APPENDIX D

NOISE MITIGATING MEASURES
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The nature of the potential impacts related to noise is complex and the range and scale of measures which may be taken to prevent or reduce such impacts are also numerous. It is therefore impractical in a document such as this to provide a detailed approach to all aspects of noise impact mitigation, as specialist background knowledge and a clear appreciation of all the specific aspects and problems related to a project/situation are essential for the formulation of an adequate solution. Some background and some basic principles, however, have been indicated hereafter.

D1 GENERAL

Measures to control or attenuate noise from any noise generating source may be implemented in three forms, namely:

- Control of the noise at source.
- Control of the noise in the area of impact (receiver position).
- Control of the noise at some convenient intermediate location (i.e. along the transmission path) between the source and impacted receiver.

D2 NOISE CONTROL MEASURES

D2.1 LAND-USE PLANNING

A pro-active approach to noise control in the land-use planning process can be one of the most effective ways in which to prevent or minimise noise impact. This may be effected through:

i) Ensuring that noise generators are separated from noise sensitive land uses as far as is practical.

ii) Rezonings are carefully assessed to ensure that any changes will not adversely affect adjacent properties.

D2.2 ROADS AND RAILWAYS

With regard to roads and railways and traffic on these facilities the methods to control noise at source can be subdivided into the following basic categories:

i) Limiting vehicle noise emissions (refer to Section D2.2.1).

ii) Limiting train noise (refer to Section D2.2.2).

iii) Limiting the noise from transportation nodes (refer to Section D2.2.2).
iv) Road traffic control measures (refer to Section D2.2.4).

v) Roadway design (refer to Section D2.2.5).

vi) Railway and track design (refer to Section D2.2.6).

Noise control in the area between source and receiver may be effected by:

i) Land-use planning (refer to Section D2.2.7).

ii) Noise attenuation barriers (refer to Section D2.2.9).

D2.2.1 Motor Vehicle Noise Control

This aspect of noise reduction relates more to manufacturer design, effective maintenance of vehicles by owners and driving techniques. Thus, the control thereof falls more into the realm of enforcement. Noise emission standards are laid down in relevant SABS Codes of Practice and in the Noise Control Regulations (refer to Section 5, References of this Policy).

D2.2.2 Noise Control from Trains

This aspect also relates to manufacturer design and effective maintenance of the propulsion units and rolling stock of the various types of trains (goods trains and rail based mass transit). This aspect cannot be dealt with further as there are no noise emission criteria which are enforced in South Africa and rail operations are excluded at present from the Noise Regulations. However, reference should be made to the US Environmental Protection Agency, the US Federal Railroad Administration and the US Department of Transportation guidelines.

D2.2.3 Noise Control from Transportation Nodal Developments

Here essentially architectural measures are required (refer to Section D2.2.8). The careful selection of the location and the sensitive design of transportation nodal facilities (stations, taxi ranks, railway marshalling yards, etc.) can also assist appreciably in the reduction of noise from these facilities.

D2.2.4 Road Traffic Control Measures

The main factors affecting the noise generated by road traffic are the total number of vehicles, the percentage of heavy commercial vehicles in the traffic flow, the traffic speed and the operational characteristics (the latter relating to whether the traffic is free flowing or subject to interrupted operation as at traffic lights and junctions where vehicle interactions occur).

i) The most obvious way to reduce traffic noise in noise sensitive areas is to divert as much traffic as possible away from these areas. However, closing sections of road or traffic
calming measures should not prejudice the access of local traffic. Note also that traffic calming measures may also increase localised noise levels. The effect of traffic volume controls depends not only on the proportion of traffic removed but also on the volume of traffic both before and after the traffic restrictions. Halving the traffic flow or a doubling of the volume will respectively reduce or increase the $L_{eq}$ levels by approximately 3dBA provided other parameters do not change. However, traffic volume and speed are generally highly correlated and so a reduction in volume is normally associated with an increase in traffic speed with the result that the optimum benefits expected from the reduced flow are not achieved. Furthermore, removing traffic from one road produces an increase in noise on other roads in the network. The fact that traffic noise level and traffic flow are logarithmically related can be used to good effect. Diverting traffic from a lightly used road and placing it on an already heavily used road will place little additional noise burden on the heavily used road, particularly if it is designed for high flow, but the benefits achieved on the lightly used road can be substantial.

ii) Restricting the numbers of heavy trucks using sensitive routes is another method used to reduce the noise from traffic. Heavy vehicles should be prevented from entering a prescribed district with the restriction being either in the form of a total ban on all commercial vehicles above a certain capacity or in the form of time entry restrictions, usually at night and over the weekend. The only exemption to the banning of trucks from entering an area would be where they are needed to collect or deliver goods in that area.

iii) The designation of special truck routes is a means of containing the noise problem in certain areas.

iv) Theoretically, the reduction of traffic speed is one of the most effective traffic measures controlling traffic noise levels. On high speed roads, halving the average vehicle speed could lead to a noise level reduction of between 5dBA and 6dBA. However, reductions of vehicle speed cannot easily be achieved in practice. In built-up areas it is clear that the design of the traffic speed restriction method is very important and the measures taken should introduce sufficient restraint on the motorist to introduce speed changes without affecting gear changing which could result in a net increase in noise levels. The methods adopted should also ensure that traffic flows freely through the site to encourage a non-aggressive style of driving.

Under high speed free flow conditions, however, other factors come into play, that is at high speeds the main component of the noise emanates from the tyre/road surface interaction whereas at low speeds and where steep gradients are involved mechanical noise from the vehicles tends to predominate. Therefore, the advantage obtained from the reduction of speed could well be offset by the increase in mechanical noise.

D2.2.5 Roadway Design
The noise radiated by traffic can be influenced by both the vertical and horizontal alignment of the road and also by the type of road surface used.

i) The variable of **horizontal alignment** of the road should be used to achieve a pleasing, safe and comfortable ride for the driver as well as giving the designer flexibility to position the road so as to avoid severe topography and to achieve an economic design. This latitude when designing can be used further to ensure adequate separation between the highway and sensitive land-uses as well as aligning the facility to use topography to shield such areas.

ii) Flexibility in the **vertical alignment** should also, where possible, be used to assist in the screening of sensitive areas. For example by placing the road in cut the walls of the excavation would act as noise attenuation barriers.

iii) **Well designed road junctions** provide the means to further control noise. Noise from individual vehicles can increase substantially during acceleration, particularly when the initial vehicle speed is low and the subsequent load on the engine is high. Vehicle interactions involving stop/start manoeuvres and vehicle acceleration and deceleration occur at, and on the approach to junctions. In order to reduce noise, therefore, it is important to consider, in the design of the junction, how best to smooth the flow of traffic to minimise the number of vehicle accelerations. Fortunately, this objective is also the objective of traffic management plans which are designed primarily to reduce journey times and collisions.

Linked and synchronised or demand-controlled traffic light systems should be installed. Unfortunately, the beneficial effect on traffic noise of these measures has been found to be less than expected partly because the improvements in flow resulting from these control systems tend to create an increase in capacity of the system which is rapidly filled and/or the speed of the traffic is increased. The overall benefits are generally small and in most cases are less than 2dBA.

Traffic circles (roundabouts) tend to produce fewer noise problems than signalised intersections. In general, studies of the noise at traffic circles have indicated that the increased noise from accelerating vehicles is within 1 dB(A) of the free flow level on the approach roads and that noise from the decelerating stream is equal or less than the free flow level. Overall, the noise at traffic circles may be increased above the level from an equivalent free flow traffic stream by approximately 1dBA to 2dBA and this increase is generally confined to within 50 metres of the centre of the traffic circle.

iv) Designing the **road surface** to control noise. The level of noise generated by a vehicle’s tyres rolling over the road surface depends primarily on the speed of the vehicle and the design of the tyre and the road surface. Studies of tyre noise have established that while some benefits can be obtained by appropriate design of the tyre tread patterns and tyre structure, the design of substantially quieter tyres conflicts with the overriding need to
maintain safety, cool running and economy. Consequently, greater scope for reducing tyre/road surface noise lies with the possible alternative designs for the road surface.

The road surface parameters which are important in governing surface noise are the road surface texture and whether the surface is a bituminous material with a random texture pattern or a concrete surface with a predominantly transverse texture. There is generally however a conflict between the specifications for low noise surfaces and good high speed safety standards, namely that a smooth road surface can be relatively quiet but is clearly unsafe for the motorist in wet weather. There are road surfaces, however, which offer the combined advantage of both low noise and good skidding resistance performance. These surfaces generally have an open texture which is pervious to surface water but which also offers good acoustic absorption. It has been found that the noise levels recorded from the open texture surfaces are all lower than the noise generated on conventional surfaces at equivalent skidding resistance values. The average reduction in peak noise level is 4dBA for light vehicles while for heavy vehicles, the reduction in noise will be slightly less, at approximately 3dBA. Consequently, the noise from traffic running on open texture road surfaces can be reduced by between 3dBA and 4dBA on average depending upon the number of heavy vehicles in the traffic and these benefits are achieved without any need to reduce the safety standards provided by the surface texture.

The pervious macadam material has been found to retain its noise reduction properties during the effective life of the surface material and, due to its rapid drainage properties it lessens the incidence of splash noise during wet weather.

In summary it may be said that perhaps the safest surface is that of a concrete road with deep transverse grooving but it is also one of the noisiest. Less noisy, but also less durable under the action of heavy traffic, is a transversely brushed concrete surface. The least noisy concrete road is one with a texture formed by longitudinal grooving or burlap drag. Drawbacks such as less effective surface drainage, tendency to rapid wear and the fact that it may cause vehicles to follow in the track of the texture pattern must be carefully weighed up when this type of surface texture is considered.

When compared on the basis of equal skid resistance, bituminous roads are on the whole less noisy than concrete roads. The general rule that noise levels increase with coarseness of surface texture also applies to bitumen bound road surfacings. Amongst these roads, those sealed with a surface dressing of stone chippings generate the loudest noise. Less noisy are asphaltic surfacings with in rolled chips, followed by smooth asphalt surfaces. The surfacing generally regarded to be the least noisy is a rubber bitumen open graded asphalt.

For the designer there is a wide range of publications on the subject.

**D2.2.6 Railway Line and Track Design**
There is generally less flexibility in design for railway lines compared to roads due to more rigid standards of horizontal and vertical alignment:

i) Wherever feasible in the horizontal alignment design, the position of the railway line should be kept away from noise sensitive areas.

ii) Likewise, the design of the vertical alignment should be sensitive to areas which need to be protected from high noise levels and, where practical, the track should be in cutting through these areas.

iii) In the design of aerial structures the emphasis should be towards the use of higher mass materials such as concrete or concrete/steel composite structures.

iv) A welded rail system laid on ballasted track bed or on concrete decks with resilient rail fasteners should be used.

v) Ancillary equipment should be designed to meet the noise criteria of the area in which it can be installed.

D2.2.7 Land-Use Planning and Noise Control

When a new transportation route is planned through an existing urban area much of the existing flanking development will remain unaltered. Under these circumstances the layout of the road or railway line and design of the facility itself becomes crucial in minimising the noise impact resulting from the traffic. Where a road or railway line passes through an area that is, as yet, undeveloped or scheduled for redevelopment, noise impact control by appropriate management of the adjoining land-use should also be considered. Opportunities for successful acoustical site planning are determined by the size of the available space, the terrain and the zoning policy applied. Appropriate techniques include:

- Placing as much distance as possible between the noise source and the noise-sensitive area (spatial separation).

- Placing noise-compatible activities such as parking areas, open spaces and commercial facilities between the noise source and the noise-sensitive areas.

- Using buildings and, to a lesser extent, plantings as barriers to screen sensitive areas.

i) Zoning and spatial separation

   a) Although dwellings can often be protected from traffic noise by setting them well back from the source of noise, this approach is generally not considered by designers because it is assumed to be an uneconomical use of valuable land. Although this premise is generally correct as high noise levels prevail close to
major highways or railway lines, spatial separation should always be evaluated as a possible solution. Mixed developments which include high-rise apartment blocks, cannot be easily screened by barriers and should, therefore, be located as far from the road or railway line as the site allows. On such sites the remainder of low-rise dwellings can often be protected by some form of roadside barrier or by reliance on ground attenuation. A balanced approach is necessary though as the high-rise buildings can often be used to screen the other buildings.

b) One way of ensuring that spatial separation is given full consideration is for the local administration to impose a zoning policy whereby land adjoining a major road has development restricted to non-noise sensitive activities (e.g. commerce, agriculture, industry). While such a technique does offer the advantages of clearly defined development policy, unfortunately there is usually not enough demand for such noise-compatible land-use to afford adequate protection for every community exposed to noise. Furthermore, this type of strip zoning may not be compatible with other plans for the orderly growth and development of the community, or it could be in direct conflict with the development patterns of adjacent communities. Where areas blighted by traffic noise are not adapted to noise-compatible uses, the land involved can become dreary, useless patches of waste-land which are often too expensive to maintain.

c) The rezoning of highly impacted residential areas to allow alternative use of premises may also provide a feasible option for some of the houses in an area. Allowance for the use of the residential premises by professional firms such as lawyers, engineers, planners, etc., is the type of restructuring suggested. This alternative will require careful review by town planners who will need to assess compatibility with the residential area, additional traffic generation, etc.

ii) Buildings and plantings as noise shields

a) Additional noise protection can be achieved by arranging the site plan to use buildings as noise barriers. A long building, or a row of buildings parallel to a highway can shield other more distant structures or open areas from noise. It is possible for a two-storey building to reduce noise levels on its far side from the roadway noise source by approximately 13 dB(A). Further rows of buildings may only produce a small additional benefit of approximately 1 dB(A) to 2 dB(A) beyond the second row. (This aspect forms part of the consideration of noise attenuation barriers as indicated in Section D2.2.9.)

b) Although trees, bushes and plants are of great value in improving the aesthetics of road environment, the noise attenuation provided by vegetation is generally overestimated. Though attenuation mechanisms are very difficult to isolate because of the complex interaction between the ground, the vegetation and
atmosphere, some theoretical explanation for screening by vegetation can be made.

Vegetation will affect the propagation of low-frequency sound by ground absorption which can be enhanced in wooded areas because of the high porosity of the ground resulting from tree roots and fallen leaves, etc. High frequency propagation is affected by scattering by tree trunks, branches and partly by leaf absorption. It is difficult, however, to provide descriptions of vegetation which can be used to gauge the attenuation of noise. Tree height, vegetation type, depth of planting and particularly density of planting appear to be dominant variables. Generalisations to dB(A) attenuation values per unit distance introduce a greater spread in the observed results.

c) Even though no precise description of the effect of vegetation has yet been determined, some general conclusions can be drawn:

- Plantings which are high and dense enough to obscure the traffic visually will provide more attenuation than provided by the mere distance which the buffer strip represents. An attenuation of approximately 1dBA to 3dBA per 10 metre depth of extremely dense planting can be expected. Shrubs or other ground cover are necessary in this respect to provide the required density near the ground. Excess attenuation with respect to grassland of the order of 0.5dBA to 1.5dBA per 10 metres of dense vegetation depth have been found. Evergreen plantings are necessary.

- The psychological effect of planting is significant, as it has been found that by removing the noise source from view, plantings reduce human annoyance to noise. The fact that people cannot see the road or railway line generally reduces their awareness of it even though the noise remains.

iii) Cluster and mixed use development

A conventional grid subdivision of land affords no real noise protection from the adjacent highway since the first row of houses bears the full impact of the noise. In contrast, cluster developments enable the whole space to be planned as a single entity taking into account the required density of housing depending upon noise exposure and the use of both space and noise-compatible development as buffers.

The above aspects are dealt with in some detail in *The Audible Landscape – A Manual for Highway Noise and Land-Use*.

**D2.2.8 Architectural Acoustic Design of Buildings**
The specific architectural issues of sound insulation of buildings have not been considered in this report as the technical details are of a specialist nature. In principle, measures to insulate houses/buildings from noise penetration is a practical means of reducing noise impact, although there are limitations, especially for houses and other residential premises in the South African context, namely that the sealing of dwellings (windows, doors, etc.) requires the installation of forced ventilation systems. It should be noted that the present construction procedures and standards for houses in South Africa make the residential dwellings extremely difficult to insulate effectively at low cost.

The location and the careful design of stations can appreciably assist in the reduction of noise from these facilities.

Acoustic treatment is an important aspect in the design of subway stations for rail transit systems. Without such treatment, subway stations tend to be highly reverberant, resulting in excessive train and patron activity noise as well as poor speech intelligibility. Acoustic treatment is generally incorporated in stations by adding sound-absorbing material to ceiling, wall and under-platform surfaces. The main purposes of this treatment are:

- to reduce noise from train arrivals and departures
- to prevent focusing of train noise at patron commuter locations
- to reduce reverberation in order to provide good hearing conditions for public address system announcements
- to limit noise radiating out from the station into surrounding community.

D2.2.9 Noise Attenuation Barriers

The concept of intervening vertical walls or earth mounds (or buildings, as indicated in Section D2.2.7(ii)) as noise attenuation barriers is a sound one and these have proved to be successful when certain conditions are met. They may not be effective, however, where all the necessary data input to the design has not been adequately appreciated. Many different types of road barriers have been experimented with since the early 1970s and various wall shapes and construction materials have been used to find the most effective solution to specific problems. Much has been learned by practical experimentation and by using an empirical approach to the development and application of different types of barriers. Barriers may be classified into one of the following types:

- wall
- earth berm
- wall/berm combination.

Barriers have been constructed from the following materials and where required various surface treatments have been used to increase the acoustic absorbency of the structure:
Barriers must be carefully integrated into the design of the road. The design objectives for a successful noise barriers are that it must possess sufficient mass to attenuate the sound, it must be relatively maintenance free once installed, and must not result in an increased risk of accident or injury. Other objectives are that it should be economical to erect and have an acceptable visual appearance. Also in order to provide the maximum degree of protection, the barrier should be sited as near to the noise source or as close to the position to be protected as possible and should completely obscure the receiver’s view of the noise source. It is also important that all gaps in the barrier are properly sealed. A hole or gap in the barrier fabric may substantially reduce the screening potential of the barrier but also, because of resonance effects created by the hole, the character of the transmitted sound can be altered from a broad band noise to one with discrete tones which are generally far more disturbing.

The sound energy generated by a transportation source can be reflected by a barrier wall, thus affecting receivers located on the source side of the barrier. Where there are barriers on both sides of the road and these do not have acoustically absorbant surfaces a further problem may occur, namely that of multiple reflections between the barrier walls which may be diffracted over the barriers.

In the United Kingdom the height of most roadside barriers is limited to 3 metres whereas in Canada, the USA and some European countries much higher barriers are permitted. Barriers higher than 4 metres are generally considered to be visually unacceptable to residents. Apart from the height, the shape of the barrier is also important. A simple wall has generally been found to be less effective than an earth berm of similar height. The location of barriers on overpass bridges and viaducts need special considerations to protect vehicles and/or pedestrians passing underneath from falling debris resulting in the event of a vehicle impact. The barrier must not deteriorate rapidly under the action of sunlight and other weathering effects.