Further background information on these issues is provided in section 1.3.5. This section details the conversions that are actually carried out.

1.3.4.2 SEL to L_{Amax}

SEL is only used for aircraft noise in this report and, according to Ollerhead et al. (1992) from ground-based measurements, the following relation was found:

$$SEL = 23.9 + 0.81 * L_{Amax} \quad [1].$$

A more general approach can be used to estimate SEL for transportation noise.

If the shape of the time pattern of the sound level can be approximated by a block form, then $SEL \approx L_{Amax} + 10lg\ t$, where t (in seconds) is the duration of the noise event. This rule can be used, inter alia, for a long freight train that passes at a short distance. When t is in the range from 3 to 30 seconds, then SEL is 5–15 dB higher than L_{Amax}. For most passages of aircraft, road vehicles or trains, the shape of the time pattern of the sound level can be better approximated with a triangle. If the sound level increases with rate a (in dB per second), and thereafter is at its maximum for a short duration before it decreases with rate -a, then $SEL \approx L_{Amax} - 10lg(a) + 9.4$. Depending on the distance to the source, for most dwellings near transportation sources the rate of increase is in the order of a few dB per second up to 5 dB per second. When (a) is in the range from 9 dB to 1 dB per second, then SEL is 0–9 dB higher than L_{Amax}.

1.3.4.3 Events to long-term

When the SEL values are known (if necessary after converting from L_{Amax}) they can be converted to L_{night}. In general terms, the relation between L_{night} and SEL is: $L_{night} = 10 * lg\ \Sigma_i\ 10^{SEL_i/10} - 10 * lg\ (T)$.

If all (N) events have approximately the same SEL level, this may be reduced to:

$$L_{night} = SEL + 10 * lg(N) - 70.2 \quad [2],$$

in which:
N = the number of events occurring in period T;
T = time during which the events occur in seconds. For a (night) year 10lg(T) is 70.2.

The notation adheres to the END where the L_{night} is defined as a year average at the most exposed facade. Any reference to an inside level is noted as such, that is, as $L_{night,inside}$. In order to avoid any doubt the notation $L_{night,outside}$ may be used, for instance in tables where both occur.

1.3.4.4 Inside to outside

As the L_{night} is a year value, the insulation value is also to be expressed as such. This means that if the insulation value is 30 dB with windows closed and 15 dB with windows open, the resulting value is 18 dB if the window is open 50% of the time. If these windows are closed only 10% of the time, the result is little more than 15 dB. The issue is complicated by the fact that closing behaviour is, to a certain extent, dependent on noise level. When results about effects are expressed with indoor (that is, inside bedrooms) exposure levels, they need to be converted to L_{night}, in accordance with the END definition. The most important assumption is the correction for inside levels to outside levels. An average level difference of 21 dB has been chosen, as this takes into account that even in well-insulated houses windows may be open a large part of the year. In general:

$$L_{night} = L_{night,inside} + Y \text{ dB} \qquad [3].$$

Y is the year average insulation value of the (bedroom) facade. In this report a default value of 21 dB is used (see also section 1.3.5). It should be stressed that this conversion is thought to be highly dependent on local building habits, climate and window opening behaviour.

1.3.4.5 Most exposed facade

If an inside level is converted to an outside level with [3], it is assumed that this is equivalent to an L_{night} value on the most exposed facade. No information is available on bedroom position and use, so no explicit conversion factor can be given in this report.

This means that the effect estimated on the basis of L_{night} corresponds to an upper limit, because part of the bedrooms will be on a less exposed facade. If an estimate of the exposed population is based on a relation derived with [3], the actual prevalence will be less. From a practical point of view the most exposed facade safeguards protection in cases where there is a possibility that rooms can be swapped.

It should be pointed out that the above does not apply if a relation is based on L_{night} values which are directly measured or computed. These relations will show a large variation because of a misclassification effect, but they give a "correct" estimate of the prevalence of effects in the population. In other words, in some cases a low effect may be attributed to a high L_{night} because the bedroom is on the quiet side.

1.3.5 INSIDE/OUTSIDE DIFFERENCES

Night-time environmental noise affects residents mainly inside their homes. In order to protect residents inside their homes from noise from outside sources, attention should be focused on windows since they are generally the weakest points in the sound propagation path. Roofs must also be considered with regard to aircraft noise.

There are many types of window in the EU, varying from single thin panes within frames without additional insulation, to four-pane windows within insulated frames. The simplest types of facade have a sound reduction (from outside to inside) of usually less than 24 dB, and the most elaborate facades (built to cope with cold climates, for example), have sound reductions of more than 45 dB. In central Europe, most windows are double-glazed, mounted in a rigid and well-insulated frame. Their range of sound reduction is between 30 dB and 35 dB when closed.

When night-time environmental noise reaches high levels, residents tend to close their bedroom windows (cf. Langdon and Buller, 1977; Scharnberg et al., 1982; Schreckenberg et al., 1999; Diaz et al., 2001). The studies by Scharnberg et al. and Schreckenberg et al. found that more than 50% of bedroom windows are closed when outside road traffic noise levels exceed 55 dB (L_{Aeq}). These findings have been replicated in Sweden, according to recent results from the Swedish soundscape research programme on road traffic noise (Fig. 1.7). Nevertheless, while residents with closed windows reported a reduction of sleep disturbances due to noise, they also reported an increase in sleep disturbances due to poor ventilation. Schreckenberg et al. (1999) report a much steeper increase in the incidence of closed windows when road traffic noise reaches high levels than is the case with increased levels of railway noise. Even when night-time noise levels reach 55 B, only 35% of the residents exposed to railway noise reported that they closed their windows at night.

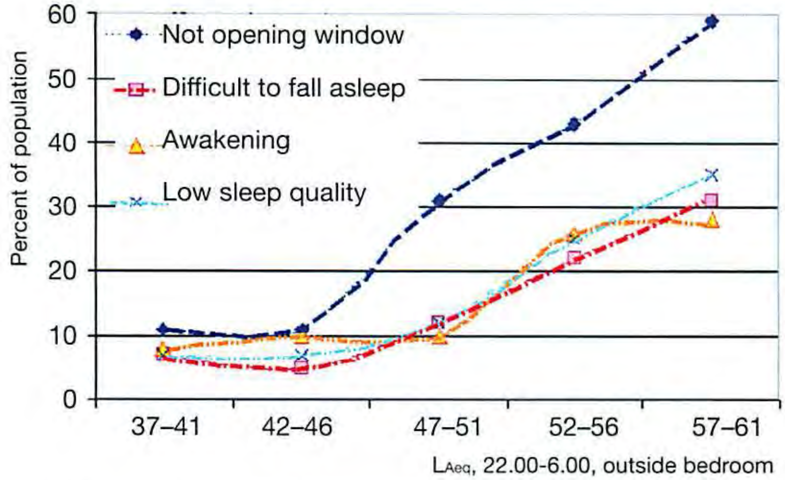

Fig. 1.7
Results from Swedish soundscape research programme on road traffic noise

Source: Öhrström, in European Commission, 2002a.

When windows are slightly open, outside sound levels are usually reduced by 10–15 dB. It should be kept in mind that most European residents want to keep their bedroom windows slightly open at night in order to provide proper ventilation (Scharnberg et al., 1982; Lambert and Plouhinec, 1985; Lambert and Vallet, 1994), and the WHO paper on community noise (WHO, 1999) also recommends that people should be able to sleep with their bedroom windows open.

Passchier-Vermeer et al. (2002) carried out detailed noise measurements inside and outside the bedroom and at the same time measured window position with sensors. The results (Table 1.3) showed that windows are fully closed only in 25% of the nights.

Table 1.3
Window positions during research period (April-November)

Window position	% nights
Closed	25
Slightly open	43
Hand width	23
Half open	5
Fully open	4

This results in average inside/outside differences of around 21 dB, with there being only a slight difference between single- and double-glazed windows (Table 1.4). The survey did not include dwellings which had been specifically insulated against noise. Nevertheless, there was a large variation in insulation values.

Table 1.4
Average inside/outside differences in dB

	Single-glazed window	Double-glazed window
Average difference at night	21.3	22.2

It should be stressed that this figure only applies to facades that have not been fitted with special appliances to reduce noise impact. To give an extreme example of where this general finding does not apply, rooms may be equipped with air conditioning so that windows can stay closed or could even be sealed. Less drastic provisions are sound-attenuated ventilation openings. Little is known, however, about the inhabitants' experiences (long-term use, appreciation) of these and other solutions. For example, sound-attenuated ventilation openings are sometimes blocked in order to cut out draughts.

A simple measure is the orientation of noise-sensitive rooms on the quiet side of the dwelling (this applies to road and rail traffic noise).

Zoning is an instrument that may assist planning authorities in keeping noise-sensitive land uses away from noisy areas. In the densely populated areas of the EU this solution must often compete, however, with other planning requirements or a simple lack of suitable space.

5.6 RECOMMENDATIONS FOR HEALTH PROTECTION

Sleep is an essential part of healthy life and is recognized as a fundamental right under the European Convention on Human Rights[1](European Court of Human Rights, 2003). Based on the systematic review of evidence produced by epidemiological and experimental studies, the relationship between night noise exposure and health effects can be summarized as below. (Table 5.4)

Table 5.4
Effects of different levels of night noise on the population's health[2]

Average night noise level over a year $L_{night,outside}$	Health effects observed in the population
Up to 30 dB	Although individual sensitivities and circumstances may differ, it appears that up to this level no substantial biological effects are observed. $L_{night,outside}$ of 30 dB is equivalent to the NOEL for night noise.
30 to 40 dB	A number of effects on sleep are observed from this range: body movements, awakening, self-reported sleep disturbance, arousals. The intensity of the effect depends on the nature of the source and the number of events. Vulnerable groups (for example children, the chronically ill and the elderly) are more susceptible. However, even in the worst cases the effects seem modest. $L_{night,outside}$ of 40 dB is equivalent to the LOAEL for night noise.
40 to 55 dB	Adverse health effects are observed among the exposed population. Many people have to adapt their lives to cope with the noise at night. Vulnerable groups are more severely affected.
Above 55 dB	The situation is considered increasingly dangerous for public health. Adverse health effects occur frequently, a sizeable proportion of the population is highly annoyed and sleep-disturbed. There is evidence that the risk of cardiovascular disease increases.

1 "Article 8:1. Everyone has the right to respect for his private and family life, his home and his correspondence." Although in the case against the United Kingdom the Court ruled that the United Kingdom Government was not guilty of the charges, the right to undisturbed sleep was recognized (the Court's consideration 96).

2 $L_{night,outside}$ in Table 5.4 and 5.5 is the night-time noise indicator (L_{night}) of Directive 2002/49/EC of 25 June 2002: the A-weighted long-term average sound level as defined in ISO 1996-2: 1987, determined over all the night periods of a year; in which: the night is eight hours (usually 23.00 – 07.00 local time), a year is a relevant year as regards the emission of sound and an average year as regards the meteorological circumstances, the incident sound is considered, the assessment point is the same as for L_{den}. See *Official Journal of the European Communities,* 18.7.2002, for more details.