanitary and heating systems	3	1
	Contact noise (footsteps on stairs, slamming of doors)	8	3
	Radio, hi-fi, TV	6	3
	DIY equipment	4	2
	Pets	5	2
Other noises in the residential environment	Neighbours gardening noises	1	0
	Noise from public spaces around one's home	1	0
	Noise from children playing outside	2	1
	Noise from street/public greenery maintenance	3	1
	Other human noises	8	3
	Noise from neighbours' pets/animals	5	2
	Church bells, mosques	3	2
	Bottle banks	1	0

In 2000, the Noord-Kennemerland Regional Health Authority carried out a written inventory study[186], in which 7728 people were invited to participate. The response rate was 68 per cent, meaning that approximately 5250 people completed the questionnaire. The subjects came from nine municipalities in the Noord-Kennemerland region (Akersloot, Alkmaar, Bergen, Egmond, Graft de Rijp, Heiloo, Limmen, Schermer and Schoorl). The questionnaire included a number of questions identical to those used for the national inventory study[9]. The levels of high sleep disturbance reported by the respondents are given in Table 22, along with the corresponding data from the national study (for comparison). The percentages of people reporting high sleep disturbance in Noord-Kennemerland are twice the corresponding national figures. Since no noise exposure data is available for Noord-Kennemerland, it is not possible to establish whether the high levels of disturbance are, at least to some extent, the result of noise exposures that are above the national averages. Data from 2000/2001 for the province of North Holland as a whole indicates that 6.3 per cent of homes in the province have an air traffic-related *Lnight* value of 40 dB(A) or higher, compared with 1.9 per cent nationwide[15]. Where noise from motorways, municipal roads and rail traffic is concerned, exposures in North Holland are close to the national averages. The correction of an RIVM report released on 24-05-2004 does not contain a provincial breakdown of urban road traffic levels (i.e. the largest source of noise exposure in the Netherlands)[15], so it is not possible to determine how the noise exposure due to urban road traffic in North Holland compares with that in the country as a whole.

Table 22 Noise-related sleep disturbance in Noord-Kennemerland[186].

Source	Percentage of Noord-Kennemerland respondents reporting to be highly sleep disturbed	Percentage of national survey respondents reporting to be highly sleep disturbed
Mopeds	10	4
Noise from neighbours	7	3
Motor cycles	6	2
Lorries	5	3
Passenger cars	5	2
Aircraft	4	2
Other	3	

Annex **E**

Sleep disorders and sleeping problems

In this annex, the Committee presents an overview of sleep disorders and sleeping problems. Particular attention is paid to insomnia, but other sleep disorders are also considered, albeit in less detail.

E.1 What is insomnia?

Insomnia can occur without being triggered by a particular illness or condition; such insomnia is known as primary insomnia. Secondary insomnia, on the other hand, is a consequence of some other illness or condition. Definitions of primary insomnia are given in the *ICD-10 classification of mental and behavioral disorders: clinical description and diagnostic guidelines* published by the WHO[90], in the *Diagnostic and Statistical Manual of Mental Disorders* (DSM-IV) of the *American Psychiatric Association*[187], and in the *Beknopte handleiding bij de Diagnostische Criteria van de DSM-IV (Guidance Notes to Accompany the Diagnostic Criteria of the DSM-IV)* produced by the Netherlands Association for Psychiatry (NVvP)[188]. In the latter publication, primary psycho-physiological insomnia is defined as a condition that satisfies the following criteria:

- The principal complaint is difficulty getting to sleep or staying asleep, or not feeling refreshed after sleep, persisting for at least a month.
- The sleep disorder (or the associated daytime tiredness) causes significant suffering or impairment of the sufferer's social or occupational performance or ability to function in some other important field.

- The sleep disorder does not only occur in the context of narcolepsy, sleep-related respiratory disorder, circadian rhythm-related sleep disorder or parasomnia.
- The sleep disorder is not a consequence of the direct physiological effects of a substance (narcotic, medication) or a somatic condition.
- The sleep disorder does not only occur in the context of another psychological disorder (such as a depressive disorder, generalised anxiety disorder, or delirium).

The occurrence of chronic primary psycho-physiological insomnia is seen as the coincidence of endogenic causal factors, initiatory factors and sustaining factors[189]. Endogenic causal factors are physiological factors such as raised heart rate, increased muscle tension and raised body temperature, together constituting a raised physiological state of arousal, and psychological factors such as anxiety, nervousness and the inability to clear the mind[190].

Factors that sustain insomnia and therefore act as obstacles to recovery include poor (non-adapted) sleeping habits (inappropriate use of somnifacient drugs, staying in bed too long, keeping irregular hours, excessive napping during the day) and worrying about the possible consequences of not getting enough sleep (anxiety about failure during the day, anxiety about losing control over situations, acquired sense of helplessness).

According to Vgontzas *et al*[191], their epidemiological research supports the hypothesis that primary insomnia mainly involves chronic hyper-arousal, which is evident not merely at night, but around the clock. They take the view that relatively little research has been carried out into the effects of primary insomnia on the cardiovascular system. They argue that their results indicate that people with primary insomnia are not only more likely to suffer from psychological conditions, but also from physical conditions such as hypertension and obesity (plus the associated metabolic abnormalities). Accordingly, the researchers argue that the focus of treatment should be the hyper-arousal, rather than the insomnia, which is merely a consequence of the hyper-arousal.

According to the *Diagnostic and Statistical Manual of Mental Disorders* (DSM-IV)[187] and the NVvP's *Guidance Notes*[188], secondary insomnia (insomnia in association with another psychological disorder) is a condition that satisfies the first four criteria given above for primary insomnia, is additionally associated with a so-called 'Axis I' or 'Axis II' disorder (such as a depressive disorder, a generalised anxiety disorder, or an adjustment disorder accompanied by anxiety), and is sufficiently serious to warrant separate medical attention.

Secondary insomnia can also be a consequence of other medical conditions, such as pain, depression, night-time restless legs syndrome and alcoholism. Working variable shifts, including night shifts, can induce or aggravate chronic insomnia.

E.2 How prevalent is insomnia?

Ohayon describes more than fifty studies concerned with the prevalence of insomnia in a broad sense (i.e. not merely primary psycho-physiological insomnia) in the population at large[192]. The reviewed studies include estimates of the prevalence of insomnia, based on four distinct criteria: difficulty getting to sleep or staying asleep, night-time manifestations of insomnia accompanied by daytime problems arising from lack of sleep, self-reported dissatisfaction with sleep quality, and insomnia diagnosed on the basis of DSM-IV. Approximately a third of the general populace is sometimes affected by insomnia satisfying the first criterion. When the second definition is applied, 9 to 15 per cent of the population are reckoned to be affected. Under the third definition, 8 to 18 per cent of the population suffer from insomnia. By application of the DSM-IV classification, one arrives at a figure of 6 per cent for the average prevalence of insomnia in the population at large. However insomnia is defined, it is more prevalent among women than among men. Furthermore, insomnia becomes more common with increasing age, except when defined on the basis of self-reported dissatisfaction with sleep quality.

Prevalence can also be expressed in terms of the estimated probability of suffering a significant sleep disorder at some time in one's life. On this basis, the prevalence of insomnia is put at roughly 30 per cent[193]; in other words, the average Dutch person has approximately a one-in-three chance of falling victim to a significant sleep disorder at some time or other.

A German study involving two thousand adult subjects looked at the possibility of a link between insomnia (as defined in the DSM-IV) and quality of life (as measured using the abbreviated SF-36 questionnaire)[194]. Some 22 per cent of insomniacs rated their quality of life as 'poor' and 28 per cent as 'good', while the corresponding figures for subjects without sleeping problems were, respectively, 3 and 68 per cent. These figures must be treated with caution, however, since subjects' quality of life will have been influenced not only by their insomnia, but also by other illnesses and conditions.

Sleeping problems are not confined to adults. Kim *et al*[195] asked 1365 Chinese youngsters aged twelve to eighteen about any sleeping problems they might have. Nearly 17 per cent reported symptoms of insomnia, including difficulty getting to sleep (11 per cent), waking up in the night (6 per cent) and waking up too early in the morning (2 per cent).

A great deal of research has been carried out into the prevalence of insomnia not only in the population at large, but also in particular groups. Hence, insomnia is known to be much more common among people affected by certain illnesses and medical conditions than in the overall population[196-221]. For example, women who are pregnant or have been pregnant in the last twelve months or so are at increased risk of insomnia[222].

E.3 The consequences of insomnia and sleeping problems; association with other illnesses and medical conditions

E.3.1 *The direct consequences of insomnia*

According to Stolk *et al*[91], insomnia has a substantial negative effect on quality of life. In the quality-of-life weighting system developed by this team, insomnia, as diagnosed by a GP, has a quality-of-life weighting of 0.83. In other words, a year suffering from insomnia 'costs' 0.17 years of healthy life. Various other authors have also reported negative effects of insomnia on quality of life[18,194,223-226]. People with chronic insomnia of any kind also tend to perform less well at work and suffer memory and concentration problems[227]. Insomniacs make disproportionately great use of healthcare facilities and medications, including somnifacient drugs and sedatives[18,194,223,224].

E.3.2 *Association of insomnia with other medical conditions and illnesses*

When considering the relationships between insomnia and other medical conditions and illnesses, it is important to distinguish between an association and a causal relationship. Many researchers have reported an association between certain abnormalities, but have failed to demonstrate the link between cause and effect. Schwartz *et al* made an extensive survey of insomnia, *cardiovascular disease* and *mortality risk* on the basis of epidemiological research data[228]. They consider it likely that insomnia and the associated daytime tiredness are part of a more general syndrome that is associated with chronic stress, causes autonomous dysfunction and brings an increased risk of cardiovascular disease. Shaver *et al*[201] drew a similar conclusion on the basis of a study of middle-aged women.

Age is not in itself a determining factor in the occurrence of insomnia[209,225,229-231], which is attributable more to age-related phenomena, such as increasing lack of physical activity, changes involving other lifestyle factors (obesity, use of alcohol), dissatisfaction with the social environment, and illnesses and abnormalities.

With a view to establishing whether chronic insomnia increased the risk of *hypertension*, Suka *et al* conducted a five-year longitudinal study involving 4,800 Japanese workers[232]. Their conclusion was that people who have difficulty getting to sleep and people who have difficulty staying asleep are more likely to develop hypertension (OR respectively 1.9 and 2.0).

Numerous studies have been carried out into the link between *depression* and (sometimes ill-defined) insomnia[196,198,201,206,207,211,212,215,218,220,221,224-226,233-246]. In most of these studies, a statistically significant association was found, but no causal relationship demonstrated. One exception in this regard was the twelve-year longitudinal study by Mallon *et al*[220]. Among women, insomnia at the start of the research period proved to be a statistically significant predictor of the development of depression during the course of the study (*odds ratio* = 4.1). Insomnia was not found to be a predictor of subsequent depression in men, however.

E.3.3 *Association of sleep disorders and sleeping problems with road traffic accidents*

Ohayon *et al*, who have carried out a large number of epidemiological studies[192,213,214,231,244,247-255], take the view that *dissatisfaction with sleep quality* is much more closely related to sleep pathology than the phenomena of insomnia as such.

It is often assumed that sleeping problems play a role in *road traffic accidents* (RTAs). In this context, it is important to distinguish between sleeping problems and incidental sleep deprivation. Having analysed data from the 1985 *CARfile study*, Webb[256] concluded that drowsiness was the primary cause of 1.6 per cent of accidents.

Connor[257] produced an extensive survey of the significance of sleep disorders in RTAs. Analysis of data from the cross-sectional studies produced no evidence of an association between insomnia and the probability of involvement an RTA. However, the case-control study[258] did show up a statistically significant association between sleep apnoea and the probability of injury in an RTA.

E.3.4 *Association of sleep disorders and sleeping problems with occupational accidents*

A number of studies indicate that sleeping problems increase the probability of involvement in a (fatal) occupational accident[256,259-263]. Over a twenty-year period, Akerstedt *et al*[259] interviewed 47,860 people (men and women) by phone regarding sleep and health factors and regarding specific work-related factors. By studying a register of deaths (from which cases of suicide were excluded), the researchers identified 166 fatal occupational accidents. Analysis found the following to be statistically significant predictors of involvement: gender, sleeping problems in the two weeks prior to the interview (relative risk 1.6, 95 per cent confidence interval 1.2 to 2.9) and working outside normal daytime working hours (relative risk 1.9, 95 per cent confidence interval 1.1 to 2.5).

A study of 880 construction workers by Chau and Gauchard[260] revealed that sleeping problems increased the probability of involvement in an accident with a moving object on site (*odds ratio* 2.3, 95 per cent confidence interval 1.3 to 4.1).

The same researchers[261] made a comparison between 427 women who had taken sick leave as a result of falling at work after (physically) losing their balance, and a control group of 427 women. On the basis of interviews conducted by industrial doctors, it was concluded that there was an association between sleeping problems and the risk of falling at work.

Lindberg *et al*[262] undertook a prospective study, in which 2,874 men completed a questionnaire at the outset, and 2,009 completed a follow-up questionnaire ten years later. Information about occupational accidents was obtained from a national register; it was found that 247 of the 2009 men who completed both questionnaires had been involved in a total of 345 accidents. Men who at the beginning of the study reported both 'napping' and feeling sleepy during the day proved to have been involved in more occupational accidents; the link was statistically significantly, even after correcting for numerous other factors capable of influencing the association between sleeping problems and occupational accidents (odds ratio 2.2, 95 per cent confidence interval 1.3 to 3.8). No statistically significant association was found involving men who napped but did not feel sleepy during the day, or involving men who felt drowsy during the day but did not take naps.

Melamed and Oksenberg[263] interviewed 532 industrial workers in order to gather information on the influence of drowsiness on the probability of involvement in an accident at work. By asking numerous questions, the number of accidents in the two years prior to the interviews was determined. Analysis of the responses revealed that the probability of involvement in an occupational accident was higher, to a statistically signifi-

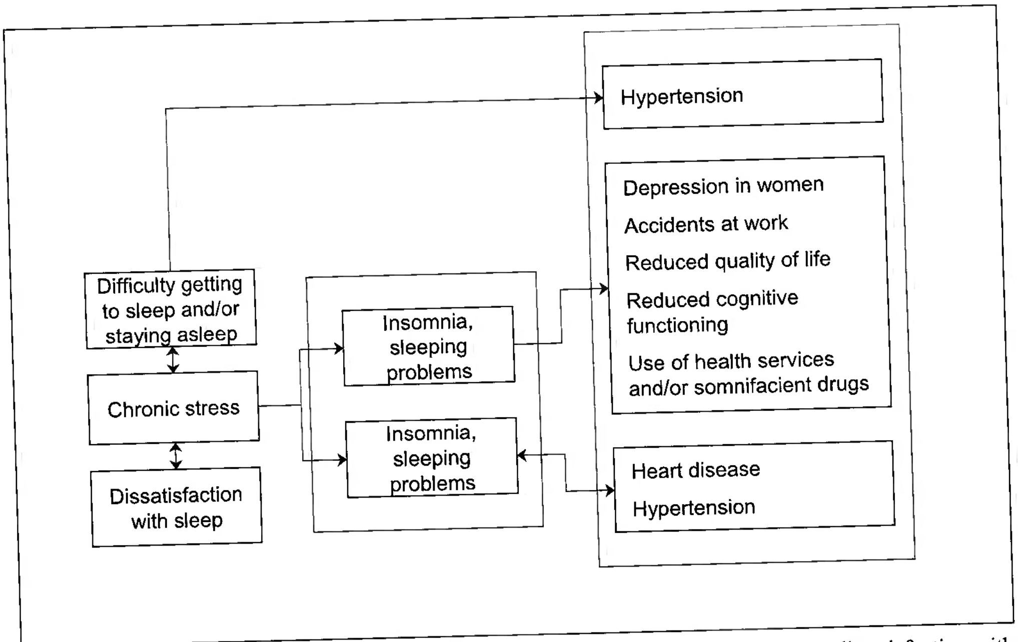


Figure 29 Causes and backgrounds of insomnia and sleeping problems (chronic stress, dissatisfaction with sleep, difficulty getting to sleep and/or staying asleep), consequences of insomnia/sleeping problems (indicated with s) and the associations between insomnia/sleeping problems and other illnesses and medical conditions (indicated with s).

cant extent, among workers who reported feeling drowsy at work than among those who did not (odds ratio 2.2, 95 per cent confidence interval 1.3 to 3.8).

Figure 29 illustrates the causes and consequences of insomnia and sleeping problems, as well as the association that insomnia and sleeping problems have with other illnesses and medical conditions.

E.3.5 *Conclusions*

On the basis of the foregoing, the following conclusions may be drawn:

- Insomnia has a negative effect on quality of life. People with chronic insomnia perform less well at work and experience memory and concentration problems. Insomnia increases usage of healthcare facilities and the consumption of medications, such as somnifacient drugs and sedatives. Insomnia and the associated daytime tiredness are part of a more general syndrome that is associated with chronic stress and causes autonomous dysfunction.
- People who are affected by insomnia are more likely to suffer depression (women), obesity (plus the associated metabolic abnormalities) and cardiovascular disease.
- People with sleeping problems are more likely to develop hypertension.
- People with general sleeping problems (difficulty getting to sleep, difficulty staying asleep, waking spells at night) are more likely to be involved in occupational accidents.

In addition, the following conclusions may be drawn regarding heightened sensitivity to insomnia:

- Because of the association of insomnia with depression, hypertension, obesity and cardiovascular disease, people with these conditions may be regarded as particularly sensitive to insomnia. Women who are pregnant or have been pregnant in the last twelve months or so are also more likely than the average person to experience a period of insomnia.
- Age is not in itself a determining factor in the occurrence of insomnia[209,225,229-231], which is attributable more to age-related phenomena, such as increasing lack of physical activity, changes involving other lifestyle factors (obesity, use of alcohol), dissatisfaction with the social environment, and illnesses and abnormalities. As a result, older people may also be regarded as particularly sensitive to insomnia and sleeping problems.

Annex **F**

Health Council Advisory Report *Assessing Noise Exposure for Public Health Purposes* (1997/23)

Methodology

In the Health Council's 1997 advisory report *Assessing Noise Exposure for Public Health Purposes*[8], the 'Uniform environmental noise exposure metric' Committee of the Health Council proposed a system for determining noise exposures representative of the twenty-four-hour daily cycle (EEL) and the overnight period (ENEL). This method involves five steps:

1. *Frequency weighting of acute sound pressure levels*
   The Committee opted for A-weighting, i.e. sound pressure levels expressed in dB(A), for both the twenty-four-hour daily cycle and the overnight period
2. *Adjustment for special characteristics and combinations of sound pressure levels*
   The Committee assigned adjustment factors, as described below, to noises and noise situations involving characteristics a, b, and c in a twenty-four-hour daily cycle or an overnight period:
   - a Exposure to low-level industrial noise without impulse components: adjustment factor above 60 dB(A), 0 dB(A); at 40 dB(A), 10 dB(A); in the range between, calculated by linear interpolation
   - b Situations in which the noise includes audible tones: adjustment factor between 0 and 5 dB(A), depending on the frequency of the tone and the difference

between the sound pressure level of the tone and the prevailing background sound pressure level

c Situations in which the noise includes (strong) impulse components: adjustment factor 5 dB(A) for impulse noise (such as the sound of a low-flying military jet, a car door slamming or church bells ringing) and 12 dB(A) for very impulse-like (such as gunshot noise, metal beating, pneumatic hammering, shunting of rail rolling stock).

The Committee attached certain qualifications to its proposal of the adjustment factors for use in the assessment of a situation over a twenty-four-hour daily cycle. With regard to assessment of the overnight period, the Committee indicated that consideration should be given to further adjustments to take account of the possibility of sleep disturbance. "Although scientific evidence is lacking, the Committee considers it likely that night-time exposure to noise with the characteristics listed above would result in increased sleep disturbance. It therefore considers it prudent to provisionally apply these adjustments also in deriving the *ENEL* metric, and recommends further research on this matter."

For the combination of sound pressure levels for parts of a day, including the application of adjustment factors for intervals in which sound with special characteristics occurs, the Committee recommended working on the basis of the equivalent sound pressure level over a given period.

3 The combination of (corrected) equivalent sound pressure levels for parts of a day to give a value that is representative for a twenty-four-hour daily cycle
The Committee recommends adjustment factors of 0 dB(A) for the daytime (7am to 7pm), 5 dB(A) for the evening (7pm to 11pm) and 10 dB(A) for the night (11pm to 7am). The corrected equivalent sound pressure levels are exponentially averaged. Step 3 is not necessary when calculating an ENEL, since the combination of day, evening and night values is clearly not relevant in relation to a night-only metric.

4 *The combination of daily exposure values to give a value that is representative for a year*
No seasonal or weekday/weekend adjustment factors are proposed. The equivalent sound pressure levels for each twenty-four-hour daily cycle of a year are exponentially averaged. This results in a Ladjusted,den value. For Ladjusted,night, the Committee also recommends the exponential averaging of equivalent sound pressure levels for the overnight period.

5 *Noise source-related adjustments*
The final step in the construction of uniform exposure metrics for the twenty-four-hour daily cycle and the night involves adjusting *Ladjusted,den* and *Ladjusted,night* so that the exposure-response relationships of the various noise sources are in line

with that of a selected source. The particular reference source selected by the Committee was road traffic. The proposed effect metric for the twenty-four-hour exposure was the percentage of people experiencing high annoyance. However, other effect metrics are generally used in other countries (in Germany for example, the percentage of people experiencing annoyance is used). Consequently, the Committee, being made up of experts from various countries, developed the EEL on the basis of the high annoyance percentage merely as an example. Using road traffic noise as the reference source, differences between EEL and Ladjusted,den are given for aviation and rail traffic noise. Depending on the noise exposure involved, these differences are between +3 and +5 dB(A) for air traffic, and between -1 and -8 dB(A) for rail traffic. The effect metrics given by the Committee for the night are the percentage of people reporting high sleep disturbance and the annual frequency of awakening due to a noise source. Because the information available at the time regarding the exposure-response relationships for road, rail and air traffic noise was not considered sufficiently reliable, the Committee decided against constructing an ENEL.

Applicability

The 'Uniform environmental noise exposure metric' Committee considered the methodology valid for the assessment of noise in most more or less stable situations, but not for the assessment of changes in noise situations over the short term. The Committee also pointed out that the method was not designed for use in relation to low-frequency noise, noise from incidental sources (such as rescue helicopters, ultra-light aircraft and advertising aircraft), neighbourhood noise or noise from neighbours.

Annex **G**

The distribution of traffic-related noise exposure in the Netherlands

Enclosure accompanying letter (reference 1034/04 LOK/HD/wh) from HSMA Diederen, Environmental and Nature Planning Office, RIVM, dated 23 June 2004 to the Health Council.

Updated distributions for *Lden* and *Lnight*

Table 1 Lden % of dwellings per noise category, cumulative distribution of road traffic, rail traffic and air traffic.

	0-50 dB	51-55 dB	56-60 dB	61-65 dB	66-100 dB
NBG2001[a]	32	31	25	9	3
2003[b]	37	31	22	8	2

[a] Corrected memorandum *Nachtelijke Blootstelling Geluid* (*Night-time Exposure to Noise*), dated 24-5-2004; noise maps 100 m resolution.
[b] Noise maps 25 m resolution.

Table 2 Lnight % of dwellings per noise category, cumulative distribution of road traffic, rail traffic and air traffic.

	0-40 dB	41-45 dB	46-50 dB	51-55 dB	56-60 dB	61-100 dB
NBG2001[a]	23	27	30	15	4	1
2003[b]	29	29	26	12	3	1

[a] Corrected memorandum *Nachtelijke Blootstelling Geluid* (*Night-time Exposure to Noise*), dated 24-5-2004; noise maps 100 m resolution.
[b] Noise maps 25 m resolution.

With regard to *Lden* and *Lnight*, we advise adhering to the distributions given for 2003 in Tables 1 and 2 above. These figures are the best estimate we can currently make, on the basis of the most recent information and modelling.

Explanatory notes

The distributions given above are based on noise maps plotted using RIVM's EMPARA model. This model makes use of data files with information on the positions of roads and railways, from which the associated noise exposures are calculated for grid squares using standard mathematics techniques. Noise maps for air traffic have also been obtained from NLR.

Since the start of 2004, noise exposures have been calculated for grid squares of 25 by 25 metres (as opposed to the old 100 by 100 metre squares). The finer resolution allows for more accurate reflection of the spatial variation in sound pressure levels actually occurring in the vicinity of roads and railways. The updated distribution data therefore differs from the distribution data published in 2001, but not to a particularly great extent.

The method we have used is described in the Ministry of Housing, Spatial Planning and the Environment's publication *Naar een Landelijk Beeld van Verstoring* (*Towards a National Picture of Disturbance*), publication no. 12, 1997. The accumulated noise exposure includes the values for road traffic, rail traffic and air traffic.

The reliability of the distribution data in Tables 1 and 2 depends not only on the scale used, but also on the current validity of the traffic data. Hence, it is worth stating that the data for motorways (obtained from AVV), railways (obtained from ASWIN), provincial roads (obtained from ERC) and air traffic (obtained from NLR) was updated for the 2004 Environmental Balance (based on the situation in 2003) and are therefore up to date.

The basic data that we used for municipal roads, however, was incomplete and somewhat out of date. To enable us to nevertheless obtain a full picture, we estimated the current traffic volumes on the majority of municipal roads using information about road types and a limited set of data from recent traffic counts. Because the municipal traffic data is to a large extent not based on recent volumetric figures and takes no account of features such as screens and quiet asphalt, the calculated noise exposures for a given location may differ considerably from the values that proper acoustic tests would return. However, it is assumed that any anomalies will, statistically speaking, balance one another out, so that the picture for the country as a whole and the associated distribution pattern constitute a reasonable approximation of the actual situation.

Address

Fingal County Council
Planning Enforcement
County Hall
Main Street
Swords
Co Dublin
K67 X8Y2

June 28th, 2023

Re: Dublin Airport Northern Runway

Dear Sir/Madam,

Please find attached a copy of a filled out complaint form regarding alleged Unauthorised Development with respect to the daa and the operation of Night time flights at Dublin Airport.

We note that the North Runway became operational on August 24th, 2022.

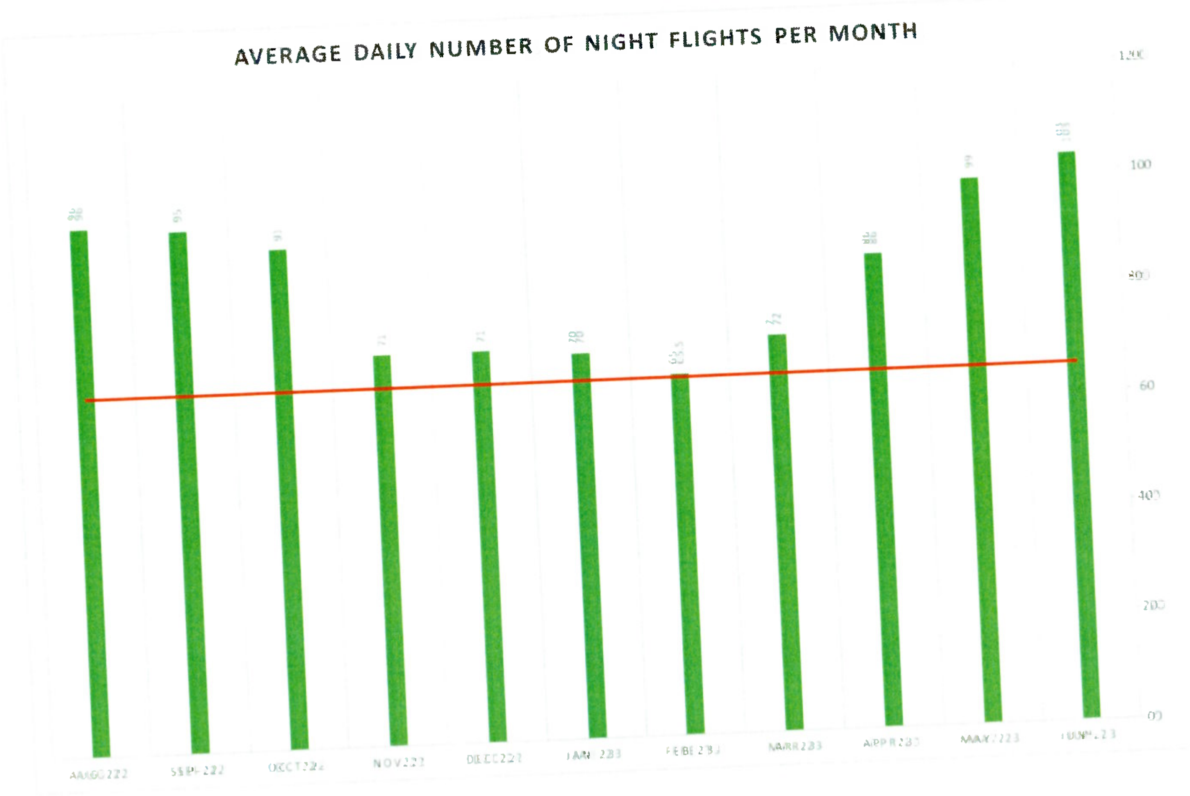
An Bord Pleanala granted planning permission for the North Runway in 2007 (F04A/1755). Condition 5 of the planning permission states that:

5. On completion of construction of the runway hereby permitted, the average number of night time aircraft movements at the airport shall not exceed 65/night (between 2300 hours and 0700 hours) when measured over the 92 day modelling period as set out in the reply to the further information request received by An Bord Pleanála on the 5th day of March, 2007.

   Reason: To control the frequency of night flights at the airport so as to protect residential amenity having regard to the information submitted concerning future night time use of the existing parallel runway.

92 day Summer period

Since August 2022, the average daily number of night-time flights per month has exceeded 65 for each month. From analysis of the further information requests during the Oral Hearing in 2006, it is clear that the intention of An Bord Pleanala was for a 65 movement limit once the North Runway had completed construction. The daa have stated that the fact that Condition 5 specifies the 92 day Summer average allows them flexibility not to enforce it until the Summer period. We are now in this Summer period and the daa continue to ignore Condition 5. Below is the average daily number of night-time flights per month since the North Runway opened.There are in excess of 100 flights since June 15th.



To avoid any confusion regarding the wording of Condition 5, below are flights that occurred over the night of June 25th/26th inside the 92 day summer period.
There were 106 aircraft movements between 23:00 and 07:00.

The list of aircraft and their arrival and departure times are as follows:

4CA280	EIN3LG	EI-DEJ	Airbus A320-214	6/25/2023 23:00
4CA4EB	RYR9SJ	EI-DPG	Boeing 737-8AS	6/25/2023 23:02
4CA217	EIN33W	EI-DEF	Airbus A320-214	6/25/2023 23:04
4CAFD2	RYR7BW	EI-GXM	Boeing 737-800WL	6/25/2023 23:09
4CA4F2	RYR3KR	EI-DPN	Boeing 737-8AS	6/25/2023 23:11
4CA214	EIN34Y	EI-DEE	Airbus A320-214	6/25/2023 23:13
4CA5C8	EIN40W	EI-DVE	Airbus A320-214	6/25/2023 23:15
4CA76A	RYR19YK	EI-EFO	Boeing 737-8AS	6/25/2023 23:18
4CA63B	EIN529	EI-FNJ	Airbus A320-216	6/25/2023 23:23
4A4D79	HYS252	YR-SKY	Airbus A320-232	6/25/2023 23:25
4A1921	FIA711	YR-FIA	Airbus A320-233	6/25/2023 23:26
4CA814	RYR60YF	EI-EKV	Boeing 737-8AS	6/25/2023 23:33
4CA245	RYR1CG	EI-DCO	Boeing 737-8AS	6/25/2023 23:40

4CADFE	RYR3JM			6/25/2023 23:42
4CAC55	RYR94GT	EI-HGR	Boeing 737-8200	6/25/2023 23:44
4CAC89	RYR47HR	EI-IFS	Boeing 737-8200	6/25/2023 23:46
4CA251	RYR4W	EI-DCR	Boeing 737-8AS	6/25/2023 23:50
4CA854	RYR2WK	EI-EML	Boeing 737-8AS	6/25/2023 23:57
4CA770	EIN4VM	EI-EDS	Airbus A320-214	6/26/2023 0:00
4CA2CB	EIN63K	EI-DER	Airbus A320-214	6/26/2023 0:10
4CA6C4	EIN24K	EI-DVI	Airbus A320-214	6/26/2023 0:13
4CAC1F	RYR5TC	EI-HEZ	Boeing 737-8200	6/26/2023 0:20
4CA215	EIN7VT	EI-DEG	Airbus A320-214	6/26/2023 0:22
4CA837	EIN497	EI-GAM	Airbus A320-214	6/26/2023 0:24
4CA27D	RYR80RR	EI-DHP	Boeing 737-8AS	6/26/2023 0:28
4CA4F8	RYR3TD	EI-DPV	Boeing 737-8AS	6/26/2023 0:31
4CAC88	RYR1443	EI-IFR	Boeing 737-8200	6/26/2023 0:33
4CADE4	RYR30UE	EI-IGY	Boeing 737-8200	6/26/2023 0:35
3412D3	EIN737	EC-HDS	Boeing 757-256	6/26/2023 0:38
4A1921	FIA712	YR-FIA	Airbus A320-233	6/26/2023 0:40
4D225B	RYR11YP	9H-QCU	Boeing 737-8AS	6/26/2023 0:40
4CAC53	RYR2BY	EI-HGO	Boeing 737-8200	6/26/2023 0:42
4CAD64	RYR9YZ	EI-HMY	Boeing 737-8200	6/26/2023 0:44
4CA92D	EIN56V	EI-DVM	Airbus A320-214	6/26/2023 0:46
49520F	TAP26T	CS-TPO	Embraer 190-100LR	6/26/2023 0:53
4CAA58	RYR733K	EI-EVS	Boeing 737-8AS	6/26/2023 0:59
4CA293	EIN4RL	EI-DEM	Airbus A320-214	6/26/2023 1:04
4D244D	TOM71D	9H-GKJ	Airbus A320-232	6/26/2023 1:14
4CAD10	RYR52CV	EI-HGX	Boeing 737-8200	6/26/2023 1:16
4CA75E	RYR45HY	EI-EFC	Boeing 737-8AS	6/26/2023 1:18
4CA2C3	RYR9PR	EI-DLF	Boeing 737-8AS	6/26/2023 1:22
4D23A4	TOM2YE	9H-GKK	Airbus A320-232	6/26/2023 1:24
4CA802	RYR930J	EI-EKD	Boeing 737-8AS	6/26/2023 1:27
4CA76A	RYR7AN	EI-EFO	Boeing 737-8AS	6/26/2023 1:32
4CA4F2	RYR7EH	EI-DPN	Boeing 737-8AS	6/26/2023 1:43
4CAC86	RYR275Y	EI-HMZ	Boeing 737-8200	6/26/2023 1:55
4CADA4	RYR3ZV	EI-IFV	Boeing 737-8200	6/26/2023 1:58
4CA2C9	EIN799	EI-DEP	Airbus A320-214	6/26/2023 2:00
4D2317	BCS5QC			6/26/2023 2:03

4CADBF	RYR8ZK	EI-IGM	Boeing 737-8200	6/26/2023 2:05
4CAFB3	RYR4QA	EI-GSG	Boeing 737-800WL	6/26/2023 2:07
4CA15D	EIN4GJ	EI-CVB	Airbus A320-214	6/26/2023 2:09
4CA27F	EIN499	EI-DEK	Airbus A320-214	6/26/2023 2:11
4CA281	EIN5HL	EI-DEI	Airbus A320-214	6/26/2023 2:20
4CADC4	RYR69SB	EI-IGG	Boeing 737-8	6/26/2023 2:28
440BC1	BCS2882	OE-LND	Boeing 757-223SF	6/26/2023 2:59
4CA15C	EIN58R	EI-CVC	Airbus A320-214	6/26/2023 3:02
451D99	BCS3TW	LZ-CGS	Boeing 737-4Q8F	6/26/2023 3:58
A48850	UPS248	N391UP	Boeing 767-304ERSF	6/26/2023 4:01
4CA614	EIN13K	EI-FNG	Airbus A330-302	6/26/2023 4:13
40087	ETH518	ET-ARE	Boeing 787-8	6/26/2023 4:23
4CAA1F	BCS2937	EI-STS	Boeing 737-48EF	6/26/2023 4:26
4CA5C7	EIN104	EI-DUZ	Airbus A330-302	6/26/2023 4:28
40102	ETH574	ET-ASH	Boeing 787-8	6/26/2023 4:45
4CABD2	EIN1TC	EI-LRF	Airbus A321-253NX\/LR	6/26/2023 4:48
4CA15E	EIN1MN	EI-DAA	Airbus A330-202	6/26/2023 4:50
4CABD4	EIN13R	EI-LRH	Airbus A321-253NX\/LR	6/26/2023 4:53
A48850	UPS248	N391UP	Boeing 767-304ERSF	6/26/2023 5:03
40106	ETH500	ET-ASL	Boeing 777-360ER	6/26/2023 5:09
4CA7D8	EIN122	EI-GAJ	Airbus A330-302	6/26/2023 5:11
40087	ETH518	ET-ARE	Boeing 787-8	6/26/2023 5:37
4CA9BB	EIN11P	EI-LRB	Airbus A321-253NX\/LR	6/26/2023 5:47
4CA2C3	RYR16UU	EI-DLF	Boeing 737-8AS	6/26/2023 5:55
40102	ETH574	ET-ASH	Boeing 787-8	6/26/2023 5:57
3C6483	DLH983	D-AIDC	Airbus A321-231	6/26/2023 6:06
AA7BA7	AAL724	N775AN	Boeing 777-223ER	6/26/2023 6:08
4CADBF	RYR4KU	EI-IGM	Boeing 737-8200	6/26/2023 6:10
4CA245	RYR1WZ	EI-DCO	Boeing 737-8AS	6/26/2023 6:12
4CA13D	EIN66V	EI-CVA	Airbus A320-214	6/26/2023 6:13
06A0B6	QTR56X	A7-BCR	Boeing 787-8	6/26/2023 6:15
39E68C	AFR47GQ	F-HZUM	Airbus A220-300	6/26/2023 6:17
4CADC4	RYR37GR	EI-IGG	Boeing 737-8	6/26/2023 6:19
4D23A4	TOM1TE	9H-GKK	Airbus A320-232	6/26/2023 6:21
4CADE4	RYR62ZZ	EI-IGY	Boeing 737-8200	6/26/2023 6:23
486493	KLM68T	PH-NXJ	Embraer 195-400STD-E2	6/26/2023 6:24

4CADA4	RYR36LU	EI-IFV	Boeing 737-8200	6/26/2023 6:26
4CAFB3	RYR6MR	EI-GSG	Boeing 737-800WL	6/26/2023 6:30
AB10CB	AAL722	N812AA	Boeing 787-8	6/26/2023 6:30
4CA7B5	RYR23XX	EI-EFZ	Boeing 737-8AS	6/26/2023 6:32
4CAC86	RYR12UY	EI-HMZ	Boeing 737-8200	6/26/2023 6:34
4CA251	RYR80CQ	EI-DCR	Boeing 737-8AS	6/26/2023 6:35
40106	ETH500	ET-ASL	Boeing 777-360ER	6/26/2023 6:37
4CA2CA	EIN23F	EI-DES	Airbus A320-214	6/26/2023 6:39
4CAC84	RYR22MD	EI-HGF	Boeing 737-8200	6/26/2023 6:41
4CA76A	RYR30QZ	EI-EFO	Boeing 737-8AS	6/26/2023 6:42
4CA15C	EIN59K	EI-CVC	Airbus A320-214	6/26/2023 6:44
4CA92D	EIN40G	EI-DVM	Airbus A320-214	6/26/2023 6:45
4CA217	EIN60H	EI-DEF	Airbus A320-214	6/26/2023 6:46
4CA640	EIN45F	EI-DVH	Airbus A320-214	6/26/2023 6:48
4CAA58	RYR952D	EI-EVS	Boeing 737-8AS	6/26/2023 6:49
4CAD7A	EIN1GT	EI-NSA	Airbus A320-251N	6/26/2023 6:51
4CAC1F	RYR30DG	EI-HEZ	Boeing 737-8200	6/26/2023 6:52
4CA280	EAI05ED	EI-DEJ	Airbus A320-214	6/26/2023 6:54
4CAC53	RYR3CL	EI-HGO	Boeing 737-8200	6/26/2023 6:55
4CABD4	EIN2MW	EI-LRH	Airbus A321-253NX\/LR	6/26/2023 6:56
4CA854	RYR7HF	EI-EML	Boeing 737-8AS	6/26/2023 6:58

Condition 5 is one of the two conditions that the daa are actively trying to amend via their planning application F20A/0668. This application is currently under appeal with An Bord Pleanala. The planning notice clearly states that it's the daa's intention to replace Condition 5 with a Noise Quota System (NQS).

The accompanying documentation for application F20A/0668 clearly states that the daa believe that flights will be lost once the North Runway commences operations. In section 3.2.10 of the revised EIAR, the daa provide figures for 2022-2025 and the projected lost passengers:

3.2.10 Table 3-1 presents the assessed impact of the Permitted Scenario is a cumulative loss over the 4-year period 2022-2025 of 6.3m passengers when compared with the Proposed Scenario.

Table 3-1: Annual TrafficImp actSummary (millon sof passengers)

	2022	2023	2024	2025	2022-2025T otal
Proposed	21.0	26.7	30.8	32.0	110.5
Permitted	19.6	24.9	29.3	304	104.2
Differ ence	-1.4	-1.8	-1 6	-1.6	-6.3[1]

Source. Quantification of Impacts on Future Growth. Update 2022 - 2025 Penod (Mott MacDonald.2021)

The daa predicted a loss of 1.4m passengers in 2022 due to Conditions 3(d) and 5. But the daa are currently ignoring Condition 5 and lost no passengers.

So the daa have used Condition 5 to mislead Fingal County Council into granting them permission for F20A/0668 and yet they are ignoring Condition 5.

The daa have stated in correspondence that they are relying on the advice of the Commission for Aviation Regulation (CAR) who is responsible for slots at Dublin Airport, for their non-compliance with Condition 5. The CAR is not the planning authority, Fingal County Council is.

In a document received via FOI titled '*20171017_388690 - DAA Operating Restrictions - 2017 report v1.2 Final_Redacted.pdf*', the daa's consultants Mott MacDonald, clearly state that '*Although the night restriction compliance is measured over the 92 day period, **spirit of the restrictions would require night period scheduling limits to be applied on a year-round basis***'.

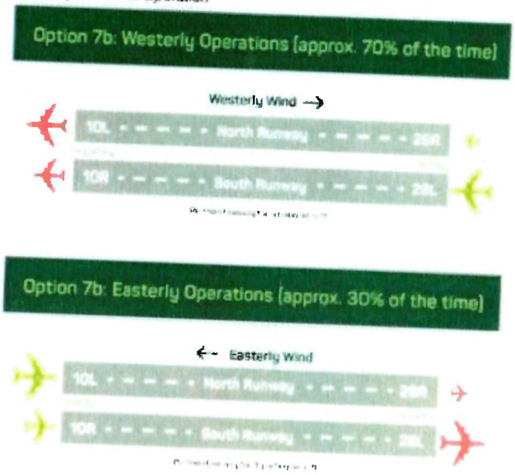
Background

Planning Conditions

- The North Runway planning permission (PL06F 21742) contains the following conditions to take effect from completion of the new runway
  - Condition 3(d) states that *Runway 10L-28R shall not be used for take off or landing between 2300 hours and 0700 hours*[1]
  - Condition 5 states that *the average number of night time aircraft movements at the airport shall not exceed 65/night (between 2300 hours and 0700 hours) when measured over the 92 day modelling period*

- This study interprets Condition 5 as follows
  - Night movements are based on actual aircraft landing or taking-off times
  - The 65/night limit is based on the average over the 92 day modelling period (16 June to 15 September)
  - All night operations, including ad hoc operations and unplanned operations (e.g., delayed daytime flights), as well as regularly scheduled night flights are taken into account
  - Therefore, scheduling limits to ensure compliance must take account of aircraft taxi times and make reasonable allowances for delayed flights
  - Although the night restriction compliance is measured over the 92 day period, the spirit of the restrictions would require night period scheduling limits to be applied on a year round basis

Runway Modes of Operation



Source: daa

(1) except in cases of safety, maintenance considerations, exceptional air traffic conditions, adverse weather, technical faults in air traffic control systems or declared emergencies at other airports

As current operations at Dublin Airport breach Condition 5 of planning application F04A/1755 and of An Bord Pleanala permission PL 06F.217429, we request that Fingal County Council immediately enforce compliance with the limit of 65 flights at night. The current operations are putting the health of residents at risk.

Yours Sincerely

Signatur e

Name

Planning Enforcement Fingal County Council

Complaint Form Regarding Alleged Unauthorised Development

(Please read the notes before completing this form)

1. Address of where the alleged unauthorised development is being carried out:	Dublin Airport and surrounding communities
2. Full description of the alleged unauthorised development:	daa operating greater than 65 flights at night contravening Condition 5 of the 2007 Planning Permission for the North Runway (F04A/1755)
3. Date work/use commenced:	2023
4. Name and Address of Property Owner/Occupier:	Dublin Airport Authority, Fingal, Co Dublin
5. Name and Address of person carrying out alleged unauthorised development:	Dublin Airport Authority and airlines arriving and departing from the airport
6. Name and Address of Developer:	Dublin Airport Authority, Fingal, Co Dublin
7. Any other relevant information regarding the location, previous use, etc.	Please see additional information above
8. Your name and address (this information will be kept confidential):	Name Address
9. Your telephone number:	Phone number
10. Your Email address:	email

I HAVE READ THE NOTES RELATING TO THIS FORM AND UNDERSTAND THE IMPLICATIONS OF SAME	
Signature:	**Signed:** **Date:**
Note: Complaints will not be investigated unless name and address are given and the form is signed	

PLEASE COMPLETE THIS FORM AND EMAIL TO: planning.enforcement@fingal.ie
OR POST TO ADDRESS BELOW

Fingal County Council
Planning Enforcement
County Hall
Main Street
Swords
Co Dublin
K67 X8Y2

ADDITIONAL INFORMATION

Site location map

CE Order Reference PENF/0133/2023

ENF No:
23/100B

COMHAIRLE CONTAE FHINE GALL

FINGAL COUNTY COUNCIL

S153 CE 1
TO ISSUE

RECORD OF CHIEF EXECUTIVE'S ORDER

IN THE MATTER OF THE LOCAL GOVERNMENT ACT 2001 (AS AMENDED)

AND IN THE MATTER OF THE PLANNING AND DEVELOPMENT ACT 2000 (AS AMENDED)

SECTION 153 OF THE PLANNING AND DEVELOPMENT ACT 2000 (AS AMENDED)

Section 153 – Decision on Enforcement

SUBJECT
Whether to issue an Enforcement Notice

Lands: Dublin Airport, Co. Dublin

Planning Permission: Planning Authority Reg. Ref No: F04A/1755
ABP Ref. No: PL 06F.217429
North Runway Permission - Condition 5

Enforcement Complaint: Unauthorised development comprising development carried out in non-conformity with Condition 5 of the North Runway Permission (Planning Authority Reg. Ref No: F04A/1755 / ABP Ref. No: PL 06F.217429)

WHEREAS Dublin Airport Authority plc ("*daa*") obtained a grant of planning permission, following an appeal to An Bord Pleanála, for development comprising, *inter alia*, the development of the North Runway ("*the North Runway Permission*" - Planning Authority Reg. Ref No: F04A/1755 / ABP Ref. No: PL 06F.217429) – the said grant of permission was subject to 31 Conditions, including Condition 5 which provides:

> "On completion of construction of the runway hereby permitted, the average number of night time aircraft movements at the airport shall not exceed 65/night (between 2300 hours and 0700 hours) when measured over the 92 day modelling period as set out in the reply to the further information request received by An Bord Pleanála on the 5th day of March, 2007.
>
> **Reason:** To control the frequency of night flights at the airport so as to protect residential amenity having regard to the information submitted concerning future night time use of the existing parallel runway."

The application documentation, including the EIS and information provided by way of further information, the Inspector's Report and the Board Order provide the context to the imposition of Condition 5;

AND WHEREAS a complaint was received by Fingal County Council ("*the Council*"), on 24th March 2023, and subsequent complaints followed, in relation to alleged unauthorised development at the Lands – being non-compliance/non-conformity with Condition 5 of the North Runway Permission (Planning Authority Reg. Ref No: F04A/1755 / ABP Ref. No: PL 06F.217429) and including an alleged exceedance over the permitted number of night time aircraft movements;

AND WHEREAS pursuant to s.152(1)(a) of the Planning and Development Act 2000 (as amended) ("*the 2000 Act*"), having considered the said complaint, the Council issued a Warning Letter, dated 25th April 2023, to the daa in respect of the alleged unauthorised development – being alleged non-compliance/non-conformity with Condition 5 of the North Runway Permission (Planning Authority Reg. Ref No: F04A/1755 / ABP Ref. No: PL 06F.217429);

AND FURTHER WHERE the daa responded to the said Warning Letter, pursuant to s.152(4)(b) of the 2000 Act, setting out its response to the allegation of unauthorised development by way of correspondence, dated 23rd May 2023 – which included support documentation;

AND WHERE, as part of the Council's investigation into the matter, further information/clarification was sought from the daa by way of correspondence, dated 9th June 2023 and 15th June 2023, and the daa responded to same by way of correspondence, dated 14th June 2023 and 19th June 2023;

HAVING CONSIDERED, *inter alia*, the complaint received and the responses from the daa, including supporting documentation (including the aforesaid) and having considered the Council's Planning Report, dated 18th July 2023, together with the Appendices to same, prepared as part of the Council's investigation into the alleged unauthorised development and the recommendation therein;

AND NOTING that the Council's Planning Report, dated 18th July 2023, provides, *inter alia*: a summary of the relevant planning history to the Lands – including matters relevant to Condition 5; a summary of the complaint received per s.152; details on the Warning Letter issued pursuant to s.152; outlines and considers the various responses/arguments made by daa in response to the said Warning Letter; a response to the said responses/arguments made by daa; outlines an interpretation of Condition 5 of the Planning Permission;

AND HAVING NOTED AND CONSIDERED the requirements of section 153 of the 2000 Act, including *inter alia* the following provisions which provide, *inter alia*:

> "(1) As soon as may be after the issue of a warning letter under section 152, the planning authority shall make such investigation as it considers necessary to enable it to make a decision on whether to issue an enforcement notice or make an application under section 160.
>
> ...
>
> (3) A planning authority, in deciding whether to issue an enforcement notice shall consider any representations made to it… and any other material considerations.
>
> ...
>
> (7) Where a planning authority establishes, following an investigation under this section that unauthorised development (other than development that is of a trivial or minor nature) has been or is being carried out and the person who has carried out or is carrying out the development has not proceeded to remedy the position, then the authority shall issue an enforcement notice under section 154 or make an application pursuant to section 160, or shall both issue such a notice and make such an application, unless there are compelling reasons for not doing so...";

RECOMMENDATION of the SENIOR EXECUTIVE PLANNER: Accordingly, in accordance with section 153(1) of the 2000 Act, having considered the proper planning and sustainable development of the administrative area of Fingal County Council including the preservation and improvement of the amenities thereof, and having carried out an investigation such as to enable it to make a decision in accordance with section 153(1) of the 2000 Act and having considered representations made to it under **section 152**(1)(a) and submissions or observations made under **section 152**(4)(b) and any other material considerations, I recommend that an enforcement notice issue pursuant to section 154 of the Planning and Development Act for the following reasons:

- The use of the airport for night-time aircraft movements was, for the reason of protecting residential amenity, limited by An Bord Pleanála in the consent of the North Runway. Night-time use of the airport was limited by Condition 5 to levels of activity submitted by the daa in the course of the application;

- Residential amenity is protected by Condition 5 by way of mitigation of an identified significant impact through the control of the frequency of that impact, to an intensity of use forecast by the daa at the time of the application to extend the airfield by construction of the North Runway. An Bord Pleanála confirmed and determined the magnitude of night-time flights acceptable in its consideration of proper planning and sustainable development. The night-time use was limited in this manner by An Bord Pleanála to address concerns regarding the cumulative impact of the proposal in combination with existing development;

- The North Runway has been constructed and became operational on the 24 August 2022. A scheduling and slot allocation process was undertaken and a summer 2023 operating schedule was determined and is currently in operation;

- The summer schedule which is being carried out is in breach of the limit applied in Condition 5;

- Taking account of the foregoing, it is therefore concluded that by virtue of the scheduled and actual operations reported, the frequency of night flights in Dublin Airport is not in conformity with Condition 5 of the North Runway permission and is for that reason unauthorised development. The 2000 Act, including s.154(5)(a)(ii) provides that the planning authority can issue an Enforcement notice to requirc the daa, to proceed with a development in conformity with Condition 5;

- Unauthorised development is occurring and will continue to occur in non-conformity with Condition 5 and that unauthorised development is occurring at the Lands and development is not being carried out in conformity with Condition 5 of the North Runway Permission (Planning Authority Reg. Ref No: F04A/1755 / ABP Ref. No: PL 06F.217429);

- The daa has not sought to remedy the said unauthorised development, there are no compelling reasons for not taking enforcement action, having regard to the nature of the unauthorised development at issue and the nature of Condition 5, including the reason/purpose of same;

- In circumstances where unauthorised development is occurring and will continue to occur at Dublin Airport, contrary to Condition 5 of the North Runway Permission (Planning Authority Reg. Ref No: F04A/1755 / ABP Ref. No: PL 06F.217429) comprising the continued and ongoing exceedance of the permitted average number of night-time (between 2300 hours and 0700 hours) aircraft movements at the airport – being a permitted average of 65 aircraft movements per night when measured over the 92-day modelling period;

- Noting the nature of the unauthorised development and the evidence presented and matters discussed in the aforesaid Report dated 18th July 2023 and appendices thereto, it is considered that a period of 6 weeks for compliance with the terms of the Enforcement Notice is reasonable and appropriate in the circumstances.

Recommender Hugh O'Neill
p.p. Senior Executive Planner

ORDER:

The report entitled *Informing a "decision on enforcement" under Section 153 of the Planning and Development Act 2000 (as amended)* from the Senior Executive Planner dated the 18th July 2023 and the appendices attached thereto have been considered. The findings and recommendations and the reasons set out therein **to issue** an enforcement notice pursuant to section 154 of the Planning and Development Act are hereby **ACCEPTED** and **ADOPTED** in this decision.

In accordance with section 153(1) of the 2000 Act, having considered the proper planning and sustainable development of the administrative area of Fingal County Council including the preservation and improvement of the amenities thereof, and having carried out an investigation such as to enable it to make a decision in accordance with section 153(1) of the 2000 Act and having considered representations made to it under **section 152**(1)(a) and submissions or observations made under **section 152**(4)(b) and any other material considerations the Planning Authority hereby **DECIDES** and **SO ORDERS** that an enforcement notice issue pursuant to section 154 of the Planning and Development Act for the following reasons:

- The use of the airport for night-time aircraft movements was, for the reason of protecting residential amenity, limited by An Bord Pleanála in the consent of the North Runway. Night-time use of the airport was limited by Condition 5 to levels of activity submitted by the daa in the course of the application;

- Residential amenity is protected by Condition 5 by way of mitigation of an identified significant impact through the control of the frequency of that impact, to an intensity of use forecast by the daa at the time of the application to extend the airfield by construction of the North Runway. An Bord Pleanála confirmed and determined the magnitude of night-time flights acceptable in its consideration of proper planning and sustainable development. The night-time use was limited in this manner by An Bord Pleanála to address concerns regarding the cumulative impact of the proposal in combination with existing development;

- The North Runway has been constructed and became operational on the 24 August 2022. A scheduling and slot allocation process was undertaken and a summer 2023 operating schedule was determined and is currently in operation;

- The summer schedule which is being carried out is in breach of the limit applied in Condition 5;

- Taking account of the foregoing, it is therefore concluded that by virtue of the scheduled and actual operations reported, the frequency of night flights in Dublin Airport is not in conformity with Condition 5 of the North Runway permission and is for that reason unauthorised development. The 2000 Act, including s.154(5)(a)(ii) provides that the planning authority can issue an Enforcement notice to require the daa, to proceed with a development in conformity with Condition 5;

- Unauthorised development is occurring and will continue to occur in non-conformity with Condition 5 and that unauthorised development is occurring at the Lands and development is not being carried out in conformity with Condition 5 of the North Runway Permission (Planning Authority Reg. Ref No: F04A/1755 / ABP Ref. No: PL 06F.217429);

- The daa has not sought to remedy the said unauthorised development, there are no compelling reasons for not taking enforcement action, having regard to the nature of the unauthorised development at issue and the nature of Condition 5, including the reason/purpose of same;

- In circumstances where unauthorised development is occurring and will continue to occur at Dublin Airport, contrary to Condition 5 of the North Runway Permission (Planning Authority Reg. Ref No: F04A/1755 / ABP Ref. No: PL 06F.217429) comprising the continued and ongoing exceedance of the permitted average number of night-time (between 2300 hours and 0700 hours) aircraft movements at the airport – being a permitted average of 65 aircraft movements per night when measured over the 92-day modelling period;

- Noting the nature of the unauthorised development and the evidence presented and matters discussed in the aforesaid Report dated 18th July 2023 and appendices thereto, it is considered that a period of 6 weeks for compliance with the terms of the Enforcement Notice is reasonable and appropriate in the circumstances.

Approver Malachy Bradley

Senior Planner

28/07/2023 **Dated**

thereunto empowered by order of the Chief Executive, Fingal County Council C.E No **8539** delegating to me all powers, functions and duties in relation to the Council of the County of Fingal in respect of this matter.

Comhairle Contae Fhine Gall
Fingal County Council

An Roinn um Pleanáil agus
Infrastruchtúr Straitéiseach
Planning and Strategic
Infrastructure Department

ENF No:	23/100B
S.153 CE No:	PENF/0133/2023
S.154 CE No:	PENF/0134 /2023

COMHAIRLE CONTAE FHINE GALL

FINGAL COUNTY COUNCIL

IN THE MATTER OF THE LOCAL GOVERNMENT ACT 2001 (AS AMENDED)

AND IN THE MATTER OF THE PLANNING AND DEVELOPMENT ACT 2000 (AS AMENDED)

ENFORCEMENT NOTICE
Section 154 of the Planning and Development Act 2000 (as amended)

DEVELOPMENT CARRIED OUT IN NON-CONFORMITY WITH A GRANT OF PLANNING PERMISSION INCLUDING CONDITIONS

To: daa Public Limited Company,
Three, The Green,
Dublin Airport Central,
Dublin Airport,
Swords, Co. Dublin K67 X4X5

**Re: Lands at Dublin Airport, Co. Dublin ("*the Lands*").
Planning Permission for the North Runway - Planning Authority Reg. Ref No: F04A/1755 / ABP Ref. No: PL 06F.217429
Condition 5**

WHEREAS Fingal County Council ("*the Council*"), being the Planning Authority for the functional area in which the above mentioned Lands are located, having considered only the proper planning and sustainable development of the administrative area of Fingal County Council, including the preservation and improvement of the amenities thereof, any representations made to the Council under section 152(1)(a) of the Planning and Development Act 2000 (as amended), any submissions or observations made under section 152(4)(b) of the Planning and Development Act 2000 (as amended) and any other material considerations, and having investigated the matter, has, in accordance with section 153 of the Planning and Development Act 2000 (as amended) decided to issue this Enforcement Notice.

AND WHEREAS subsequent to the 1st day of October 1964 and within seven years immediately preceding the date of this Notice, the following development is being carried out, and will continue to be carried out, in non-conformity with Condition 5 of the Planning Permission for the North Runway (Planning Authority Reg. Ref No: F04A/1755 / ABP Ref. No: PL 06F.217429) being the continued and ongoing exceedance of the permitted average number of night time aircraft movements at the airport being 65 aircraft movements per night namely between 2300 hours and 0700 hours (when measured over the 92 day modelling period as set out in the reply to the further information request received by An Bord Pleanála on the 5th day of March, 2007).

AND WHEREAS the reason for Condition 5 was to control the frequency of night flights at the airport so as to protect residential amenity having regard to the information submitted concerning future night time use of the existing parallel runway.

YOU ARE HEREBY REQUIRED, pursuant to section 154 of the Planning and Development Act 2000 (as amended) within **6 weeks** of the date of the service this Notice to proceed with the development in conformity with Condition 5 of the Planning Permission for the North Runway (Planning Authority Reg. Ref No: F04A/1755 / ABP Ref. No: PL 06F.217429) so that the average number of night-time (between 2300 hours and 0700 hours) aircraft movements at the airport is 65 aircraft movements per night or less - when measured over the 92-day modelling period;

AND TAKE NOTICE that you are further required to refund the Council the sum of €350.00 being the sum of costs and expenses reasonably incurred by it in relation to the investigation, detection and issue of this Enforcement Notice and any Warning Letter issued under s.152 of the Planning and Development Act 2000, as amended, including costs incurred in respect of the renumeration and other expenses of its employees, consultants and/or advisors pursuant to s.154(5)(d) of the Planning and Development Act 2000, as amended.

AND TAKE NOTICE that, if within the period specified above, or within such extended period (not being more than 6 months) as the Council may allow, the steps specified in this Notice to be taken are not taken, the Council may, insofar as same is relevant/applicable to the unauthorised development complained of herein, enter on the land and take such steps, including the removal, demolition or alteration of any structure, and may recover any expenses reasonably incurred by them in that behalf.

AND TAKE FURTHER NOTICE that if, within the said period above, or within such extended period as may be allowed by the Council (not being more than six months), the steps in this Notice to be taken by you, have not been so taken, you may be guilty of an offence.

If the Council decides to prosecute you for non-compliance with this Notice and you are found guilty of an offence by the Courts, you may be liable on summary conviction to a fine not exceeding €5,000 and/or imprisonment for a term not exceeding 6 months or both or on conviction following trial on indictment to a fine not exceeding €12,697,381 and/or a term of imprisonment not exceeding 2 years or both.

You will further be liable on conviction for the costs and expenses of such prosecution.

Dated: The 28th day of July 2023

Signed: [signature]
SENIOR PLANNER

To whom the appropriate powers have been delegated by Order of CE 8539 of the Chief Executive, Fingal County Council.

To be Served On: daa Public Limited Company,
Three, The Green,
Dublin Airport Central,
Dublin Airport,
Swords, Co. Dublin K67 X4X5

being the owner and person carrying out the unauthorised development.

Outlook

RE: ENF 24/263 - Dublin Airport 32 Million Cap

From Planning Enforcement <Planning.Enforcement@fingal.ie>
Date Mon 23/12/2024 05:14

Dear Sir/Madam,

I wish to inform you that a Warning Letter pursuant to Section 152 of the Planning and Development Act 2000, as amended, issued on the 17th December 2024, in relation to your complaint regarding the above. The particulars of the Warning Letter are as follows:

This alleged unauthorised development comprises:

- **Exceedance/breach of the 32 million per annum passenger capacity restriction for the year 2024 (January 2024-December 2024) contrary to Condition No. 3 of Planning Permission F06A/1248 (PL 06F.220670) and Condition No. 2 of Planning Permission of F06A/1843 (PL 06F.223469).**

Please be advised that this matter is receiving the full attention of the Planning Enforcement section. When an update is available to you, you will be notified in writing.

Kind regards,
E. H.

On behalf of
Fearghal McSweeney | Administrative Officer | Planning & Strategic Infrastructure Department | Fingal County Council | County Hall | Main Street | Swords | Co. Dublin | K67 X8Y2
Ph : (01) 8905000
Email: planning.enforcement@fingal.ie

Comhairle Contae Fhine Gall
Fingal County Council

bheith slán nó saor ó earráidí mar d'fhéadfadh faisnéis a bheith idircheaptha, truaillithe, caillte , scriosta, nó teacht déanach nó neamhiomlán . Dá bhrí sin , ní féidir linn glacadh le freagracht as aon earráidí nó easnaimh atá sa teachtaireacht seo , nó aon iatán , a tháinig chun cinn mar thoradh ar an tarchur ríomhphoist . Tá an teachtaireacht cuardaithe ag bogearraí Frithvíreas.