Guidelines for Environmental Noise Limits and Control

Third Edition

DEPARTMENT OF ENVIRONMENT
MINISTRY OF ENERGY, SCIENCE, TECHNOLOGY,
ENVIRONMENT & CLIMATE CHANGE (MESTECC)

GUIDELINES FOR ENVIRONMENTAL NOISE LIMITS AND CONTROL

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FOREWORD

Assalamualaikum Warahmatullahi Wabarakatuh & Salam Sejahtera

The *Guidelines for Environment Noise Limits and Control* hereby published by the Department of Environment is a new publication to supersede the previously published *Planning Guidelines for Environmental Noise Limits and Control* (first edition and second edition 2007).

The preparation of this new Guidelines was guided by findings of an Ambient Noise Study Project undertaken by the Department of Environment (DOE) in 2017 which collate data and analysis of measured ambient noise levels in Malaysia with an intent of establishing ambient noise standards based on land use, activities and noise sources. The Study also reviewed and benchmarked existing noise standards in Malaysia against international standard and best practices which provided key input into the preparation of this Guidelines.

The Noise Study Project, and this Guidelines, is consistent with the Department's responsibility for ensuring sustainable development in the course of national development while ensuring a clean, healthy and safe environment for its people. This includes the ever increasing concern for noise and vibration arising from the major infrastructure, industrial and other economic development in Malaysia.

As DOE is disseminator of information, skills and ideas for the development of the people's minds towards continual appreciation of the natural environment, this Guidelines promotes self-regulation by the industries and other stakeholders in environmental noise management.

I would like to acknowledge the expert contribution of the Institute of Noise & Vibration University Technology Malaysia, in particular Professor Dr. Mohd Salman Leong, the relevant agencies and all other individuals in providing the input, comments and recommendations in the preparation and publication of this Guidelines.

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GUIDELINES FOR ENVIRONMENTAL NOISE LIMITS AND CONTROL

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TITLE

1.0 SCOPE

1.1 This document presents technical guidance and recommendations for:
(a) Ambient noise standards to minimize disturbance in the environment;
(b) specifying noise limits in the environment for new development and projects for protection of the public from excessive noise;
(c) procedures on environmental noise measurements, assessment and mitigation.

1.2 For purpose of these guidelines, methodology and definitions used are consistent with those given in ISO 1996-1: 2016 and BS 4142: 2014 (or any latest revision). A glossary of definitions is included in this document.

1.3 The guidelines present noise acceptance criteria upon which a quantitative assessment of noise could be made. This eliminates subjective judgment of parties involved, ambiguity in defining a noise disturbance, and for assessment of noise based on measured or calculated noise levels.

2.0 PURPOSE

2.1 The purpose of this guidelines is:
(a) for planning required of parties involved in the planning process;
(b) for noise impact assessments, pre- and post EIA compliance verification;
(c) for quantifying noise disturbance on a quantitative basis; and
(d) for guidance in environmental noise mitigation through planning and control.

2.2 The guidelines should be used in new and existing projects planning, that may not necessarily require an Environmental Impact Assessment (EIA). All projects requiring noise assessment an EIA must be undertaken in accordance to this Guidelines.

The guidelines are suitable for all projects and other applications where noise is a potential concern, and other situations where a noise need to be measured and assessed, and noise mitigation to be implemented. The guidelines cover all common types of environmental noise sources and noise pollution in general.

3.0 LEGISLATIVE RELEVANCE

3.1 Section 23 under the Environmental Quality Act 1974 stipulates that *"no person shall, unless licensed, emit or cause or permit to be emitted any noise greater in volume, intensity or quality in contravention of the acceptable conditions specified under section 21"*.

3.2 Approval of projects subjected to Environmental Impact Assessment (EIA) stipulate requirements for noise levels compliance, monitoring and mitigation during construction and operations of the project.

3.3 The guidelines present recommendations for noise limits and basis of assessment. Compliance to these limits may be made mandatory using legislative instruments available to the authorities (DOE, Local Authorities, City Halls, etc).

3.4 This Second Edition of the guidelines supersede the first edition of 2004 and 2007 Reprint.

4.0 NOISE LIMITS

4.1 Ambient noise in the environment are dependent on the noise sources that pre-exist and/or additional noise source(s) that may be introduced to a location of concern. The limits to be set should be consistent with the environmental noise climate that currently exists at this location - such that an adverse impact on the environment and adjacent affected land use are avoided, and at the same time maintain a reasonable balance with physical development and/or activities that shall or had taken place.

4.2 Ambient noise limits may be set based on either of the following, depending on circumstances:
(a) an absolute limit based on the average level of noise which should not be exceeded in a specified period;
(b) a relative limit based on the permitted increase in noise level with respect to the background level.

4.3 These limits may either be a single value over the relevant time periods, or different values for day and night. It may also be appropriate to set an evening value where the noise source requires such control. The setting of an absolute limit is often desirable, but would require monitoring and assessment to ensure that unrelated or extraneous noise (which may increase the measured noise level) do not influence the assessment.

4.4 Relative limits in general may not be appropriate when the permitted increase in noise over prevailing background noise is substantial (15 dB or more). Since background noise varies during the day, the background noise level determined should be representative of a typical quiet period during the working day.

4.5 Recommended maximum permissible sound levels for different noise sources measured at the real property boundary and assessed based on receiving land use are given in the Schedules of Permissible Sound Levels for different conditions.

4.6 The sound levels shall apply to outdoor locations at the real property boundary of the receptor (typically residential areas, or other noise sensitive area) for assessment of noise from road traffic, railways and other diffused noise source(s). For industrial noise sources in an industrial zone, the assessment location may be at the property boundary of the industrial site or plant.

4.7 Schedule 1 prescribes recommended permissible sound level (L_{Aeq}) for planning purposes and new development. These are deemed desirable limits to be used for new industrial, commercial or housing areas; and/or development in undeveloped areas (rural and/or ungazetted areas).

4.8 The recommended permissible sound level (L_{Aeq}) at receptor locations in context of an existing developed area is prescribed in Schedule 2. This is a more practical limit in most applications representative of pre-existing noise that is present in a developed and populated area.

4.9 In situations where the existing noise climate (L_{Aeq}) is higher than the recommended limits prescribed Schedule 2, an acceptance criterion based on maintaining the noise to similar levels of prevailing conditions (at existing L_{Aeq} level). Due to uncertainty in measurements, noise levels within $\pm$ 1.5 dBA of the Existing L_{Aeq} is acceptable and deemed maintained at the existing noise climate.

4.10 Recommended limiting sound levels (L_{Aeq}) from road traffic for proposed new roads and/or redevelopment of existing roads are prescribed in Schedule 4. In situations where the existing noise climate (L_{Aeq}) is higher than the recommended limits prescribed in Schedule 4, an acceptance criterion based on Schedule 3 may be more appropriate.

4.11 Recommended limiting sound levels (L_{Aeq}) from railways for new development or re-alignments are prescribed in Schedule 5. A maximum permissible instantaneous maximum sound pressure levels for the transient pass-by noise is also prescribed. The stated L_{max} limit is the trains' pass by event instantaneous noise level. Care shall be exercised during measurement to ensure that that the transient noise measured are for train noise events, and not from other unrelated high noise sources (such as heavy vehicles pass-by events, construction or other activity noise).

The equivalent steady state noise level (L_{Aeq}) is governed by the prevailing ambient noise with the cumulative contribution of the trains' pass-by noise. It is therefore necessary that the prevailing (baseline) L_{Aeq} level be determined in the absence of trains operations for a more accurate assessment of a noise disturbance from trains. In situations where the existing noise climate (L_{Aeq}) is higher than the recommended limits prescribed in Schedule 5, an acceptance criterion based on Schedule 3 may be more appropriate.

4.12 Recommended maximum permissible sound levels (statistical centile L_{10}, and maximum instantaneous sound pressure level L_{max}) for construction, maintenance and demolition works are prescribed in Schedule 6. Fluctuating and impulsive noise sources (for example piling, pneumatic tools, etc.) are best quantified and assessed with the L_{10} and L_{max} levels. Assessment of equivalent steady state noise level (L_{Aeq}) were required shall be based on Schedule 2 or Schedule 3 if the prevailing noise levels is already high.

5.0 NOISE MEASUREMENTS

5.1 Measurements of noise levels are necessary for any of the following purpose:

(a) assessing an existing noise climate.

(b) assessing compliance to noise limits for noise source(s) and/or project development.

(e) assessing environmental impact and potential community response.

5.2 Noise measurements shall typically include the following:

(a) baseline (ambient) sound pressure levels at a receptor's location(s), and/or at the real property boundary of a noise source(s). These may be undertaken at a location(s) prior to a project development. It could also be undertaken in the absence of the noise source(s) and after (example with a plant or facility not operating).

(b) sound pressure levels at a receptor's location(s), and/or at the real property boundary of a noise source with the plant or facility operating, or during operation of a project (highway, transit trains, industrial plant, etc.).

(c) sound pressure levels of each noise source may be required to evaluate the contribution of each source.

5.3 Measurements of noise indoors may also be undertaken but is usually not desirable for environmental impact assessments of a project development or noise source(s) unless otherwise required by prior conditions or assessment requirements. It may nevertheless be undertaken for purpose of comparisons of noise levels before and after a project or in situations of complaints with and without the presence of a noise source(s).

Indoor measurements are dependent on the severity of the outdoor noise source, sound insulation properties of the building facades, acoustic characteristics of the interior space and any other indoor noise sources that may be present. Other noise generated within the inside the building not related to the offending outdoor noise should be excluded in the assessment.

5.4 Procedures for measurement of sound levels in the environment and noise source(s) severity assessment given in Annex B shall be used. Guidance on the use and selection of an appropriate noise measurement parameters and sampling methods are also given in Annex B.

5.5 Because noise vary over time and have different characteristics, different noise parameters (indices) are available to describe noise levels. The equivalent continuous noise level over a period T ($L_{Aeq,T}$) is the preferred general-purpose parameter for environmental noise. For road traffic noise A-weighted $L_{10,\ 18h}$ may also be used. The A-weighted ten-percentile noise level (L_{10}) and instantaneous maximum level (L_{max}) is also often used for fluctuating and/or transient noise events.

6.0 MONITORING LOCATIONS

6.1 Noise assessment is usually to be undertaken at the nearest noise-sensitive receptors, and the preferred monitoring location(s) shall be outdoors at the real property boundary of the receptor.

For measurements of industrial noise, the measurements may also be at the property boundary of the industrial premises. This however does not mean that the monitoring location must always be close to the premises. Noise measurements are usually undertaken on grade at 1.5m to 4m above ground. Monitoring locations shall preferably be readily accessible to all parties concerned.

6.2 In situations when extraneous noise makes measurements difficult or may result in inaccurate levels, it may be permissible to monitor at alternative locations at the site boundary.

6.3 Noise monitoring locations in high rise buildings may be undertaken at the building facades in addition to the property boundary. Measurements in buildings should be undertaken in open spaces such as an open terrace, balcony, open car park and other suitable locations with a minimal on obstructions or shielding.

6.4 A more detailed guidance on monitoring locations and examples for different applications are given in Annex B.

7.0 NOISE SOURCES TO BE MEASURED

7.1 Noise sources to be monitored is dependent on the purpose of measurements and assessment. The underlying intent is that the severity and origin of noise source(s) could be quantified, assessed and if required corrective measures can be undertaken to address any potential noise disturbance originating from the noise source(s).

The measurements in general could be for purpose of one or combination:

i. Baseline measurement to obtain prevailing ambient levels for which the measurements would include the cumulation of all noise sources existing at the location of measurement;

ii. Road traffic noise measurements and assessment of existing and new highways (before and after commencement of new highways);

iii. Railways and transit trains measurements and assessment of existing new highways (before and after commencement of new railway lines);

iv. Industrial premises and plants;

v. Commercial and recreational activities from street markets (*pasar malam*), entertainment outlets (discotheques, pubs);

vi. Construction and demolition works noise (and vibration) from a project site;

vii. Airport and aircrafts.

7.2 Some of the above noise sources and activities measurements are mandatory for compliance reporting for projects required in an Environmental Impact Assessment (EIA) and the corresponding Environmental Management Plan (EMP).

7.3 The Department of Environment, Local Authorities and other licensing agencies may also require noise measurements of some of the above activities and sources (highway concessionaries, railways operators, industrial premises owners or occupiers, construction works, entertainment outlet operations, etc.).

7.4 International best practices (and International Civil Aviation Organization) also recommends permanent noise monitoring at airports and receptors along flight paths for aircraft noise emissions and compliance reporting tagged against aircraft and flights identifications. This may involve integration with a Flight Information System or alternatively off-line identification against a flight tracking platform.

7.5 Guidance for noise measurement procedures for different types of measurements covering different noise sources are provided in the Guidelines herein Annex B.

8.0 NOISE SEVERITY AND IMPACT ASSESSMENT

8.1 Noise could be assessed against an absolute numerical noise limit (as described in Section 4 based on Schedules given in this document), or alternatively assessed based on the change in noise levels relative to an existing baseline level.

8.2 Assessment of noise levels against a noise limit merely requires comparison of the measured noise level against the permissible sound pressure levels. Assessment of the impact of a noise level in the environment, and the anticipated community response to the noise may require evaluation of the magnitude by which the noise level exceeds the existing ambient (baseline) sound level.

8.3 Noise assessment at times may refer only to noise from the source under consideration and not to the total measured value which may include, for example, extraneous noise from activities or road traffic.

8.4 Further guidance from ISO 1996-1: 2016 Acoustics – Description, measurement an assessment of environmental noise: Part 1: Basic quantities and assessment procedures is recommended for community annoyance response evaluation. Procedures as adopted from ISO 1996-1: 2016 and BS 4142: 2014 9 (and latest revision) are given in Annex C.

9.0 RECORD KEEPING

9.1 The following information shall be recorded and kept for record purposes.

(a) The measured values of L_{Aeq} and, where appropriate $L_{pA,\ max}$ or L_{10}, L_{90}, together with details of the appropriate time periods.
(b) Details of the instrumentation and measurement methods used, including details of any sampling techniques, position of microphone(s) in relation to the site and system calibration data.
(c) Any factors that may have adversely affected the reliability or accuracy of the measurements.
(d) Plans of the site and neighbourhood showing position of plant, associated buildings and notes of site activities during monitoring period(s).
(e) Notes on weather conditions, including, where possible, wind speed/direction, temperature, relative humidity, presence of precipitation, etc.

9.2 Noise monitoring for projects subjected to an Environmental Impact Assessment shall be submitted to the Department of Environmental in accordance to the approval conditions of the EIA.

Local authorities and parties with supervisory capacity over the person(s) or party generating the noise (for example Malaysian Highway Authority or Land Transport Authority) may also make it mandatory for results of noise measurements to be submitted to these Authorities.

10.0 NOISE AND PLANNING

10.1 The impact of noise should be considered in the planning of a project development and in general be guided by these Guidelines.

10.2 For the consideration of noise in planning, the following information may reasonably require:

(i) the existing daytime and night-time (L_{Aeq}) equivalent sound levels for a representative sample of locations, existing noise zones; identification of major sources of sound;

(ii) any projected or proposed new or expanded sources of sound which may affect exposure of the site after completion of the project and the projected future daytime and night-time (L_{Aeq}) equivalent sound levels; projected noise contours; and changes to existing noise zones at the site resulting from these new or expanded sources;

(iii) where applicable, plans for noise mitigation measures and anticipated sound reduction.

10.3 The Project Proponent and any other Person(s) who would operate or cause to operate equipment, plant, process or activity with noise generation should undertake all reasonable measures to control the source of, or limit exposure to, noise. Such measures should be proportionate and reasonable, which may include one or combination of the following:

(a) land use compatibility: proposed operations shall be compatible with designated land use;

(b) layout: adequate distance between source and noise-sensitive neighbours, building or area; the usage and designation of buffer zones shall be in accordance to Planning Guidelines issued by the Department of Environment from time to time; screening by barriers, (natural, man-made or otherwise) and other buildings;

(c) engineering measures: reduction of sound at point of generation, containment of noise generated by adequate design of building envelope, and protection of adjacent noise-sensitive buildings by sound insulation or screening of the buildings;

(d) administrative measures: limiting the operating time of noise source(s); restricting the activities and ensuring acceptable sound emission limits of noise source.

10.4 In situations where noise would be potential concern, the Project Proponent and/or parties responsible for the noise source or emissions should undertake sound propagation predictions to the environment using acoustic modelling and/or calculation procedures in accordance to ISO 9613-2 (or latest revision) such that the impact of noise could be assessed. Parameters used in the analysis shall include but not limited to sound power levels (actual or estimated), directivity factors, ground effect, distance, meteorological influences, and transmission path.

11.0 NOISE MAPPING

11.1 For assessment and planning approval, noise mapping in the form of noise contours is usually required. Noise contours should clearly show sound level with respect to the location of the site and sound source(s).

11.2 Noise zones may be presented in sound level ranges of 5 dBA L_{Aeq} increment (for example 40-45 dBA, 45-50 dBA, etc.).

11.3 The mapping of noise zones without the influence of the noise source(s) under evaluation should be obtained and compared with noise zones with the subsequent contribution of the above said noise source(s).

11.4 Noise mapping for existing noise sources can be obtained from measurements undertaken at regular intervals in a grid manner upon to develop the contour lines representing constant sound pressure levels. Noise contours are also generated from computer modelling for existing noise sources (to be validated against measurements), and/or for new noise sources.

11.5 Examples of noise maps and its use for visualisation of the extent of sound propagation in the environment are given below.

Figure 1 shows an example of a noise map generated from site measurements of an existing industrial premise superimposed onto the plant layout drawing. Figure 2 shows an example of a noise map generated from noise modelling of an industrial premise with predicted noise levels at property boundary shown.

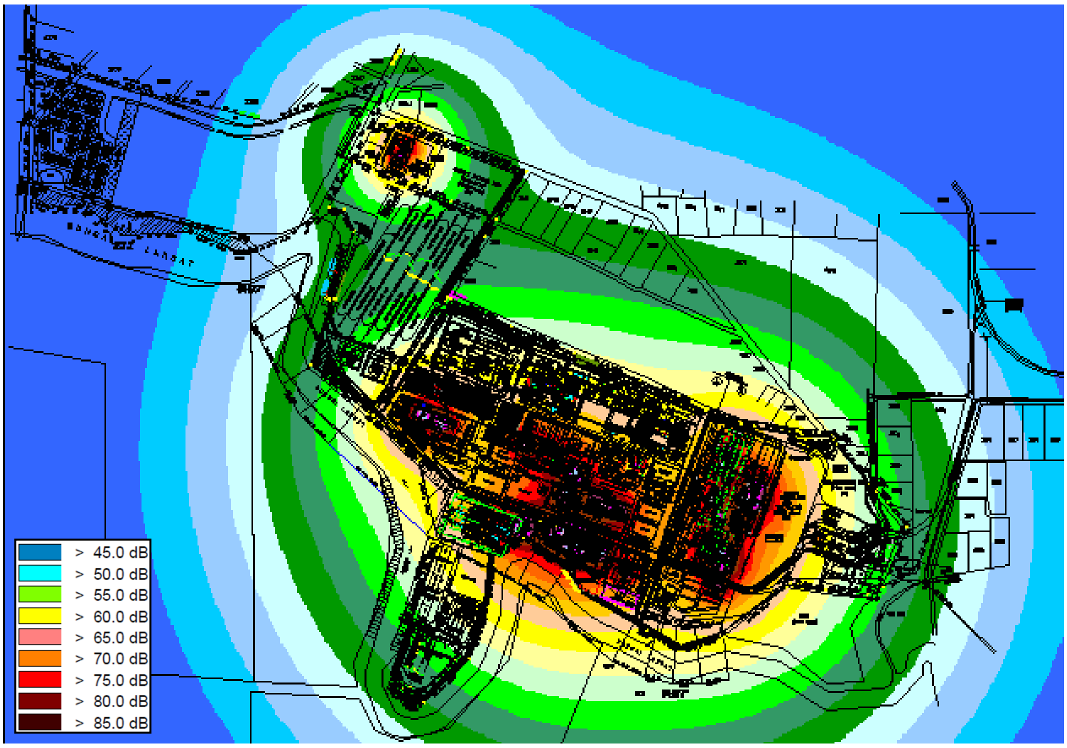


Figure 1: Example of noise map of an existing industrial premise generated from site noise measurements

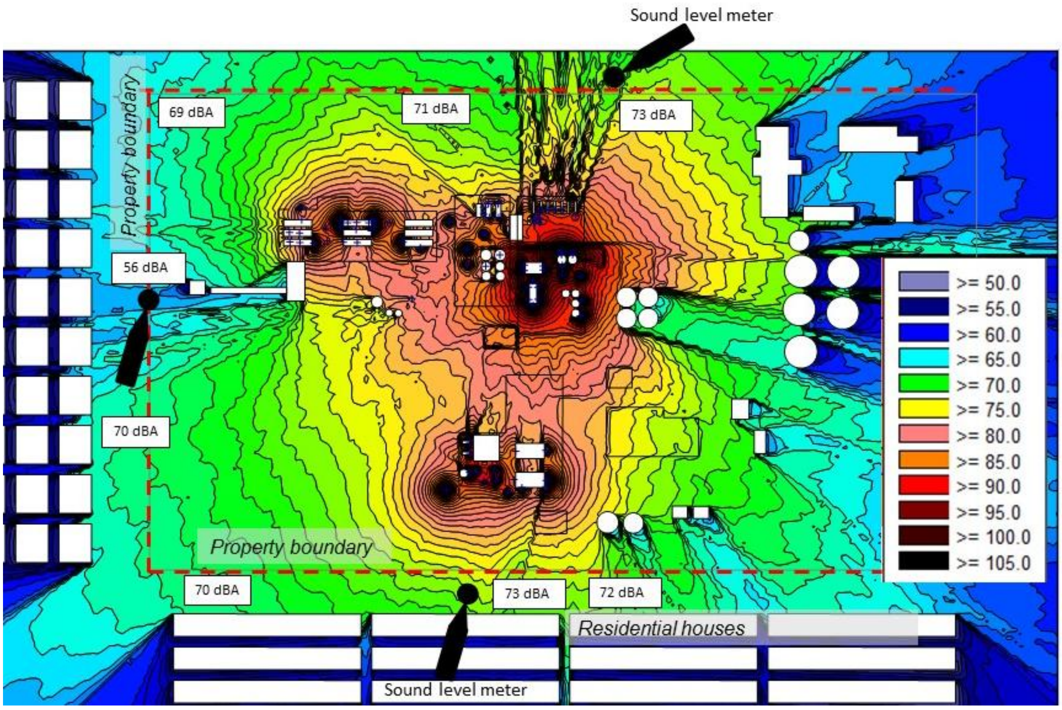


Figure 2: Noise map of an industrial premise showing in plant and boundary noise levels generated from noise modelling.

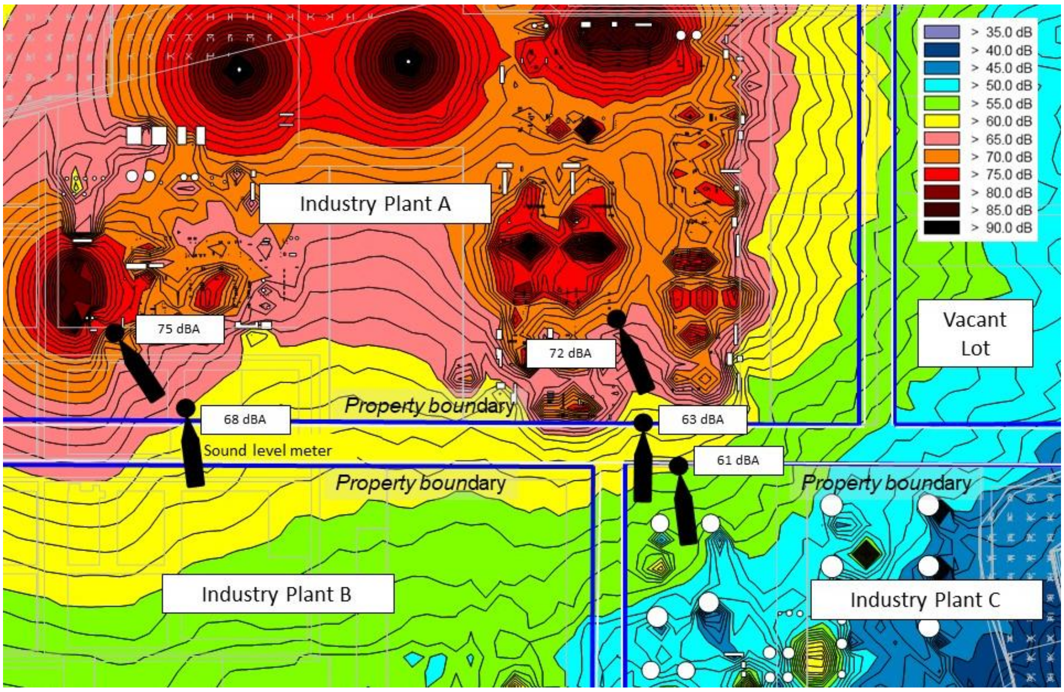


Figure 3: Noise map and suggested measurements at property boundary and sources to determine premise creating high noise

Figure 3 shows an example of noise measurements supported by noise modelling of multiple industrial premises for identification of high noise sources and severity assessment of noise propagation originating from different industrial sites. Such measurements and noise maps can be used to identify equipment and the industrial premise contributing to the overall noise levels of the entire site.

Figure 4: Noise map (L_{10} levels) of a proposed elevated highway to be built amongst existing developed area

Examples of noise maps generated for roads and highways are given in Figure 4 and Figure 5. The noise contours were obtained from modelling of road traffic noise (and measurements for existing roads where applicable). Figure 4 shows noise propagation from a highway main line located amongst an existing developed area. Figure 5 shows a more complex highway model with main line, interchanges and slip roads. The noise modelling were from 3D representation of the physical site with noise contours generated at receptors level on grade.

Noise maps may be generated for steady state equivalent noise levels (L_{Aeq}) or alternatively based on the L_{10} percentile levels depending on the assessment parameter used.

While noise maps are conventionally shown in plans view, noise contours can also be generated and plotted from 3-D environmental noise modelling showing cross sections across the noise source and receptors. These plots in cross-sectional views are useful to determine noise levels at different relative heights from ground level (RL) and at building façade of high- rise buildings.

An example of a noise contour plot of an existing and new elevated highway at affecting high rise buildings is shown in Figure 6.

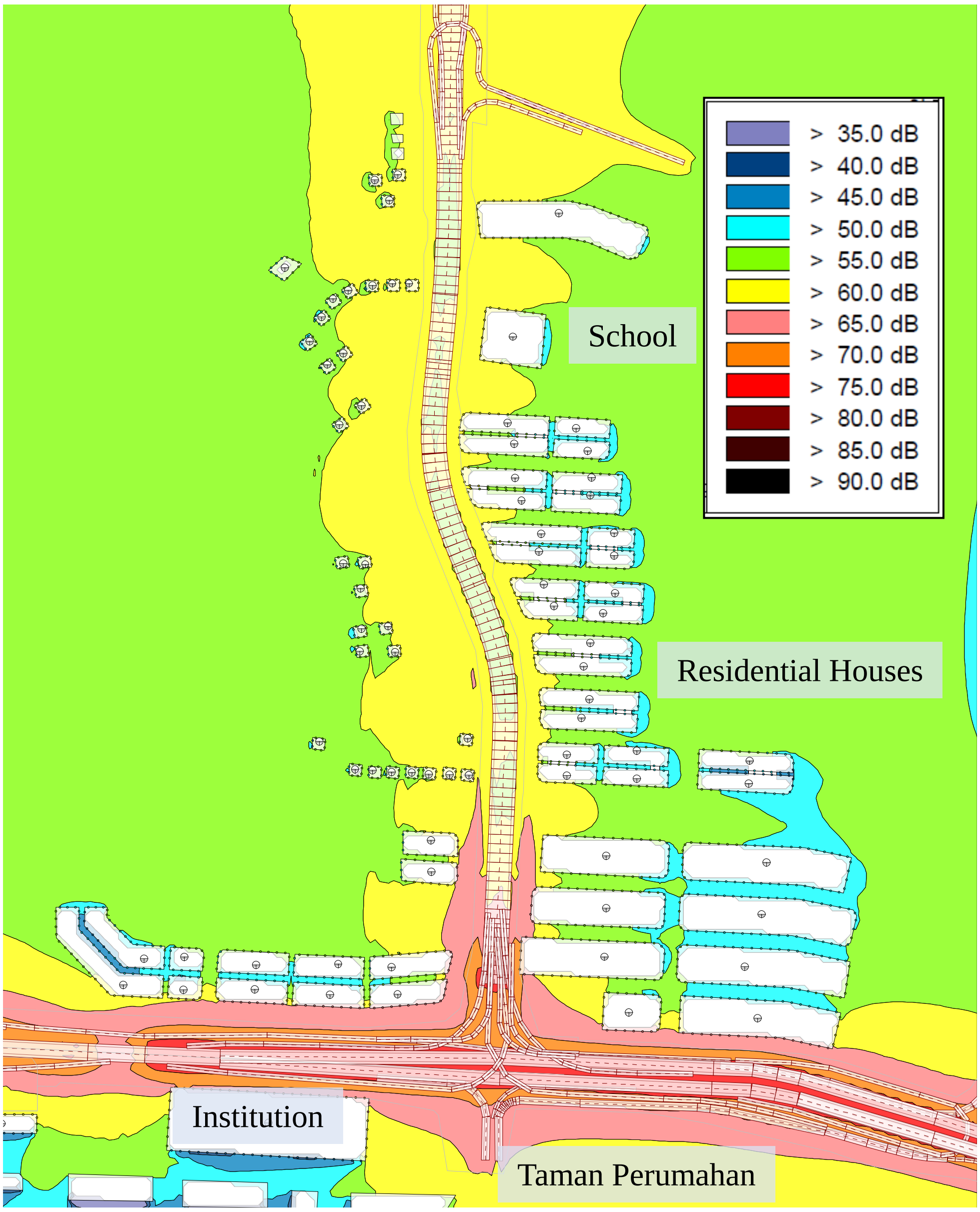


Figure 5: Noise map (L_{Aeq} levels) from 3D noise modelling at an interchange of a highway development with slip roads and different lanes represented in the noise modelling

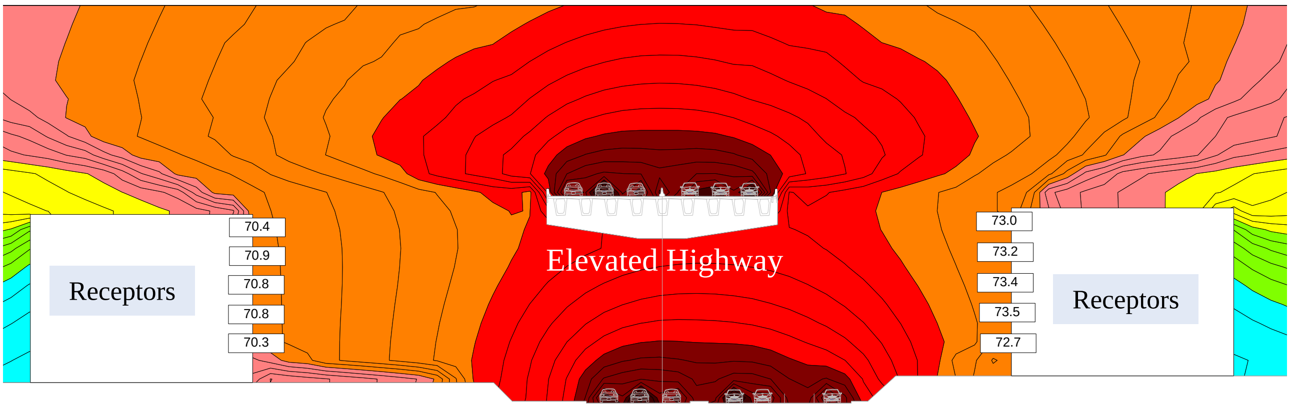


Figure 6: Noise contours (L_{Aeq} levels) in a cross-sectional plot from 3D noise modelling of an elevated highway superimposed onto existing roads showing noise levels at different floors in multi-storey buildings

Figure 7: Noise contours (L_{max} levels) on grade for transit trains from 3D noise modelling of trains pass by on elevated viaducts to the environment

Noise contours for railways and transit trains are similar to highways (being line sources). The contours are generated for trains pass-by along the railway alignment. Noise contours for the train pass-by events are usually generated for the L_{max} noise levels corresponding to the trains pass-by noise emissions. The resulting steady state equivalent noise levels are then determined based on pass by noise levels, number of trains pass by per hour and the existing background noise levels to determine the L_{Aeq} day and night levels at the receptors of concern.

Figure 7 shows an example of trains pass-by L_{max} noise contours from an elevated viaduct located amongst a developed area. The noise contours may be plotted for noise from trains pass-by only (i.e. without existing road traffic) for clarity and assessment of trains noise only, in addition to contours with combined noise sources (roads, etc.) for assessment of cumulative noise levels.

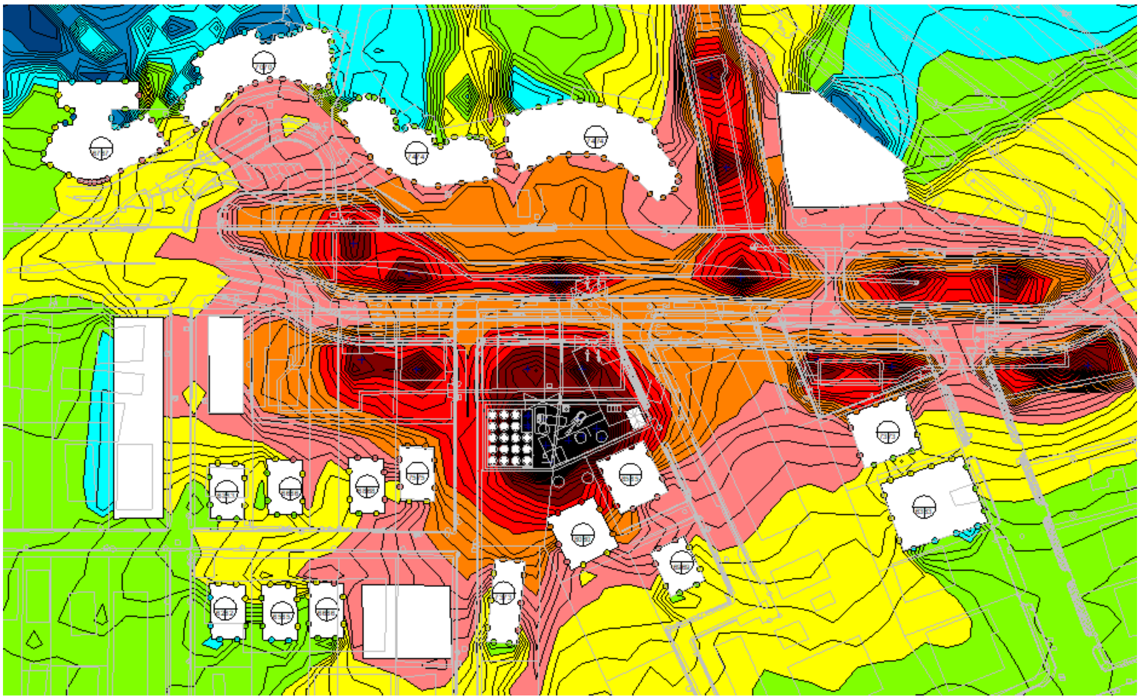


Figure 8: Noise map (L_{Aeq}) for a construction site located amongst built up areas

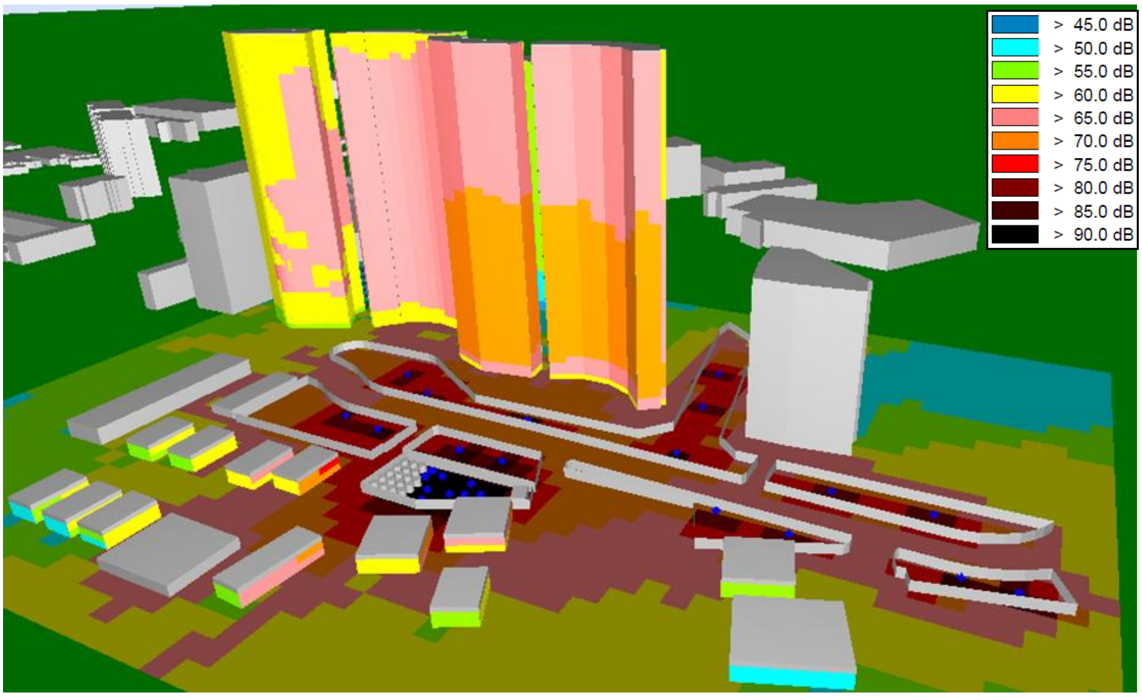


Figure 9: 3-D noise modeling of a construction site located amongst built up areas showing noise levels in the environment and at building facades

Noise maps are also generated for construction sites to be used in assessment of construction works and for identification of possible noise mitigation measures at the work site.

Figure 9 shows an example of a 3-D noise modelling of a construction work site located amongst dense built up areas. The noise modelling included major noise sources (piling machines, gensets, machineries, etc.) and temporary barriers/hoarding at construction site boundaries. The noise contours at ground level (RL 4m on plan view) are shown in Figure 8.

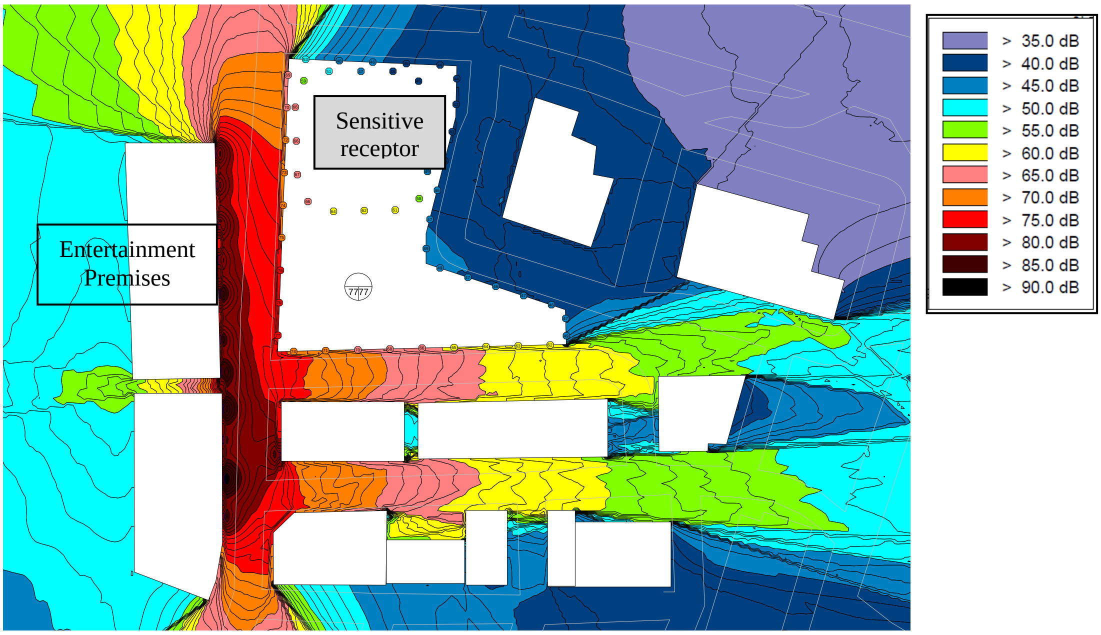


Figure 10: Noise mapping of entertainment noise propagation (night time) from a row of entertainment premises to adjacent sensitive receptors

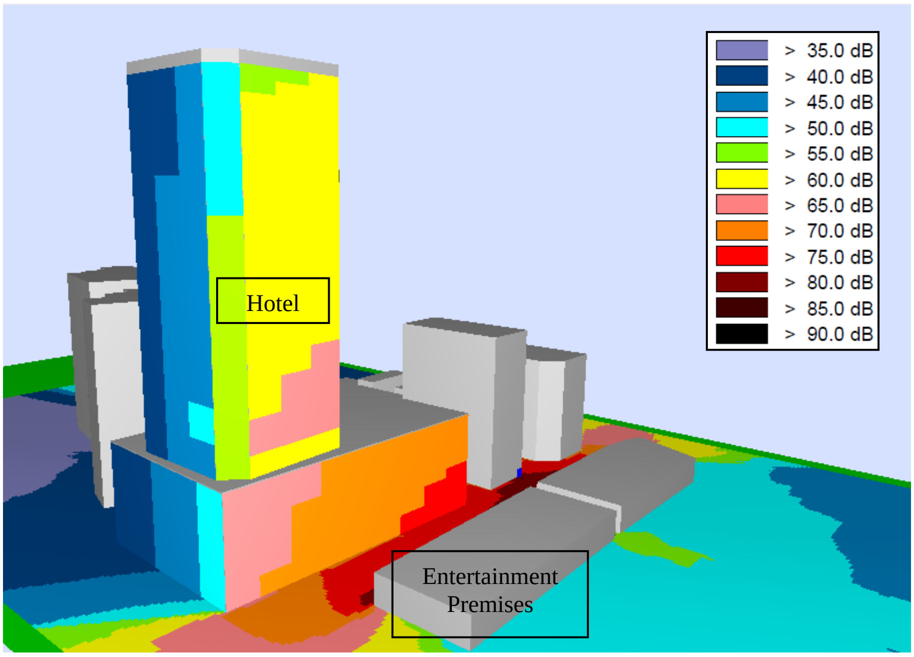
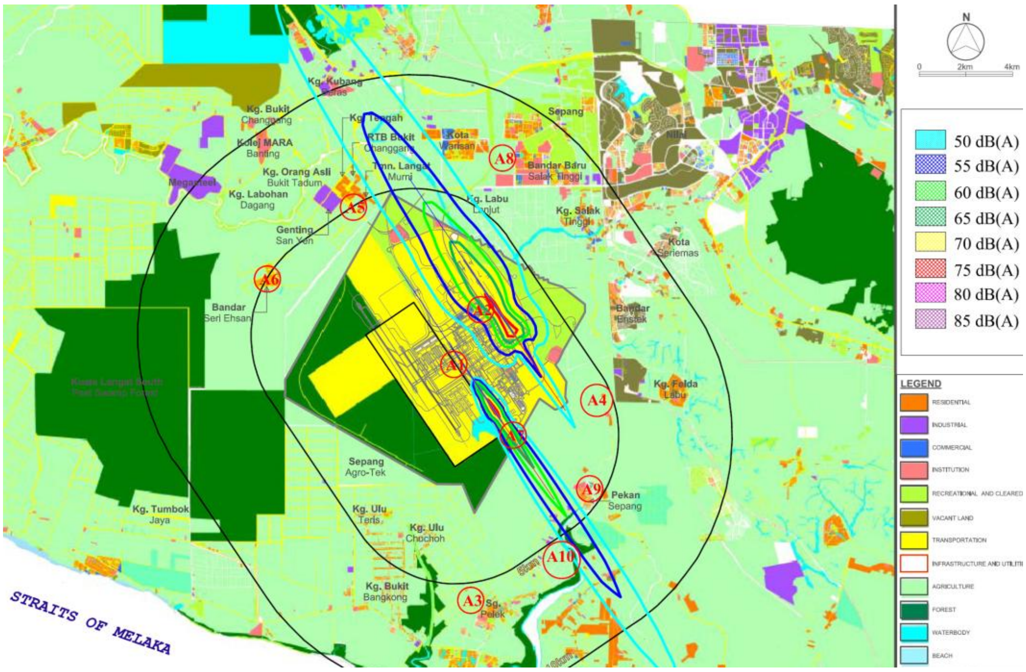


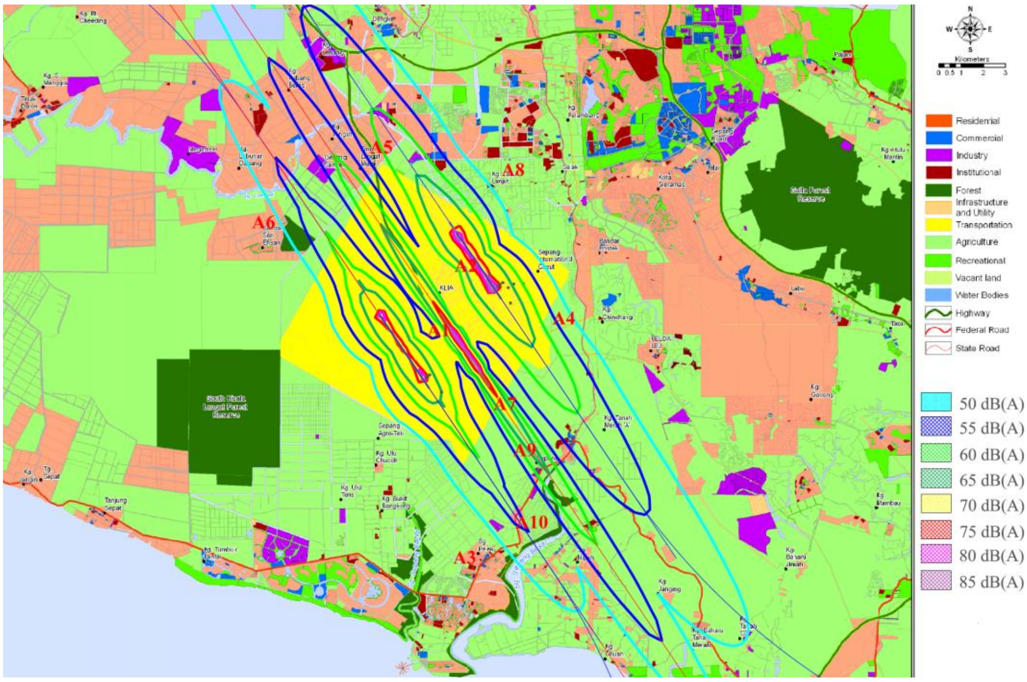
Figure 11: Noise propagation from 3-D noise modelling of entertainment noise sources from a row of entertainment premises affecting adjacent sensitive receptors

Noise mapping can also be used to visualize the extent of noise propagation from entertainment and commercial noise sources affecting the surrounding community. Figure 10 and Figure 11 shows noise propagation and contours obtained from 3-D noise modelling of entertainment noise sources (assumed as a series of multiple point sources) using measured noise emission levels from the premises as data input. Night time and day time scenarios may be considered in the modelling and assessment.



Source: EIA Report for Proposed New LCC Terminal and Associated Works at KL International Airport

Figure 12: Airport L_{Aeq} noise contours showing typical noise level in vicinity of airport (KLIA 2009 traffic operations)



Source: EIA Report for Proposed New LCC Terminal and Associated Works at KL International Airport

Figure 13: Projected airport noise contours (L_{Aeq}) superimposed onto existing land use in vicinity of airport (Year 2056 for KLIA 1 & 2 operations).

Noise maps are routinely used in assessing impact of aircrafts and airport operations (existing and projected future air traffic in airport planning). Examples of noise contours for an airport obtained from noise modelling of existing and future airport operations are shown in Figure 12 (existing airport operations in Year 2009) and Figure 13 (future operations for one of several scenarios) undertaken in an EIA for an airport expansion project.

12.0 NOISE WORK SCOPE IN ENVIRONMENTAL IMPACT ASSESSMENT

12.1 This Section of the guidelines presents specific guidance on requirements to be considered and the work scope to be undertaken for noise aspects in an Environmental Impact Assessment (EIA).

12.2 The major items that shall be included in the EIA for noise are:

- Identification of sensitive receptors;
- Establishing noise acceptance criteria;
- Baseline noise monitoring;
- Noise modelling;
- Noise impact assessment;
- Noise mitigation; and
- Environmental Management Plan requirements.

The modelling, impact assessment and mitigation shall cover:

- Construction (and demolition works where applicable); and
- Operations.

12.3 For industrial projects and other projects within a specific site, the assessment shall be at the project site property boundary and nearby / nearest residential and other sensitive receptors.

For infrastructure projects (often referred as linear projects such as highways, railways and transit trains), the assessment shall cover the entire alignment with emphasis to all developed or populated areas along the alignment corridor (typically 200m to 500m of alignment). Alignment passing thorough lesser populated areas has its own unique concerns due to the inherent low ambient noise which should also be addressed.

12.4 Circumstances which could lead to potential problems and significant residual impact on sensitive receptors that should be addressed in the noise assessment include:

- Close proximity of the alignment (typically less than 200 m from receivers to highways and railway corridors) for infrastructure projects;

- Close proximity of outdoor noise sources and/or high noise emissions from plants and machinery for industrial and petrochemical projects;

- Some industrial projects (petrochemical, power generation including wind turbines in particular) may also have additional concern of low frequency sound.

- Receptors in high rise buildings or dwellings on elevated terrain overlooking the noise sources (highways, railways, or industrial premises) with a direct line of sight that may limit effectiveness of mitigation measures (e.g. noise barriers);

- Low ambient existing noise climate (without significant noise sources or major roads);

- Construction noise (and vibration) which are often deemed disturbing (being a new noise source imposed onto the receptors).

12.5 Intent and Expectations of Noise Assessment in an EIA Project

The assessment shall establish impacts of noise (and vibration) propagation during the construction and operation phase of the project.

For industrial and project sites with defined boundaries, environmental sound propagation noise contours covering the project site up to and beyond project property boundaries to adjacent communities shall be prepared. For linear infrastructure projects, the noise contours shall be along the entire alignment corridor.

Existing environment noise (and vibration) climate shall be determined from baseline monitoring at identified sensitive receptors. The baseline measured levels shall be used as a basis of establishing acceptance criteria and impact assessment from the project.

Noise modelling shall be undertaken to establish noise levels from construction and operations at the project site and at all sensitive receptors. From the predicted noise levels, undertake impact assessment to all sensitive receptors. Mitigation measures shall be identified for the project during construction and operations.

The mitigation measures identified in the EIA are conceptual in nature that shall be subject to detailed design during project implementation. Detailed design of mitigation measures is not within the scope of an EIA. The mitigation design measures may however be subject to review by DOE in accordance to the EIA Approval Conditions.

12.6 Work Scope for Noise Assessment in an EIA Project

The following describe tasks that should be undertaken for noise aspects in an EIA. The list is not necessarily exhaustive and should be refined to suit the project on a case by case basis. Some of the tasks described are also applicable only to certain projects type (e.g. railways, airport, etc.), and may not be applicable for other projects.

(i) To review project description, site and project drawings and relevant project design documents (where applicable) to obtain all necessary information relating to works that shall be undertaken in the EIA.

The review shall include equipment lists, specifications and/or ratings, operational and construction activities to identify high noise (and vibration) sources and activities.

(ii) To undertake site inspection(s) at the project site and nearby areas to validate land use information, and to identify potential sensitive receptors and other issues of potential concern at the project site (or along proposed alignment for linear infrastructure projects). This shall initially involve review of aerial photographs and site plans showing land use and/or affected residential areas along the project site (or alignment corridor for linear infrastructure projects) to be followed by physical site inspection(s).

(iii) To identify and undertake baseline noise (and vibration) measurement at locations where the existing environment need to be established. This usually involves measurements at locations and areas with potential concerns that may occur during operations and constructions for which noise (and vibration) modelling and impact assessment shall be undertaken.

(iv) Based on the noise (and vibration) baseline levels, review and propose noise (and vibration) acceptance limits reflecting the existing ambient conditions for project impact assessment.

(v) To review equipment noise data sheets (if available) and noise database from published literature and past or similar projects to establish sound emission levels for data input in the noise modelling. Where feasible, to undertake noise measurements from similar equipment, facilities or installation or process activities to obtain field measured data for noise levels of similar sources for validation of noise input data.

(vi) For projects involving Plant expansion of an existing operational plant or facilities, undertake in-plant noise measurements inside the Plant compound and at existing operational equipment and/or process lines to obtain noise emission levels of high noise sources for existing plant / facilities. This shall include detailed measurements at strategic locations to be used as noise modelling validation (calibration) of the existing plant / facilities.

(vii) For projects involving Plant expansion of an existing operational plant or facilities, set up noise computational model of the existing (current) Plant under current operating conditions with existing high noise sources represented in the computer modelling of the existing Plant (before proposed expansion).

(viii) Set up noise computation model(s) of the proposed new Plant or facilities. For projects involving Plant expansion of an existing operational plant or facilities, new noise sources shall be added onto the existing Plant model. For new Projects, all high noise sources shall be set up into the project site at the respective equipment locations with the respective noise emission levels represented. Other dominant existing noise sources including roads and railways may be included into the modelling.

(ix) For linear infrastructure projects, the noise computation models may be set up in segments or sections along the entire alignment corridor for easier data handling and analysis. Data input for sources (highways, railways, etc.) in the modelling shall be based on design parameters of the project (road traffic volume, traffic mix, speeds, highway design; train types, train speed, viaduct design, etc.).

(x) The noise modelling shall be set up in a representative physical site model (spatial model to include buildings, large structures, existing barriers, embankment, etc.) so that sound reflections, shielding and ground effects are included in the modelling.

Existing roads / railway lines shall also be included in the modelling, where applicable. Noise modelling of existing conditions shall be validated against measured baseline levels.

Noise emissions from the existing noise sources (including road traffic and/or railways) may be initially switched off in a noise prediction scenario for new sources only. This shall then be followed by a combined noise prediction scenario which includes existing noise sources to obtain cumulative noise levels with the project operations.

(xi) Noise modelling shall be carried out using proven environmental noise modelling software with noise prediction algorithms based on ISO 9613-2: "*Acoustics-Attenuation of sound propagation outdoors- Part 2 General method of calculation*".

(xii) Ground effects, atmospheric absorption and any potential screening from terrain and existing buildings and large structures are to be considered in the modelling. All noise sources shall be located at the respective locations and/or alignment (as the case may be) at the Project site and to be at representative elevations with respect to the ground terrain and receptors. High rise buildings shall also be represented in the modelling to obtain predicted noise levels at the receptors' building facades.

(xiii) Calculations in principle shall be undertaken in octave band centre frequencies upon which overall A-weighted noise levels shall be determined.

(xiv) For industrial and petrochemical projects, calculations in non-weighted linear (or dBZ frequency weighting) shall also be undertaken for identification of potential low frequency noise sources and impact to sensitive receptors, where applicable.

(xv) Noise maps (noise contours) at constant RL, i.e. at ground levels and/or appropriate RL above ground shall be obtained.

(xvi) The noise computational models in principle shall involve predictions of the steady state equivalent noise levels (L_{Aeq}). For railway and transit trains projects, the noise predictions shall be undertaken for trains pass-bys instantaneous maximum L_{max} levels; and equivalent continuous L_{Aeq} levels (taking into consideration service operations frequency) determined from the trains pass by events noise levels. Cumulative effects of the train noise with existing road traffic noise should be considered in urban built up areas.

(xvii) For airport projects, the noise modelling shall be undertaken using computer-based programmes in accordance to procedures and recommendations of the Federal Aviation Administration for aircraft noise calculations and generation of airport noise contours. Calculation considerations shall include but not limited to proposed airport operations (flight paths, air traffic volume, fleet mix, flight frequencies, etc.) and parameters influencing outdoor sound propagation.

(xviii) To undertake noise modelling and assessment for access roads for projects where there is an anticipated increase in road traffic along existing access roads (for plant expansion, railway stations and airport terminals, etc.).

(xix) Set up noise computational models for construction works at the project site with typical and expected noise sources that shall be present at the work site. For linear infrastructure projects, the noise modelling shall be at the viaducts' piers and stations, etc. at selected and/or representative sensitive receptors' locations.

(xx) Conduct an assessment of the predicted noise levels at sensitive locations and all monitoring locations in accordance to limits stipulated in the DOE Guidelines for Environmental Noise Limits and Control.

(xxi) To establish a list of sensitive receptors that are anticipated to be affected by the Project during construction and operations phases.

(xxii) To review and propose mitigation measures for noise (and vibration) during construction and operations.

(xxiii) To propose monitoring requirements during construction in the Environmental Management Plan, and post construction monitoring for EIA limits compliance.

13.0 NOISE MITIGATION

13.1 The Project Proponent, and/or any other occupier of any industrial or trade premises, construction sites, and/or person(s) responsible for excessive sound generation should use the "best practical means" to minimise the sound generation and reduce its propagation to the environment.

13.2 Excessive sound generation is deemed to occur when noise levels above the noise limits prescribed in these Guidelines are exceeded. "Best practical means" in the context of these guidelines, shall include but not limited to:

(a) the size, design and inherent operation characteristics of the plant, equipment, process or activity;
(b) the adjustment of operational parameters to limit the intensity of sound emissions,
(c) the selection and usage of low sound power level equipment;
(d) the provision if necessary, and appropriate use of sound attenuators/silencers, acoustic plenum, and other acoustic filtering devices;
(e) the provision if necessary, and appropriate use of acoustic enclosures and other sound enclosing devices;
(f) the provision if necessary, and appropriate use of screening barriers;
(g) the proper conduct and adequate supervision of operation; and
(h) regular and efficient maintenance of plant and control equipment.

13.3 In instances of high noise disturbance, the Authority with legislative authority over the person(s) generating the noise (Local Authority, City Hall, Highway Authority, Land Transport Authority, Department Civil Aviation, Department of Environment, etc.) at its discretion may make it mandatory for the or person(s) responsible for the excessive sound generation (project proponent, operator, premise occupier, noise source originator) to undertake mitigation measures for reducing sound levels to comply with limits as prescribed in these Guidelines.

13.4 An example of siting of noise sources and planning of land use in proximity of noise sources in a large scale industrial project is shown in Figure 6. This example shows implementation of a buffer zone within the industrial complex for noise mitigation to adjacent receptors.

An example of an industrial plant located adjacent a noise sensitive receptor is shown in Figure 7 to 8. Noise propagation plots are shown demonstrating sound propagation from the plant to the environment and adjacent sensitive receptors. This example illustrates how industrial noise sources and siting of the plant result in sound propagation that may potentially affect the adjacent receptors.

An example of aircraft noise in vicinity of an airport and receptors along flight paths is shown in Figure 9 (for pre-existing airport operations, KLIA Year 2009) and in Figure 10 (for projected airport operations Year 2056). Such noise contours can be used for land use planning and development in areas near airports and locations in proximity to flight paths.

Noise modelling examples for noise mitigation are given in Figures 11 to 12. The noise control implemented on the various noise sources include use of acoustic enclosure for open equipment (gen-sets, compressors, etc.), silencers for fans, and semi-enclosures and noise barriers for noise work areas.

14.0 GLOSSARY

"commercial area/zone" A designated area/zone as approved or gazetted by the local authority under the relevant act, regulations, rules and by-laws made thereunder for purpose of business, trading, financial, commercial and other similar activities.

"community" The body of people gathered or living in the same locality.

"construction" Any site preparation, assembly, erection, substantial repair, alteration, refurbishment, renovation or similar action, but excluding demolition, for or of public or private rights of-way, structures, utilities or similar property.

"dBA" The decibel unit of measurement of sound level corrected to the "A" weighted scale.

"decibel, dB" A unit of measurement of sound level equal to 20 times the logarithm to the base 10 of the ratio of the pressure of the sound measured to the reference pressure of 20 micropascals.

"demolition" Any dismantling, intentional destruction or removal of structures, utilities, public or private right-of-way surfaces, or similar property.

"emergency work" Any work performed for preventing or alleviating the physical trauma or property damage threatened or caused by an emergency.

"equivalent A-weighted sound level (L_{Aeq})" The constant sound level that, in each situation and time period, conveys the same sound energy as the actual time-varying A-weighted sound. For the purpose of these Guidelines, the day time L_{Aeq} is the equivalent A-weighted sound level for the day time period of 7.00 am to 10.00 pm (0700 to 2200 hours) and the night time L_{Aeq} is the equivalent A-weighted sound level for the night time period of 10.00 pm to 7.00 am (2200 to 0700 hours).

"impulsive sound" Sound of short duration, usually less than one second, with an abrupt onset and rapid decay. Examples of sources of impulsive sound are explosions, drop hammer or driven impacts, and the discharge of firearms.

"industrial area" A designated area as approved or gazetted by the local authority for the purpose of siting industrial, manufacturing or processing plants, factories or facilities.

"licensing authority" The local authority or state agencies or agents of the State that grants licence, approval or similar permission for a specific activity.

"local authority" The local planning authorities, agencies, or agents of the State as defined in the Town and Country Planning Act, 1976 and such rules, regulations and by-laws made thereunder. These include City Halls, City Councils, Municipal Councils, Town Council and District Councils.

"maximum instantaneous sound level (L_{max}) The maximum instantaneous sound level of a measurement time period. This is highest sound level measured, and represents the peak amplitude of the noise event(s).

"mixed development area" A designated area as approved or gazetted by the local authority under the relevant act, regulations, rules and by-laws made thereunder, permitting business, commercial, trading or similar activities, together with residential uses.

"noise sensitive area or zone" Low density residential areas, schools, hospitals, and nursing homes, places of worship, religious buildings and courts of law.

"percentile sound level (L_n)" The sound level ***L*** that is exceeded **"*n* percent"** of the measurement time.

"ten percentile sound level (L_{10}) is the sound level that is exceeded ten percent of the time; and tend to be the peak noise from high noise events (typically vehicles pass by and construction activities).

"ninety percentile sound level (L_{90}) is the sound level that is exceeded ninety percent of the time; and is dictated by the prevailing background threshold from distant noise sources in the absence of noise generated nearby.

"pure tone" Any sound which can be distinctly heard as a single pitch or a set of single pitches. A pure tone exists if the one-third octave band sound pressure level in the band with the tone exceeds the arithmetic average of the sound pressure levels of the two contiguous one-third octave bands by 5 dB for centre frequencies of 500 Hz and above, and by 8 dB for centre frequencies between 160 and 400 Hz, and by 15 dB for centre frequencies less than or equal to 125 Hz.

"real property boundary" An imaginary line along the ground surface, and its vertical extension, which separates the real property owned by one person from that owned by another person, but not including intra-building real property divisions, as delineated in the land title appearing in the Certificate of Title.

"residential area" A designated area as approved or gazetted by the local authority for purpose of human dwellings and residence. **"low density residential areas"** is defined as areas with a population of less than 75 persons per acre; "suburban residential (medium density) areas" is defined as areas with a population of 75 to 200 persons per acre; and "urban residential (high density) areas" is defined as areas with a population exceeding 200 persons per acre.

"rms sound pressure" The square root of the time averaged square of the sound pressure, denoted as P_{rms}.

"sound attenuator" or "**sound dissipative device**" An acoustic filtering device for the attenuation of sound energy for airborne sound as transmitted to the atmosphere or surroundings of an equipment or sound source; such as muffler as used for engines exhausts, and silencer for air distribution equipment or enclosures.

"sound emission" Sound as emitted or discharged from a sound source(s).

"sound immission" Sound as propagated onto and received by a receptor from source(s) external to the receptor or real property boundary.

"sound level" The weighted sound pressure level obtained by the use of a sound level meter and frequency weighting network, such as A, B, or C as specified for sound level meters. If the frequency weighting employed is not indicated, the linear non-weighting level shall apply.

"sound pressure level" 20 times the logarithm to the base 10 of the ratio of the RMS sound pressure to the reference pressure of 20 micro-pascals. The sound pressure level is denoted Lp or SPL and is expressed in decibels.

SCHEDULE OF PERMISIBLE SOUND LEVELS

FIRST SCHEDULE

RECOMMENDED PERMISSIBLE SOUND LEVEL (L_{Aeq}) BY RECEIVING LAND USE FOR NEW DEVELOPMENT

Receiving Land Use Category	L_{Aeq} Day 7.00 am - 10.00 pm	L_{Aeq} Night 10.00 pm - 7.00 am
Low Density Residential, Noise Sensitive Receptors, Institutional (School, Hospital, Worship).	55 dBA	50 dBA
Suburban Residential (Medium Density), Recreational	60 dBA	55 dBA
Urban Residential (High Density), Mixed Development	65 dBA	60 dBA
Commercial Business Zones.	65 dBA	60 dBA
Industrial Zones	70 dBA	65 dBA

SECOND SCHEDULE

RECOMMENDED PERMISSIBLE SOUND LEVEL (L_{Aeq}) BY RECEIVING LAND USE FOR EXISTING BUILT UP AREAS

Receiving Land Use Category	L_{Aeq} Day 7.00 am - 10.00 pm	L_{Aeq} Night 10.00 pm - 7.00 am
Low Density Residential, Noise Sensitive Receptors, Institutional (School, Hospital, Worship).	60 dBA	55 dBA
Suburban and Urban Residential, Mixed Development	65 dBA	60 dBA
Commercial Business Zones.	70 dBA	65 dBA
Industrial Zones	75 dBA	75 dBA

Note: The above prescribed L_{Aeq} limits are representative noise levels consistent with developed areas without noise disturbance generally deemed acceptable to majority of receptors occupying in premises at the respective land category.

THIRD SCHEDULE

RECOMMENDED PERMISSIBLE SOUND LEVEL (L_{Aeq}) TO BE MAINTAINED AT THE EXISTING NOISE CLIMATE

Existing Levels	Recommended Permissible Levels*
L_{Aeq}	Existing L_{Aeq}

Notes

1. Existing L_{Aeq} is determined from baseline measurements of the prevailing noise in the absence of the new noise sources(s); typically undertaken just prior to the operations of the new road, railway line or industrial premises operations, or alternatively with the noise source(s) being assessed to be temporarily disabled.
2. Due to uncertainty in measurements, noise levels within $\pm$ 1.5 dBA of the Existing L_{Aeq} is acceptable and deemed maintained at the existing noise climate.

FOURTH SCHEDULE

LIMITING SOUND LEVEL (L_{Aeq}) FROM ROAD TRAFFIC (FOR NEW ROADS AND/OR REDEVELOPMENT OF EXISTING ROADS)

Receiving Land Use Category	L_{Aeq} Day 7.00 am - 10.00 pm	L_{Aeq} Night 10.00 pm - 7.00 am
Noise Sensitive Areas Low Density Residential Areas	60 dBA	55 dBA
Suburban and Urban Residential (Medium and Density)	65 dBA	60 dBA
Commercial and Mixed Development	70 dBA	65 dBA
Industrial	75 dBA	70 dBA

Note: In situations where the existing sound levels of receptors are higher than limits prescribed above, or within (less than) 2 dBA of the above prescribed limits, the maximum permissible levels stipulated in Schedule 3 shall apply.

FIFTH SCHEDULE

LIMITING SOUND LEVEL (L_{Aeq} and L_{max}) FROM RAILWAY AND TRANSIT TRAINS (FOR NEW RAILWAY & TRANSIT LINES AND RE-ALIGNMENTS)

Receiving Land Use Category	L_{Aeq} Day 7.00 am - 10.00 pm	L_{Aeq} Night 10.00 pm - 7.00 am	L_{max} Day & Night
Noise Sensitive Areas, Low Density and Suburban Residential Areas	60 dBA	55 dBA	75 dBA*
Urban Residential Areas	65 dBA	60 dBA	80 dBA*
Commercial, Mixed Development	70 dBA	65 dBA	80 dBA*
Industrial	75 dBA	75 dBA	NA

Note:

1. *L_{max} noise levels prescribed herein are for train pass-by events only; assessed on trains pass-by events averaged over one hour (i.e. averages of train pass-by L_{max} noise levels from all trains in one hour).

   Care in measurements must be exercised to ensure the L_{max} levels being measured and assessed are not from extraneous noise sources (typically road traffic vehicle pass-by, horns, siren, etc.) not related to train pass-by events.

2. In situations where the existing L_{Aeq} sound levels of receptors are higher than limits prescribed above or within (less than) 2 dBA of the prescribed limits, the maximum permissible L_{Aeq} levels stipulated in Schedule 3 shall apply.

SIXTH SCHEDULE

MAXIMUM PERMISSIBLE SOUND LEVELS (PERCENTILE L_{10} AND L_{max}) OF CONSTRUCTION, MAINTENANCE AND DEMOLITION WORK BY RECEIVING LAND USE

Receiving Land Use Category	Noise Parameter	Day 7.00 am - 7.00 pm	Evening 7.00 pm - 10.00 pm	Night 10.00 pm - 7.00 am
Residential, Sensitive Areas (Note 2 **)	L_{10}	75 dBA	70 dBA	70 dBA
	L_{max}	90 dBA	85 dBA	85 dBA
	L_{Aeq}	-	-	*Note 1
Commercial, Mixed Development	L_{10}	80 dBA	80 dBA	75 dBA
Industrial	L_{10}	80 dBA	80 dBA	80 dBA

Note

*1. At night time, the maximum permissible levels as stipulated in Schedule 3 for respective residential density type shall apply.

**2. Limits for daytime L_{Aeq} or reduction of L_{10} levels in vicinity of sensitive premises (such as schools and hospitals) may be exercised by the Local Authority or Department of Environment. In such situations, limits for daytime L_{Aeq} +3 dBA based on Schedule 3 may apply.

3. There are no prescribed limits for L_{max} and L_{Aeq} levels for construction noise for commercial and industrial land use. Assessment of L_{Aeq} levels if required shall be based on comparison against prevailing ambient noise (Schedule 3).

ANNEX A

SOUND PROPAGATION IN THE ENVIRONMENT

Sound propagated from a sound source to a receptor is given by the following equation:

$$L_p = L_W + log\left(\frac{Q}{4\pi r^2}\right)$$ *Equation A- 1*

where L_p = *Sound pressure level at receptor, dBA(ref 20 micro Pascals)*
L_w = *Sound power level of source, dBA*
r = *Distance of receptor to source, m*
Q = *Directivity factor (=1 for source in mid-air, =2 for source on ground)*

For outdoor sound propagation, there are additional factors that comes into consideration where the basic sound propagation equation A-1 is given by:

$$L_p = L_W + log\left(\frac{Q}{4\pi r^2}\right) + Additional\ loss$$ *Equation A-2*

The "*additional losses*" for outdoor sound propagation are from effects of spreading, absorption, ground configuration, terrain profile, obstacles and other secondary factors such as wind and metrological conditions.

It can be seen from the above equation, that the sound intensity follows an inverse square law where acoustic energy twice as far is spread over four times the area over a spherical surface for a point source (e.g. a machine, exhaust, single aircraft, etc.). For a line source (e.g. a highway with a continuous vehicle flow) the energy is over a line and the dispersion is over a cylindrical surface.

The above equation A-2 for sound pressure level propagated to the environment is often expressed in a simpler form given by the following equation

$$L_p = L_w - D_c - A$$ *Equation A-3*

where L_p = *Sound pressure level, dBA (ref 20 micro Pascals)*
L_w = *Sound power level, dBA*
D_c = *Directivity constant (dependent on orientation & location of noise source)*
A = *Attenuation factor, dBA*

The attenuation factor (A) is the cumulative attenuation due to distance and geometric spreading loss (A_{div}) i.e. distance, r of a receiver from the noise source, atmospheric absorption (A_{atm}), ground effects (A_{gr}) and other miscellaneous loss (A_{misc}). In addition to the above, barrier shielding effects (from noise barrier, shielding screens, etc.) offers further sound attenuation ($A_{barrier}$).

The attenuation factor for distance and geometric spreading loss is given by:

$$A_{div} = 20\ k_g \log (r/r_o)\ dB$$ *Equation A-4*

where r = *is the distance from source to receiver (m)*, r_o = *is a reference distance (1 m)*
k_g = *is a geometry constant (=1 for point source, = 0.5 for line source)*

For sound propagation to distance less than 100m to 500m without shielding, the attenuation factor (*A*) would be mainly from distance and geometric spreading loss A_{div}.

The attenuation factor for atmospheric absorption is given by:

$$A_{atm} = \alpha_r / 1000 \text{ dB per km} \qquad \textit{Equation A-5}$$

where α_r = *atmospheric absorption constant, dB.*

The constant α_r is dependent on atmospheric conditions as defined in ISO 9613 Part 1.

The ground effects (A_{gr}) are given in Equation 8.5 of ISO 9613 – Part 2, and barriers loss ($A_{barrier}$) are given in Equation 8.6 to Equation 8.11 in ISO 9613 – Part 2.

Additional information for calculations of sound propagation are given in ISO 9613 – Part 2 Acoustic- Attenuation of sound propagation outdoors- Part 2: General method of calculation.

Sound level reduction with distance under idealized condition

An example of sound propagation and calculation for noise attenuation (reduction) for a receptor for different distances for a point source (e.g. equipment, single vehicle, etc.) is given in Figure A-1. A similar example for a line source (such as highways and railways) is given in Figure A-2. The calculations are for idealised conditions without other effects (other than distance and geometric spreading).

The examples show noise levels at different distances from the source. The equation used for the calculation for distance loss (based on Equation A-4) is simplified to Equation A-4(a) and Equation A-4(b) as shown in the respective figures.

Noise levels from a point source reduces 6 dB for doubling of distance; and for line sources 3 dB reduction for doubling of distance.

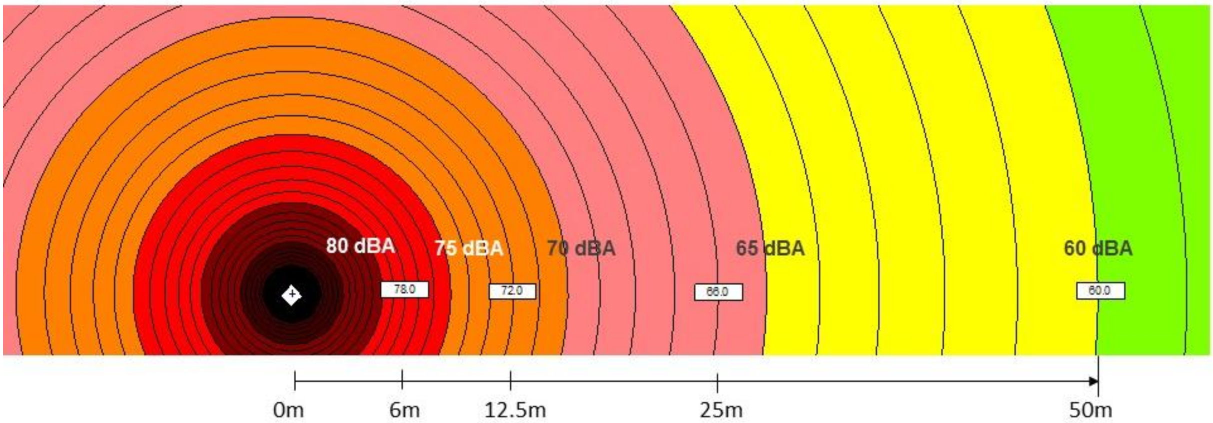
Sound level reduction with distance from line source under practical situations

Practical situations would have several line sources and reflections from buildings and ground effects. Figures A-3 to A-4 shows noise propagation from line source (roads and highways) under practical situations which includes ground and building reflections of sound waves. Noise levels at different distances away from the roads, and also at different locations of receptors in a high-rise building are also illustrated.

Sound level reduction with distance from point sources under practical situations

Practical situations usually involve multiple point sources, ground effect, (reflections and shielding). Examples of multiple point sources noise propagation from industry premises are given in Figure A-5 to Figure A-8. The examples show noise levels at receptors located at different distances away from the noise sources.

As shown here, under practical situations where noise sources and receptors are located close to large reflection surface, sound reflections occur which distorts and reinforce multiple sound reflections influencing final noise level perceived at receptors.

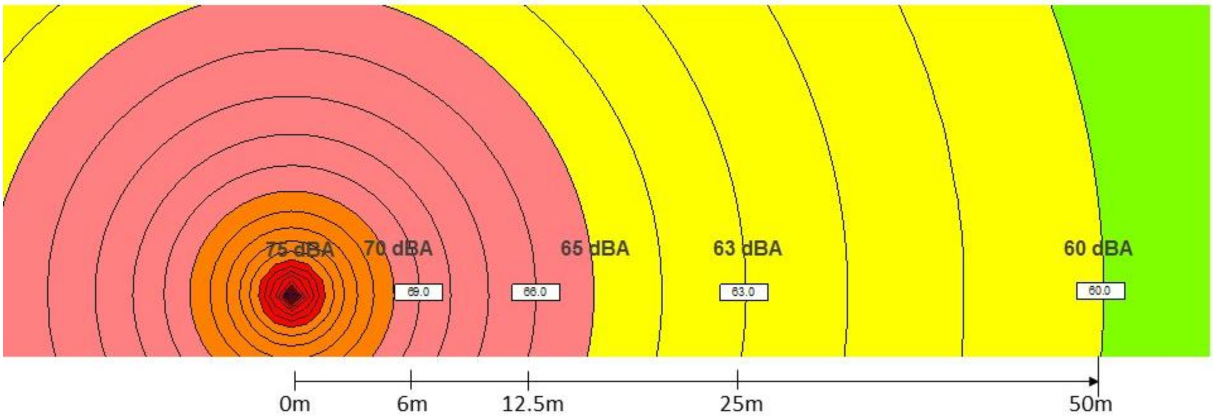


$$\textbf{Distance Loss } (A_{div}) = 20 \log (r/r_o) \text{ dB} \qquad \textit{Equation A-4(a)}$$

$$L_{p2} = L_{p1} - 20 \log (r_2/r_1) \qquad \textit{Equation A-6}$$

Line source	Reference	Noise levels				
Distance, m	6.0	12.0	25.0	50.0	100.0	200.0
Noise level, dBA	69.0	66.0	62.8	59.8	56.8	53.8
dB Difference		3.0	3.2	3.0	3.0	3.0

Figure A-1: Noise attenuation with distance for point source



$$\textbf{Distance Loss } (A_{div}) = 10 \log (r/r_o) \text{ dB} \qquad \textit{Equation A-4(b)}$$

$$L_{p2} = L_{p1} - 10 \log (r_2/r_1) \qquad \textit{Equation A-7}$$

Point source	Reference	Noise levels				
Distance, m	6.0	12.5	25.0	50.0	100.0	200.0
Noise level, dBA	78.0	71.6	65.6	59.6	53.6	47.5
dB Difference		6.4	6.0	6.0	6.0	6.0

Figure A-2: Noise attenuation with distance for line source

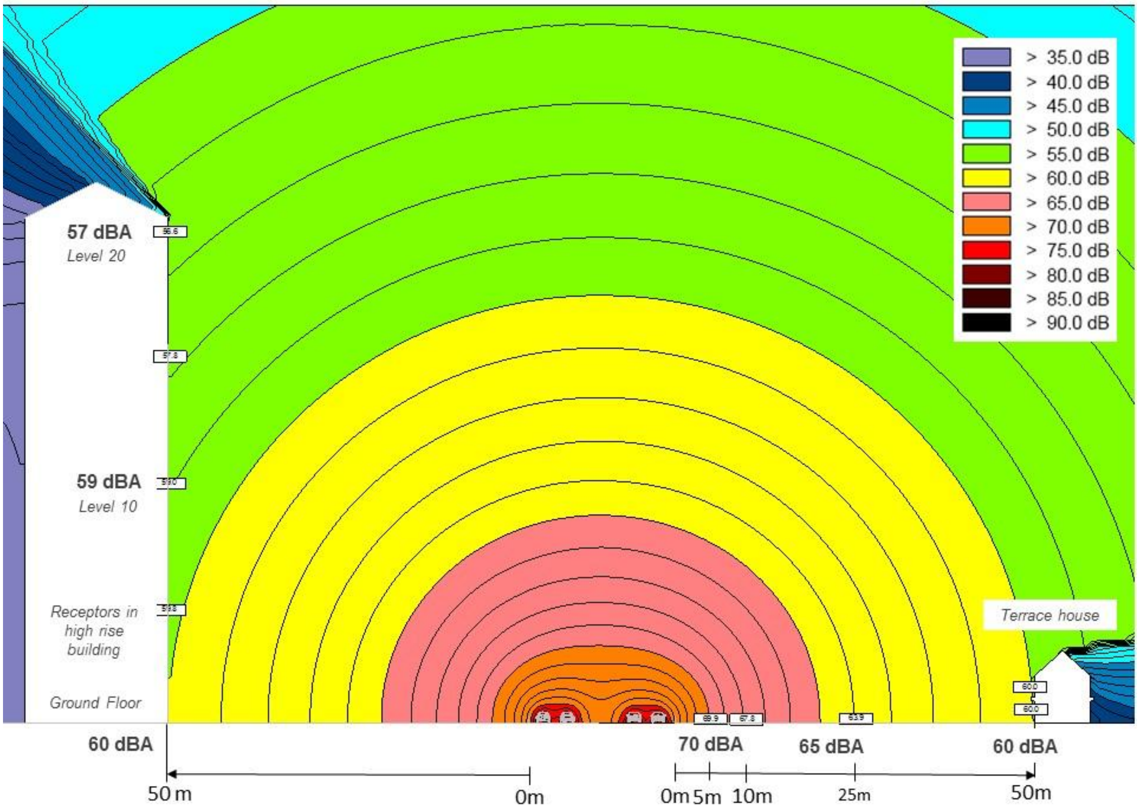


Figure A-3: Noise propagation from line sources (highway) on grade to receptor at different distance and elevation to source

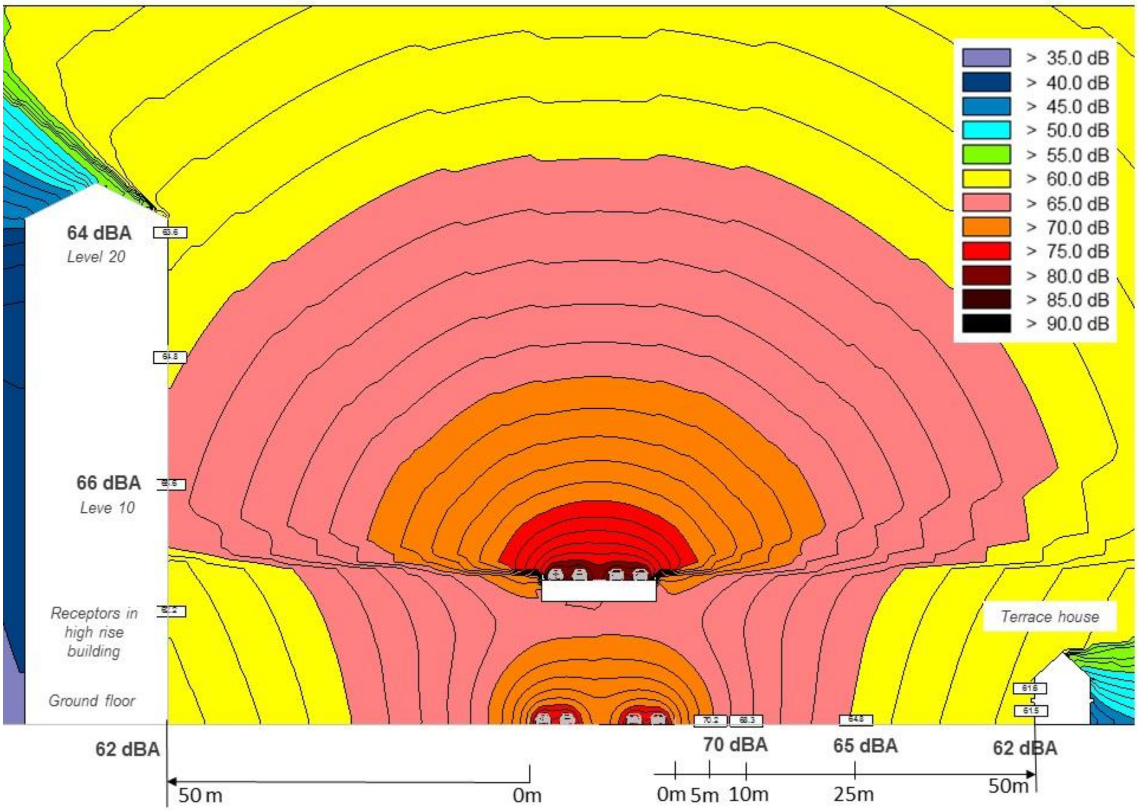


Figure A-4: Noise propagation from line sources (highway) on grade and elevated viaduct to receptor at different distance and elevation to source

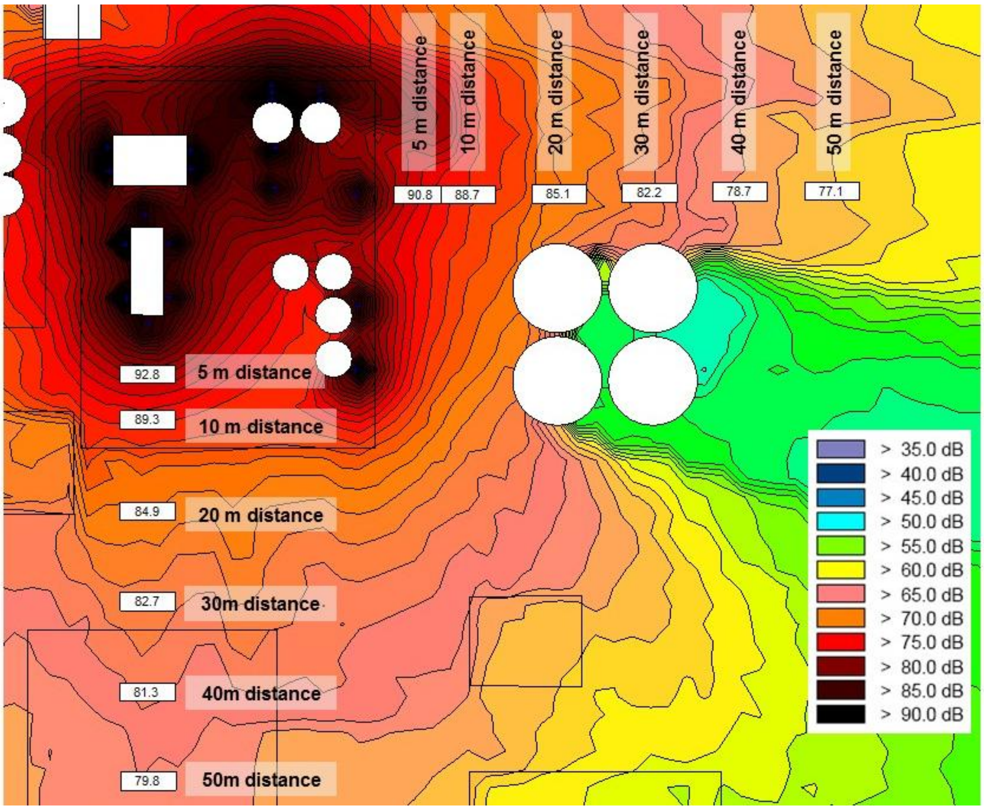


Figure A-5: Noise propagation from point sources in an industrial plant to receptor at different distances from noise sources

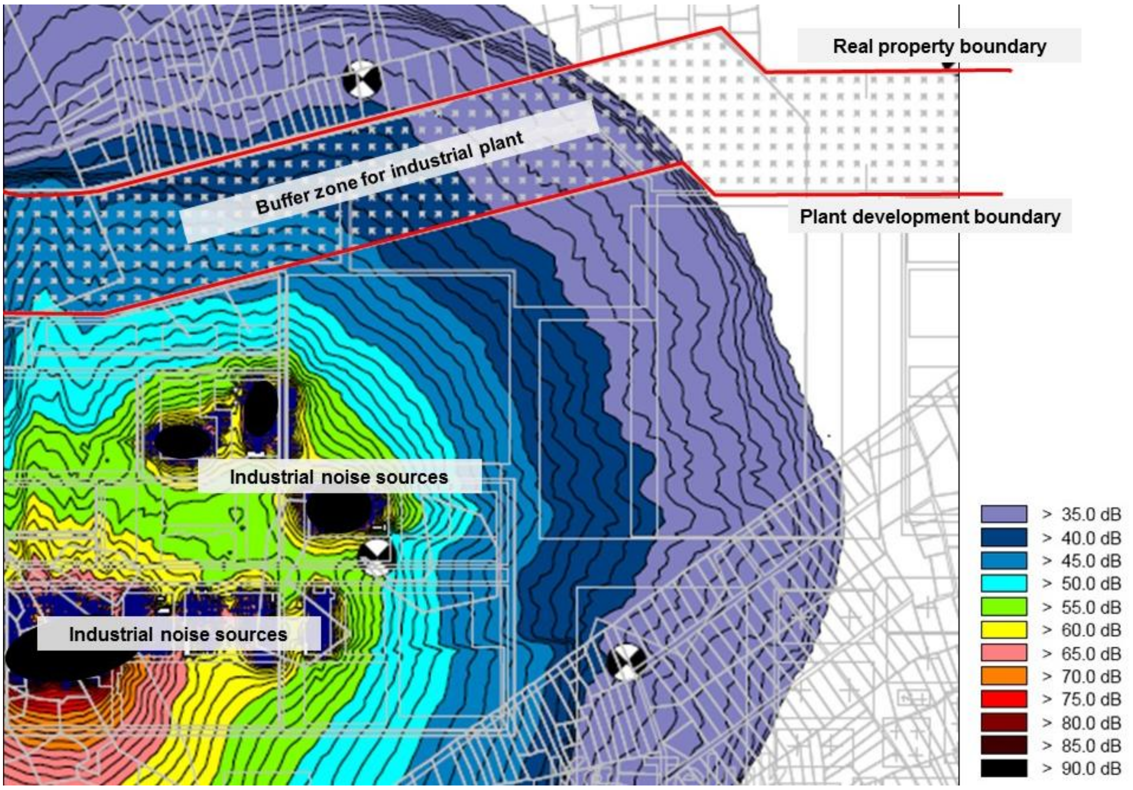


Figure A-6: Noise propagation from industrial plant to environment (with buffer zone) at far distances

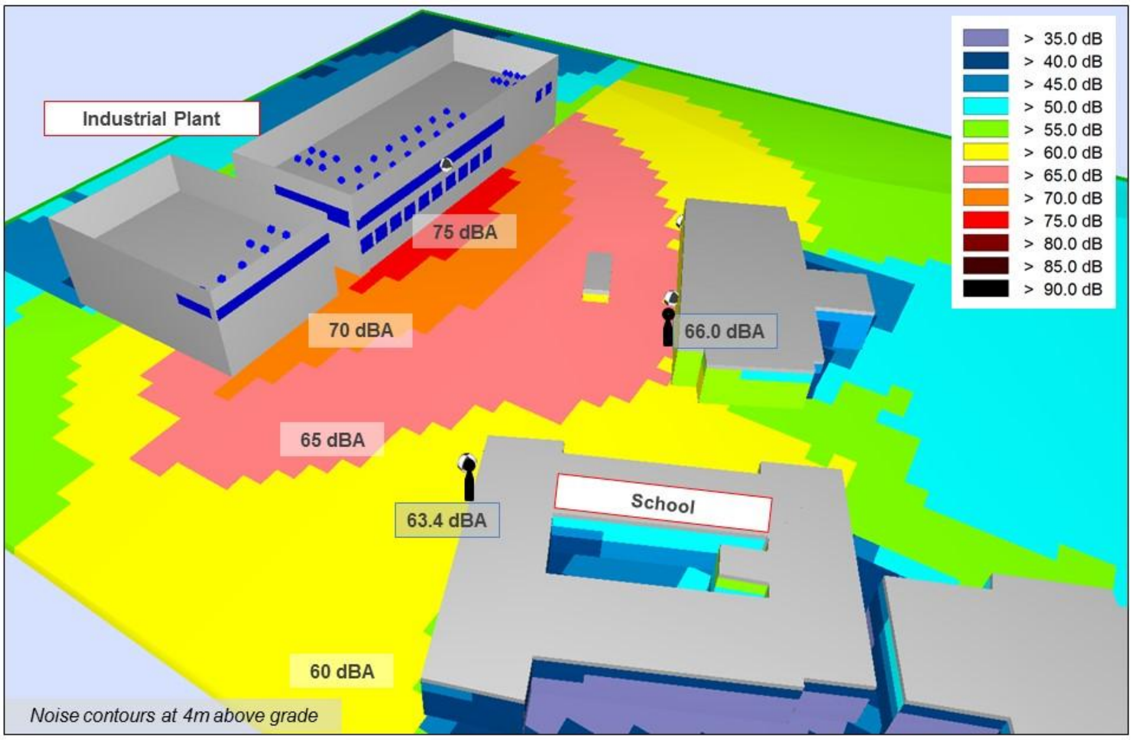


Figure A-7: Example of a sensitive receptor adjacent an industrial plant in an urban environment (3-D view)

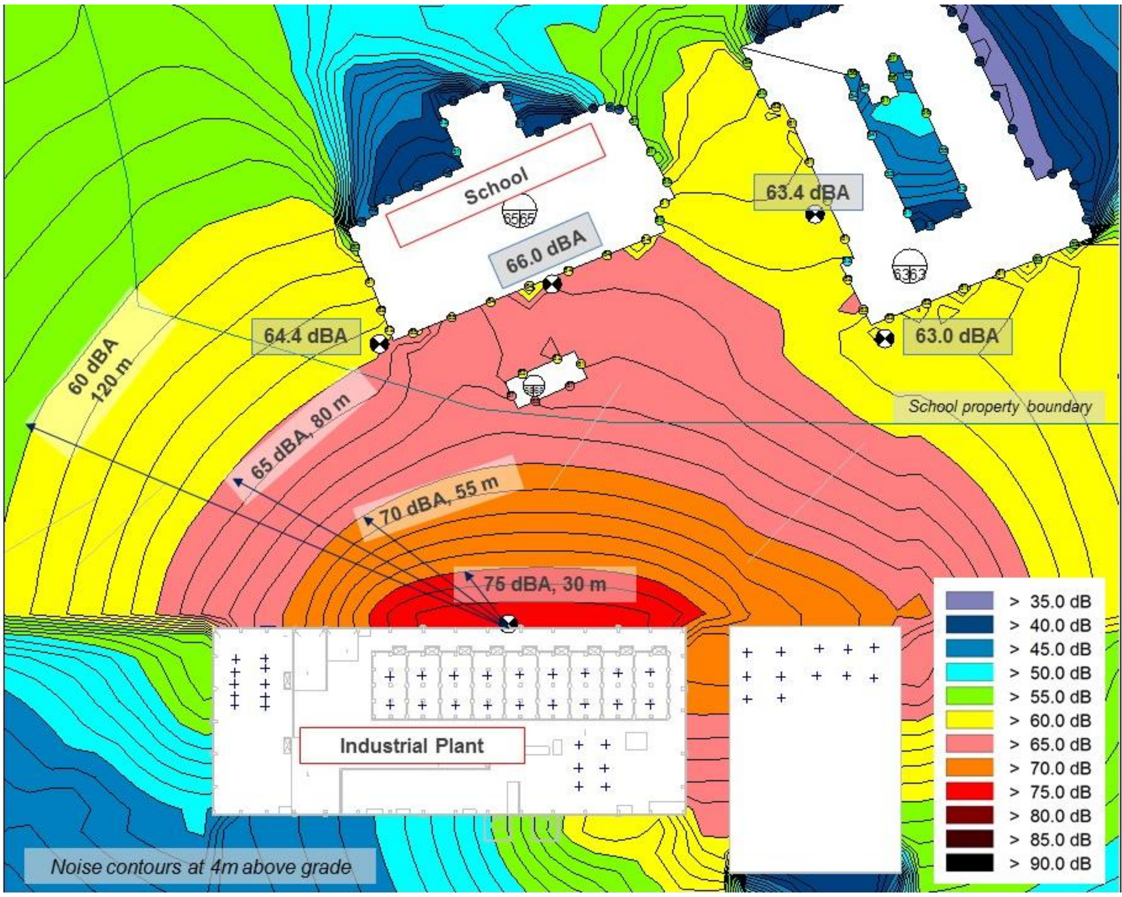


Figure A-8: Example of a sensitive receptor adjacent an industrial plant in an urban environment showing noise levels (and contours) at different distances from noise sources

Worked Examples

1 Noise measured outdoors at a plant boundary from a genset located 12m from the boundary was 72 dBA. What is the expected noise level at a house located 6m from the plant boundary?

L_{p1} = 72 dBA — Boundary to source, $r_1 = 12m$
L_{p2} = ? — Receptor to source, $r_2 = 6m + 12m = 18m$

$$\mathbf{L_{p2} = L_{p1} - 20 \log (r_2/r_1)}$$
$$L_{p2} = 72 - 20 \log(18/12) = 72 - 3.5 = \mathbf{68.5\ dBA}$$

2 For the same plant in Question 1 above, what is the required distance for a receptor to be away from the genset for a noise level at receptor to be 65 dBA?

Re-arranging equation $\mathbf{L_{p2} = L_{p1} - 20 \log (r_2/r_1)}$ *to the following form to determine* r_2 *with a known value for* L_{p2}

$$\mathbf{r_2 = r_1 \times 10^{((Lp1-Lp2)/20)}}$$ *Equation A-8*

Required distance: $r_2 = 12 \times 10^{((72-65)/20)} = 12 \times 10^{(7/20)} = 12 \times 10^{(0.35)} = \mathbf{26.9\ m}$

3 Road traffic noise measured in an open field 8m from a highway was 78 dBA. What is the noise level for a roadside receptor standing 3m away from the highway?

L_{p1} = 78 dBA — Measurement location to highway, $r_1 = 8m$
L_{p2} = ? — Receptor to highway, $r_2 = 3m$

$$\mathbf{L_{p2} = L_{p1} - 10 \log (r_2/r_1)}$$
$$L_{p2} = 78 - 10 \log(3/8) = 78 - (-4.3) = \mathbf{82.3\ dBA}$$

4 Based on the above measured highway noise in Question 3 above, what is the minimum distance away from the highway for new houses planned adjacent this Highway to comply with a noise level at the houses not exceeding 65 dBA (assuming road traffic conditions do not change and without highway noise barriers)?

Re-arranging equation $\mathbf{L_{p2} = L_{p1} - 10 \log (r_2/r_1)}$ *to the following form to determine* r_2 *with a known value for* L_{p2}

$$\mathbf{r_2 = r_1 \times 10^{((Lp1-Lp2)/10)}}$$ *Equation A-9*

Minimum distance: $r_2 = 8 \times 10^{((78-65)/10)} = 8 \times 10^{(13/10)} = 8 \times 10^{(1.3)} = \mathbf{160\ m}$

ANNEX B

PROCEDURES FOR MEASUREMENT OF ENVIRONMENTAL NOISE

1.0 Measurement Equipment

1.1 Overview

1.1.1 Instrumentation for environmental noise measurements are of the following generic types:

- Hand held sound level meters; and
- Permanent or semi-permanent noise monitoring terminals.

1.1.2 Hand held sound level meters in general are manually operated and are intended for short term measurements (typically up to a day). These meters are either hand held or mounted onto a tripod with the entire instrument exposed or alternatively with a detachable pre-amplifier and microphone exposed (and instrument body only inside a weather proof casing).

Microphones that are supplied with general purpose sound level meters are usually not suitable for extended outdoor noise measurements as these microphones are not water proof and prone to drift with humidity exposure. Dedicated microphones for all weather monitoring are recommended.

1.1.3 Permanent or semi-permanent noise monitoring units and smart monitors are purposed built noise monitoring devices (from original equipment manufacturer and not end user modified sound level meter) intended for long term automated outdoor all-weather noise monitoring over extended period for all weather conditions with no sensitivity degradation from long term outdoor exposure. The data logging unit is enclosed in a weather proof casing, or alternatively come fitted with an integral all-weather casing.

Microphones for permanent noise monitoring units are purpose designed waterproof all weather use with long term stability to metrological exposure.

1.2 Hand held Sound Level Meters

1.2.1 Sound level meters may be of the following basic types:

- Simple sound level meter
- Integrating-averaging sound level meter
- Integrating sound level meter.

Simple sound level meters typically provide overall A-weighted sound pressure levels (L_p dBA) and instantaneous maximum levels (L_{max}). Integrating sound level meter shall be required to determine the A-weighted equivalent steady state sound pressure levels (L_{Aeq} dBA). Sound level meters with statistical functionality are required to determine the percentile sound pressure levels (L_{10}, L_{90} levels).

Sound level meters may have additional functions for frequency analysis with octave and one third octave frequencies to provide noise frequency spectrum information of the noise.

1.2.2 IEC standards divide sound level meters into two "classes". Sound level meters of the two classes have the same functionality, but different tolerances for error. Class 1 instruments have a wider frequency range and a tighter tolerance than a Class 2 unit.

1.2.3 Measurements for compliance reporting (EIA and EMP for example) must be undertaken using Class 1 meters.

Sound level meter shall be certified to IEC 61672-1 (*or latest revision*) Class 1 specifications including windscreen/windshield effects (for both reference directions 0 degrees and 90 degrees); and conform to IEC 60651 Class 1, IEC 60804 Class 1.

1.2.4 The sound level meter may be hand held for simple spot readings, but for extended monitoring shall be mounted onto a tripod during the entire measurement duration. A standard accessory of extension cable with pre-amplifier may be used to enable the microphone to be installed at higher levels detached from the sound level meter body.

1.2.5 Microphone used for continuous monitoring shall be an outdoor weatherproof type. The use of general-purpose microphone not intended for all weather outdoor use should not be permitted.

An example of sound level meters used for outdoor noise monitoring is shown in Figure B-1.

1.2.6 Noise dosimeter or simple integrating sound level meter intended for personnel noise dose monitoring for occupational noise exposure purpose must not be used as an alternative to sound level meters or noise monitoring units.

1.3 Permanent or Semi-Permanent Noise Monitoring Units

1.3.1 Permanent or semi-permanent noise monitoring units are recommended for continuous outdoor environmental noise monitoring. Recommended features and functionalities are as follows:

(a) The monitoring unit have self-monitoring capabilities with automated data storage with on-board memory and automatic downloading of data and data transmission.

(b) The microphone is waterproof and have a self-checking system.

(c) The monitoring unit have 3G and WLAN communication capabilities for remote operation and communications. Communications typically conform to industry standard internet and security protocols for safe and reliable data transfer.

(d) The monitoring unit shall have automatic audio recording of noise events exceeding pre-defined thresholds for data playback for audio recognition of noise events.

(e) The monitoring unit shall have automatic notification capabilities (text message via sms, etc.) for noise events exceeding pre-defined thresholds.

(f) Microphone shall have selectable reference direction between 0 degrees (top) and 90 degrees (side) intended for outdoor environmental noise measurements

1.3.2 The monitoring unit are certified to IEC 61672-1 Class 1, specifications including windscreen/windshield effects (for both reference directions 0 degrees and 90 degrees); and conform to IEC 60651 Class 1, IEC 60804 Class 1.

1.3.3 Permanent or semi-permanent noise monitoring units are recommended for continuous monitoring of construction works as these devices require no manual operations and data recording setting after the initial setup.

1.3.4 Data retrieval are either by means of wireless communication at periodic intervals at site or via 3G data transfer from the built-in communications protocol.

1.3.5 Use of permanent automatic monitoring units are recommended for extended continuous monitoring when manned monitoring using sound level meters is not viable or practical. An example is shown in Figure B-2.

1.4 Calibration

1.4.1 Calibration of sound level meters and noise monitoring units should be conducted by a calibration laboratory or original equipment manufacturer at intervals not exceeding two years or other frequency determined by DG or recommended by manufacturer.

1.4.2 It is recommended that calibrated reference sound sources used to check calibration in the field (sound level calibrators) should also be calibrated at two years interval.

1.4.3 A field check of instrument calibration shall be made before and after each set of measurements, using a calibrated reference sound source to ensure accuracy of ± 1 dB.

1.4.4 Notwithstanding the above, where instrumentation used for long term permanent monitoring to be checked at regular intervals (once every 6 months) to ascertain reliability and stability of the monitoring system.

1.4.5 If during a field check of instrument calibration, the sound level meter reading differs from the calibrated reference level, the difference must be noted. Any measurements taken in the interval since calibration was last checked should be adjusted accordingly. In all cases, where a difference in field calibration of more than 1 dB is noted between consecutive checks, measurement data obtained during the previous interval should be discarded.

Figure B-1: **Example of sound level meter for environmental noise measurements**

Figure B-2: Example of semi-permanent and permanent outdoor monitoring unit

2.0 Monitoring Locations

2.1 Noise monitoring locations at sensitive receptors may typically involve one of the following land use types and receptors:

a. Residential areas (houses, condos, apartments, etc.)
b. Mixed land use (usually with residential dwellings at higher floors)
c. Service apartment and hotels (even if located in commercial zones)
d. Schools, institutions of learning (colleges, universities, kindergarten, etc.)
e. Hospitals, medical buildings, nursing homes, etc.
f. Places of worship (mosques, church, temples)
g. Commercial buildings (in close proximity)
h. Special buildings (performing theatres, museums, etc.).

2.2 Monitoring locations in general shall be at the real property boundary of receptors of concern such that noise propagated to the receptors could be quantified. In high rise buildings additional monitoring locations may include open facades at higher floors of the receptors' building.

2.3 For permanent noise monitoring at construction or industrial sites the noise monitoring units may also be located at the work site or plant boundary away from extraneous noise source(s) not related to the noise source of concern.

2.4 Measurements shall be made at all strategic location representative of affected receptors. They should include locations at closest proximity to noise source.

2.6 The measurement location shall not be located within 3.5 m adjacent any sound reflecting surface, or other extraneous sources (not related to source of interest).

2.7 Care shall be taken to avoid influence on the result from other unwanted sound signals, for example noise from wind on the microphone of the measuring equipment, noise from electrical interference or noise from extraneous sources.

2.8 Illustrations showing recommended measurement positions for several typical scenarios are given in Figures B-3 to B-10.

Figure B-3 shows recommended measurement locations at the property boundary of a residential property, with measurements on grade either at ground level, or on an elevated position above ground. Figure B-4 shows recommended minimum distances of the microphone positions to be away from reflecting surfaces.

Illustrations of measurements undertaken before a project commencement and after completion (with new highway operations) is shown in Figure B-5 and B-6 respectively with recommended measurement locations of affected receptors shown (residing in low and high-rise buildings).

Examples of measurement locations for industrial plants are shown in Figures B-7 to B1-10. The locations shall be at property boundary. Where required, monitoring may also include locations inside the plant boundary to obtain near field noise data on noise emission levels of outdoor sources for severity assessment and noise source ranking.

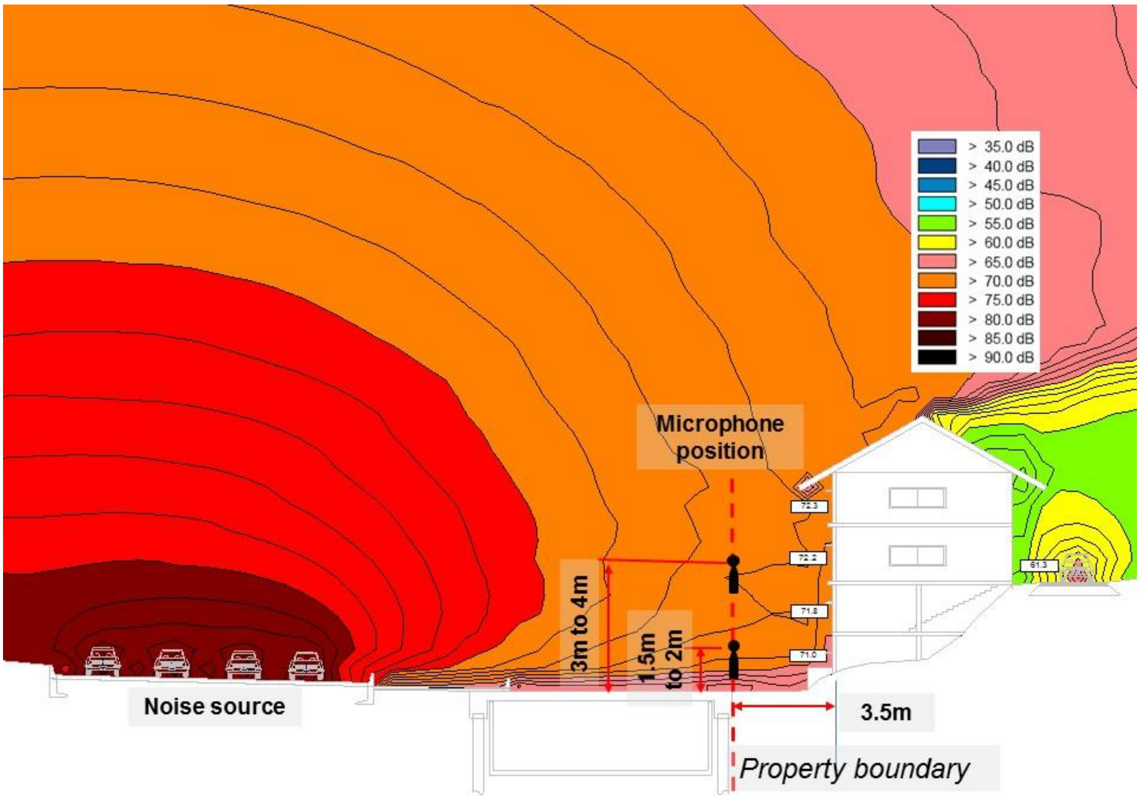


Figure B-3: Recommended noise measurement location

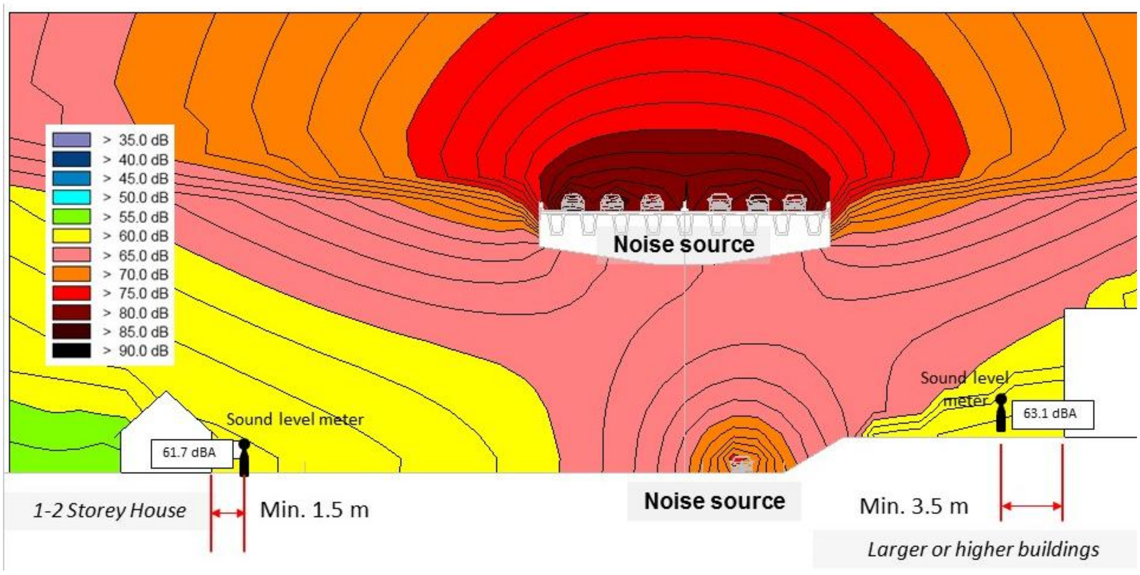


Figure B-4: Microphone position located near buildings or refection surface

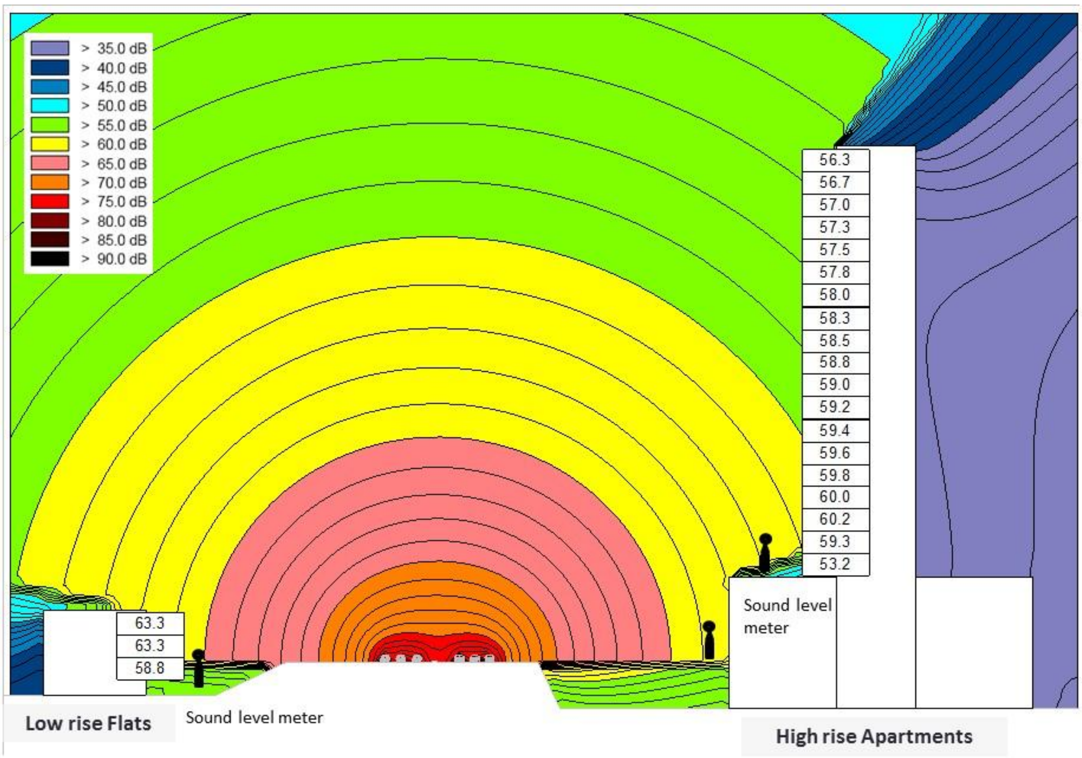


Figure B-5: Baseline noise measurement before project commencement

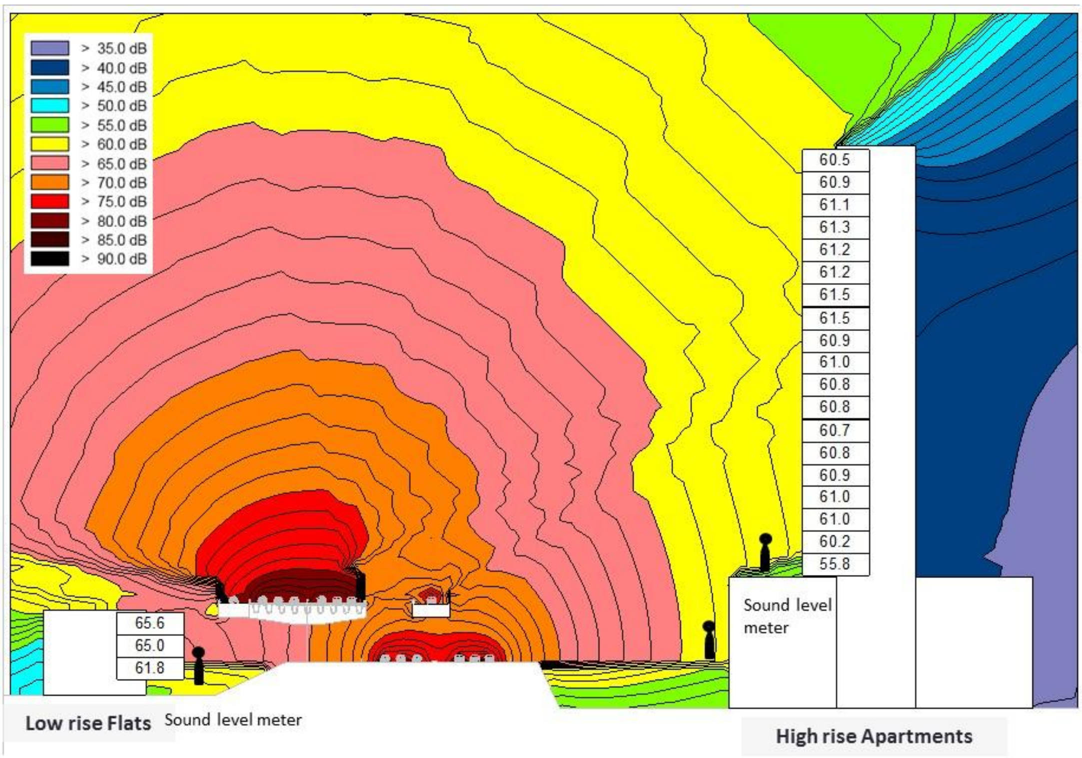


Figure B-6: Noise measurement after project completion

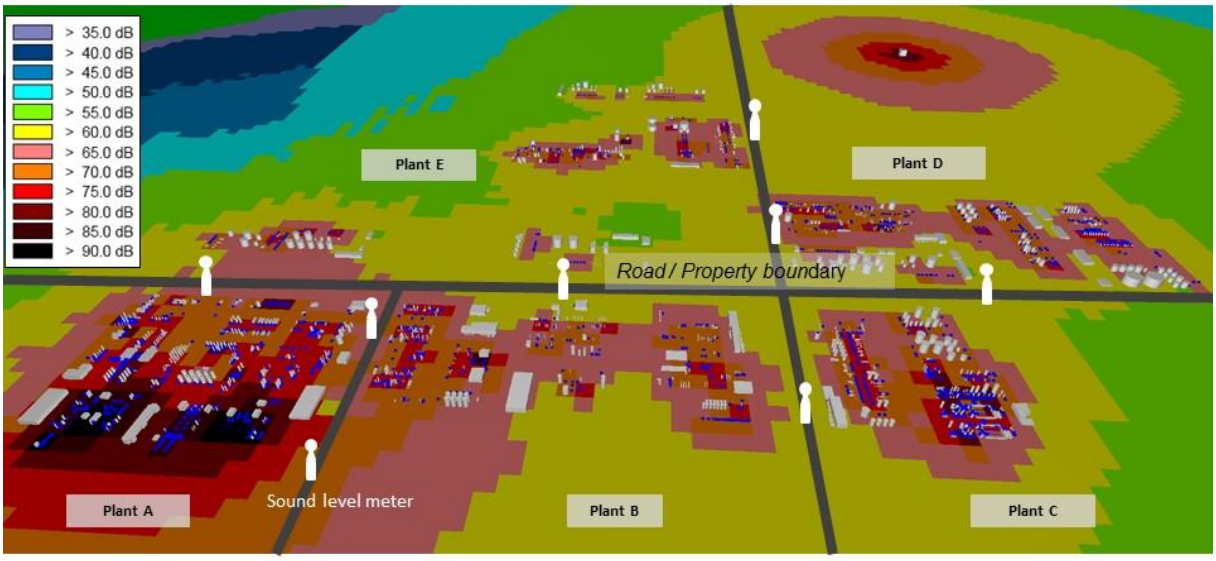


Figure B-7: Example of noise measurement locations at industrial sites

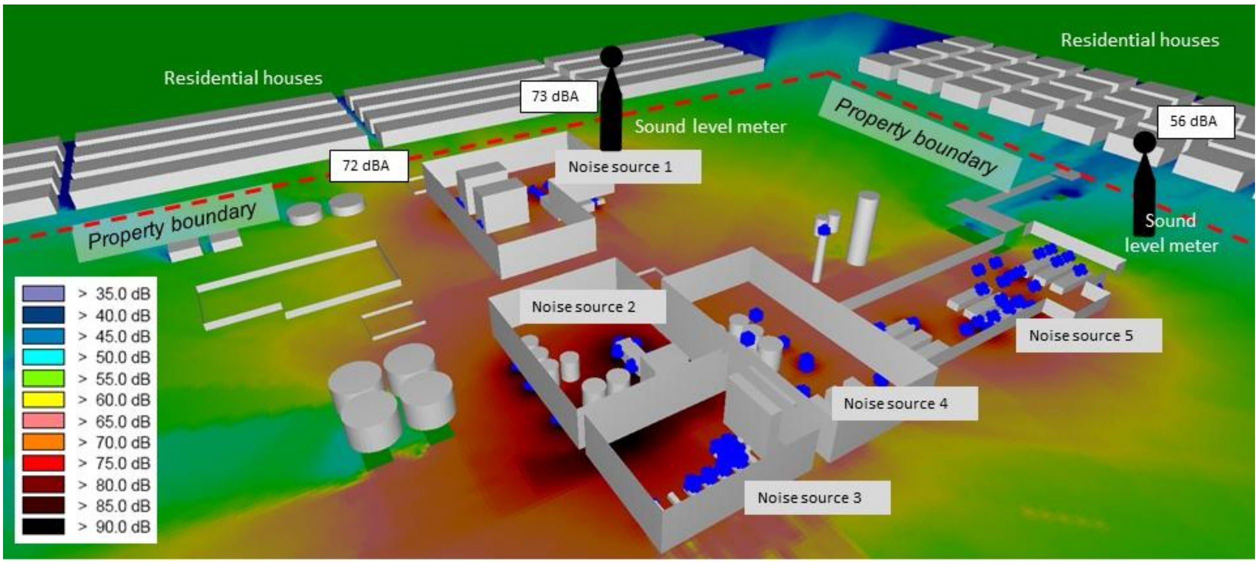


Figure B-8: Example of boundary noise measurement locations for industrial plants

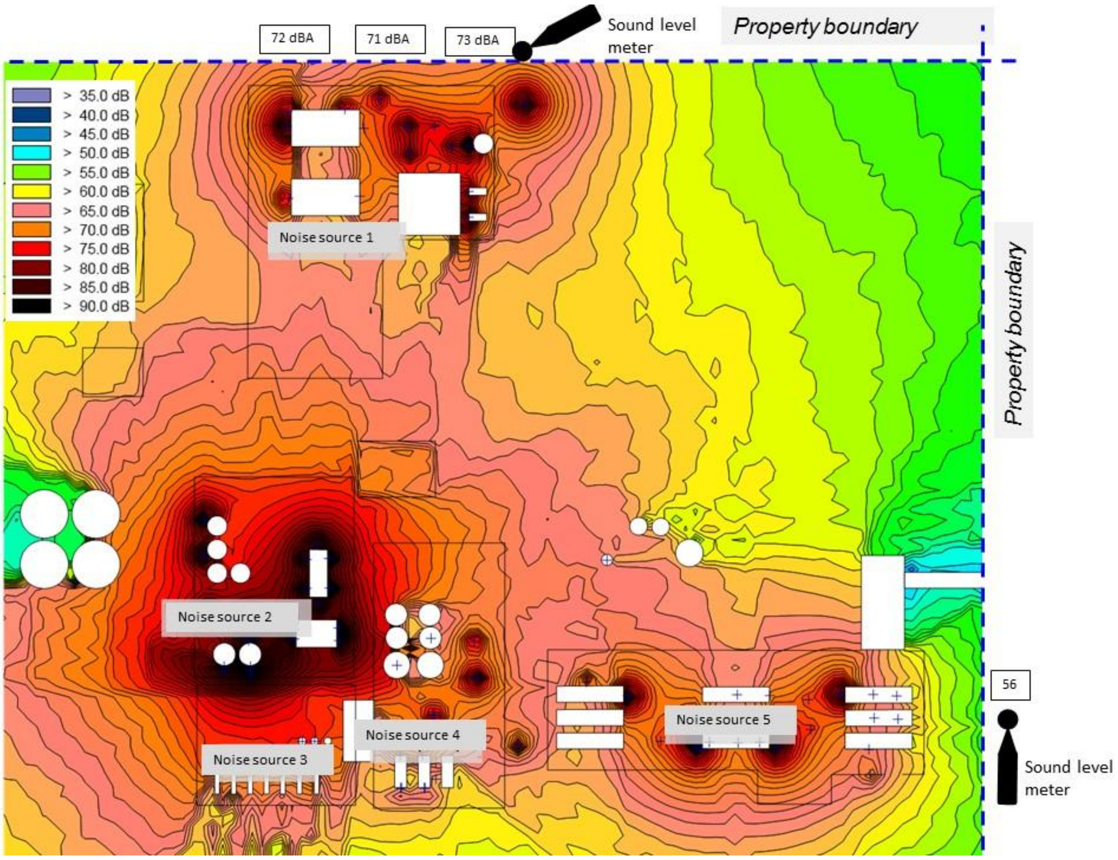


Figure B-9: Example of boundary noise measurement locations for industrial plants

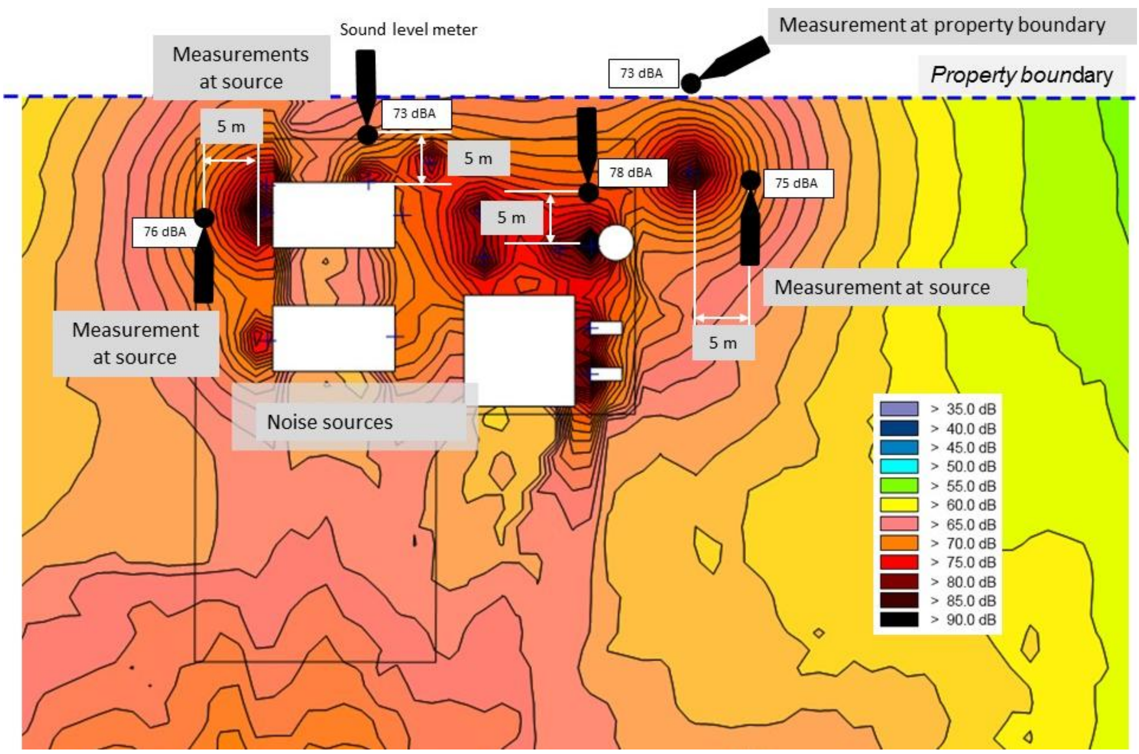


Figure B-10: Example of noise source measurement in industrial plants

3.0 Measurement Procedures

3.1 Noise measurements may be undertaken using sound level meters or semi-permanent / permanent noise monitoring units.

3.2 Measurements for environmental noise shall be made outdoors. Sound level meters shall be mounted on a tripod with the microphone at least 1.2 to 1.5 m above the ground. Examples are shown in Figure B-1 and Figure B-11.

Figure B-11: Example of noise measurement of trains pass by noise on grade

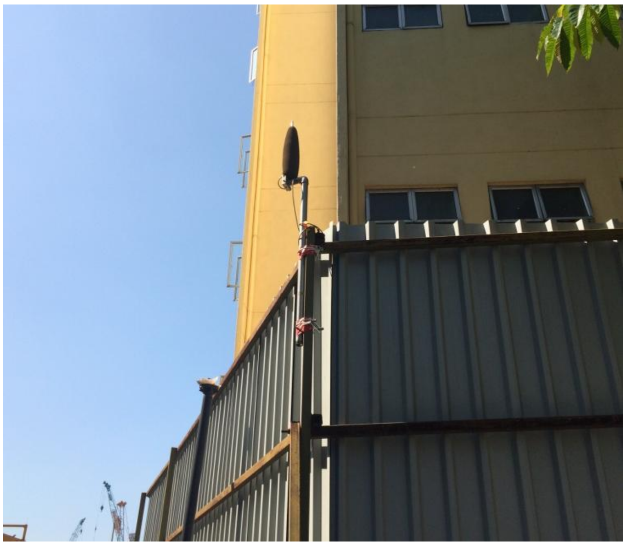


Figure B-12: Example of continuous noise monitoring using permanent noise monitoring unit at site boundary adjacent sensitive receptor

For continuous noise monitoring using permanent noise monitoring instrument, the unit may be secured onto a fixed structure or suitable mounting location no less than 1.5m and preferably 4m above ground. An example is shown in Figure B-12.

3.3 Measurements for noise assessment of receptors in high rise buildings may be undertaken at open spaces or terraces (such as recreational floor, open deck, car park or corridor spaces in the building) at elevated floors balcony of affected units in the building with a line of sight to the noise source.

The intent here is to determine noise levels at the respective affected floors along the building façade in situations where measurements at grade may not necessarily provide an accurate measurement of elevated noise sources (such as elevated highways or transit trains on viaducts).

An example showing measurements at the open terrace in building in a high-rise building is shown in Figure B-13. Another example is shown in Figure B-14 where the microphone fitted with an extension cable was located beyond the building façade typically used for measurements from open car park and balcony.

Figure B-13: Example of noise measurement at open terrace in a high-rise building

Figure B-14: Example of microphone located beyond building facade

It is important that the measurement is not affected by other extraneous noise from equipment (such as air conditioning unit, pumps, etc.) that may be located nearby.

3.4 The measurement location shall be at least 3.5m away from walls, buildings or other sound reflecting structures.

3.5 When circumstances dictate, measurements may be made at greater heights or closer to a wall (for example 0.5 m in front of an open window); and these special conditions indicated in the measurement records.

3.6 The microphone shall be installed in its correct orientation corresponding to the designed directivity (i.e. reference directions of either 0 degrees or 90 degrees) in the direction of the noise source(s).

3.7 Hand held sound level meters must not be placed into an enclosure of any time. Placement of a sound level meter with the microphone per-amplifier stem inside an enclosure or cabinet must not be done.

Figure B-15: Examples of unacceptable use of sound level meter installed in a casing as an alternative to permanent noise monitoring units

Examples showing unacceptable monitoring using hand held sound level meter installed into an enclosure for continuous monitoring (instead of using purpose designed permanent monitoring unit) are shown in Figure B-15.

The exception to the above is when the microphone is fitted onto an extension cable with a pre-amplifier, and the sound level body is housed in a protection casing as part of an OEM supplied outdoor monitoring system as shown in Figure B-1.

3.8 Hand held sound level meters shall preferably be manned during the duration of monitoring.

3.9 Unmanned monitoring shall only be undertaken with monitoring units or smart monitors designed for automated unmanned environmental noise monitoring fitted with all-weather waterproof microphone and automatic data logging. Examples of unmanned semi-permanent noise monitoring is shown in Figure B-2, and long term permanent monitoring in Figure B-12.

3.10 The microphone must be placed in an open location without any obstructions or affected by reflections or shielded from the noise sources. This includes sound level meter underneath an umbrella or adjacent an air quality measurement equipment (which inherently emits noise) as shown in Figures B-16 and B-17.

Figure B-16: Example of unacceptable monitoring in progress with sound level meter placed under an umbrella (apparently for weather protection)

Figure B-17: Example of unacceptable monitoring in progress with sound level meter obstructed by objects (and adjacent extraneous noise source)

3.11 A wind shield approved by the microphone manufacturer shall be used.

Measurements cannot normally be made if the wind speed exceeds 5m/s at the microphone position. For continuous remote monitoring, the wind speed may be monitored concurrently with the sound levels.

3.12 Noise measurements shall be conducted with the sound level meter set to "A-weighting" scale with "Fast" time response.

3.13 Measurements shall provide equivalent steady state noise levels L_{Aeq} in 15 minutes or one-hour time segments sampled continuously over 24 hours day night cycle. L_{max} noise levels shall be reported for hourly period over the entire 24 hours cycle, and statistical percentile noise levels L_{10} and L_{90} reported hourly period over the entire 24 hours cycle.

3.14 Measurement for blasting and other explosion related activities shall be made using Z-scale or linear weighting network for peak value ("peak" time constant setting) with a "maximum hold" function of the sound level meter.

3.15 Other supplementary measurement(s) of impulsive sound, for reporting and record keeping, shall be measured using an "impulse" time weighting response.

3.16 Where required, measurement for low frequency or infra-sound shall be measured using the Z-scale weighting network.

3.17 For measurements of special events and/or for noise control measurements and data reporting for noise frequency spectrum in octave band or one third octave band center frequencies may also be undertaken.

3.18 Unless required otherwise, noise level measurements shall be presented to a single decimal place with the appropriate units specified (e.g. 64.3 dBA).

4.0 Number, duration and stages of measurements

4.1 The number and duration of measurements in general depends in the purpose of the measurements, resources available and time over which the noise sources(s) is to be measured.

4.2 Measurements are usually undertaken for the following purpose:
(a) Baseline noise measurements to establish the prevailing ambient noise levels.
(b) Measurements as part of an Environmental Management Plan (during construction works for example).
(c) Measurements post construction and before operational phase.
(d) Measurements during service operations
(e) Measurements for investigations and/or data gathering (for noise control).

4.3 Duration of measurements are generally in three broad categories. The data sampling deemed most appropriate is dependent on the purpose and accuracy required of the monitoring.

(a) *Continuous day night sampling*
This measurement involves the continuous sampling of instantaneous sound pressure level for the entire duration of a day (0700 to 2000 hours) and/or night (2000 to 0700 hours) to obtain the day time $L_{Aeq\ day,\ 15h}$ and night time $L_{Aeq\ night,\ 9h}$.

Data sampling can be undertaken in a continuous mode (with data sampling once every second minimum) for the entire day/night period using an integrated sound level meter, or sampled continuously on an hourly basis and repeated continuously over the hours to obtain the $L_{Aeq,\ 1h}$ levels, and the $L_{Aeq\ day}$ and $L_{Aeq\ night}$ computed from the hourly $L_{Aeq,\ 1h}$ noise levels time profile.

The monitoring can be for a complete 24 hours day night period; and if necessary repeated over multiple days or longer as the case may be in semi-permanent monitoring over the entire construction period, or perpetual for permanent service monitoring.

(b) *Short term sampling*
This measurement involves continuous sampling of instantaneous sound pressure level over a designated duration (for example 30 minutes or one-hour duration) for specific time of a day. Due to measurements not undertaken for the entire day night duration, readings at best may be deemed to be an approximate representative level if there are no significant variations over time. Uncertainty and errors in the L_{Aeq} values are nevertheless inevitable.

(c) *Events monitoring*
This measurement involves sampling of instantaneous sound pressure level over a specific event(s) to obtain noise levels related to the activity or events. This may typically include piling noise, trains pass-by noise, aircraft noise and any work activities noise that may occur from time to time. Monitoring of piling noise may include the entire duration of the piling works and if required to follow the location of piling works as in railways or highway projects. Trains pass by noise may be over an hour or/and repeated over different time periods of the day or night to obtain train pass by hour averages.

4.4 Measurements for equivalent sound levels (L_{Aeq}) and statistical centile levels (L_{10}, L_{90}, and L_{max}) shall be undertaken with continuous sampling for the entire period of interest, i.e. daytime, evening, and night-time.

4.5 The frequency of measurements (how often) and duration (for how long) in principle are dependent on the purpose of the measurements, and submission requirements of the measurements to parties requiring the measurements.

The frequency may be a one-off measurement for baseline data; or repeated over regular intervals for compliance reporting and audit. Monitoring may even be on a perpetual continuous permanent basis (e.g. in airport and construction work sites monitoring).

4.6 In the interest of protection of public, including abatement for community annoyance response, the Department of Environment or Local Authorities may at its discretion require permanent or semi-permanent long-term monitoring for sound to be undertaken by person(s) responsible for the excessive noise generation consistent with the period or duration the noise source(s) may be in operation or anticipated to be a nuisance.

This may include construction work sites, highways and airports for example.

4.7 To illustrate the type and different stages of noise measurements to be undertaken during different stages of a project, examples are shown in Figure B-18 to Figure B-23 as described below.

Figure B-18 shows a typical measurement for baseline noise measurement as routinely undertaken in an EIA or during project implementation prior to commencement of construction works for the project. The measurements typically shall include all prevailing existing noise sources (and in this example noise from existing roads, etc.).

The baseline measurements shall include L_{Aeq} levels, L_{max} and usually L_{10} and L_{90} levels. Figure B-19 illustrates the L_{max} noise events form heavy noise events (such as lorries or motorcycles pass by noise) for baseline conditions of Figure B-18.

Noise measurements in this example were undertaken at the open terrace at higher floors overlooking the roads below (and future railway viaducts), Noise levels at the building façade at higher floors as shown in the Figures were extrapolated (using computer modelling) from the measured noise levels at the open terrace.

In critical cases, actual measurements may be undertaken at the receptors' balcony at higher floors (depending on access availability).

Figure B-20 shows a typical measurement for baseline noise measurement undertaken upon completion of the project's construction works before commencement of the project (highway / railway etc. operations). In this example, the elevated viaduct is shown (but without trains operations). Measurements shall be undertaken at the same position as the previous baseline.

Figure B-21 illustrates measurements undertaken for operational stage noise (with highway / railway, etc.) with noise levels from the noise source(s) only without contribution of the existing / prevailing noise sources. Such a scenario can only occur during quiet period without noise from existing sources.

Under practical conditions, a more likely measurement scenario is given in Figure B-22 with measurements of the new noise source combined with the prevailing noise (from existing road traffic, etc.). Figure B-23 shows high noise events L_{max} at the same site but without high noise events of the new noise source (trains, etc.).

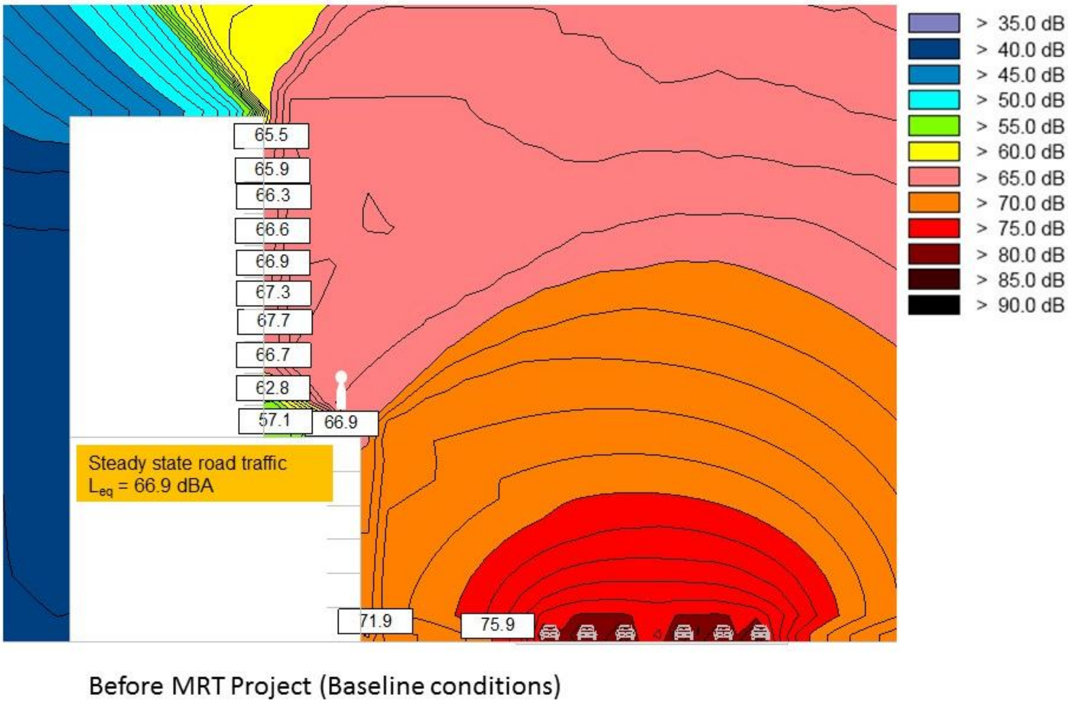


Figure B-18: Example of steady state road traffic noise L_{Aeq} conditions (baseline conditions before project commencement)

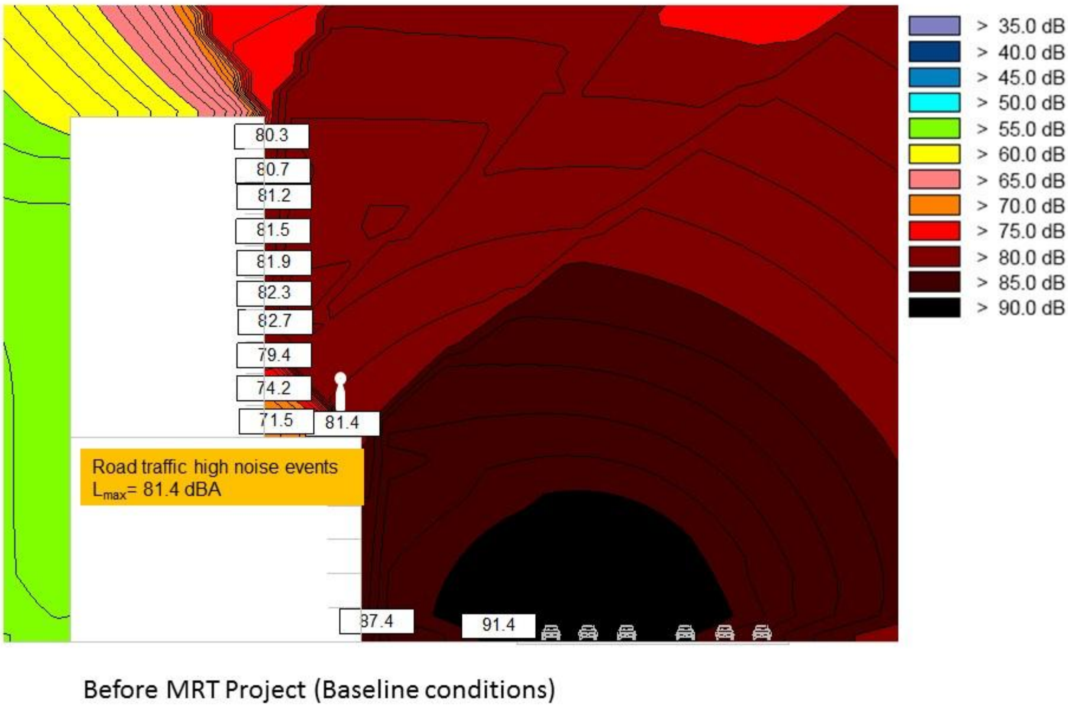


Figure B-19: Example of road traffic transient high noise event L_{max} levels (e.g. lorry pass-by under baseline conditions before project commencement)

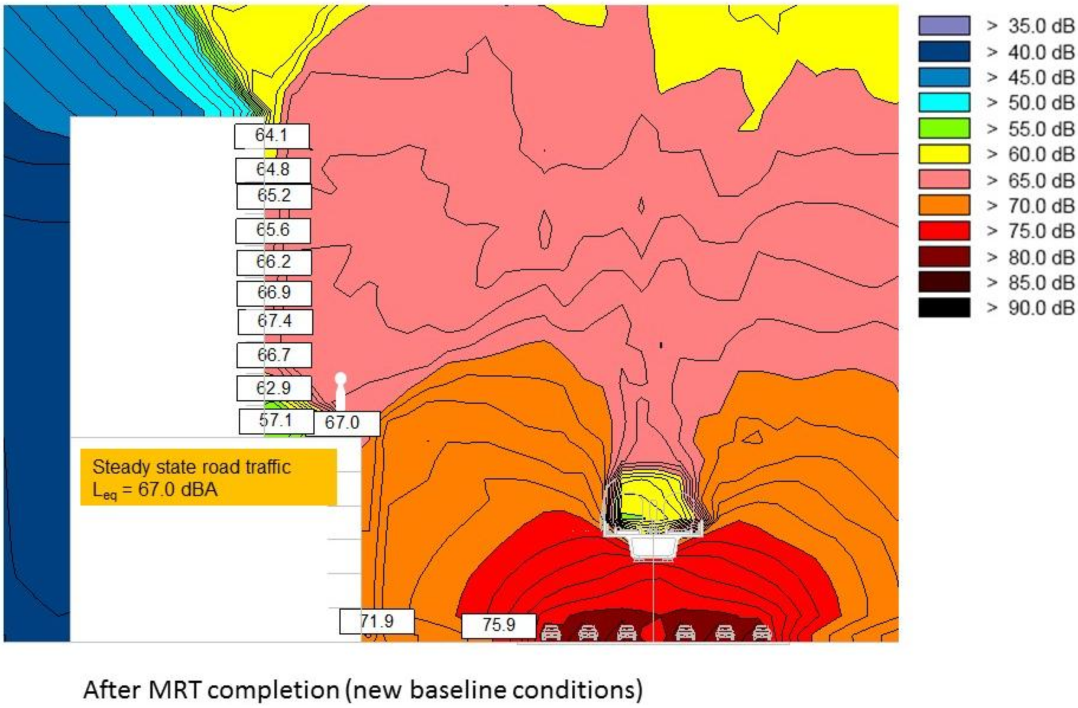


Figure B-20: Example of steady state road traffic noise L_{Aeq} conditions (prevailing conditions after project completion)

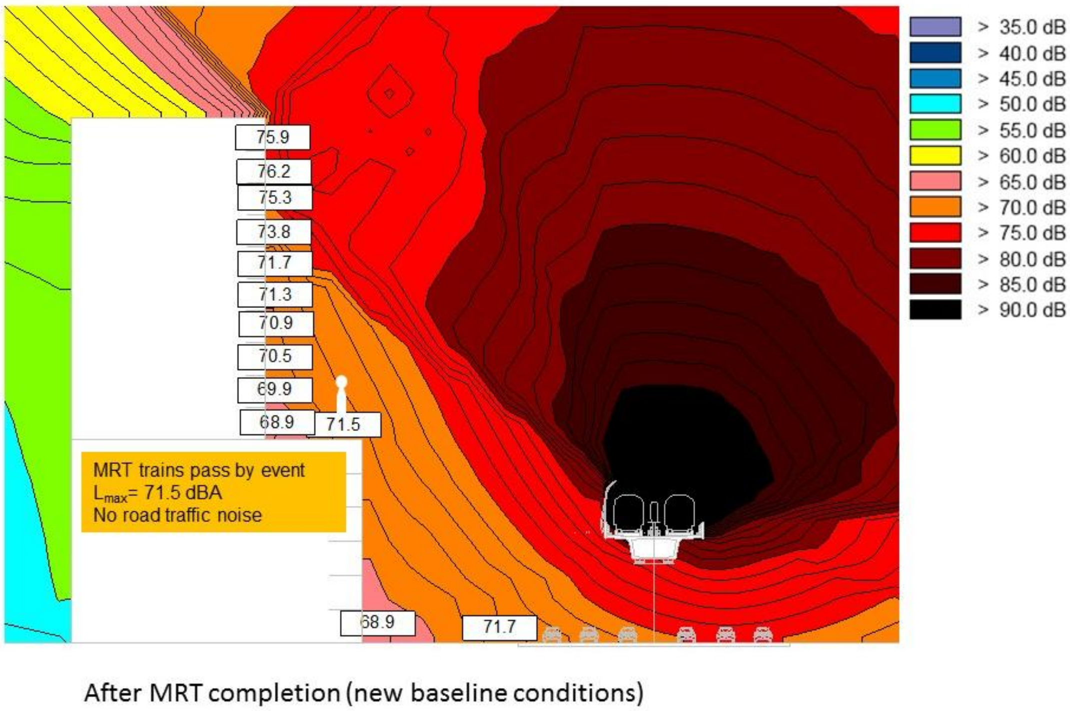
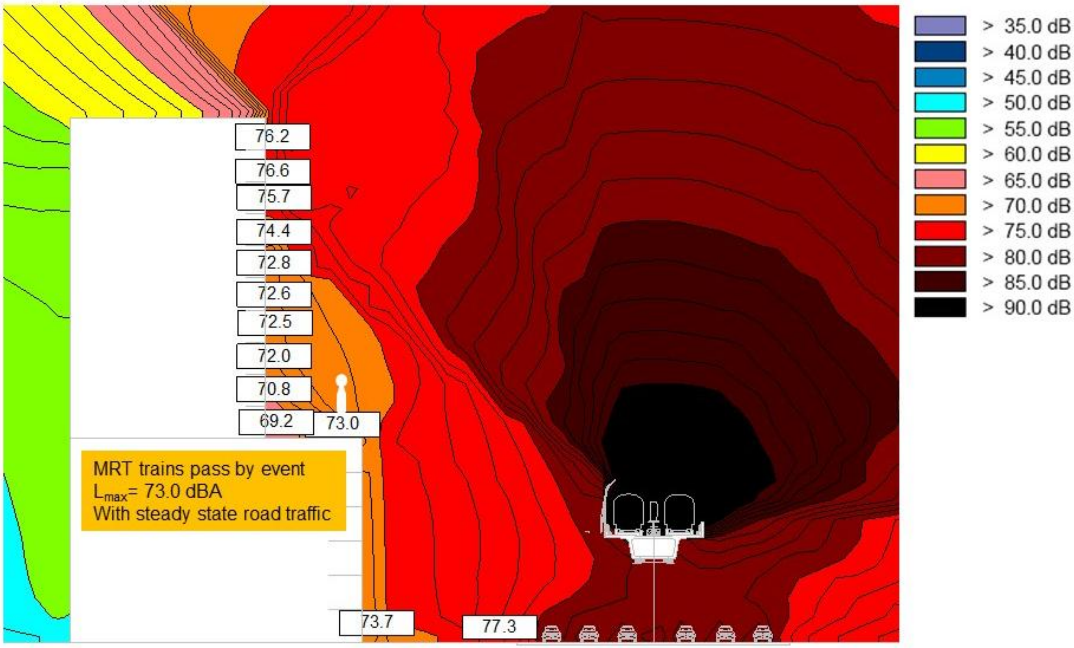
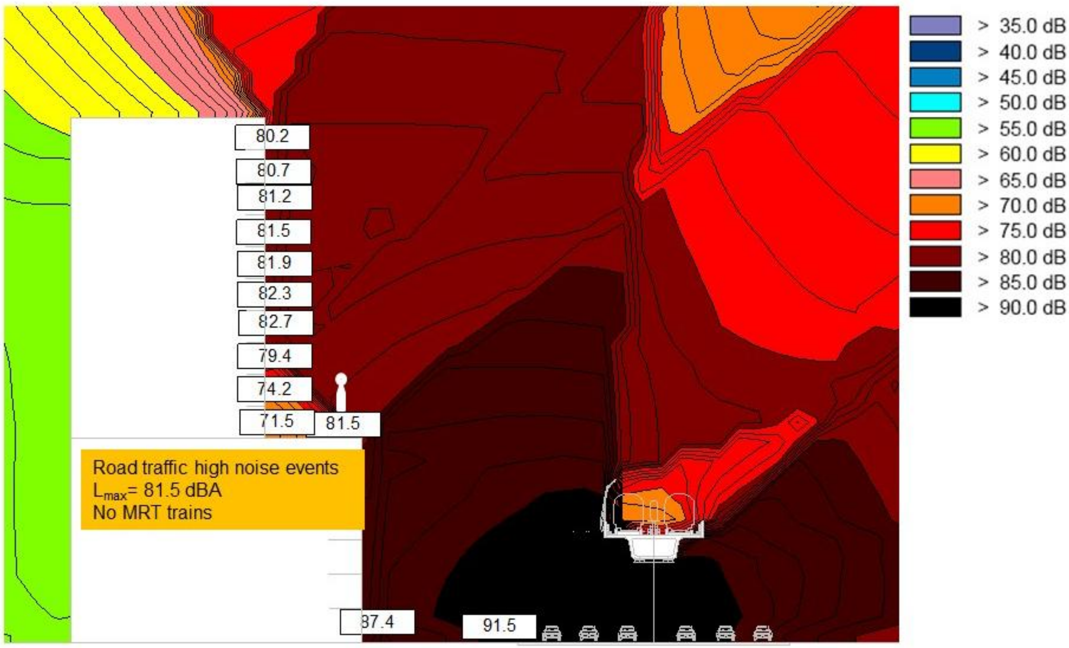


Figure B-21: Example of railway train pass-by noise event L_{max} level (during operations stage) in the absence of prevailing road traffic noise



After MRT completion (with MRT trains pass-by)

Figure B-22: Example of railway train pass-by noise event L_{max} level (during project operations stage) cumulative with prevailing steady state road traffic noise



After MRT completion (no MRT trains pass-by but with road traffic high noise events)

Figure B-23: Example of road traffic transient high noise event L_{max} level (e.g. lorry pass-by) without trains pass by events for prevailing steady state road traffic conditions

5.0 Parameters, Instrument Setting and Data to be Recorded

5.1 Noise measurement parameters, instrument setting, data sampling and recording shall be selected to match the purpose of measurements and to be appropriate for an accurate assessment to be made.

5.2 In this respect, the measurement parameters, instrument setting, data sampling are dependent on the type of noise sources to be assessed.

The following section present guidance with specific requirements of measurements for different noise source assessment. The requirements of this section do not exclude the general requirements and best practices described in other sections of this Technical Guidelines.

6.0 Specific Guidance for Different Noise Sources

6.1 Ambient and Baseline Noise Measurements

The procedure referred to in this sub-section cover the measurement of existing and prevailing ambient noise (baseline levels) in a specific receptor location.

(a) Purpose

Baseline noise measurements are required in an Environmental Impact Assessment and other applications where the prevailing or existing noise climate is to be determined (such as assessment of an offending noise source or complaint, etc.).

The baseline noise level should be a fair representation of the existing prevalent ambient, and often intended to be a reference level against which an intrusive noise is assessed.

Under normal circumstances, ambient noise level will change with the time of day. Baseline measurements shall require noise levels to be measured continuously over a day night time period that are divided into the following periods:

Day	7.00 am to 10.00pm
Night	10.00pm to 7.00 am the following day.

Some variations may occur on weekends and public holidays. In critical applications, it may be necessary that baseline levels to be measured for a week day and weekend (typically 72 hours continuously time period).

(b) Site selection

Site selection depends on the purpose for which the measurement is made; and is typically at locations that may be affected by noise or for which a noise severity assessment is to be undertaken. The site can be residential and other noise sensitive premises, commercial or industrial premises. The measurement shall be at the receptors' property boundary.

(c) Microphone position

Unless otherwise stated in the preceding sections of this Technical Guidelines, microphone positions shall be mounted at least above 1.2 m above the ground and at least 3.5 m away from any reflecting surfaces other than the ground. The microphone shall be orientated so that it is most uniformly sensitive to the incident sound from prevailing noise source(s).

(d) Measurement conditions

Baseline measurement is intended to provide an indication of the ambient existing conditions to be representative of the site over an extended area. As such, the noise condition should not change significantly. The measurement shall nevertheless include all prevailing and/or existing activities representative of the site.

Any non-representative or temporary noisy sources, such as roadworks, construction works (unless the construction work is the subject of assessment) shall be avoided where feasible.

The sound being measured will generally be a mixture of noise from all prevailing sources, noise from human activity including traffic, and natural noises including wind noise and animal and insect sounds. It is important that the different components of the noise at the receptor premises or measurement site be identified and ranked to provide a comparative list of the audible sources of sound.

In applications where an offending noise is to be assessed, it is often necessary to measure the contribution of the other ambient sound at a position that excludes the particular noise sources of interest.

(e) Noise parameters to be measured

For most applications, the noise parameters to be measured shall be L_{Aeq} and the L_{max} over the nominated measurement interval.

The measurements may include other statistical parameters such as the L_{90}, L_{50} and L_{10}, or a full statistical distribution of the sound pressure levels recorded over the measurement interval.

(f) Results to be reported

Results to be reported shall be $L_{Aeq\ Day}$, $L_{Aeq\ Night}$ and $L_{Aeq\ 24\ hours}$. The hourly L_{Aeq} levels shall also be reported. These steady state equivalent noise levels can be reported in 15 minutes period or hourly period over a 24 hours day night measurement duration.

Other statistical parameters such as the L_{90}, L_{50}, L_{10} and L_{max} levels should also be reported in situations when noise levels are fluctuating in nature.

Results shall be presented in a tabulation and graphical plots over the measurement period. Graphical plot provides easier interpretation and visual presentation of the sound variations over different time of the day.

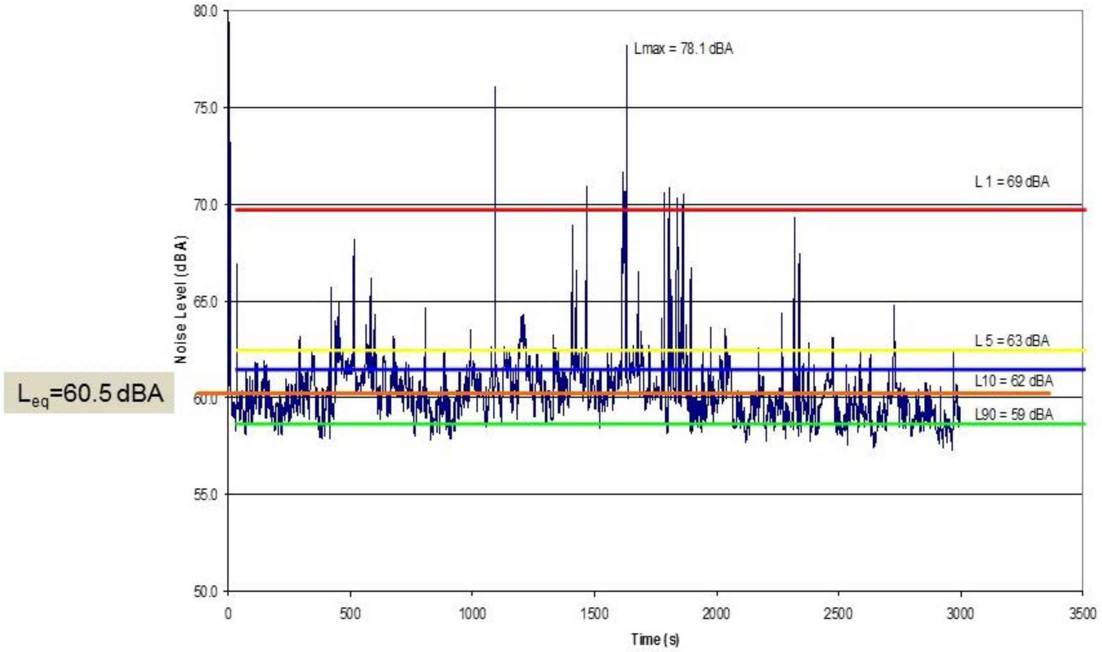


Figure B-24: Noise measurement parameters

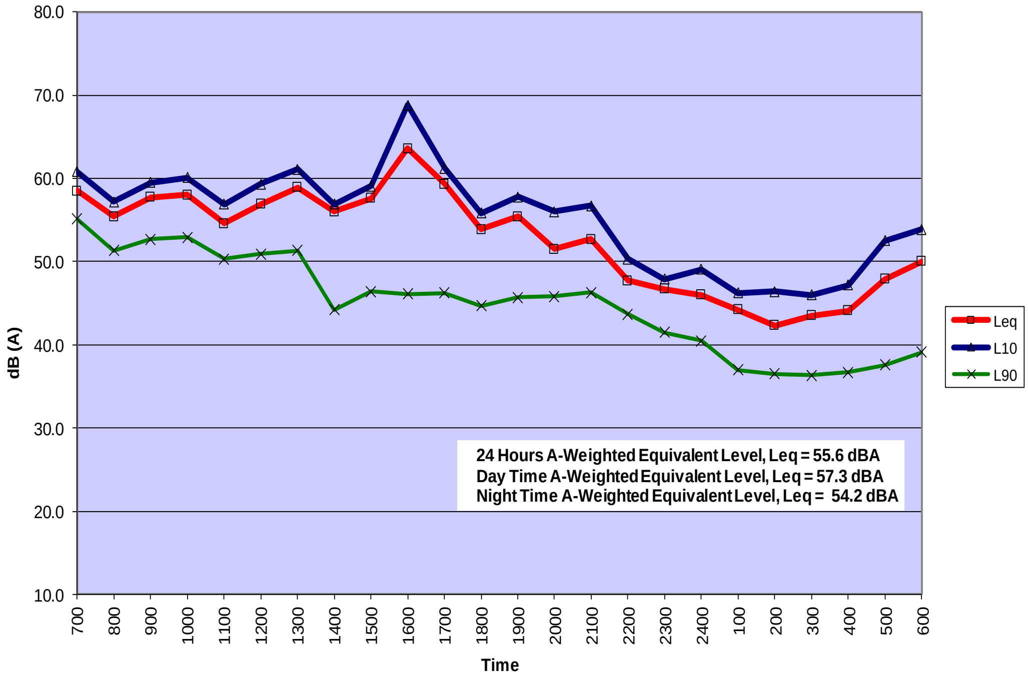


Figure B-25: Example of 24 hours baseline noise measurements in a school property boundary

Figure B-24 shows an example of typical results for measurements with data sampling every 2 seconds over a one hour period to determine the one hour L_{Aeq} level. Percentile statistical parameters (L_1, L_5, L_{10} and L_{90} corresponding to the one percent, five percent, ten percent and ninety percent parameter) and the L_{max} (maximum instantaneous level) for the period of measurement are also presented

An example of a twenty-four (24) hours plot of continuous noise monitoring for baseline noise measurements over a day night period from morning 7am to the following morning from data sampled continuously once every second for 24 hours is shown in Figure B-25. This plot presents hourly L_{Aeq} and statistical parameters L_{10} and L_{90} levels plotted over the 24 hours period.

The 24 hours A-weighted equivalent level $L_{Aeq24hrs}$, day time equivalent $L_{AeqDay15hrs}$ and night time equivalent $L_{AeqNight9\ hours}$ were also determined and reported.

6.2 Road Traffic Noise Measurements

The procedure referred to in this sub-section cover the measurement of road traffic noise in a specific receptor location.

(a) Purpose

Road traffic noise measurements are required in an Environmental Impact Assessment for highway projects and other applications where existing road traffic noise is to be determined.

Under normal circumstances, road traffic noise level will change with the time of day dependent on road traffic conditions. Road traffic noise measurements shall require measurements to be undertaken continuously over a day night time period that are divided into the following periods:

Day	7.00 am to 10.00pm
Night	10.00pm to 7.00 am the following day.

Some variations may occur on weekends, public holidays and school holidays. In critical applications, it may be necessary that measurements to be undertaken for a week day and weekend. Non-representative situations such as public holiday and school holidays shall be avoided unless deliberately intended.

(b) Site selection

Site selection shall be at property boundary of the receptors of concern. The site can be residential and other noise sensitive premises (hospital, schools, etc.) and where required commercial or industrial premises. For most applications, measurements shall not be at the roadside kerb or adjacent highway emergency lanes unless otherwise intended for highway noise source determination (for used in noise modelling data input for example).

(c) Microphone position

Unless otherwise stated in the preceding sections of this Technical Guidelines, microphone positions shall be mounted at least above 1.2 m above the ground and at least 3.5 m away from any reflecting surfaces other than the ground. The microphone shall be orientated so that it is most uniformly sensitive to the incident sound from the roads or highway.

(d) Measurement conditions

Road traffic conditions should be representative of the roads or highway being assessed. Road traffic noise are dependent on traffic volume, speed, percentage mix of heavy vehicles (including motorcycles) and road gradient amongst several other parameters (road pavement, etc.). For highway projects it may be necessary that measurements are repeated at periodic intervals (once a year for example) due to changes in road traffic volume, congestion, traffic mix, etc.

The noise measurement condition should not change significantly during the measurement period except for fluctuations associated with the roads or highway traffic conditions. The measurement may however include all other prevailing and/or existing activities representative of the site.

Non-representative or temporary noisy sources, such as roadworks and construction works shall be avoided.

It is important that extraneous noise at the receptor premises or measurement site be identified and reported accordingly as observations that may have influenced the measured noise levels.

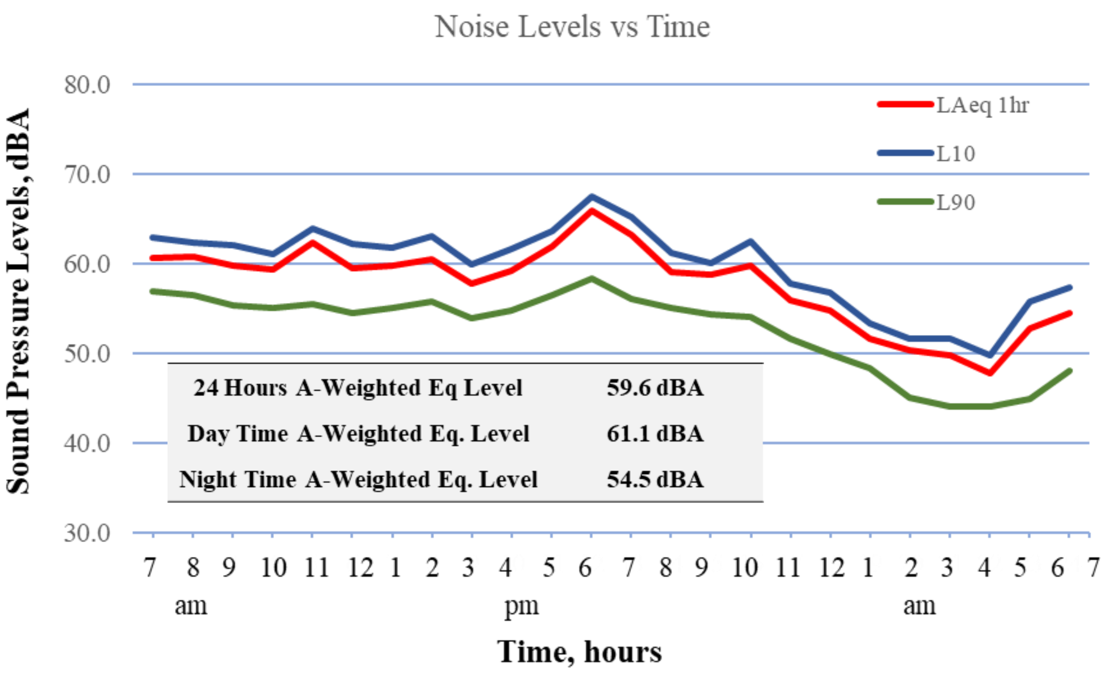
(e) Noise parameters to be measured

Noise parameters to be measured shall be L_{Aeq}, together with the statistical parameters L_{10} and L_{90} levels. Full statistical distribution of the sound pressure levels recorded over the measurement interval shall be included.

It is also recommended that the instantaneous L_{max} peak levels to be measured and the peak noise event identified for information purpose.

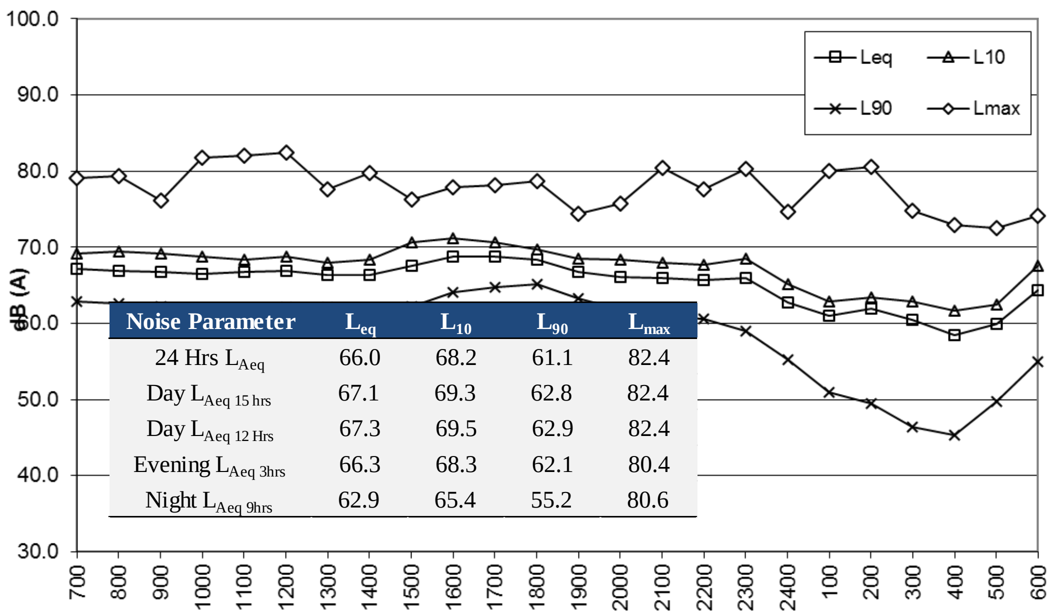
(f) Results to be reported

Results to be reported shall be $L_{Aeq\ Day}$, $L_{Aeq\ Night}$ and $L_{Aeq\ 24\ hours}$. Hourly L_{Aeq} and statistical percentile L_{10} and L_{90} levels shall be reported. The L_{max} levels shall also be reported when measured with identification of the peak noise events (heavy vehicles, horns, siren, etc.).



24 Hours A-Weighted Eq Level	59.6 dBA
Day Time A-Weighted Eq. Level	61.1 dBA
Night Time A-Weighted Eq. Level	54.5 dBA

Figure B-26: Example of road traffic noise measurements with low ambient



Noise Parameter	L_{eq}	L_{10}	L_{90}	L_{max}
24 Hrs L_{Aeq}	66.0	68.2	61.1	82.4
Day $L_{Aeq\ 15\ hrs}$	67.1	69.3	62.8	82.4
Day $L_{Aeq\ 12\ Hrs}$	67.3	69.5	62.9	82.4
Evening $L_{Aeq\ 3hrs}$	66.3	68.3	62.1	80.4
Night $L_{Aeq\ 9hrs}$	62.9	65.4	55.2	80.6

Figure B-27: Example of road traffic noise in urban environment

An example of typical road traffic noise measurements suburban residential areas is given in Figure B-26, and in urban residential areas adjacent major roads is given in Figure B-27. The noise profiles over 24 hours clearly demonstrate the fluctuations in noise levels during peak traffic hours and at night early hours in Figure B-26.

In urban areas with major roads and constant traffic, noise levels from roads are often fairly constant during daytime, except for early morning hours as seen in Figure B-27 (where L_{max} levels are also plotted).

6.3 Railways and Transit Trains Noise Measurements

The procedure referred to in this sub-section cover the measurement of railways and transit trains noise in a specific receptor location.

(a) Purpose

Railway and transit trains noise measurements are required in an Environmental Impact Assessment for noise compliance purpose in railway projects and other applications where noise from existing railway or transit trains (LRT, MRT, etc.) is to be determined.

Under normal circumstances, railways noise emission at source will not change over different time period of the of day except for changes in trains service frequency, changes in prevailing ambient from surrounding road traffic and human activities. Measurements shall be undertaken continuously over a day night time period that are divided into the following periods:

Day	7.00 am to 10.00pm
Night	10.00pm to 7.00 am the following day.

It is critical that trains pass-by events be identified by events marker (i.e. positive identification of the trains pass by transient noise events) or alternatively time stamped in the data sampling for each train pass-by so that the measured L_{max} levels are from the trains and not from other high noise events (example road traffic noise events) not associated with the trains. In most cases this shall require the noise monitoring to be manned for visual observations of the train pass by

(b) Site selection

Site selection shall be at property boundary of the receptors of concern. The site can be residential and other noise sensitive premises (hospital, schools, etc.) and where required commercial or industrial premises. For most assessment applications, measurements should not be within or at trackside or directly beneath trains elevated viaducts unless otherwise intended for rails noise source determination from the trains.

(c) Microphone position

Unless otherwise stated in the preceding sections of this Technical Guidelines, microphone positions shall be mounted at least above 1.2 m above the ground and at least 3.5 m away from any reflecting surfaces other than the ground. The microphone shall be orientated so that it is most uniformly sensitive to the incident sound from the rail tracks or viaducts.

(d) Measurement conditions

Measurement conditions should be representative of the railways or transit trains operations being assessed. Railway noise dependent on train and tracks condition and type of trains (cargo, commuter and passenger trains, etc.). For railway operations it may be necessary that measurements are repeated annually due to changes in trains operation frequency and maintenance related issues (degradation in trains and tracks).

The noise measurement condition should not change significantly during the measurement period except for changes due to trains operations frequency (number of trains per hour) and fluctuations associated with the prevailing ambient (road traffic conditions, commercial activities, etc.).

Non-representative or temporary noisy sources, such as roadworks and construction works shall be avoided.

It is important that extraneous noise and other high L_{max} events (non- trains related) at the measurement site be identified and reported accordingly as events that may have influenced the measured noise levels.

(e) Noise parameters to be measured

Noise parameters to be measured shall be L_{Aeq} with statistical parameters L_{10} and L_{90} levels, as well as trains pass-by L_{max} levels monitored continuously over the trains' operational hours. Reporting shall be on an hourly basis to obtain the trains pass by L_{max} and L_{Aeq} levels for the measurement duration.

It is mandatory that the data sampling (instrument data recording) be set at **no more than 2 seconds** (and preferably one second) interval per data stored/recorded. Data sampled with a time interval of more than 2 seconds (example 1 minute, etc. as commonly used in general purpose baseline measurements) shall inevitably result in wrong L_{max} levels from other extraneous events (typically road traffic events) being assigned to the trains pass-by.

Train pass-by events typically last a few seconds only, and data sampled longer than the train event will inherently capture other high noise events such as road traffic events not related to the train. This is illustrated in an example given in Figure B-28 and elaborated in Table B-1.

(f) Results to be reported

Results to be reported shall be $L_{Aeq\ Day}$, $L_{Aeq\ Night}$ and $L_{Aeq\ 24\ hours}$ with hourly L_{Aeq} for steady equivalent noise levels as well as statistical percentile L_{10} and L_{90} levels. Trains pass by noise levels shall be reported for each pass by event and one hour averages of trains pass by determined and reported on hourly basis. Identification of peak noise events from trains and other road traffic or extraneous sources be positively identified.

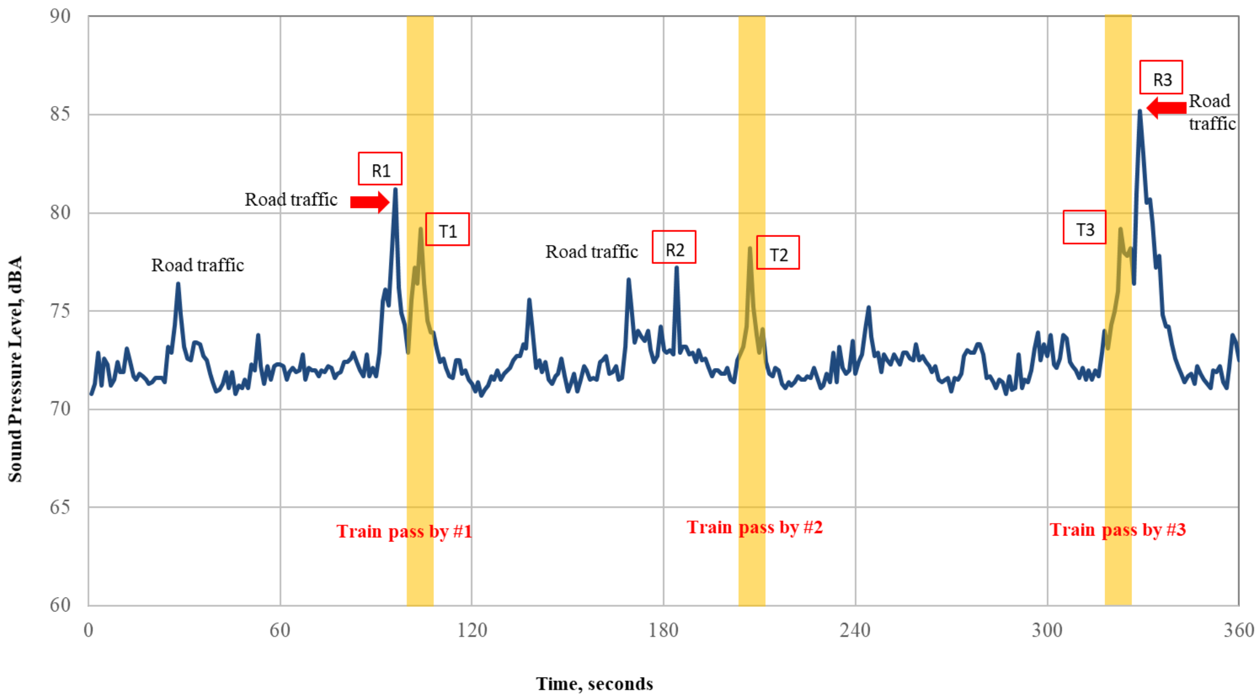


Figure B-28: Noise levels vs time plotted in 1 second intervals over several trains pass-by events measured in urban environment with road traffic

Table B-1: Example of noise levels results (correct and wrong readings) from trains pass-by measurements

Time of monitoring	$L_{Aeq\ 60s}$	**L_{max} Reading (Trains Pass-By)**		**Remarks** (with reference to Figure B-28)
		1 minute sampling	2 seconds sampling	
0 to 60 secs	72.3 dBA	81.2 dBA	79.2 dBA	*Train pass-by #1 at 104 seconds. Train pass-by noise T1=79.2 dBA. Data sampled in 2 secs interval correctly record train pass-by L_{max}. Data sampled in 1 minute segment record R1=81.2 dBA as the highest $L_{max\ (60\ secs)}$ - which happened to be from road traffic. R1* ***reading wrongly reported*** *as trains noise.*
61 to 120 secs	73.9 dBA			
121 to 180 secs	72.5 dBA	78.2 dBA	78.2 dBA	*Train pass-by #2 at 207 seconds. Train pass-by noise T2=78.2 dBA. Data sampled in 2 secs interval and 1 minute interval are both correct. Data sampled in 1 minute interval was* ***correct by chance*** *because train noise happened to be higher than road traffic noise with R2 L_{max} =77.2 dBA.*
182 to 240 secs	72.7 dBA			
241 to 300 secs	72.4 dBA	85.3 dBA	78.9 dBA	*Train pass-by #3 at 323 seconds. Train pass-by noise T3=78.9 dBA. Data sampled in 2 secs interval correctly record train pass-by L_{max}. Data sampled in 1 minute interval recorded R3 L_{max} =85.3 dBA as the highest L_{max} - which happened to be from road traffic. R3* ***reading is wrong*** *(not from train) but inevitably reported as trains noise.*
301 to 360 secs	75.8 dBA			

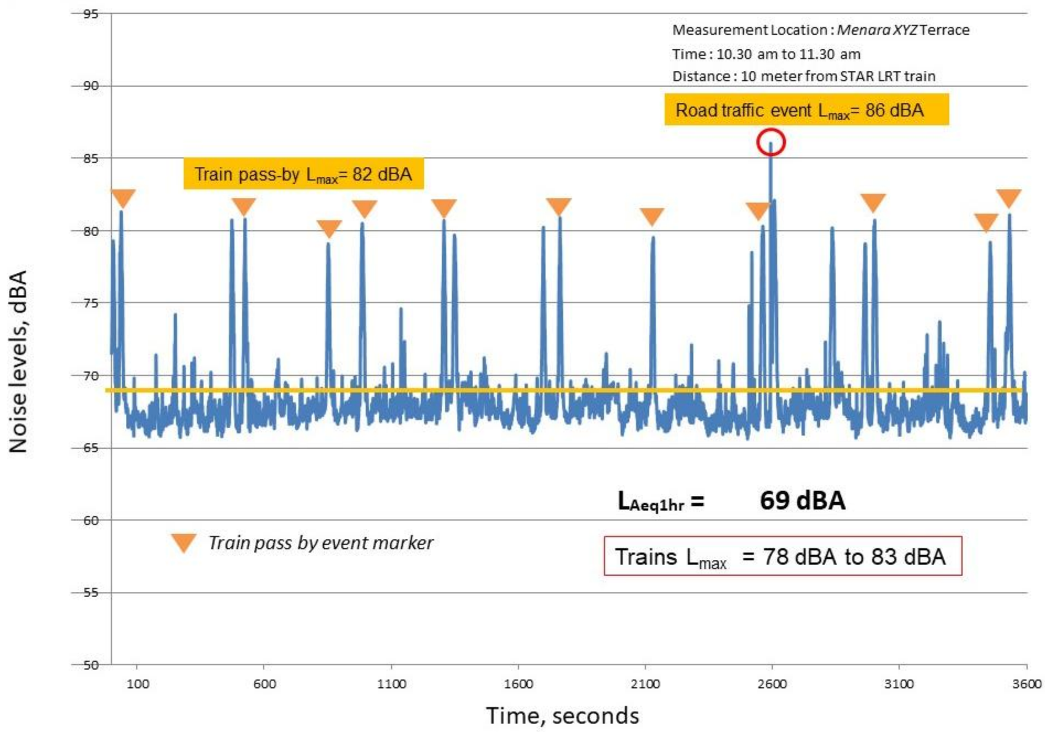


Figure B-29: Example of railway (and road traffic) noise levels versus time

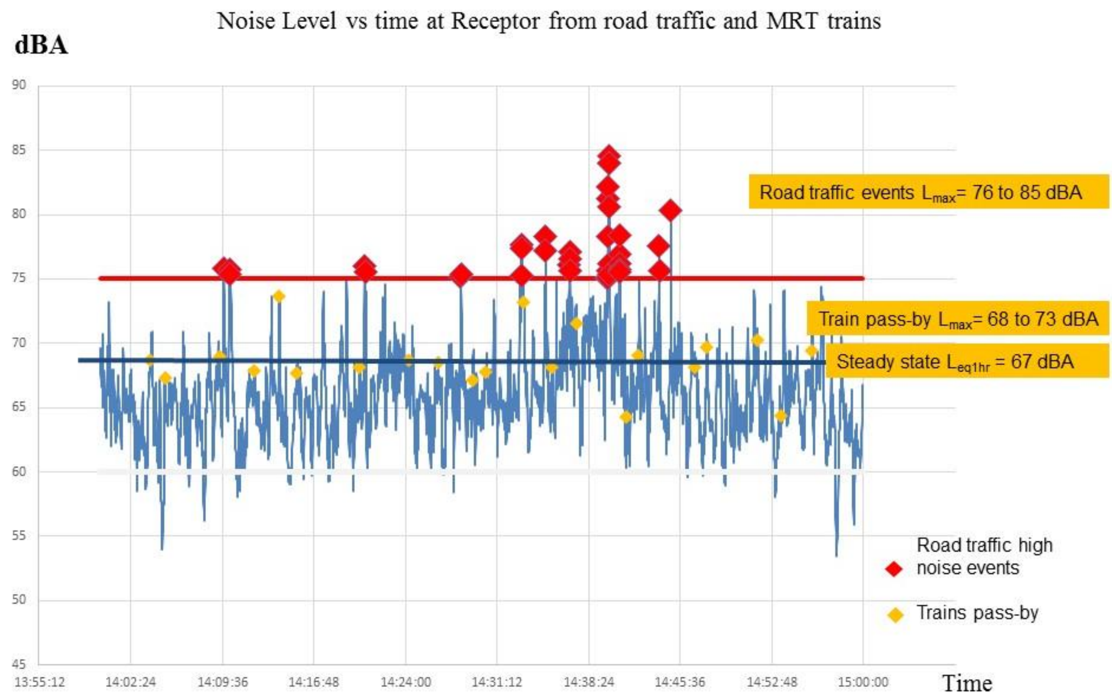


Figure B-30: Example of transit trains (elevated viaduct with noise barrier) and ambient road traffic noise measurements

An example of trains pass-by noise continuously monitored over 1 hour (data sampled in 1 second interval) is shown in Figure B-29, where train pass by noise were significantly higher than surrounding ambient. In another example in Figure B-30, noise at a receptor fronting an MRT elevated viaduct (installed with noise barrier) had trains pass-by noise levels significantly lower than existing road traffic noise. This demonstrate the necessity for positive identification of trains pass-by events for correct measurement and reporting of the noise measurements.

6.4 Industry Noise Measurements

The procedure referred to in this sub-section cover the measurement of industry noise in a specific receptor location.

(a) Purpose

Industry noise measurements are required in an Environmental Impact Assessment for industrial plants and petrochemical projects, and other applications where noise from industrial premises is to be determined.

Industry noise levels may remain constant or fluctuate with operations over day and night depending on sources and activities from the industrial premise(s). Measurements all be undertaken continuously over a day night time period that are divided into the following periods:

Day	7.00 am to 10.00pm
Night	10.00pm to 7.00 am the following day.

Some variations may occur on weekends and public holidays where some industry (including adjacent premises) may not operate.

In situations where there is a need to investigate complaints against a particular premise or plant, it is preferable that additional measurements be undertaken with the noise source(s) switched off (i.e. not operating) so that comparison can be made.

(b) Site selection

Measurement site selection shall be at property boundary of the industrial premise and/or nearest receptors of concern. Where feasible, the measurements shall not be immediately adjacent major roads or highway to minimize masking from road traffic noise.

In some cases, measurements may also have to be undertaken inside the premise/plant compound at close proximity to the noise sources to establish source emission levels for noise severity ranking. These in-plant measurements at the equipment /noise sources (typically at 1 to 5 meters away) are undertaken to determine sound power levels for use in computer modelling of the plant under existing operating conditions.

(c) Microphone position

Unless otherwise stated in the preceding sections of this Technical Guidelines, microphone positions shall be mounted at least above 1.2 m above the ground and at least 3.5 m away from any reflecting surfaces other than the ground. The microphone shall be orientated so that it is most uniformly sensitive to the incident sound from the industrial premises away from road traffic.

(d) Measurement conditions

Measurement conditions should be representative of the industry premise and plant/equipment normal operations. Unless otherwise intended, measurements shall not be undertaken under abnormal or emergency conditions.

It is imperative to check if all outdoor equipment and process lines are operating during the measurements period. In some cases, it may be necessary for measurements to be repeated for different plant operating conditions or process lines configurations in situations where noise emissions may vary with different operational configurations. This may include plants that may have one unit, multiple units and all units operating simultaneously.

The noise measurement condition should not change significantly during the measurement period except for fluctuations associated with the industrial premise and plant normal operation events. The measurement may however include all other prevailing and/or existing activities representative of the site.

Non-representative or temporary noisy sources, such as roadworks and construction works shall be avoided. It is important that extraneous noise at the receptor premises or measurement site be identified and reported accordingly as observations that may have influenced the measured noise levels.

(e) Noise parameters to be measured

Noise parameters to be measured shall be L_{Aeq} together with the statistical parameters L_{10} and L_{90} levels. Full statistical distribution of the sound pressure levels may be recorded over the measurement period for noise sources that are fluctuating in nature. In situations where the noise is fluctuating in nature, data sampling in one second to one minute intervals may also be required and noise assessment and comparison between noisy and quiet periods. It is also recommended that the instantaneous L_{max} peak levels to be measured and the peak noise event identified.

It may be necessary for sound pressure levels to be measured with linear or Z-weighted frequency in additional to A-weighting scale for assessment of low frequency noise. Measurements for octave and one-third octave frequency spectrum sound pressure levels are required (in addition to overall levels) for tonal noise assessment and noise control purpose.

(f) Results to be reported

Results to be reported shall be $L_{Aeq\ Day}$, $L_{Aeq\ Night}$ and $L_{Aeq\ 24\ hours}$. Hourly L_{Aeq} and statistical percentile L_{10} and L_{90} levels shall be reported. The L_{max} levels shall also be reported with identification of peak noise events (from impulsive sound and other transient events such as blow-outs, etc.). Results shall be reported for A-weighted levels, and to include where applicable linear or Z-weighted for assessment of low frequency noise. In situations with tonal noise, results shall include frequency spectrum measured in one-third octave bands.

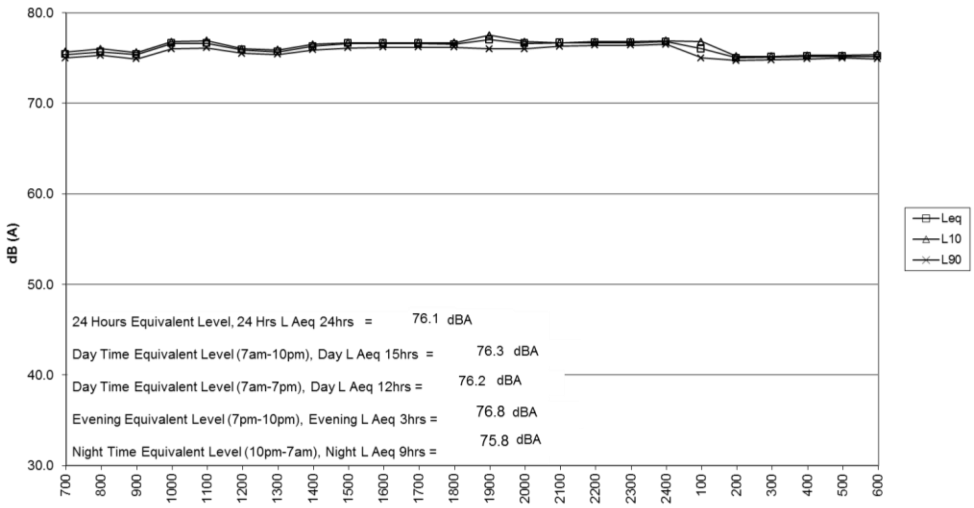


Figure B-31: Example of industry noise measurements with constant plant noise emission

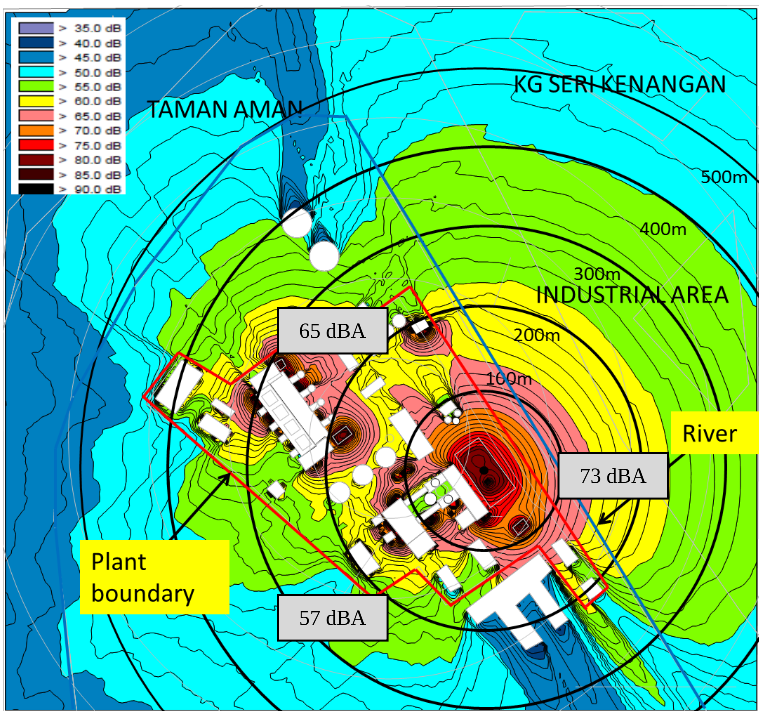


Figure B-32: Example of industry noise propagation to plant boundary and environment adjacent industry premise

An example of typical industry noise measurements from plants with constant sound emissions is shown in Figure B-31. In such cases, the L_{Aeq} and statistical percentile L_{10} and L_{90} levels are within a narrow range (i.e. with small level fluctuations). Subjectively such noise is perceived as a constant monotonous sound, and subjectively deemed less disturbing.

In situations where noise levels are fluctuating with time, measurements and noise levels plotted against time (plotted over 1 hour for example) may be required. Figure B-33 shows an example of simultaneous measurements at industry plant boundary and receptors at a residential housing estate 1 km away from a steel mill with time varying noise levels repeated over time from the work process (arcing of furnaces).

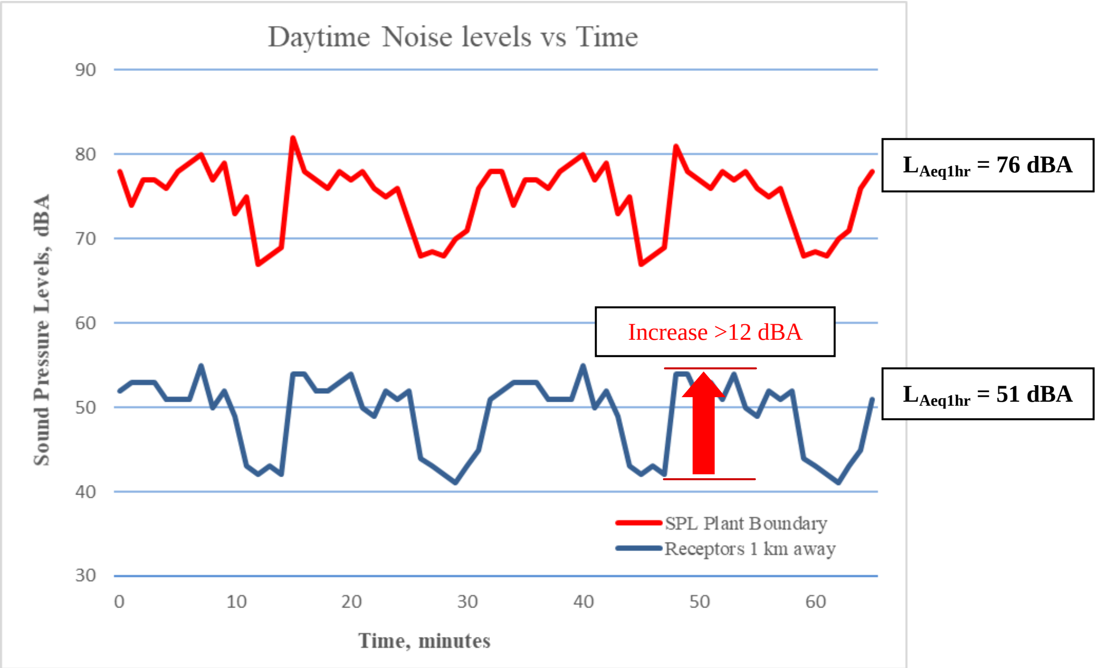


Figure B-33: Example of industry noise measurements with fluctuations over time, measured at plant boundary and receptors

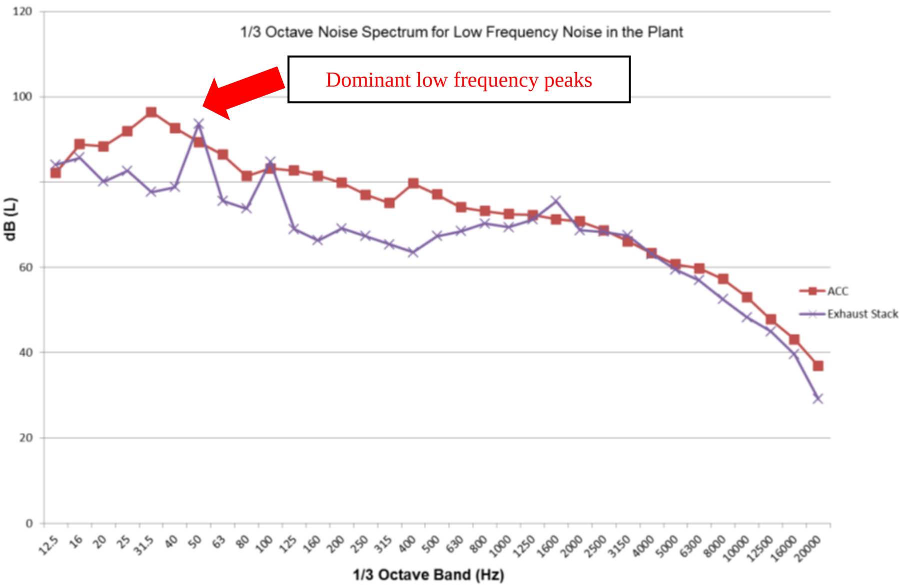


Figure B-34: Example of noise measurements using linear weighting (or Z-weighting) in one-third octave centre frequencies for assessment of low frequency noise

While noise levels at the receptors are relatively low (L_{Aeq1hr} = 51 dBA), there had been complains of industry noise due to the perceived higher noise (during the plant noisy period) as compared to the quieter time period repeated over approximately 30 minutes cycles. (Noise more than 12 dBA above relatively quiet periods ambient).

An example of noise measurements using linear (or Z-weighting scale) with spectrum in one-third octave centre frequencies is given in Figure B-34. This example shows relatively high low frequency spectral noise levels associated with a potential low frequency noise problem (typical in exhaust stacks, low speed fans and wind turbines). Such measurements are necessary for assessment of low frequency noise concerns in industry.

6.5 Construction Noise Measurements

The procedure referred to in this sub-section cover the measurement of construction noise from construction sites which includes demolition works at work site boundaries and at specific receptor location.

(a) Purpose

Construction noise measurements are often required in an Environmental Management Plan, and for projects subjected to an Environmental Impact Assessment with Approval Conditions stipulating noise compliance monitoring and mitigation during construction works for the project. The procedures are also for other applications where noise from construction and demolition works is to be determined.

Under normal circumstances, construction noise level will change with the time of day and also for different days or stages of the construction works depending on the construction activities.

In this respect the measurements may be required to be undertaken over the entire construction period. The measurements may either involve continuously monitoring on a long term or specific duration (using automatic permanent noise monitoring units), or where appropriate involve periodic monitoring over a typical work day night that may be repeated weekly or monthly.

Construction and demolition works' measurements shall require noise levels to be measured continuously over a 24 hours day night time period that are divided into the following periods:

Day	7.00 am to 6.00pm
Evening	6.00pm to 10.00pm; and
Night	10.00pm to 7.00 am the following day.

Some variations may occur on weekends and public holidays where construction works may not be undertaken.

In situations where there is a need to investigate complaints against a construction work site or activity, it is desirable that additional measurements be undertaken without construction works or without the noisy activity for comparison.

In most applications, prior baseline noise measurements should be undertaken at locations of concern before commencement of the construction works (in accordance to guidance in Sub-section 6.1 of this Guidelines, Annex B) for assessment purpose.

Noise (air blast over-pressure) from blasting which may be undertaken as part of construction works requires different instrumentation and are not included in this procedure here. Guidance is given in the DOE Guidelines for Vibrations.

(b) Site selection

Measurement site shall be at the property boundary of the construction work site and/or at property boundary of the nearest receptors of concern. The site can be residential, other noise sensitive premises (hospitals, schools, places of worship, etc.) and commercial premises.

(c) Microphone position

Unless otherwise stated in the preceding sections of this Technical Guidelines, microphone positions shall be mounted at least above 1.2 m above the ground and at least 3.5 m away from any reflecting surfaces other than the ground. The microphone shall be orientated so that it is most uniformly sensitive to the incident sound from the construction site. Measurements shall be undertaken outdoors in an open environment.

(d) Measurement conditions

Construction noise measurement is intended to provide an indication of the noise generated from construction works and should be undertaken when construction activities are prevalent. It should include all prevailing and current activities representative of the construction works in progress.

During to the varying nature of construction activities, measurements shall include situations when high noise activities are undertaken (such as piling works, excavation, demolition works with mechanized equipment, etc.). These may involve monitoring covering several days/weeks/months of construction works on site over the duration of the construction period (till project completion).

The sound being measured will generally be a mixture of noise from all prevailing sources and work process, movement of materials, heavy vehicles, human activity and natural noises. It is important that the different components of the noise at the receptor premises or measurement site be identified and ranked to provide a comparative list of the noise sources.

(e) Noise parameters to be measured

Noise parameters to be measured shall be L_{Aeq}, L_{max} and statistical parameters L_{10}, L_{50} and L_{90} over the nominated measurement duration.

Measurements for octave and one-third octave frequency spectrum sound pressure levels may also be required for tonal noise assessment and for noise control purpose.

In situations with large plants (batching plants, slurry treatment plant, power generation units, etc.) it may also be necessary for sound pressure levels to be measured with linear or Z-weighted frequency in additional to A-weighting scale for assessment of possible low frequency noise.

(f) Results to be reported

Results to be reported shall be $L_{Aeq\ Day}$, $L_{Aeq\ Evening}$, $L_{Aeq\ Night}$, $L_{Aeq\ 24\ hours}$ and L_{Amax}. The hourly L_{Aeq} levels shall also be reported. These steady state equivalent noise levels can be reported in 15 minutes period or hourly period over a 24 hours day night measurement duration. Statistical parameters for L_{10} and L_{90} shall also reported.

Results shall be presented in a tabulation and graphical plots over the measurement period.

In situations where noise monitoring is undertaken on a periodic basis over the duration of the project construction period, a summary and trending of results from previous measurements (typically 3 months to 12 months) comparing current results should also be included.

Construction noise are assessed against the statistical ten percentile L_{10} level and instantaneous maximum L_{max} for noise events in addition to the steady state equivalent L_{Aeq} day, evening and night levels.

An example of construction noise measurement with piling located amongst existing residential development (typical of highways and urban transit railways linear projects) is shown in Figure B-35. Measured L_{10} levels at three receptors location are shown. The noise map as shown illustrates typical sound propagation from piling typically affecting receptors in close proximity with a direct line of sight to the piling works.

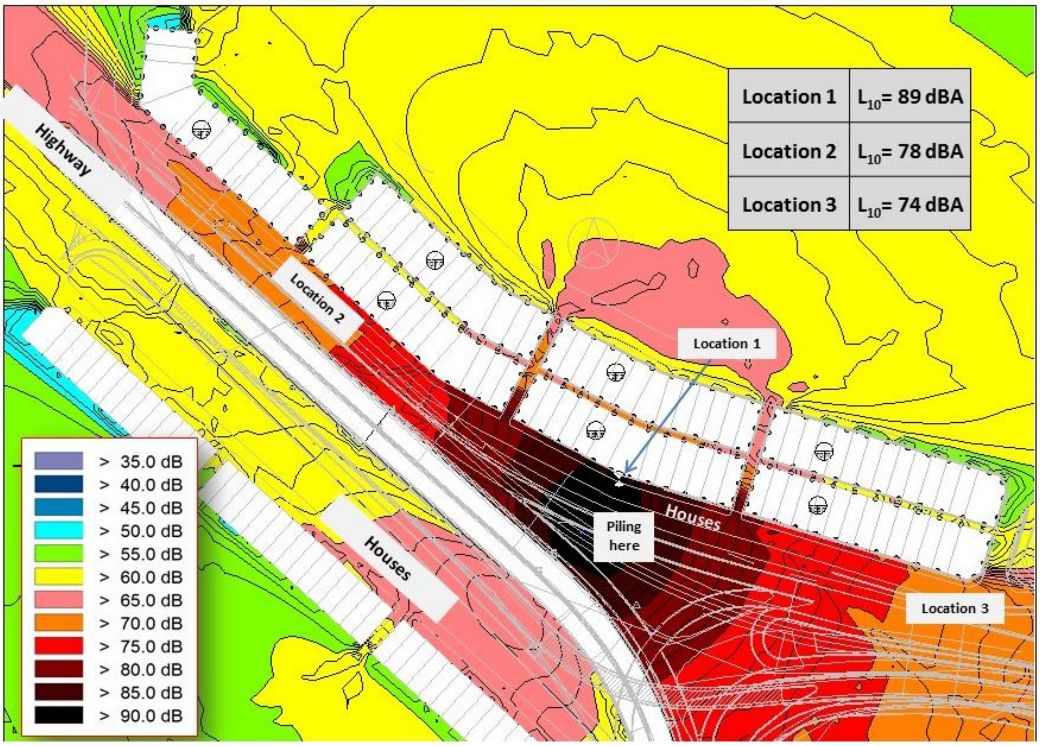


Figure B-35: Example of noise measurements of construction piling (L_{10} levels)

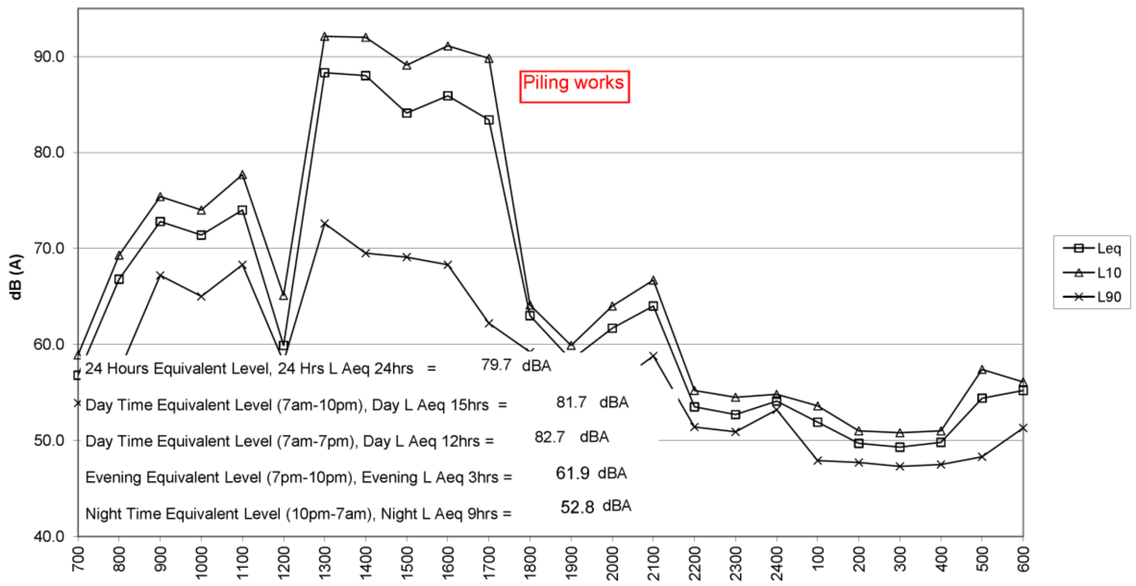


Figure B-36: Example of 24 hours continuous noise measurements with piling works measured at an adjacent receptor property boundary

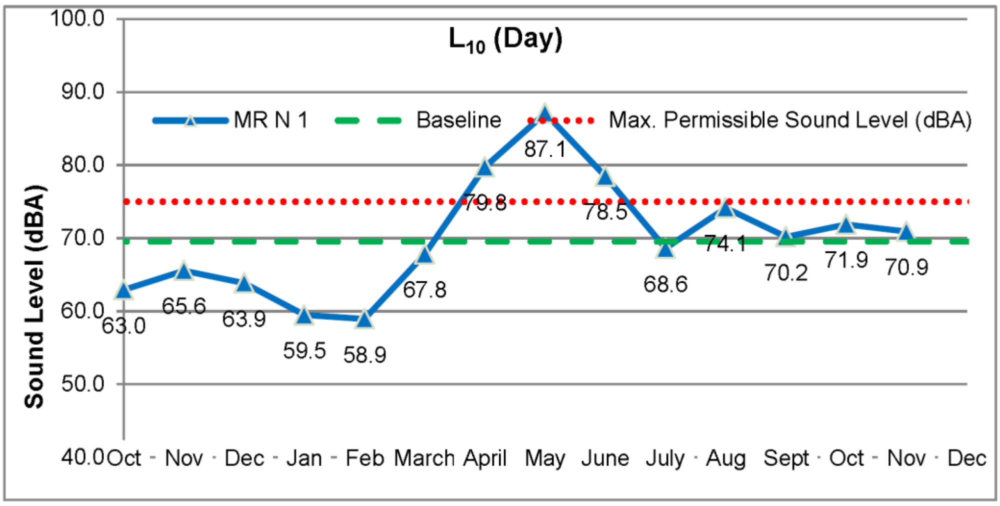


Figure B-37: Example of trending of noise measurements results (Daytime L_{10} levels) over one year assessed against permissible and baseline levels

An example of continuous 24 hours noise measurement results (data sampling at 2 seconds intervals with $L_{Aeq\ 1hr}$, L_{10} and L_{90} hourly plot over 24 hours) at a receptor adjacent a construction site with piling works in progress is shown in Figure B-36. The graphical plot in particular illustrate the relatively higher noise levels (L_{10} in particular corresponding to the piling activities).

Figure B-37 shows an example of trending of the monthly measured L_{10} levels (Day) as assessed against maximum permissible levels and the baseline level. Trending of parameters that are required in the reporting (L_{AeqDay}, $L_{AeqEvening}$, $L_{AeqNight}$, $L_{Aeq24\ hours}$, L_{10} and L_{Amax}) should be undertaken as shown in this example.

6.6 Aircraft Noise Measurements

The procedures referred to in this sub-section cover the measurement of aircraft noise measurements at airports, and at receptors or development near airports or located along flight paths.

(a) Purpose

Aircraft noise measurements are required in in an Environmental Impact Assessment of airports and other applications where aircraft noise is of concern. It is also required in noise monitoring of existing airports. The measurements shall apply for existing, new and re-development or airport expansion to determine baseline and aircraft transient noise levels; and for other development with receptors near airports or beneath aircraft flight paths.

Aircraft referred herein includes civil and military aircrafts as well as helicopters.

The measurements are for all intent and purpose are ambient noise measurements with aircraft pass by, take offs and landings being the noise source of concern, which may include other existing noise source(s) such as road traffic and other activities prevalent at the measurement site.

(b) Site Selection

Measurement site selection for airport development (new, existing or expansion) shall be at the airport boundary at strategic locations to determine aircrafts take off and landing noise. It is to be noted that aircrafts take-off and landing may be in either direction of the runway depending on wind conditions. Measurement sites shall also include receptors of concern in the vicinity of the airport.

Other measurement sites shall be at receptors along the flight paths. The receptors may be existing or prosed new development with concern of aircrafts noise along the flight paths.

It is recommended that the site(s) be checked against existing and planned flight paths and air tracks information with the Airport authorities (Department of Civil Aviation, etc.) .

(c) Microphone position

Microphone position shall be in an open environment preferably away from any building or large reflecting surfaces, and preferably away from roads or other noise sources that may mask or affect the aircraft noise. This in particular refers to plant and equipment that may exist in the measurement site.

The microphone positions shall be mounted at least above 1.2 m above the ground and at least 3.5 m away from any reflecting surfaces other than the ground. The microphone shall be orientated so that it is most uniformly sensitive to the free field sound that exists in an open environment, as shown in Figure B-38.

Figure B-38: Example of microphone position in aircraft noise measurements

(d) Measurement conditions

Aircraft noise measurement is intended to provide an indication of ambient noise inclusive of the aircrafts transient noise to be representative of the measurement site.

The ambient noise condition should be representative of the prevailing and/or existing activities representative of the site, with transient changes in noise levels from aircrafts activities (aircrafts pass by, take-offs, landings, taxiing, and other airport operations).

Measurements shall be undertaken in the absence of construction activities, unless otherwise not possible in situations with long term construction works at the measurement site.

For permanent airport noise monitoring, the measured noise from aircrafts should be correlated against aircrafts and flight information (from flight tracking information to identify the aircraft with the measured L_{max} levels). Permanent airport noise monitoring systems have aircraft tracking functions connected to the Airport Flight Information System.

(e) Noise parameters to be measured

Noise parameters to be measured shall be L_{Aeq} and L_{max} .to be measured continuously over a 24 hours day night period. Statistical parameters of L_{10}, L_{50} and L_{90} may also be measured.

(f) Results to be presented

Results shall be presented in a tabulation of measured L_{Aeq} and L_{max} levels in hourly duration over a 24 hours day night period, with graphical plots over the measurement period. Statistical L_{10} and L_{90} levels should also be presented if measured.

Measured noise levels ($L_{Aeq\ 1hr}$) could also be correlated against total number of aircraft movements for the day and night time period.

Aircraft noise levels and ambient noise levels shall be reported over the measurement period on an hourly interval. This information could be obtained from post-processing of measured noise data with events marker algorithm (intended to mark noise data of transient events from an aircraft flyover) to determine a specific noise (aircraft noise) together with the ambient residual noise.

In an airport permanent monitoring system at airports, results shall be presented for all the designated noise monitoring stations.

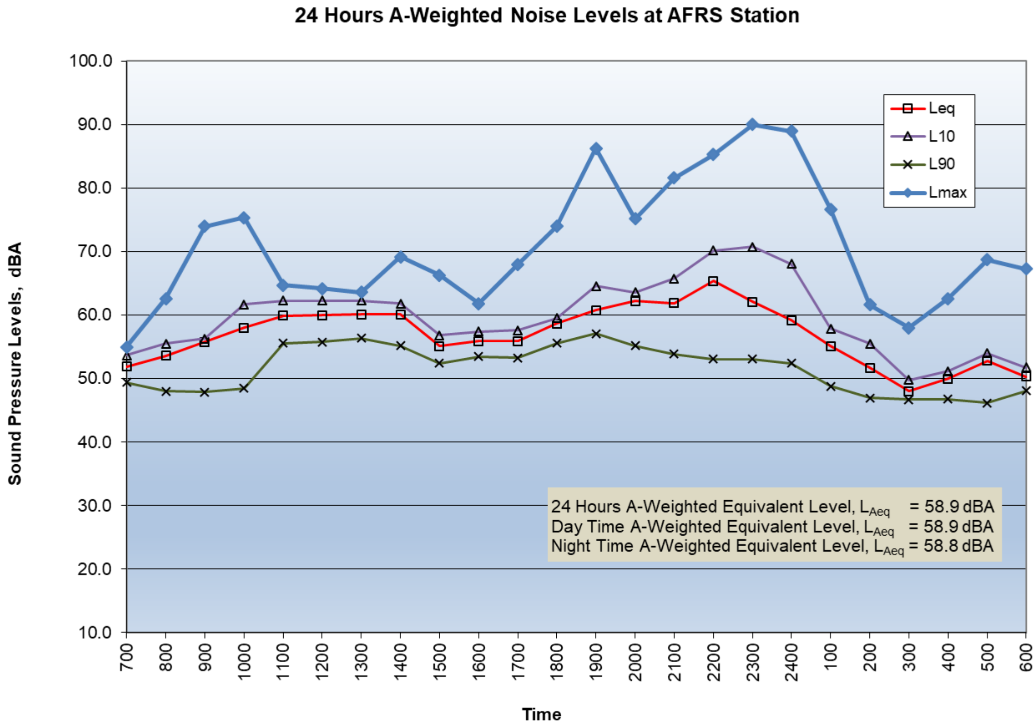


Figure B-39: Example of 24 hours continuous noise measurement of aircraft noise at receptor nearby Airport

Figure B-39 shows an examples of 24 hours continuous noise measurement of aircraft noise at a receptor nearby Airport. The hourly LAeq, L_{max}, percentile L_{10} and L_{90} levels are plotted. The hourly L_{max} levels from the above measurement were also plotted as shown in Figure B-40. A tabulation of these hourly L_{max} levels with the actual time of the L_{max} events could be prepared such that the flight number (aircraft responsible for the L_{max} event) can be identified if required.

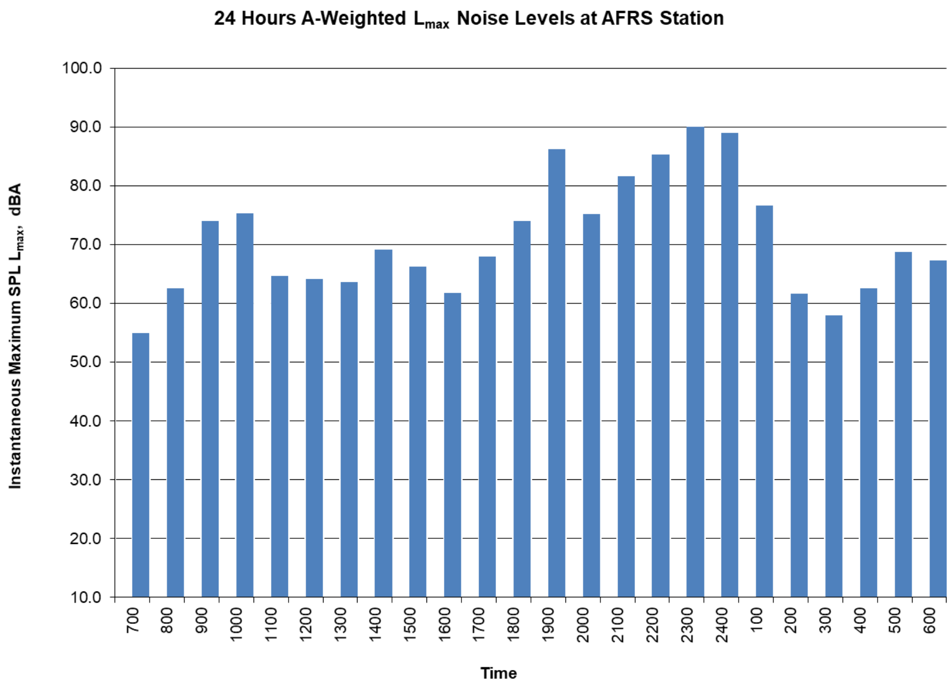


Figure B-40: Example of 24 hours continuous noise measurement of aircraft noise at receptor nearby Airport showing hourly L_{max} levels

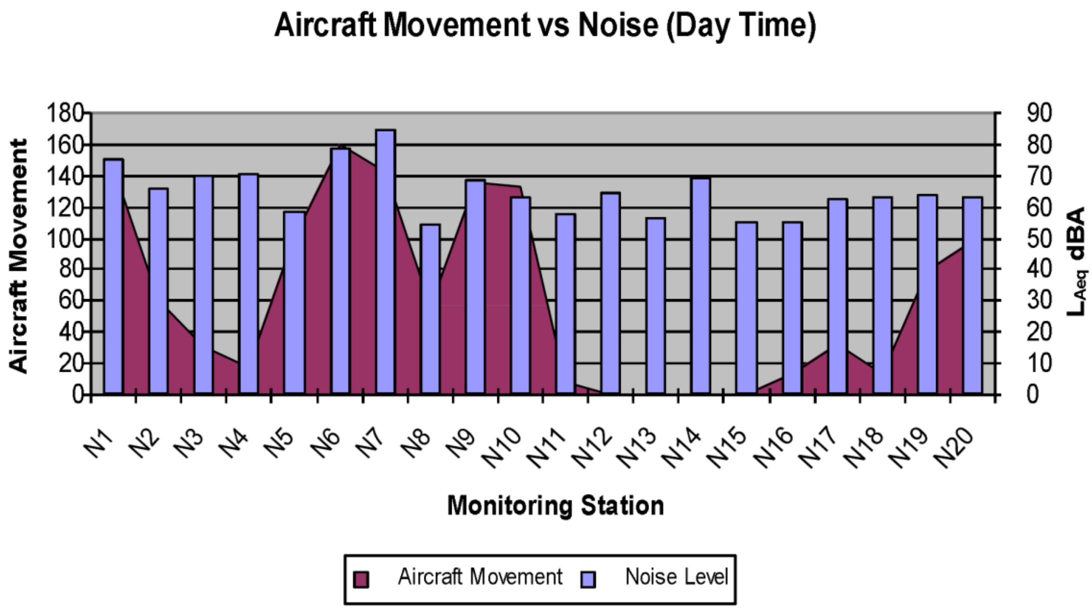


Figure B-41: Example of Daytime L_{Aeq} for aircraft noise measurement correlated against total number of aircraft movements at 20 monitoring locations

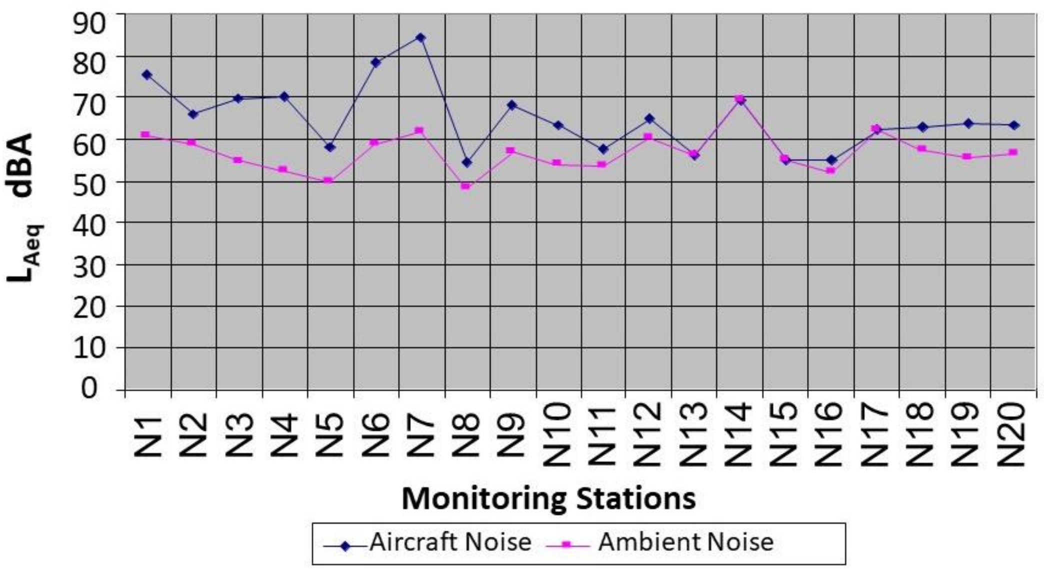


Figure B-42: Example of Daytime L_{Aeq} for aircraft noise measurement correlated against total number of aircraft movements at 20 monitoring locations

Figure B-41 shows an example of aircraft noise $L_{Aeq\ Day}$ levels and the corresponding total number of aircraft movements at twenty number noise monitoring stations (referred in the chart as N1, N2, N3 …. to N20). The monitoring stations were at receptors' locations close to the Airport, and other sensitive receptors further away located beneath flight paths. Similar plots and correlation of number of aircraft movements for night-time $L_{Aeq\ Night}$ levels should also be prepared.

Examples of results of aircraft specific noise levels (obtained from post-processing of noise data with events marker algorithm) and the residual ambient noise levels at the respective monitoring locations (N1, N2, N3 …. to N20) for daytime are given in Figure B-42. Similar results should be presented for night-time.

The aircraft noise level as compared against the ambient noise (i.e. level increase above ambient) would provide an indication of noise disturbance perceived at the respective monitoring location. (Refer to Annex C and Table C-1 in this Guideline for information on assessment of human perception and annoyance).

6.7 Noise Disturbance Measurements: Commercial Activities & Entertainment Premises, Neighbourhood Disturbance

The procedure referred to in this sub-section cover the measurement of noise disturbances from commercial activities and entertainment noise affecting specific receptors. The procedure can also be used for other events related noise disturbance such as neighborhood noise (*gangguan kejiranan*), etc.

(a) Purpose

Commercial activities (night markets, *pasar malam*, etc.) and entertainment noise measurements are usually undertaken for assessment and investigations of noise disturbance affecting an aggrieved party (noise sensitive receptors such as residential dwellings, hotel, etc.).

Commercial activities noise levels usually fluctuate over the night day time period; while entertainment noise is often associated with night time operations. Neighborhood disturbance is usually events related that may be temporary in nature but repeated over different time periods.

Measurements are usually short term events monitoring corresponding to commercial activities, entertainment operations or events. The measurements shall nevertheless include measurements over a night day time cycle for full reporting of the noise profile and comparison purpose. Noise variations (increased noise levels) may occur on weekends and eve of public holidays with increased night time activities and road traffic congestion at the site.

In situations where there is a need to investigate complaints against a particular premise or entertainment outlet, it is preferable that measurements be undertaken without the activities or entertainment noise at different period of the evening/night, and/or on nights where the outlet or premise is not operating (while other noise sources remaining fairly similar).

(b) Site selection

Measurement site selection shall be at property boundary of the entertainment premise(s) or location of commercial activities and at the receptors (property boundary and/or where feasible at receptors building balcony/terraces). Measurement sites shall preferably include locations exposed to the noise sources and away / shielded from noise sources so that comparisons can be made on the relative differences in the noise intrusion.

In special cases, it may be necessary to measure inside the receptors building (hotel and apartment units) when access can be arranged to assess the severity of noise disturbance. It is to be noted that noise measurements undertaken inside a building would inherently involve other factors such sound insulation of building elements (glazing, doors, walls, quality of construction) as well as acoustic properties of the room/spaces inside the building. This would vary for different buildings.

In neighborhood noise disturbance, the measurements would often involve measurements undertaken indoors in the affected unit or receptor dwelling.

(c) Microphone position

Microphone positions shall be mounted at least above 1.2 m above the ground and at least 3.5 m away from any reflecting surfaces other than the ground. .

(d) Measurement conditions

Measurement conditions should be representative of the commercial activities or entertainment noise emissions. The noise emissions are usually limited to several hours corresponding to the operational hours. During operational hours noise levels may also peak at maximum crowd capacity.

In addition to the noise from the premises there may also be road traffic house from traffic congestion along or nearby the premises.

In cases where measurements are to be undertaken in response to complaints against an offending party and/or by authorities investigating a particular premise, experience had shown that most offending parties would attempt to reduce the intensity of sound emissions (turning down volume of sound systems or/and not operating sub-woofers, etc.) during the time of noise surveillance so that lower noise levels would be reported. It is therefore advisable that the measurements shall be undertaken as discretely as possible, or with the use of unmanned semi-permanent noise monitoring instruments installed in a suitable location. The use of unmanned noise monitoring units shall have audio recording for aural playback and off-site data analysis and data reduction.

(e) Noise parameters to be measured

Noise parameters to be measured shall be L_{Aeq} together with the statistical parameters L_{10} and L_{90} levels (with data sampling typically one seconds or up to 1 minute intervals). Full statistical distribution of the sound pressure levels should be recorded over the measurement period. It is also recommended that the instantaneous L_{max} peak levels to be measured.

Sound pressure level measurements and frequency analysis in one octave frequency bands are necessary for assessment of entertainment noise (low frequency noise components from music bass/sub-woofers, etc.).

(f) Results to be reported

Results to be reported shall be $L_{Aeq\ 1\ hr}$ and statistical percentile L_{10} and L_{90} levels on an hourly basis. The L_{max} levels may also reported. Daytime L_{AeqDay} and night-time $L_{AeqNight}$ over a 24 hours day night period shall also be reported for comparison.

Entertainment noise shall also include results of measured sound pressure levels in one octave band frequencies.

Measurements for neighbourhood noise disturbance and all other events related noise disturbances would inherently require noise levels corresponding to the noisy events to be reported. This may be based on short term L_{Aeq1hr} levels (with data sampling and plot with 1 to 2 seconds time intervals). These would also require comparisons against measured noise levels undertaken in the absence of the offending events. Assessment would inherently be based on noise level differences between the two different conditions (with and without offending noise).

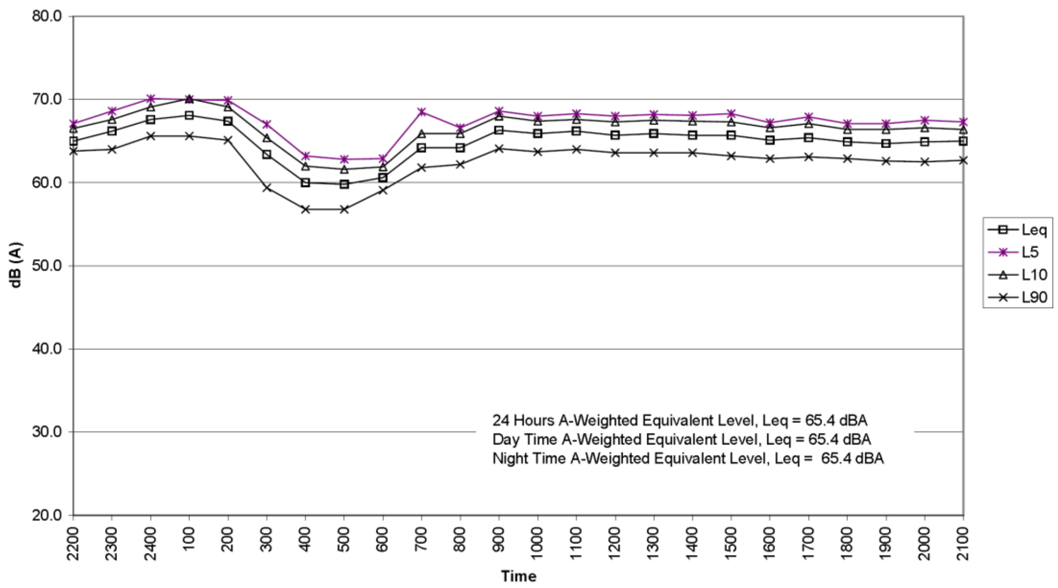


Figure B-43: Example of outdoor entertainment noise measurement results measured at receptors building open terrace (5th floor) fronting entertainment outlets.

Figure B-43 above shows an example of outdoor noise from a row of entertainment premises (with live music and sound systems from multiple outlets) affecting noise sensitive receptors (in a hotel) measured in an open terrace on the 5th floor overlooking the entertainment premises. Measurements were undertaken continuously 24 hours commencing at night till the following night. It was evident from the measurements that the steady state equivalent noise levels do not necessarily reflect the severity of a noise disturbance based on the L_{Aeq1hr} noise levels. In this example the one-hour steady state equivalent L_{Aeq1hr} noise levels during entertainment operations were only marginally higher than non-operational hours.

Comparison of the instantaneous sound pressure levels plotted continuously over time for different periods of the evening and night during entertainment operations as shown in Figure B-44 offers better visualisation of the noise disturbance with significant increase of noise levels (more than 10 dB) between operating and non-operating conditions.

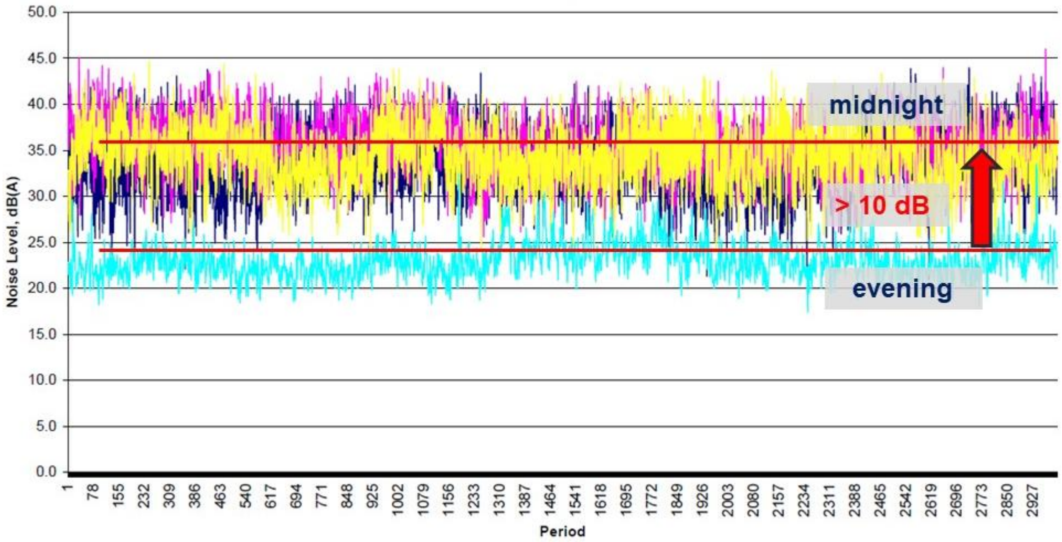


Figure B-44 Instantaneous sound pressure levels in octave band frequencies plotted against time during evening and midnight for entertainment noise measured indoors at receptor location

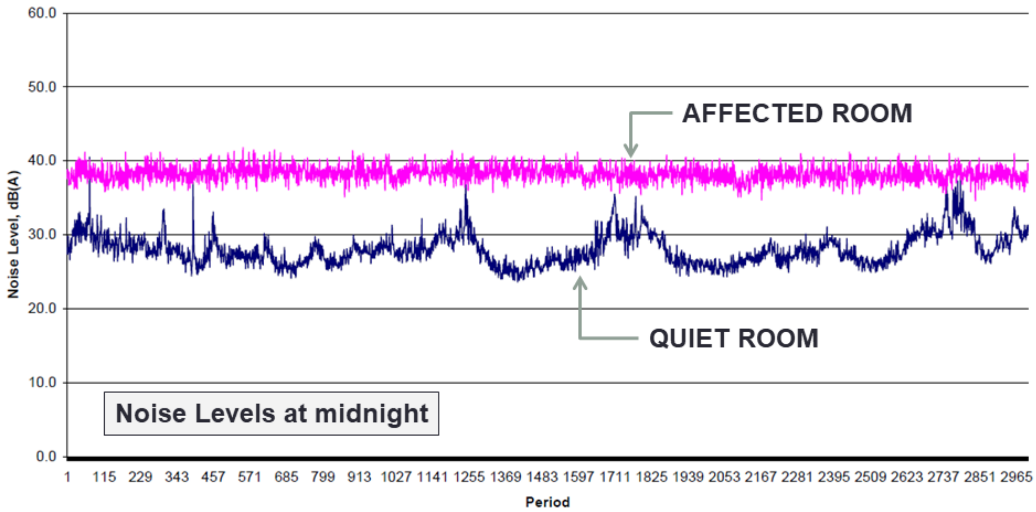


Figure B-45: Instantaneous overall sound pressure levels plotted against time measured indoors in room with line of sight to offending source and another room away from source

Simultaneous measurements in different rooms with and without line of sight to the offending noise also offered a better comparison of the relative degree of noise intrusion to the receptor, as shown in Figure B-45.

The above results and graphical plots demonstrate the need for comparison of noise levels with and without the noisy activities or events. The severity of the noise disturbance could then be assessed based on increase in noise levels between the two conditions. Noise level increase of 10 dB is subjectively perceived as twice as loud and may be deemed objectionable for noise sensitive receptors, especially if the disturbance occurs at night.

The results and assessment as shown above in principle also apply to neighbourhood noise disturbance (renovation works in terrace houses between units, home theatre sub-woofer disturbance, etc.) with comparison of noise levels ($L_{Aeq1\ min}$ or $L_{Aeq\ 15\ mins}$) with and without the offending event.

7.0 Report Template

The following section presents a template as general guidance (example of items to be reported and report format) for preparation of a noise measurement report. The reporting shall be based on guidance for noise measurement parameters and items to be reported as described in the earlier Section 6.0 for different types and noise source measurements.

Results tabulation and types of graphical plots and charts shall correspond to the type and noise sources monitored. Examples given in Section 6.0 shall be used as guidance.

Company/Institution Logo and Letterhead

Document No. ………………

Report Date ………………

Report for ………………

Measurement by …………………………………
Report by …………………………………
Person Responsible ………………………………….
DOE Registration Number ………………………………….

1. SCOPE OF MEASUREMENTS

Describe the Scope/Objective/Extent of the Measurements.
Why is the measurements undertaken? What is the purpose or significance of the measurements? Where is the area of measurements? How many number and locations of measurements?

2. MEASUREMENT LOCATIONS

List out the locations. Give GPS coordinates of locations.
What is the significance of these locations?
Provide a drawing / map and aerial photo (Google map) of the locations.
Nature and state of ground between noise source(s) and measurement positions.

3. MEASUREMENTS DATE

Give dates of measurements. Duration of monitoring
Note if they are on week days, weekends, public holidays or school holidays

4. MEASUREMENTS STANDARDS

State the Standards or Guidelines applicable for the measurements undertaken.

5. ACCEPTANCE LIMITS

State the noise acceptance limits or acceptance criteria to be used for assessment of the measured levels.

6. INSTRUMENTATION

Instruments Used

List our instruments used and Serial Number.
List out calibrator used and calibration details.

Instruments Settings

Indicate the instrumentation settings used:
Time weighting: *Fast / Slow / Impulse / Peak Hold*
Frequency weighting: *A / C / Linear Weighting (dBA, dBC, dBZ, dB Lin)*
Noise indices: L_p, L_{Aeq}, L_{10}, L_{90}, L_{max}

Measurements Accuracy

Indicate instrumentation type: Type 0 / 1 / 2
State accuracy of measurements: $\pm$1dB, for example.

7. MEASUREMENT PROCEDURES

Describe the measurement set up
Describe the measurement methodology, and data recording procedures.
Duration of measurements period and measurement type: *continuous 24 hours, short term events measurement (1 hr, etc.)*
State sampling duration (*data storage intervals: seconds/minutes),* etc.

8. CONDITIONS PREVAILING DURING MEASUREMENTS

Atmospheric weather conditions: wind speed and direction, temperatures at site, atmospheric pressure, relative humidity, rainfall.
Variability of emission of noise sources: *Fluctuations of noise levels*
Report special events or factors that may have adversely affected the reliability or accuracy of the measurements.

9. RESULTS

Quantitative Data

Present results in a table(s) and plot all necessary charts.
Day time and Night time L_{eq}, L_{10r}, L_{90}, L_{max} and other data where applicable.
Data to be reported shall be based on guidance given in this Guidelines, Annex B Section 6.0 for different noise sources.

Qualitative Data

Possibility of locating origin of noise, Identification of source, nature of source, character of source, significance of source (noise source ranking).

10. ASSESSMENT AND / OR FINDINGS

Summarise key finding and observations of the measurements.
Present an assessment of the measured noise levels.
Tabulate comparisons of acceptance limits, measured noise levels, exceedance and statements of likely impact.
Explain severity of the exceedance and reasons.
Where applicable, state possible mitigation measures that may be required.

11. ATTACHMENTS

Attach drawings, maps, charts, tables, photographs, noise maps/noise contours. Measurement record sheets shall also be included.

ANNEX C

PROCEDURES FOR ASSESSMENT OF COMMUNITY ANNOYANCE

1. A quantitative assessment of noise involves measuring (or predicting) noise levels and comparing them against levels recommended in this Guideline.

2. In addition to this, it is possible to assess a noise with respect to community annoyance based on human perception of sound level change and whether the sound is deemed intrusive.

3. Notwithstanding what the absolute noise levels are, receptors experiencing a noise intrusion would typically perceive the noise increase based on their subjective perception compared against the prevailing background noise in the absence of the noise intrusion.

   The table below tabulates typical human subjective perception of loudness change in sound level. Noise increase of 10 dB will be subjectively perceived as twice as loud (and a noise reduction of 10 dB perceived as half as loud).

   Table C-1: Human perception of sound and likely environmental impact

Increase in sound level, dB	Subjective change in perceived loudness	Environmental Impact
3	Just perceptible	None
5	Noticeable difference	Little
10	Twice as loud	Medium
15	Large change	Strong
20	Four times as loud	Very strong

4. For purpose of quantifying residual impact in Environmental Impact Assessment, generalised descriptors as indicated in Table 1 to describe the noise level increase may be used. (These descriptors were adapted from an earlier version of British Standards BS 4142 which is now superseded) .

5. The current British Standards BS 4142: 2014 (*or latest revison*) "Methods for rating and assessing industrial and commercial sound" states that:

   a. A difference of around +10 dB or more indicates that complaints are likely
   b. A difference of around +5 dB is of marginal significance
   c. If the sound level is more than 10 dB below the prevailing (baseline) level, complaints are unlikely.

   *The greater the difference of the rating level (*offending noise*) above the background noise level (*prevailing sound*), the greater the likelihood of complaints*.

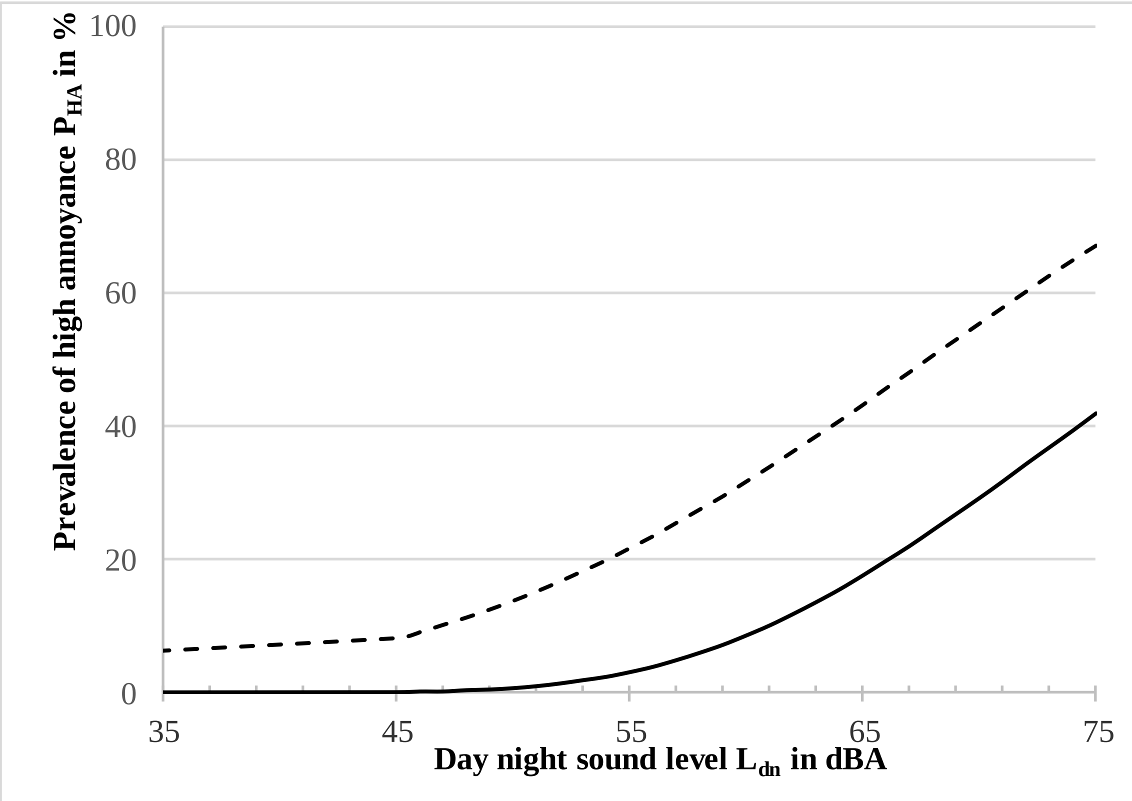
6. For noise which has an audible tone (e.g. whine) a +5dB tonal correction shall be added to the offending sound (rating level) in the determination of the level difference

for assessment using the above Clause 5. For impulsive noise (e.g. from piling) a +5dB impulsive correction shall also added to rating level.

7. International Standard ISO 1996-1: 2016 (*or latest revison*) "Acoustics- Description, measurement and assessment of environmental noise – *Part 1: Basic, quantities and assessment procedures*" may also be used to quantify likely annoyance.

Annex E of ISO 1996-1: 2016 (*or latest revison*) provides guidance on the estimation of prevalence of a population highly annoyed as a function of adjusted day-evening-night or day-night sound levels using the community tolerance formulation.

The prevalence of high annoyance PHA expressed as a percentage of the population as a function of noise levels (adjusted day-evening-night L_{den} or day-night L_{dn} sound levels). Figure 1 provides an estimation of the prevalence of high annoyance to road traffic as a function of noise levels. Higher noise levels shall have a higher percentage of the population perceiving the noise to be *highly annoying* (high annoyance).



Source: ISO 1996-1:2016 Annex E.

Figure C-1: Prevalence of high annoyance to road traffic noise (solid line) and the corresponding 95% prediction interval (upper limit as dashed line) versus L_{dn}

8. Estimation for annoyance to aircraft noise is also given in ISO 1996-1: 2016 Annex E.

9. Example

An example of annoyance assessment using ISO 1996-1: 2016 is given below.

Consider a case where road traffic noise levels measured at two receptors are as follows:

Location A L_{dn} = 70 dBA
Location B L_{dn} = 60 dBA

Using chart given in Figure C-1, there is a 30% prevalence of high annoyance at Location A compared to 10% prevalence of high annoyance at Location B.

The upper limits of high annoyance are 60% at Location A and 30% at Location B.

ANNEX D

BEST PRACTICE TO MINIMISE NOISE DISTURBANCE

1 General

No person should unreasonably make, continue, or cause to be made or continued, any noise disturbance. Lawful non-commercial public speaking and public assembly activities conducted on any public space or public right-of-way are exempted.

In the context of this Guideline, noise disturbance shall mean any sound which:

(i) exceeds the existing ambient equivalent A-weighted sound level (L_{Aeq}) by 10 dB; or

(ii) exceeds the sound level limits as prescribed herein in these Guidelines.

2 Construction

Project proponents or person(s) should not operate or permit the operation of any tools or equipment used in construction, maintenance, or demolition work:

(a) Between the hours of 10.00 p.m. and 7.00 a.m. the following day on weekdays or at any time on weekends or public holidays, such that the sound therefrom creates a noise disturbance across a residential real property boundary or within a noise sensitive zone, except for emergency work of public service, and utilities.

(b) At any other time, such that the sound level at or across real property boundary exceeds the stipulated maximum permissible sound levels as defined in this Guideline for the daily period of operation.

(c) The use of low noise (and vibration) generation equipment, process or activity shall be required in noise sensitive areas.

3 Industrial sites

(a) Project proponents and Plant operators should not operate or permit the operation of equipment or facilities in an industrial site such that noise levels exceed the maximum permissible limits as prescribed in the Guidelines.

(b) Equipments or facilities located outdoor, exhaust, discharge vents, ventilation openings which generate excessive noise should be fitted with sound attenuators, enclosures or barriers as deemed appropriate.

4 Transportation

(a) Project proponents of new highways, road re-development or expansion, and rail or transit trains system(s) should minimize noise intrusion to residential areas and noise sensitive premises with alignments offering the maximum possible buffer zones and/or natural shielding.

(b) In situations where meaningful buffer zone is not possible, or when noise levels exceed recommended limits as prescribed in the Guideline the use of noise shielding (man-made barriers or natural shielding) may be required. Man-made barriers should be aesthetically compatible with the surroundings.

5 Entertainment noise

Person(s) who organise, or operate a business or permit the hosting of activities, within their private property or public right of way, should ensure that these activities would not create a noise disturbance from their entertainment and recreational activities which result in sound levels exceeding maximum permissible limits as prescribed in this Guideline.

6 Loudspeakers and sound reinforcement systems

(a) Sound amplified system, public address system, or similar device should not be used between the hours of 10:00 p.m. and 7:00 a.m. the following day, such that the sound therefrom creates a noise disturbance across a residential real property boundary or within a noise sensitive zone.

(b) Music and other life performances in entertainment premises shall be carried out inside the premises and all music (noise) are confined strictly within the building envelope. This shall require the building to be constructed with adequate sound insulation and all openings (doors, windows and fresh air openings) to be have adequate sound insulation such that a noise disturbance does not occur outside the said premise.

(c) Sound amplified systems used in conjunction with mosques and other places of religious worship shall be exempted. Notwithstanding this exemption, the occupier or owner if the said places are encouraged to exercise goodwill in minimizing any potential noise disturbance that may occur.

7 Radios, television sets, musical instruments and other devices

The operation or playing of any radio, television, musical instrument, sound amplifier, or similar device which produces, reproduces, or amplifies sound should not be:

(a) in such manner to create a noise disturbance across a real property boundary or within a noise sensitive zone, except for activities open to the public and for which a permit has been issued by the appropriate licensing authority;

(b) in such manner to create a noise disturbance at 15 meters from such device, when operated in or on a motor vehicle on a public right-of-way or public space, or in a boat on public waters;

8 Rearing of swiftlets (*burung walit*)

(a) The rearing of swiftlets (*burung walit*) or similar for commercial or otherwise is prohibited in residential dwellings or in vicinity of residential areas and other noise sensitive receptors.

(b) Such activities may be permitted in agriculture zones away from residential dwellings or areas, and that no noise disturbance is generated.

(c) Any other rearing of swiftlets or bird(s) for recreational purpose shall be in reasonable quantity and shall not result in a noise disturbance to the adjacent property.

9 Street vendors

(a) The offer for sale, to purchase or sell anything by shouting or outcry within any residential or commercial area when licensed by the appropriate licensing authority should not be between the hours of 7.00 a.m. and 10.00 p.m., or in such a manner as to cause a noise disturbance.

(b) Night markets, *pasar malam* or similar shall be permitted in designated locations and time as approved and/or licensed by the Local Authorities.

10 Loading and unloading

Person(s) when licensed by the local authority should not load, unload, open, close or engage in activities related to other handling of goods, cargo, boxes, crates, containers, building materials, garbage or similar objects between the hours of 10.00 p.m. and 7.00 a.m. the following day, or in such a manner as not to cause a noise disturbance across a residential real property boundary or within a noise sensitive zone.

11 Stationary non-emergency signaling devices

(a) The sounding of any electronically-amplified signal from any stationary bell, chime, siren, whistle, or similar device, intended primarily for non-emergency purposes, from any place, should not be more than 5 minutes in any hourly period.

(b) Devices used in conjunction with places of religious worship are exempted.

12 Emergency signaling devices

(a) The sounding outdoors of any fire, burglar, or civil defense alarm, siren, whistle or similar stationary emergency signaling device for testing, except for emergency purposes, should occur at the same time of day each time such a test is performed, but not before 8.00 a.m. or after 10.00 p.m. Any such testing should use only the minimum cycle test time. In no case should such test time exceed 60 seconds.

(c) The sounding of any exterior burglar or fire alarm or any motor vehicle burglar alarm should automatically terminate within 5 minutes of activation.

ANNEX E

GUIDANCE ON NOISE CONTROL

1.0 Introduction

1.1 Noise control is an activity directed towards modification of the sound generation and propagation reaching receptors to be within a required noise limit. It usually involves an engineering approach for the generation, containment and/or limitation of the sound propagated to the receptors.

1.2 Noise control requires a systematic approach addressing the sound generation and transfer consisting of the three basic elements:

- Source
- Transmission path
- Receiver (receptor).

1.3 Noise control involves addressing the respective elements as shown in Figure E-1.

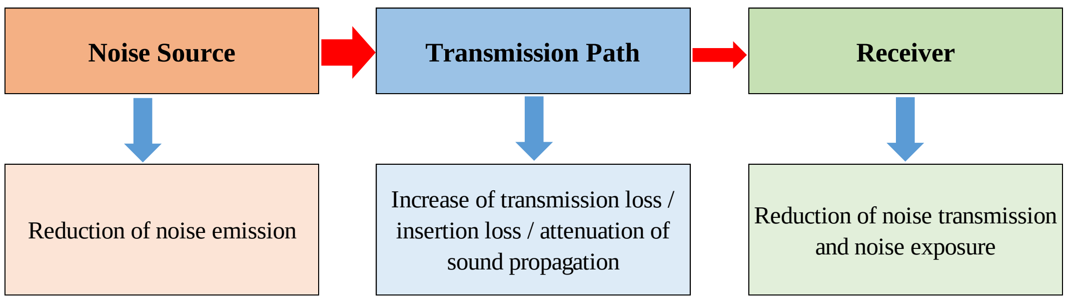


Figure E-1: Basic elements in noise control

1.4 Noise control methods can be implemented at all stages in this sound transfer chain in order that the desired overall sound reduction shall be obtained. Effective noise control requires the most significant contibuting elements and paths to be addressed accordingly in order of severity.

1.5 The source is the point of origin of the noise (and vibration excitation) where the offending high noise is emitted. The source(s) will normally need to be identified, even though reduction of the noise generated at source may not necessarily be viable in a pre-existing problem.

1.6 The transmission path is the medium through which sound waves transmission takes place from the source(s) to the receptor. The transmisison paths consist of one or combination of the following:

- Direct airborne sound transmission
- Reflected airborne sound transmission
- Reverberant sound fields (noise built up in confined space)
- Duct-borne noise (in ventilation system)

- Ground-borne vibration
- Structure-borne sound
- Liquid-borne sound and vibration (in pipes).

1.7 The receiver is the occupant of the location (receptor) affected by the excessive noise. It may a single individual or group of persons or the entire community.

1.8 Noise (and vibration) control at source may involve any or combination of the following

- Reduction of sound power level of source.
- Reduction of vibration energy generated at source.
- Modification of spectral content of noise.
- Modification of wave forms of impulsive sounds.

The above essentially reduces the noise emitted from the equipment or work activity.

1.9 Noise control in the transmission path may involve increasing the distance between the noise source and the receiver, or introducing elements to attenuate (reduce) the sound propagation by means of screens, barriers, enclosures, silencers, etc.

Increasing the distance between the noise source and sensitive receptors is often the most effective method of controlling noise. This may not be possible for existing noise sources and development. Sound intensity decreases as a function of distance (doubling of distance between source and receiver for a point source is 6 dB, and for a line source 3 dB for simple geometric propagation).

Noise screening or attenuation devices therefore represent the most common option for noise reduction in the transmission path for environmental noise sources. These would include but not limited to the following:

- Permanent noise barriers
- Movable and/or temporary barriers
- Partial enclosures
- Full enclosures
- Silencers and mufflers
- External lagging.

Description and variants of the above devices as used in practical applications for noise reduction in the transmission path are given in the following sub-sections of this Annex.

1.10 Noise reduction at receiver could involve any or combination of the following

- Sound insulation within the receptor dwellings
- Modification of acoustics properties within the receptor.

In practice, the noise reduction at the receiver involves sound insulation of windows (increasing glass thickness and/or type) and blanking of openings with direct sound path into the receptors' dwellings.

2.0 Source Path Receiver Typical Control Options for Environmental Noise

The following sub-sections present examples of possible source, path and receiver control options for typical environmental noise sources. The noise sources listed in each respective noise source type (road traffic, highways, industry, etc.) although generic and likely to be representative for most applications are however by no means exhaustive which would require further analysis on a case by case basis.

2.1 Noise control for road traffic and highways

Reduction at Source		Transmission Path	Receiver
Road Alignment	Buffer Zone	Noise Barriers	Building Orientation
Highway Design Pavement, parapet, etc.	Vehicles Noise Emission	Enclosures	Sound Insulation: Windows, doors
Speed Limit	Construction Workmanship		
Traffic Restrictions: Heavy vehicles, operating hours	Road Maintenance		

2.2 Noise control for railways and transit trains

Reduction at Source		Transmission Path	Receiver
Railway Alignment	Buffer Zone	Noise Barriers	Building Orientation
Viaduct Design Viaduct type, parapet, etc.	Trains Design & Noise Emission (OEM)	Enclosures	Sound Insulation: Windows, doors
Rails: Continuous welded tracks, rail grinding, rail damping	Construction Workmanship	Trackside rail screening & absorption	
Wheels screening / Trains undercar skirt	Speed Limit		
Wheels: Wheels roundness, wheels damping	Tracks & Wheels Maintenance		

2.3 Noise control for noise from industry premises

Reduction at Source		Transmission Path	Receiver
Plant Design	Buffer Zone	Noise Barriers	Building Orientation
Outdoor equipment: Location and shelter	Equipment selection	Enclosures	Sound Insulation: Windows, doors
Vibration damping & control at source	Operations: Process and Operating hours	Silencers	
Design & Mitigation at ventilation & access openings	Plant & Machinery Maintenance	Cladding	

2.4 Noise control for construction

Reduction at Source		Transmission Path	Receiver
Site Planning: Plant & Machinery location	Operations: Process and Construction hours	Temporary Noise Barriers	Sound Insulation: Windows, doors
Piling Methods: Low noise & vibration alternatives	Equipment selection	Movable barriers	*Temporary relocation (shifting out)*
Alternative construction methods	Construction vehicles traffic control	Partial Enclosures	
Vibration damping & control at source	Plant & Machinery Maintenance	Silencers	

2.5 Noise control for commercial activities and entertainment premises

Reduction at Source		Transmission Path	Receiver
Zoning control	Re-location of premises / pasar malam, etc.	Transparent Noise Barriers at frontage of premises / perimeter of pasar malam site	Sound Insulation: Windows, doors
Licensing control	Operating hours		Sound Masking with water feature at receptors
Containment of noise within entertainment premises	Traffic control	Transparent Noise Barriers at receptors boundary or façade	
Restraint / limits on volume from live music & sound system			

2.6 Noise control for airport and aircraft noise

Reduction at Source		Transmission Path	Receiver
Land use planning and abatement	Air traffic management	Noise barriers & partial enclosures (for aircrafts engine ground testing)	Township planning
Aircrafts as per ICAO Noise Standards (Annex 16 Vol.1)*	Noise preferential routes / runways		Building codes
Fleet and traffic evolution *New generation aircrafts*	Operational procedures noise abatement		Sound Insulation: Windows, roof, openings
Operating restrictions on aircraft / Flights curfew	Limited engine ground running		

**Reduction of noise at aircrafts source*

The International Civil Aviation Organisation (ICAO) had developed a *Balanced Approach to Aircraft Noise Management* to address problems and management of airport and aircraft noise. Mitigation of airport and aircraft noise should be guided by the ICAO "*Guidance on the Balanced Approach to Aircraft Noise Management*" *(Doc 9829 AN/451) Second edition 2008*, (and any subsequent revision).

3.0 Noise Barriers

3.1 Noise barriers are the most common noise control option for many environmental noise sources, as evident in Section 2.0 above.

3.2 Barriers or screens placed in the path of a source free field sound propagation will create a relatively quieter zone behind the noise barrier (known as acoustic shadow) thereby proving shielding of the sound waves. There are nevertheless waves diffraction propagated beyond the barrier that are frequency dependent, as shown in Figure E-1.

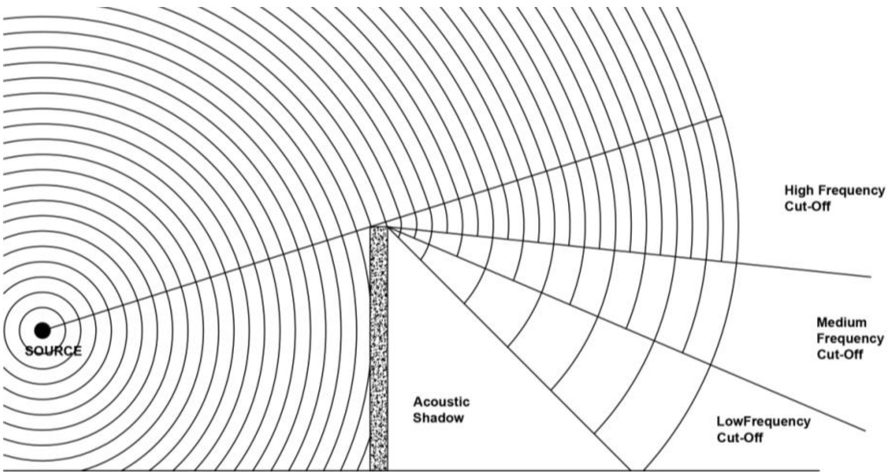


Figure E-2: Acoustic screening of source in the airborne transmission path

3.3 Noise barriers must be an impervious element (panels without gaps) installed in the airborne sound transmission path between the noise source and receptor to be protected. For general applications the panel minimum sound insulation should be more than 25 dB to 30 dB (typically barrier with surface weight not less than 10 kg/m^2 to 20 kg/m^2).

3.4 For the barriers to be effective there should be no line of sight from the receptor to the noise source. The minimum height of the barrier shall therefore be such that no part of the noise source will be visible from the receptor point.

3.5 Care is needed in the design, placement and construction of a barrier for the screening to be effective. A barrier can, by reflecting sound, simply transfer a problem from one receiving position to another. On level sites, for maximum effectiveness a barrier needs to be brought as close as possible to either the noise source or the receiver, with no gaps or openings at joints in the barrier.

3.6 Since barriers do not provide encapsulation of the sound field (such as a full enclosure of the source), barriers can only be expected to provide moderate levels of sound reduction (commonly referred as attenuation). In most practical situations the overall reduction would be limited by the shielding effects dictated by the path difference.

3.7 The attenuation (noise reduction) from a noise barrier is governed by the path difference. The path difference is basically the difference in distance for a sound wave travelling over the diffracting edge minus the direct distance (for an unobstructed sound travelled) between source point and receiver, as shown in Figure E-3

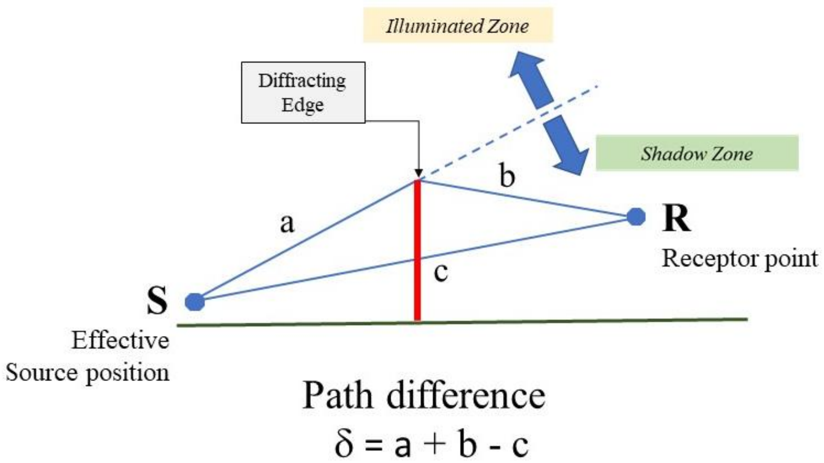
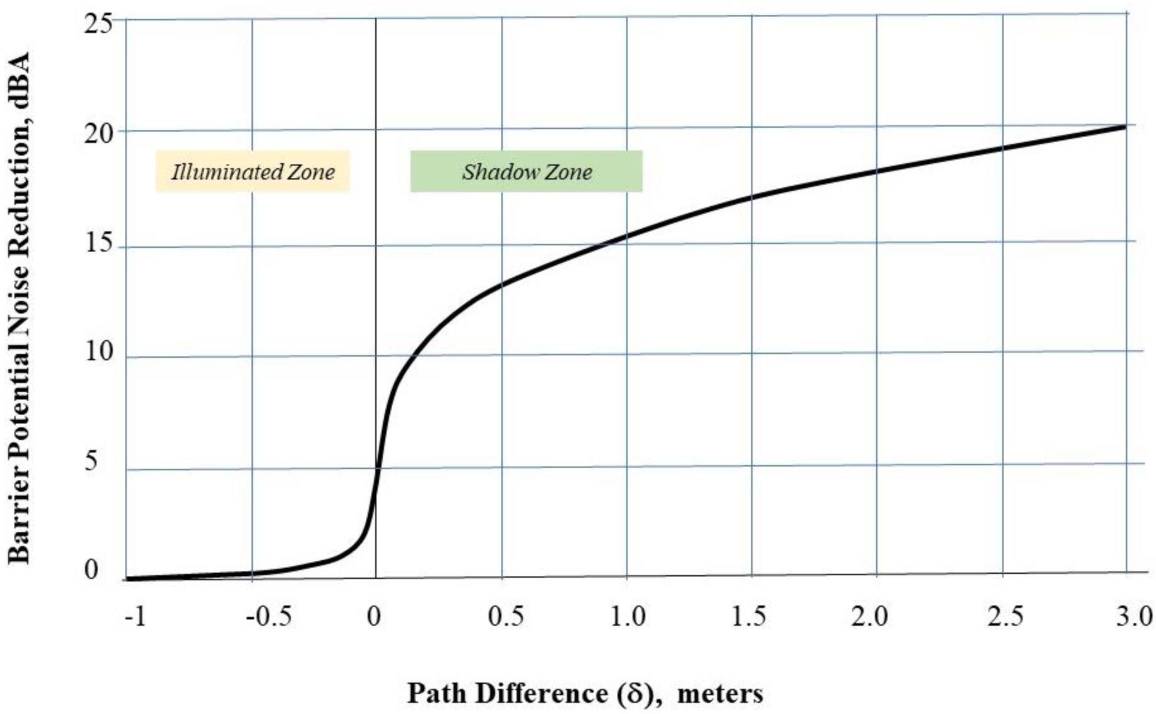


Figure E-3: Path difference for barrier



Source: Calculation of Road Traffic Noise, Dept of Transport & Welsh Office, UK, 1998

Figure E-4: Estimation of barrier attenuation based on path difference

3.8 An estimate of a barrier potential noise reduction based on the path difference is given in Figure E-3 (source: United Kingdom Department of Transport, “Calculation of Road Traffic Noise”).

This offers a simple estimation of the noise barrier attenuation for a specific path difference value. The path difference is determined from the relative distances between the source, receiver, barrier distance from source, and barrier height.

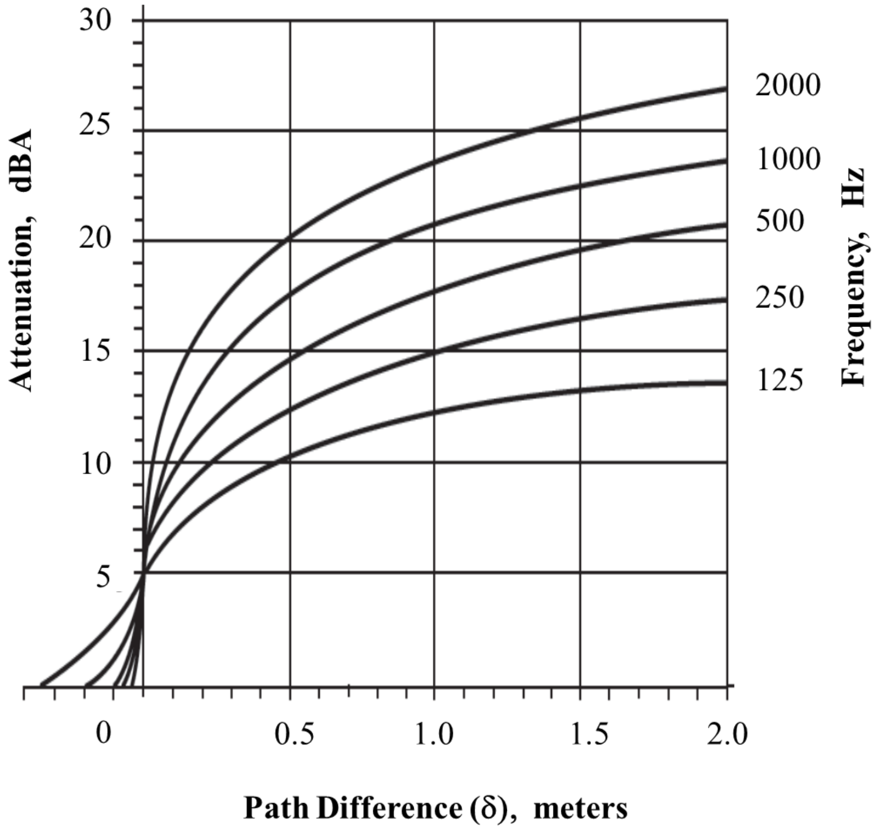


Figure E-5: Estimation of barrier attenuation at different frequencies based on path difference

3.9 As shown in Figure E-2, sound waves diffraction varies with frequencies - where the lower the frequency, the more diffraction would occur (bending around into the shadow zone). This inherently means that barrier attenuations at low frequencies are not as high as the higher frequencies; i.e. barrier attenuation is frequency dependent.

3.10 The chart given in Figure E-5 can be used to estimate the barrier attenuation at different frequencies based on the path difference.

3.11 A more accurate calculation of the noise level with the use of a noise barrier in a given application therefore requires calculations to be carried out in octave band frequencies (instead of overall levels only) which requires information on the noise frequency spectrum as well as the barrier attenuation values determined at different frequencies.

3.12 Barriers in practice are of finite length, where there is also sound diffraction at the start and end of the barriers. This is often the case in industry and construction sites applications as well as roads and railway barriers (at the start and end locations).

The nett reduction from the barrier would also be dictated by the path differences at both end edges of the barrier. The various path differences depend on the geometry between source – receiver - barrier positions and barrier height and length, as shown in an example in Figure E-5.

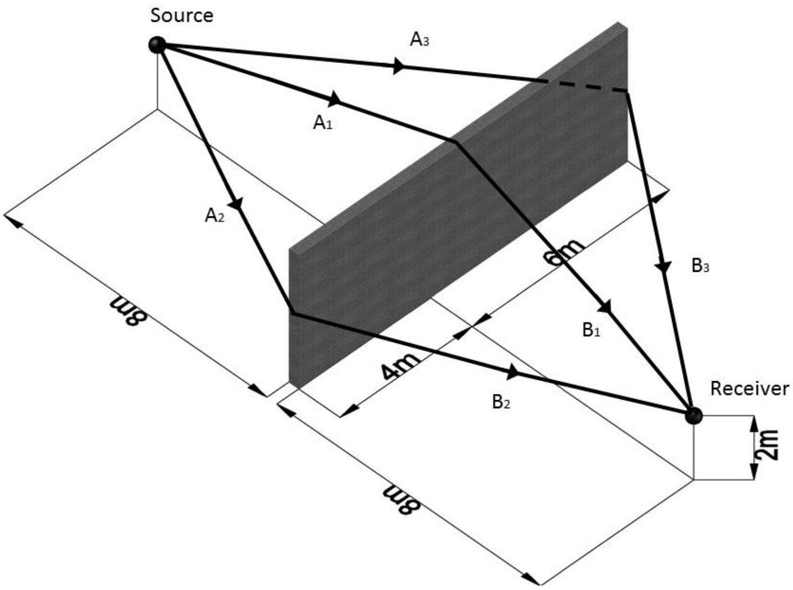


Figure E-6: Path differences of finite length barrier

3.13 Noise levels perceived at the receptor with a noise barrier as compared to the original noise level at the receptor without barrier is given by the following:

$$L_{p2} = L_{p1} - A_{barrier} \qquad \textit{Equation E-1}$$

where L_{p1} = *Sound pressure level without barrier, dBA*
L_{p2} = *Sound pressure level with barrier, dBA*
$A_{barrier}$ = *Barrier attenuation, dB*

3.14 Noise barriers could be categorized as follows according to the acoustic properties of the barrier surface (absorptivity):

- Absorptive
- Diffusive
- Reflective.

Absorptive barriers have acoustic absorption infill or equivalent (such as Helmholtz cavity absorption) rendering the barrier / panels to be acoustically absorptive. Diffusive barriers are when the surfaces are rendered with modulations on the surface so that sound is diffused (“scattered”). Reflective barriers are when the barrier or panel surfaces are acoustically hard (reflective).

3.15 Common noise barrier constructions are sheet metal panels (aluminum, steel), masonry, plastic, composite panels, transparent panels (perspex, polycarbonate, laminated glass), and often comes with an acoustic infill for acoustic absorption.

3.16 Noise barriers in practice can either be permanently erected as a fixed structure (referred as permanent barriers) or alternatively may be erected on a temporary basis (referred as temporary barriers). Moveable barriers are temporary barriers that may be moved from one place to another following the noise source or activity.

3.17 Permanent barriers are used in road, railway and industry noise mitigation. Examples of permanent noise barriers are shown in Figure E-7 and Figure E-8.

Figure E-7: Metal noise barriers used in railway noise mitigation

Figure E-8: Masonry noise barriers used in highway noise mitigation

3.18 Temporary barriers are often used in construction sites noise mitigation. These barriers are typically installed at the perimeter of a construction site adjacent noise sensitive receptors (residential houses, hospitals, etc.). Examples of temporary noise barriers are shown in Figure E-9 and Figure E-10.

Figure E-9: Temporary noise barriers used in construction noise mitigation

Figure E-10: Temporary noise barriers used in MRT construction noise mitigation

3.19 Movable barriers are often used in construction works for localized shielding of noise emissions from mobile equipment or activity. These are often required at work sites adjacent sensitive receptors. Examples of movable noise barriers are shown in Figure E-10 and Figure E-11.

Figure E-11: Movable barriers used for mobile noise source in construction works

Figure E-12: Movable barrier used for piling noise mitigation

4.0 Enclosures

4.1 Enclosures are sound insulating structures designed for the total containment of the offending sound to reduce propagation outside the enclosure, i.e. exclusion of the sound field propagation. An illustration of the concept of sound containment (“boxing up”(of the sound field is shown in Figure E-13.

The quantum of containment (exclusion of sound) depends on the sound insulation properties of the material used in the enclosure construction (and amount of sound leakage via openings and gaps in the enclosure).

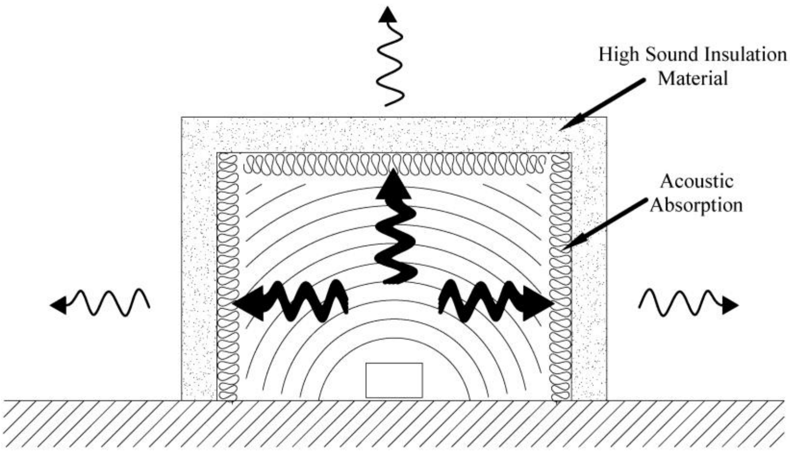


Figure E-13: Enclosure for containment of noise at source

4.2 Enclosures often incorporate sound absorption inside the enclosure to reduce the reverberant noise built up inside the enclosure.

4.3 Noise reduction in enclosure is for air-borne sound propagation only (direct sound path transmitted through the air). Structure-borne path could de-rate the enclosure sound reduction, and in critical applications should be addressed by vibration isolation of the noise (and vibration) source.

4.4 Relatively lightweight full enclosures can provide sound reduction of up to 20 dBA, and properly engineered enclosures can provide reduction of up to 40 dBA or more.

4.5 The primary parameter governing the sound reduction potential of an enclosure is the sound insulation value of the material(s) used in its construction. Factors affecting sound insulation are

- Weight (mass)
- Homogeneity and uniformity
- Stiffness
- Discontinuity or isolation.

Amongst the factors above, weight is the most important.

4.6 Transmission loss (TL) is the acoustic property used in describing the sound insulation performance of a material. The Airborne Sound Reduction index (R_w) or alternatively Sound Transmission Class (STC) is the acoustic rating that is used in acoustic tests reporting for sound transmission loss of material or products.

4.7 Noise levels perceived at the receptor after installation of an enclosure compared with original noise level before (without enclosure) can be determined by:

$$L_{p2} = L_{p1} - A_{enclosure} \qquad \textit{Equation E-2}$$

where L_{p1} = *Sound pressure level without enclosure, dBA*
L_{p2} = *Sound pressure level with enclosure, dBA*
$A_{enclosure}$ = *Enclosure Insertion Loss, dB*

4.8 The insertion loss of the enclosure (attenuation) is either determined from testing (manufacturer's test data) or estimated as a first approximation from transmission loss of the material(s) used in the enclosure construction as follows:

$$A_{enclosure} = TL_{material} \qquad \textit{Equation E-3}$$

where $TL_{material}$ = *Transmission loss of enclosure panels, dB*

There is a correction factor $10\log(S_p/R)$ assumed here as 0 that is normally included in Equation E-3 used partitions/enclosure calculations. This factor is dependent on surface area and absorptivity of the partition/enclosure. For most situations this is however significantly low (0 to 3 dB) as compared to the TL value.

4.9 In practice the actual noise reduction would be lower than the calculated value due to sound leakages (gaps, openings, etc.) and secondary noise flanking paths.

4.10 Theoretical predictions of transmission loss as a function of weight of the sound insulating material (unit mass per square metre, kg/m^2) is given in the chart below. The predictions are typically undertaken using a mass law relationship. Upper and lower range of predicted value are indicated. Typical values for common materials are also given in the chart.

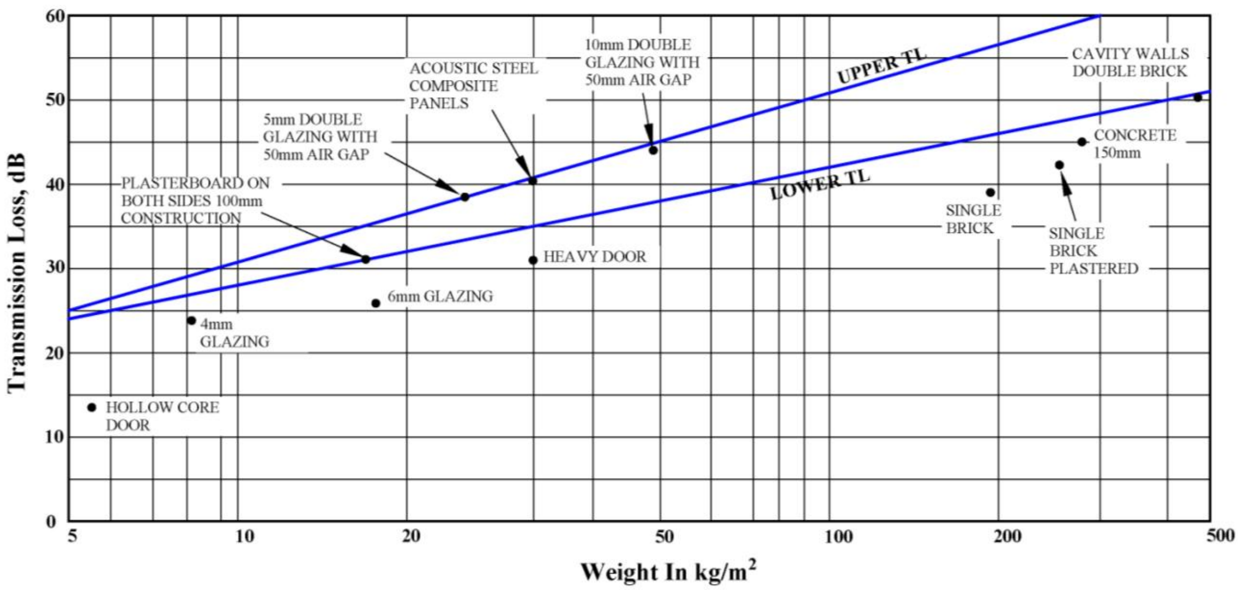


Figure E-14: Transmission loss predictions and typical values for common materials

4.11 Enclosures may be fabricated from proprietary modular sound-insulating and/or acoustic panels or common industrial and building materials.

Commercially available proprietary acoustic enclosures are usually available in modular panels which can be combined to form an infinite variety of enclosures of any size or shape. Industrial and building materials can also be customized built to specific requirements and design.

The primary requirements are to use panels or materials with the required sound insulation ratings to achieve the noise reduction (often higher than original estimated requirements to compensate for the inevitable acoustic degradation from flanking and sound leakages).

4.12 Enclosures would usually require some form of ventilation (mechanical ventilation or natural ventilation). The openings for ventilation shall require sound attenuators (silencers/mufflers) or/and acoustically lined ducts or plenums.

4.13 There are also requirements for access openings for doors and/or work process access, conveyors, etc. These openings must be kept as small as possible, and to include some form of acoustic filters (acoustically lined openings, plenums, sound traps, etc.). Access doors shall also be acoustically rated to similar sound insulation ratings as the enclosure.

4.14 As far as reasonably practical, enclosures should be used for high noise sources in very sensitive applications and/or in situations where noise shielding from simple barrier is ineffective (such as outdoor equipment or work process affecting large number of sensitive receptors in high rise dwellings).

4.15 A commonly used example of an acoustic enclosure for power generating sets in industry is shown in Figure E-14.

Figure E-14: Full enclosure for power generating sets

Figure E-15: Full enclosure for slurry treatment plant in Klang Valley MRT construction work site adjacent sensitive receptors

Figure E-16: Full enclosure for MRT trains noise mitigation adjacent sensitive receptors in high rise buildings

4.16 Examples of a full enclosures used in enclosing plant and machinery (slurry treatment plant, batching plant, chillers, compressors, large pump-sets, etc.) at work sites with long period construction period is shown in Figure E-15. Example of full and semi-enclosures used for railways and highways are shown in Figure E-16.

5.0 Partial Enclosures

5.1 Partial enclosures are commonly used in situations where it is not possible to totally enclosure an equipment and where there is a requirement for access or work flow process in and out of the enclosure. Partial enclosures are also less elaborate in design and is often a more viable alternative for applications requiring less stringent mitigation.

5.2 The effective mitigation of the partial enclosure is in the direction for which the sound propagation is enclosed or shielded. The sound reduction from partial enclosure is therefore dictated by shielding effects from the panels making up the partial enclosure.

5.3 Examples of different geometric form of partial enclosures are shown in Figure E-17. The permutation of side walls and roof / hood above the noise source varies and are customized to suit the noise source and shielding requirements.

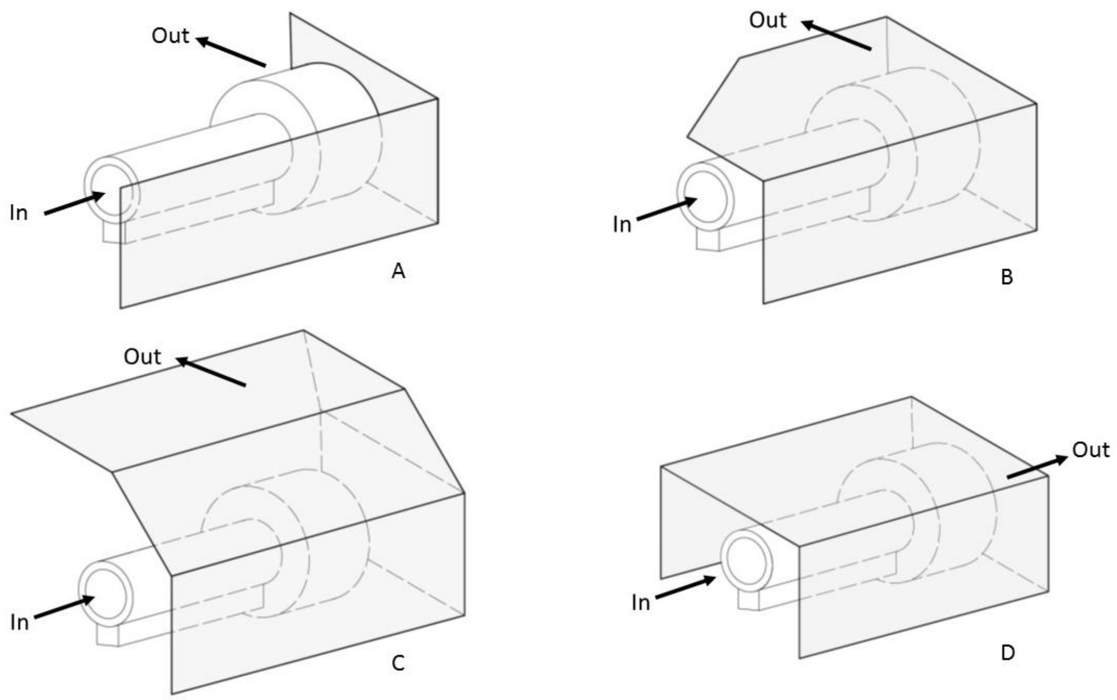


Figure E-17: Examples of different partial enclosures

5.4 Effectiveness of partial enclosures are similarly dependent on occlusion of the sound field propagation governed by the path difference on the respective diffraction edges similar to a basic noise barrier.

Figure E-18: Movable partial enclosures for construction works noise mitigation

Figure E-19: Semi and partial enclosure for highway and railway noise mitigation.

5.5 Figure E-18 show an example of partial enclosures used in construction sites. The enclosure could be made with lightweight or flexible sound insulating sheets for mobility to be used mobile equipment and/or localized work site.

Figure E-19 show examples of permanent partial and semi-enclosures typically used in railway and highway noise mitigation.

6.0 Silencers & Acoustic Louvers

6.1 Silencers are sound attenuating devices that allows air flow through the device but at the same time have sound attenuation properties to minimize the amount of high noise propagating out of the air passage(s). It is also commonly referred as sound attenuators and mufflers.

These devices are basically "noise filters" that are used in applications where there is a need to have sound attenuation at openings, pipes, ducts and other air passages.

6.2 Silencers and mufflers are commonly used in motor vehicles exhaust, genset exhaust, fans and ventilation openings in enclosures, plantrooms, etc.

6.3 There are two common types of silencers:

- Dissipative silencers
- Reactive silencers / mufflers.

6.4 Dissipative (or absorptive) silencers use sound absorption materials for attenuation of sound waves. The absorption materials are typically mineral fibers (rockwool, fiberglass, polyester, etc.) and other open pores porous material. The incident sound energy is transformed to heat by causing motion in the absorption fibers during its passage through the material. These are widely used in air condition, ventilation and ducted air distribution and exhaust systems.

Figure E-20: Dissipative silencers in a plantroom application, with a close up view of typical sound absorption splitters

6.5 Reactive silencers have tuned cavities or membranes and are designed to for attenuation within narrow frequency band, typically low frequencies from equipment (motor vehicles, genset, compressor, etc.) and exhaust systems. The reactive silencer is non-fibrous, cleanable and has negligible pressure loss.

Reactive silencers are specifically used for low frequency sound attenuation (as in exhaust and blow-outs, etc.) and where dust or moisture affect the attenuation of conventional absorptive silencers. It is widely used in exhaust systems and gas streams containing particulate matter and moisture that affects absorptive material (deterioration and perforations becoming blocked.

Figure E-21: Reactive silencers used in exhaust noise mitigation

6.6 Attenuation of silencers and mufflers are described by the insertion loss values, typically obtained from acoustic tests (manufacturers' data sheets). Dissipative silencers insertion loss is dependent on the silencer length and design (number and thickness of the absorption modules in the silencer). Reactive silencers insertion loss is dependent on the geometries of the silencer (expansion chamber, Helmholtz, quarter wave resonator, etc., cavity / membrane design) which are tuned to a required frequency of concern.

6.7 Acoustic louvres are often used in plantrooms and other confined spaces where air flow is required (for ventilation purpose). In high noise situations, acoustic louvres are used instead of ordinary architectural louvres. Sound absorption infill in the louvre elements (blade/fin) provide sound attenuation as sound propagates through the air passageways.

6.8 The acoustic louvers have attenuation (sound insertion loss) dependent on the design of the splitter elements (depth and thickness of absorption elements similar to a dissipative silencer)

6.9 Examples of louvres as used for noise mitigation in industry are given in Figure E-22 and Figure E-23.

Figure E-22: Acoustic louvres used for natural ventilation opening in power station turbine hall

Source: https://news.flexshield.com.au/acoustic-louvres-for-atp/

Figure E-23: Acoustic louvres used for cooling towers and chillers noise mitigation

7.0 External Lagging and Cladding

7.1 External lagging is used to reduce noise radiation from machine casings, pipes and ducts.

7.2 This external lagging usually takes the form of a compliant wrapping of mineral fibre mat or foam overlaid with one or more sound insulation layers. The frictional constraint so applied to the sound radiating surface serves to damp its vibration and reduces the radiated sound levels. The external insulating jacket further reduces the radiated sound and the fibrous layer serves to dissipate some of the acoustic energy transmitted through it.

7.3 The basic construction of external lagging used for pipes is shown in Figure E-24.

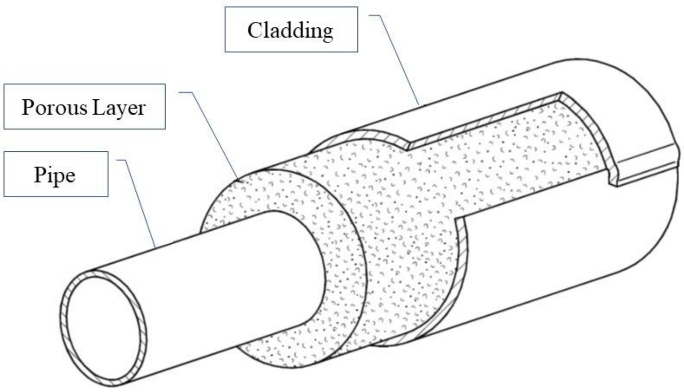


Figure E-24: External lagging for pipes

7.4 For flat surfaces, external lagging (also refereed as cladding) are also used for flat surfaces to reduce the sound radiation from the surfaces. This is often due to structure-borne re-radiated sound or vibration generated sound from vibrating surfaces. This includes machine housing and casings, bins and chutes where impacts from materials handling, etc. and work process often result in high noise emitted from light weight panels.

7.5 For machine casings and panels, the external cladding material can be in the form of hardboard or steel plate applied over an intermediate damping or porous layer, as shown in Figure E-25. An alternative is to apply thick damping layer (bitumen or other similar viscous compound) applied directly onto the steel layer for increased damping of metal sheet.

7.6 An example of external lagging as commonly used in petrochemical and power generation mitigation of high noise from gas pipes and valves (structure-borne noise from cavitation and acoustic induced vibrations) are shown in Figure E-26.

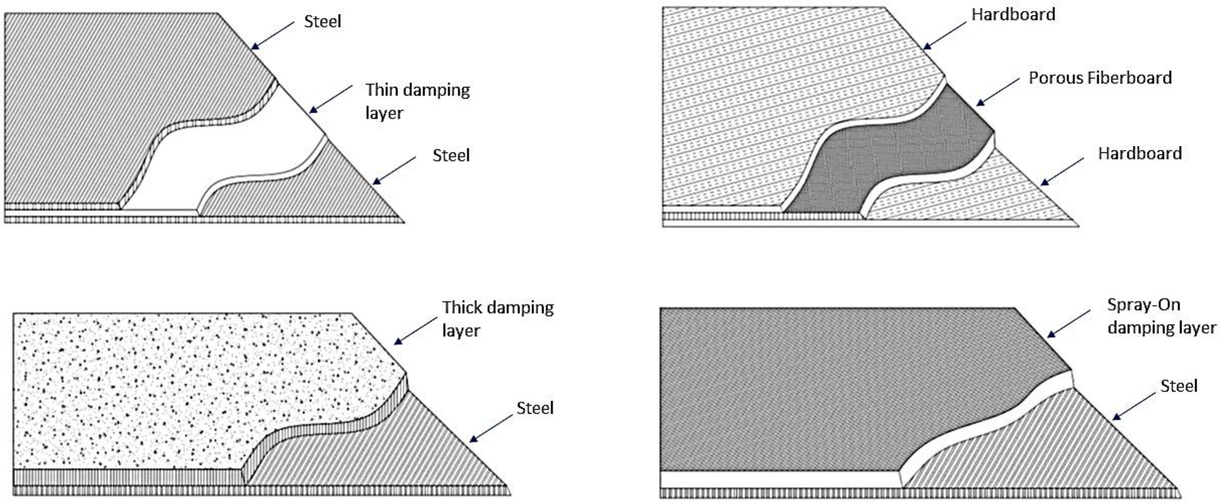
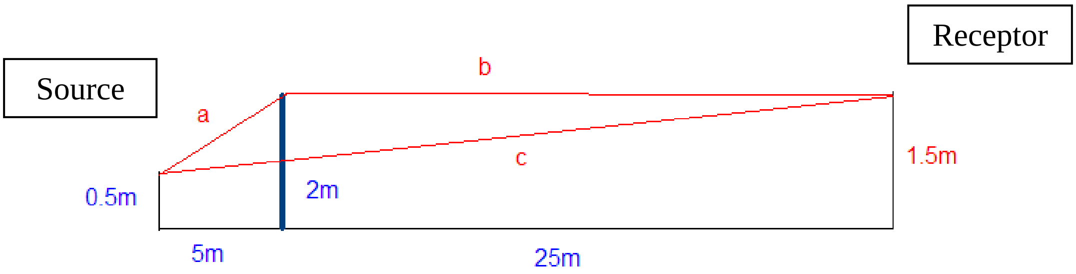


Figure E-25: Cladding of sheet metal and panels

Figure E-26: Example of gas pipes external lagging in industrial noise mitigation

8.0 Worked Examples

1 A compressor is located 30m away from a house (receptor). A long barrier of 2m height is to be erected 5m from the compressor, as shown below. The ground is flat and hard. The compressor is placed 0.5m above the ground. Calculate the barrier attenuation for a receptor at 1.5m height.



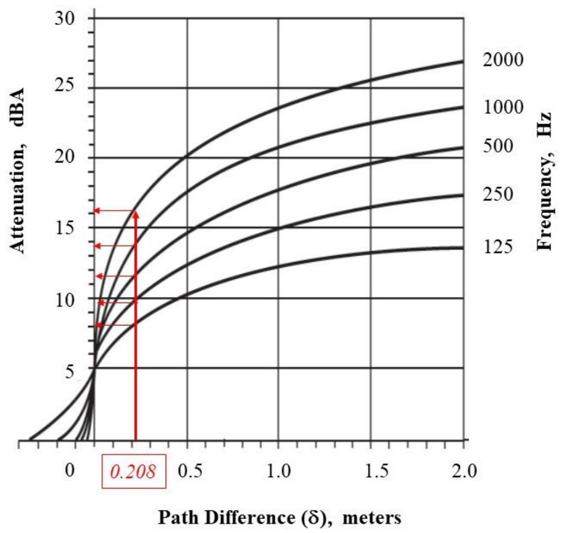
$a^2 = 5^2 + (2 - 0.5)^2 = 27.25$
$a = 5.220$
$b^2 = 25^2 + 0.5^2$
$b = 25.005$
$c^2 = 30^2 + 1^2$
$c = 30.017$
$\delta = 5.220 + 25.005 - 30.17 = 0.208\text{m}$

Referring to Figure E-4, for path difference of 0.208m, barrier attenuation = **11 dB.**

2 For the same barrier in Question 1, what is the barrier attenuation at octave band center frequencies 125 Hz to 2000 Hz?

<u>*Answer*</u>

For a path difference δ = 0.208m, the barrier attenuation is determined from Chart in Figure E-5 as shown below. The attenuation values are tabulated in the table.



Description	Frequency Hz				
	125	250	500	1000	2000
Barrier Attenuation, dB	8.2	9.8	11.7	13.9	16.2

3 A noise measurement was undertaken at the receptor house 30m away from the compressor under existing conditions (without mitigation). The measured overall noise level was 79.8 dBA, with sound pressure levels in octave band centre frequencies as given in the table below. What is the expected sound pressure levels in octave band frequencies and overall noise level at the receptor with a 2m height noise barrier (as per Question)?

Description	**Frequency Hz**					**Overall Levels dBA**
	125	**250**	**500**	**1000**	**2000**	
Existing Noise without Barrier, dBA	69	77	73	71	66	**79.8**

Answer

Using the attenuation values in octave band frequencies determined from Question 2 and noise levels given above, sound pressure levels at each frequency are computed in the tabulation as given below.

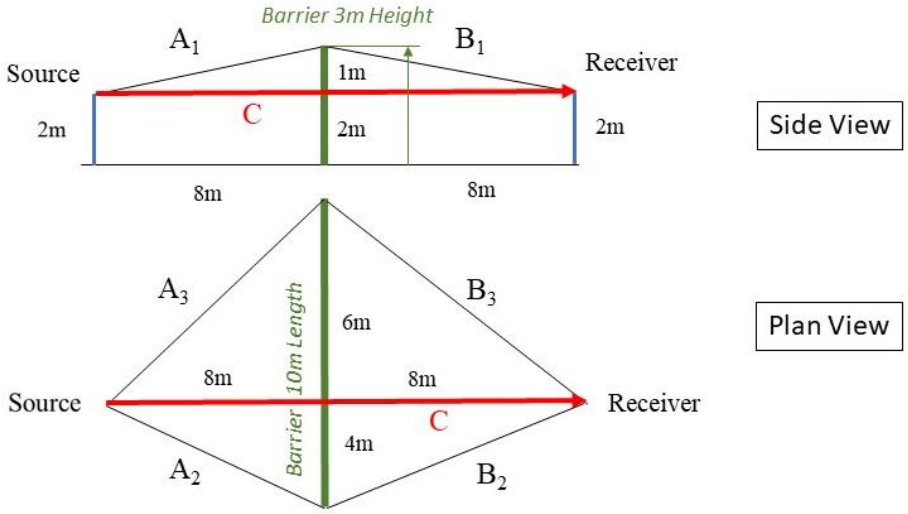
Description	**Frequency Hz**					**Overall SPL Level dBA**
	125	**250**	**500**	**1000**	**2000**	
Existing Noise without Barrier, dBA	69	77	73	71	66	**79.8**
Barrier Attenuation, dB	8.2	9.8	11.7	13.9	16.2	
Noise with Barriers installed, dBA	**60.8**	**67.2**	**61.3**	**57.1**	**49.8**	**69.2**
Overall Reduction						**10.5**

The overall noise levels calculated from the sound pressure levels at each frequency are as follows:

Overall SPL = $10 \log (10^{6.08} + 10^{6.72} + 10^{6.13} + 10^{5.71} + 10^{4.98})$
= **69.2 dBA**

If the Chart in Figure E-4 is used, where the attenuation of 11 dB (answer in Question 1), the **Overall SPL** would be: 79.8 dBA – 11 dB = **69.8 dBA**

4 For the finite length barrier as shown in Figure E-6 with a source located at height 2m, determine the different path differences and the potential barrier attenuation for the respective paths for barrier top and ends diffraction.



Calculate the respective distances using trigonometry as follows:

$A_1 = \sqrt{1^2 + 8^2} = 8.06$ m , $B_1 = \sqrt{1^2 + 8^2} = 8.06$ m

$A_2 = \sqrt{4^2 + 8^2} = 8.94$ m , $B_2 = \sqrt{4^2 + 8^2} = 8.94$m

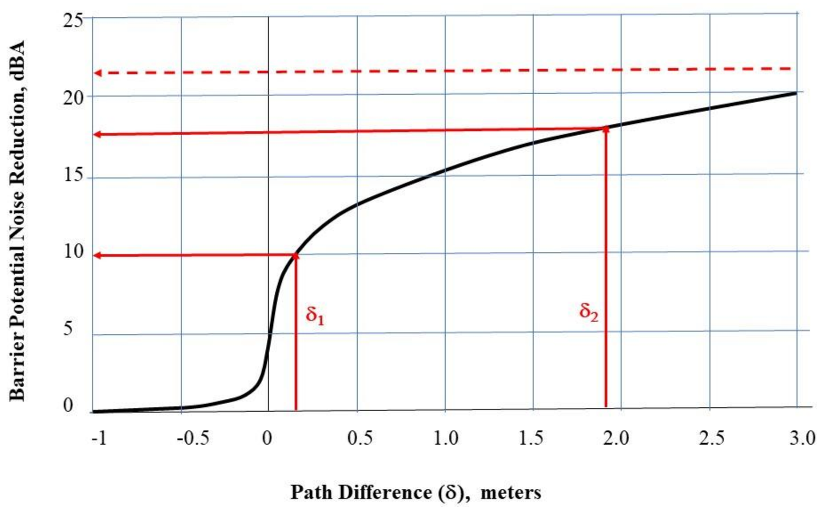
$A_3 = \sqrt{6^2 + 8^2} = 10.0$ m , $B_3 = \sqrt{6^2 + 8^2} = 10.0$ m

$\delta 1 = A_1 + B_1 - C = 8.06 + 8.06 - 16 = 0.12$ m

$\delta 2 = A_2 + B_2 - C = 8.94 + 8.94 - 16 = 1.88$ m

$\delta 3 = A_3 + B_3 - C = 10 + 10 - 16 = 4.0$ m

Attenuation read from chart: **Path 1 = 10 dB, Path 2 = 17 dB, Path 3 = 22 dB**



5 For the same compressor in Question 1 and Question 3 where the compressor noise at the receptor was 79.8 dBA, what is the predicted noise level at the receptor if a full enclosure is used for noise control at the compressor instead of a noise barrier? Determine the noise levels for two different enclosure materials as given below:

(a) Acoustic steel composite panels (30 kg/m^2)
(b) Plasterboard on both sides 100mm thick (18 kg/m^2).

<u>*Answer*</u>

From the chart in Figure E-14, the transmission loss for the two materials are obtained as

Acoustic steel panels TL = 45 dB

Plasterboard 100 thick TL= 30 dB.

Using Equation E-2 and Equation E-3,

$$L_{p2} = L_{p1} - A_{enclosure}$$

$$A_{enclosure} = TL_{material}$$

The noise levels at receptor with an enclosure are calculated to be

Enclosure Acoustic steel panels, $Lp_2 = 79.8 - 45 =$ ***34.8 dBA***

Enclosure Plasterboard panels, $Lp_2 = 79.8 - 30 =$ ***49.8 dBA***

ANNEX F

STATUTORY INSTRUMENTS, STANDARDS AND OTHER GUIDANCE

Statutory instruments in Malaysia

(1) The Environmental Quality Act

Under the Environmental Quality Act, 1974 (Amendment), 1985, there are several provisions that could be utilized to control and abate the noise pollution problems. The following are statements of the Environmental Quality Act, 1974.

Section 21:

The Minister, after consultation with the Council, may specify the acceptable conditions for the emission of noise into any area, segment or element of the environment and may set aside any area, segment or element of the environment within which the emission is prohibited or restricted.

Section 23:

1. No person shall, unless licensed, emit or cause or permit to be emitted any noise greater in volume, intensity or quality in contravention of the acceptable conditions specified under section 21.

2. Any person who contravenes subsection (1) shall be guilty of an offence and shall be liable to a fine not exceeding five thousand ringgit or to imprisonment for a period not exceeding one year or to both and to a further fine not exceeding five hundred ringgit a day for everyday that the offences is continued after a notice by the Director General requiring him to cease the act specified therein has been served upon him.

Section 8A:

The Director General or any other officer duly authorized by him, has the power to test and prohibit use of vehicle.

Section 51:

The Minister after consultation with the Council may make regulations for or with respect to:

(i) prohibiting the use of any equipment, facility, vehicle, or ship capable of causing pollution or regulating the construction, installation or operation thereof so as to prevent or minimize pollution, and

(ii) defining objectionable noise and prescribing standards for tolerable noise.

(2) Environmental Quality (Motor Vehicle Noise) Regulation, 1987

This regulation stipulates permissible noise emission from motor vehicles as measured in accordance to procedures stated here in the regulations.

(3) Local Government Act 1976

The Local Government Act 1976 and the various Town Board Enactment also contain provisions enabling due action to be taken against, including prosecution of owners or occupiers of premises, whether public or private, emitting noise that are deemed to be a nuisance. For quantifying the acceptable noise levels, limits based on the best judgment of these Authorities had been used. Noise limits to be used by these Authorities could now be base on these Guidelines.

(4) Minor Offences Ordinance 1953

Minor Offences Ordinance 1953 prohibits noise after 11.00 p.m., and the police are empowered to act forthwith on complains. Annoyance and nuisance could be assessed based on procedures presented in this guideline.

(5) Civil Aviation Act

Under the Civil Aviation Act, aircraft and airport authorities are absolved from paying compensation for nuisance noise only if the aircraft and airport authorities are operated in conformance with international civil aviation procedures.

(6) Occupational Safety and Health (Noise Exposure) Regulations 2019

The Occupational Safety and Health (Noise Exposure) Regulations came into force on 1 June 2019 superseding the Factories and Machinery Act (Noise Exposure) Regulations 1989. The Regulations are aimed at minimizing workers exposure to noise in the workplace. These Regulations stipulate maximum allowable noise exposure limits with stipulated maximum allowable noise levels and personal noise dose. The Regulations also prescribe actions required of the Employer for workers occupational safety and health related to noise in the workplace.

Standards

ISO 1996-1:2016
Acoustics - Description, measurement and assessment of environmental noise –
Part 1: Basic quantities and assessment procedures

ISO 1996-2:2017
Acoustics - Description, measurement and assessment of environmental noise –
Part 2: Determination of sound pressure levels

ISO 9613-2: 1996
Acoustics - Attenuation of sound during propagation outdoors –
Part 2: General method of calculation

BS 4142: 2014
Methods for rating and assessing industrial and commercial noise

BS 5228-1: 2009+A1: 2014.
Code of practice for noise and vibration control on construction and open sites.
Part 1: Noise

DIN 45680
Measurement and assessment of low frequency noise immissions in the neighbourhood

IEC 61672-1
Electroacoustics — Sound level meters — Part 1: Specifications

IEC 616723-3
Electronics – Sound level meters. Part 3: Periodic tests

IEC 60942
Electroacoustics – Sound calibrators

IEC 61260
Electroacoustics – Octave-band and fractional-octave band filters

ISO/IEC 17025
General requirements for the competence of testing and calibration laboratories

ISO/IEC Guide 98-3
Uncertainty of measurement. Part 3: Guide to the expression of uncertainty in measurement.

Department of Environment
Ministry of Natural Resources and Environment
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