16. Impacts on the noise environment

HOW TO USE THIS CHAPTER IN THE CONTEXT OF EA AND ROAD PLANNING

Stage in road planning (A)	EA activity (B)	Involvement in addition to EA team (C)
	Screening	
	Scoping	Proponent
Concept	Consultation	Key regulatory agency
Pre-feasibility	Determination of baseline conditions	Other government agencies
Feasibility	Selection of preferred solution	NGOs
Engineering design	Assessment of alternative designs/methods	Research groups
Construction	Development of environmental management plan	Public/community organizations
Operation & maintenance	Effects and compliance monitoring	Advisory experts
	Evaluation	
	Reporting	

Shaded area = (A) Stages of EA covered in this chapter; (B) focus of this chapter; and (C) primary target readers.

KEY QUESTIONS ADDRESSED:

? How can road noise affect human welfare?

? What are the major sources of road noise?

? Can noise pollution be measured? What instruments or methods are used to measure it?

? What can be done to compensate for or mitigate the impacts of road noise?

16.1 IMPACTS AND SETTING

In many areas, noise is one of the most obvious impacts of daily road use. However, its effects are often given lower priority than economic or other environmental impacts, largely because they are rarely visible and are difficult to quantify monetarily. Yet most humans and animals that suffer chronic exposure to severe noise pollution are keenly aware of its presence, and may experience a range of problems as a result of this exposure. It is therefore important to understand how road noise comes to exceed acceptable levels, and what can be done to prevent, mitigate, or compensate for its effects.

16.1.1 Sources of road noise

Noise associated with road development has four main sources: a) vehicles; b) friction between vehicles and the road surface; c) driver behavior; and d) construction and maintenance activity.

Vehicle noise

Vehicle noise comes from the engine, transmission, exhaust, and suspension, and is greatest during acceleration, on upgrades, during engine braking, on rough roads, and in stop-and-go traffic conditions. Poor vehicle maintenance is a contributing factor to this noise source.

Road noise

Frictional noise from the contact between tires and pavement contributes significantly to overall traffic noise. The level depends on the type and condition of tires and pavement. Frictional noise is generally greatest at high speed and during quick braking.

Driver behavior

Drivers contribute to road noise by using their vehicles' horns, by playing loud music, by shouting at each other, and by causing their tires to squeal as a result of sudden braking or acceleration.

Construction and maintenance

Road construction and maintenance generally require the use of heavy machinery, and although these activities may be intermittent and localized, they nevertheless contribute tremendous amounts of sustained noise during equipment operation.

16.1.2 Road noise impacts

Noise associated with road development affects the environment through which roads pass by degrading human welfare, by sonically vibrating structures, and by disrupting wildlife.

Human welfare

Even when it is not perceived consciously, chronic exposure to road noise can affect human welfare in varying degrees, both physiologically and psychologically. Chronic noise exposure can be a source of annoyance, creating communication problems and leading to elevated stress levels as well as associated behavioral and health effects. It can cause auditory fatigue, temporary and permanent lessening of hearing ability, sleep disorders, and can even contribute to learning problems in children.

Vibration

The vibration induced by the resonance of traffic noise can have a detrimental effect on structures standing near the road. This is of particular concern in the case of cultural heritage sites, which may have been standing for many centuries, but which were not designed to withstand such vibration. Makeshift or lightly constructed buildings, common in many developing countries, may be the first to succumb to vibration damage.

Wildlife disturbance

Noise may prevent many animal species from approaching or crossing road corridors because they are afraid. As a result, road corridors become barriers to regular wildlife travel routes, effectively rendering roadside habitat areas inaccessible to some species. Such disturbance reduces the success of these species and contributes to ecological alteration (see Chapter 10).

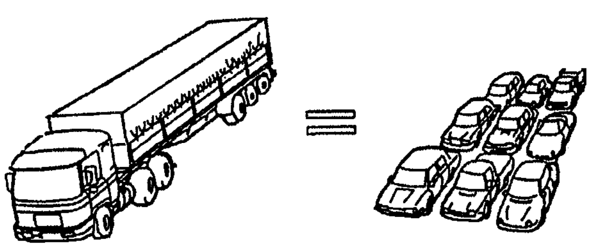
16.2 DETERMINING THE NATURE AND SCALE OF IMPACTS

Motor vehicles are inherently noisy, and noise impacts are inevitable in any road development, regardless of scale or character. The factors contributing to noise impacts are, however, highly variable; consequently, the nature of the noise impacts associated with individual road projects differ greatly. Contributing factors fall into six groups:

Vehicular factors

Different vehicle types produce different levels of noise. In general, heavy vehicles such as transport trucks make more noise than do light cars; they tend to have more wheels in contact with the road (see Figure 16.1), and often use engine brakes while decelerating. Poorly maintained vehicles, such as those with incomplete exhaust systems or badly worn brakes, are noisier than well-maintained ones. Also, certain types of tires, such as off-road or snow tires, are especially noisy.

FIGURE 16.1
ACOUSTIC EQUIVALENCE BETWEEN HEAVY AND LIGHT VEHICLES



Road surfaces

The physical characteristics of the road surface and its surroundings play a large role in determining noise output. Well-maintained, smooth-surfaced roads are less noisy than those with cracked, damaged, and patched surfaces. Expansion joints in bridge decks are especially noisy. Roadside surfaces such as vegetated soil tend to absorb and moderate noise, while reflective surfaces like concrete or asphalt do not have any beneficial function.

Road geometry

The vertical alignment of the road can affect the ease with which noise can be transmitted to roadside receptors. For instance, siting a road in a cut below ground level or on a raised platform may serve to keep receptors out of the impact zone. This concept is illustrated in Figure 16.2. Also, the presence of barriers along the roadside, whether specially installed for noise control or naturally occurring, can lower the impact of road noise.

Vehicles tend to produce the most noise while ascending and descending steep slopes and while rounding sharp corners; this means that roads which incorporate these features will tend to be noisier at those points.

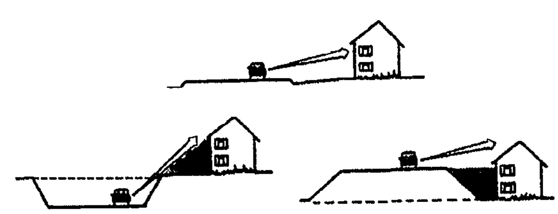
Environmental factors

Weather conditions such as temperature, humidity, wind speed, and prevailing wind direction can play a role in determining how individual sites are affected by road noise. Temperature and humidity determine air density, which in turn affects the propagation of sound waves. Downwind sites are generally exposed to greater noise levels than are sites upwind of roads.

Ambient noise levels, associated with industrial and other human activity, affect the perception of the magnitude of the road noise impact. In areas with low ambient noise levels, the noise from a new road development will generally be more noticeable than a similar noise level would be in an environment with higher ambient noise levels. New roads in quiet areas or noisy trucks at night are often perceived as worse than higher levels of noise in a busy area during the workday. On the other hand, measured noise levels and potential health impacts are highest where traffic noise combines with noise from other sources, possibly producing an unacceptable overall noise level.

Topography can also help determine noise impact. For instance, noise from roads occurring in mountain valleys or canyons tends to be more noticeable than that from a similar road

FIGURE 16.2
RELATIVE POSITIONS OF ROADWAY AND RECEPTOR

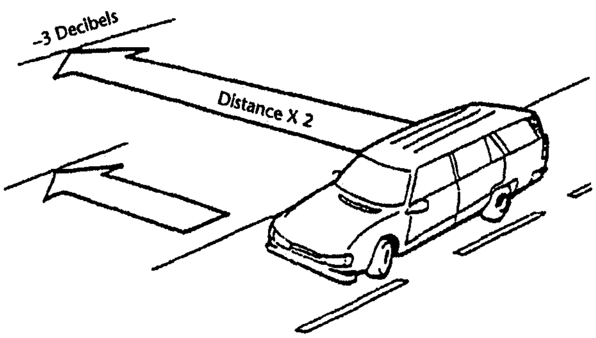


Audible nuisance is higher when the residence is located at pavement level on a flat plain, because noise is reflected off valley walls. By the same token, hills and knolls can act as natural barriers to noise if they occur between the road and receptors. Above-grade roads, which are often necessary in flood-prone areas, tend to broadcast noise over greater distances.

Spatial relationships

Perhaps the greatest determinant of noise impacts is the spatial relationship of the road to potential noise receptors. The closer the road to receptors, the greater the impact (see Figure 16.3). The higher the population density in roadside areas, the greater the number of people likely to be receptors, and, consequently, the greater the impact.

FIGURE 16.3
DOUBLING THE DISTANCE BETWEEN THE ROAD AND THE RECEPTOR RESULTS IN A DECREASE OF 3 dB(A) IN THE NOISE LEVEL

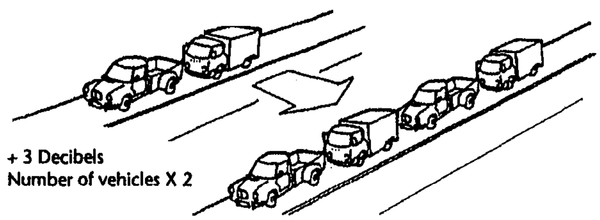


Traffic stream

The noise production of a particular traffic stream is determined by a number of factors: the type of vehicles in the stream and their level of maintenance; the number of vehicles passing per unit time (see Figure 16.4); the constancy of flow—vehicles tend to be noisier in stop-and-go traffic; and the speed of traffic flow—noisiest at high speeds (see Figure 16.5).

The relationship between traffic stream cycles and ambient noise is also important; ambient noise levels are generally lowest at night, and if traffic noise peaks at night, the impact will be great. Conversely, if traffic noise peaks at the same time that ambient noise levels do, the effects will be less noticeable.

FIGURE 16.4
WHEN TRAFFIC ON A ROAD IS DOUBLED, THE NOISE LEVEL INCREASES 3 dB(A), ALL OTHER FACTORS BEING EQUAL



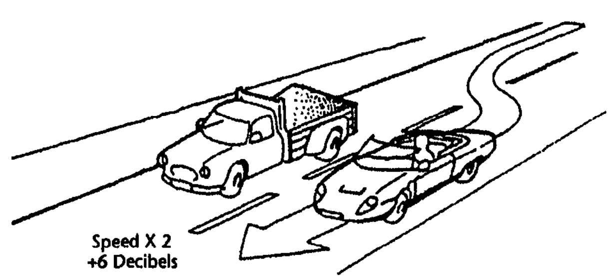
16.2.1 Assessing noise impacts

Assessment of potential road noise impacts relies on an accurate evaluation of the baseline conditions, a thorough knowledge of the characteristics of the proposed road development, and a good understanding of how roadside activity will evolve in the medium and long term.

When assessing the potential noise impact of a road development, it may also be helpful to keep the following in mind.

- Road noise impacts will be greatest where busy roads pass through densely populated areas.
- If, at the outset, there are indications of complex noise impacts, consultation with a noise engineer may prove helpful.
- Some receptors are more sensitive to noise exposure than others. Road noise in industrial zones and uninhabited areas without much wildlife is not likely to be particularly problematic, whereas residential suburbs and particular localities such as schools or hospitals may experience significant impacts.

FIGURE 16.5
DOUBLING THE SPEED RESULTS IN AN INCREASE OF 6 dB(A)



- It should be recognized that there are some locations (such as busy urban intersections) where it is very difficult to implement noise-limiting measures.

16.2.2 Noise measurement

Noise measurement specifications require definition of the period of measurement, the noise parameter to be recorded, and the position of the recording instrument relative to the road and adjacent properties.

Measurement units

The indicator used to measure sound levels is a logarithmic function of acoustic pressure, expressed in decibels (dB). The audible range of acoustic pressures is expressed in dB(A). The human ear perceives a constant increase in sound level whenever the acoustic pressure is multiplied by a constant quantity. The scale of sound levels shows that calm environments correspond to a level of 30 to 50 dB(A), and that beyond 70 dB(A) sound becomes very disruptive (Figure 16.6). Note that, because the decibel is a logarithmic function of acoustic pressure, the noise levels of two or more sounds are not added up as in conventional mathematics, but are multiplied.

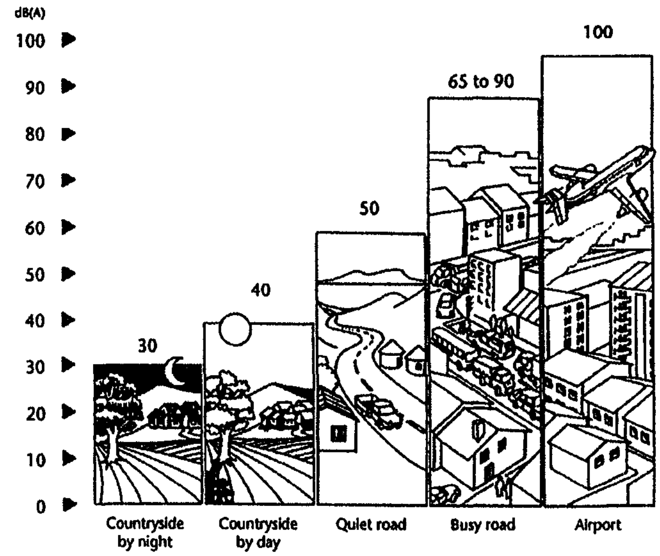
Since noise is variable over time, measurements and forecasts are expressed as mean values or other indicators over a given period of time.

The equivalent acoustic level (Leq) is the sound level of a stable noise which contains the same energy as a variable noise over the same period. It represents the mean of the acoustic energy perceived during the period of observation. The equivalent acoustic level of noise during the period 8 a.m. to 8 p.m. is written as Leq (8 a.m. - 8 p.m.) or Leq (12hr).

L10(12hr) is an alternate measure, indicating the noise level exceeded 10 percent of the time over a twelve-hour period. For the 18-hour period 6 a.m. to 12 midnight, L10(18hr) is typically 3dB(A) higher than Leq for the same period.

Nocturnal noise levels are generally lower than are diurnal levels. For example, the nocturnal Leq (12 a.m. - 6 a.m.) is typically 10 dB below the Leq (8 a.m. - 8 p.m.), except in the case of especially high nocturnal traffic with a high percentage of heavy goods vehicles.

FIGURE 16.6
SCALE OF SOUND LEVELS



The equivalent acoustic level in front of (outside) a building facade facing the traffic determines the building's exposure to noise. This is the best indicator of the discomfort caused to the building occupants.

Measuring instruments

Existing noise levels can be measured using devices called sonometers, which convert sound wave energy into an electrical signal, the magnitude of which is displayed or recorded.

Measurements obtained using these instruments can become valuable baseline data, but their further usefulness is somewhat limited, both in terms of sampling period and as a result of their inability to distinguish separate sources of noise.

Forecasting noise levels

Forecasting methods include equations, computer models, and physical models. The simplest are equations, which estimate noise from information on traffic flow, composition, and speed.

Computer models are perhaps more widely employed and can be used to forecast future changes in baseline conditions and the likely impacts of a project and various mitigation options. A few examples of computer noise models in use are the FHWA model (USA); STAMINA 2.0 (USA); OPTIMA (USA); and Microbruit (France). Up to date information on the availability and use of computer noise models should be available from national transportation agencies.

16.2.3 Noise level standards

National standards may specify one noise level not to be exceeded for all types of zones (such as Leq"12hr" under 70 dB"A") or, more realistically, different noise levels for different zones, such as industrial, urban, residential, or rural areas. Lower limits are sometimes specified for nocturnal noise.

Details of road noise standards are usually available from national transportation agencies.[1] If no national standards exist, objectives can still be established for various types of road projects. Indicative standards used in Western Europe might be not to exceed a Leq (8 a.m. - 6 p.m.) of 65 dB(A) for residences in urban areas, and 60 dB(A) for rural areas. It is important, when considering international standards, to take into account the differences in noise criteria, measurement methods, and applicability to various types of projects.

It should be noted that noise standards are only applicable for a defined measurement method which specifies the location of measurement devices and the duration of measurement. Indeed, one obstacle to consistent compliance with standards is the fact that noise measurement is dependent on so many variables, such as weather and the type, position, and number of sensors. Unless the values of the variables are clearly defined and strictly adhered to, compliance with standards may not be especially meaningful.

16.3 REMEDIAL MEASURES

16.3.1 Prevention

Noise problems can be avoided by moving the road alignment or diverting traffic away from noise-sensitive areas using bypass roads. Choosing alignments which minimize steep slopes and sharp corners, especially at sensitive locations, can also prevent noise problems.

16.3.2 Mitigation

Vehicular measures

Motor vehicle noise can be reduced at source, for example through vehicle construction, selection of tires and exhaust systems, as well as vehicle maintenance. Control of vehicle noise emissions can be attempted using vehicle design rules and in-use noise regulations and enforcement, subjects beyond the project-level scope of this handbook.

Surface design and maintenance

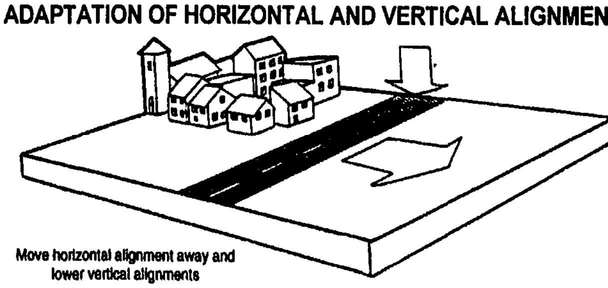
The application of a bituminous surface layer over worn concrete roadways is effective in reducing frictional noise. The use of open-graded asphalt and the avoidance of surface dressings may also be effective in reducing frictional noise in sensitive areas (see Box 16.1). Some jurisdictions are experimenting with asphalt made using discarded tires, which appears to reduce frictional noise as well. Generally, smooth, well-maintained surfaces such as freshly laid asphalt without grooves and cracks will keep noise to a minimum.

Road geometry

Road design should avoid steep grades and sharp corners to reduce noise resulting from acceleration, braking, gear changes, and the use of engine brakes by heavy trucks at critical locations.

Figures 16.2 and 16.7 illustrate how adapting the vertical alignment of a road can decrease noise at nearby buildings.

FIGURE 16.7
ADAPTATION OF HORIZONTAL AND VERTICAL ALIGNMENTS

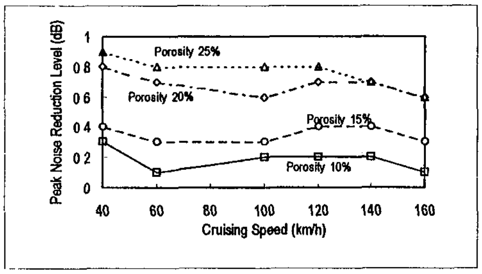


[1] Sinha et al (1989) includes details of noise level standards for several countries.

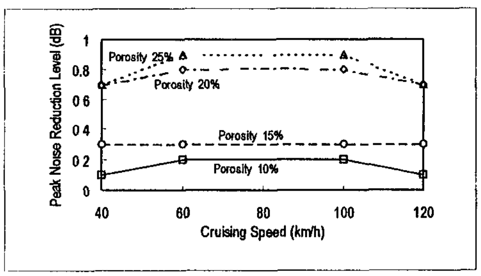
BOX 16.1
REDUCING ROADSIDE NOISE LEVELS BY CHANGING THE PAVEMENT COMPOSITION AND POROSITY

Conventional asphalt pavement usually consists of a mixture of bitumen and a range of graded aggregate materials, yielding *densely graded asphalt pavement.* In contrast, *drainage asphalt pavement* uses an open graded asphalt mixture, which eliminates the aggregates of intermediate grading to obtain a higher porosity mixture.

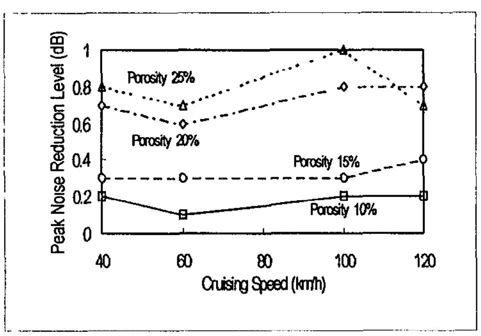
The noise levels from vehicles traveling on the drainage asphalt pavement (DA) are lower than on the densely graded asphalt pavement (DGA). In comparison to the DGA pavement, the peak noise levels at various cruising speeds are reduced on the DA pavement as shown in the line graphs. For example, the peak noise reduction would be in the range of 0.1 and 0.4 decibel with the DA porosity of 10 to 15 percent. With the porosity of 20 to 25 percent, the peak noise levels would decrease by the range of 0.1 to 1.0 decibel. The two bar charts compare the measured noises between the DGA pavement, with a porosity of 5 percent (upper chart), and the DA pavement, with a porosity of 20 percent. The noise reduction by the DA pavement falls in the range of 5 to 6 decibels in the former case, and from 1 to 3 decibels in the latter case. Compared with the DGA pavement, the noise levels of vehicular traffic drop by some 10 decibels on the porous elastic pavement that uses urethane-bonded rubber particles.



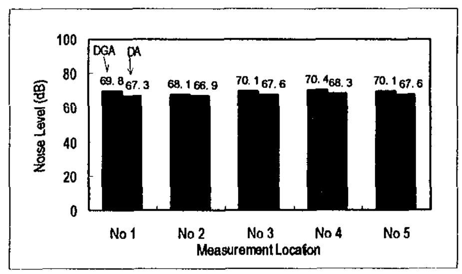
Car



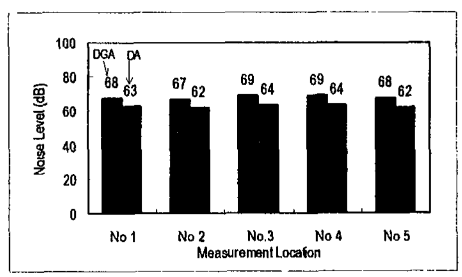
Light Truck



Heavy Truck



DA: porosity 5%



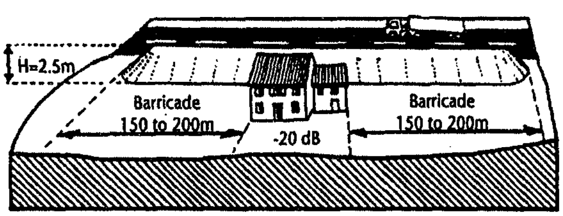
DA: porosity 20%

Source: Meiarashi and Ishida, 1996.

Noise barriers
Noise barriers are among the most common mitigative measures used. They are most effective if they break the line of sight between the noise source and the receptors being protected, and if they are thick enough to absorb or reflect the noise received. Various materials and barrier facade patterns have been extensively tested to provide maximum reflection, absorption, or dispersion of noise without being aesthetically ugly.

The types of noise barriers most commonly employed consist of earth mounds or walls of wood, metal, or concrete which form a solid obstacle between the road and roadside communities (Figure 16.8). Noise mounds require considerable areas of roadside land; for narrow alignments, bridges, and roads on embankments, wall-type barriers may be the only viable option. Two or more barrier types are often combined to maximize effectiveness. Plantations of trees and shrubs, for instance, contribute little to actual noise reduction, but they do confer a psychological benefit in reducing the perceived nuisance of traffic noise, and they are often used to 'soften' the visual appearance of mounds and walls.

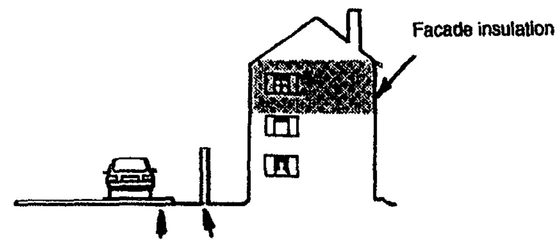
FIGURE 16.8
POSITIONING A BARRIER OR SCREEN



Insulation
Building facade insulation, such as double window glazing, is an option usually adopted as a last resort in order to dampen noise in buildings. It is most likely to be needed in cases where noise impacts result from an unforeseen expansion of traffic volume along existing roads.

The relative costs and effectiveness of some of the measures outlined above are compared in Table 16.1. A successful mitigation plan will often incorporate several of the measures (see Figure 16.9). A busy road passing by a high-rise building, for example, may require specialized surfacing, a barrier or screen to reduce traffic noise at lower levels, and facade insulation for the upper floors of the building.

FIGURE 16.9
COMBINATION OF TECHNIQUES



16.3.3 Compensation

The purchase of roadside properties by governments may, in many cases, be more viable than the implementation of extensive measures to protect only a limited number of people. Monetary compensation for noise impacts is currently offered only in a small number of countries and cases.

16.4 AVOIDING IMPACTS ON THE NOISE ENVIRONMENT: AN ACTION CHECKLIST

Road development has the potential to degrade the quality of life experienced by those who inhabit areas near roads if noise concerns are not dealt with. This section highlights the more important steps in the EA process which incorporate noise considerations into the road planning and development process.

Baseline data and potential impacts
Basic information must be gathered on current properties that may be affected by road noise, and on areas of potential future development, especially for housing. Where sensitive zones or potential problems are identified, measurements should be taken of current noise levels, and models should be used to predict future noise levels, including longer-term (i.e. five- and ten-year) estimates. The analysis should highlight currently quiet locations likely to experience a large change in noise levels, as well

TABLE 16.1
INDICATIVE COMPARISON OF VARIOUS NOISE MITIGATIVE MEASURES

Measure	*Effectiveness*	*Comparative costs*
Earth barrier	Same as that of other types of barriers (e.g. wood or concrete); needs more space	Very cheap when spare fill material is available on site.
Concrete, wood, metal or other barrier fences	Good; requires less space	10 to 100 times the cost of an earth barrier, but may save land cost
Underground road (cut and cover)	An extreme option for very heavy traffic; requires ventilation if over 300m long.	80 to 16,000 times the cost of an earth barrier
Double glazing of windows for facade insulation	Good but only when windows are closed; doesn't protect outside areas	5 to 60 times the cost of an earth barrier

as locations which could experience problems from construction noise.

Analysis of alternatives
Areas of choice include road alignment, barriers, pavement design, and building modifications. In some industrial or urban areas, ambient noise levels are already high, and the noise from new road works may be of the same order. In other cases, there may be tradeoffs between noise protection and increased land consumption, which will prove undesirable for other environmental and community reasons. Consultation with affected communities and individuals can assist in identifying preferred solutions within budgetary and other constraints.

Mitigation plan
Noise protection measures will usually be incorporated into road design and construction. Ongoing maintenance actions are necessary, for example, to ensure effectiveness of open-graded asphalt road surfacing. Long-term noise monitoring may also be appropriate.

Environmental specifications for contractors
Specifications for building noise protection devices should clearly indicate the location, design, and materials and methods of construction, and should account for future road maintenance needs. In carrying out construction, quarrying, or other such activities in noise-sensitive areas, special attention may have to be paid to equipment noise standards, hours of operation, material haulage routes, and other aspects of work-site management.

Legislation
Laws and regulatory measures can assist efforts to reduce noise impacts by, for example, not allowing new residential buildings near major roads; by requiring by-pass routes for the noisiest vehicles, especially at night; and by limiting speed and construction operations near especially sensitive areas such as schools and hospitals, particularly during periods of low ambient noise.

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