TECHNICAL GUIDELINE
FOR
LAND TRAFFIC
NOISE IMPACT ASSESSMENT

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This document was developed by the National Environment Agency (NEA) in consultation with the following:

Agencies

Land Transport Authority (LTA)
Housing & Development Board (HDB)
Urban Redevelopment Authority (URA)

Industry Partners

Singapore Institute of Architects (SIA)
The Institution of Engineers, Singapore (IES)
Association of Consulting Engineers (ACES)

TECHNICAL GUIDELINE FOR LAND TRAFFIC NOISE IMPACT ASSESSMENT

Purpose

The technical guideline serves to provide general reference for Acoustic Consultants and Qualified Persons (QPs) to prepare land traffic Noise Impact Assessment (NIA) for designated projects. A typical NIA would take about 1-2 months to complete and sufficient time should be catered for consultants /QPs to carry out NIA.

2 The technical guideline will be reviewed and updated by NEA in consultation with the relevant government agencies and professional association regularly to take into account changing circumstances.

Scope

3 The technical guideline consists of the following parts.

(i) **PART 1** – Land traffic Noise Impact Assessment on **new** residential and noise sensitive developments located in close proximity to **existing** land traffic noise sources/hotspots (e.g. expressways/major arterial roads/MRT tracks); and

(ii) **PART 2** – Land traffic Noise Impact Assessment on **existing** residential and noise sensitive developments located in close proximity to **new** transport-related developments (e.g. expressway/major arterial roads/MRT tracks/bus interchanges/ bus depots), inclusive of the expansion of existing transport-related infrastructures.

PART 1

4 This Part would focus on the land traffic Noise Impact Assessment on **new** residential and noise sensitive developments located in close proximity to **existing** land traffic noise sources/hotspots (e.g. expressways (CAT 1), major arterial roads (e.g. CAT 2 or NCAT[1]), above-ground MRT tracks, etc.).

5 New residential and noise sensitive developments located within 70m[2] from the land traffic noise sources/hotspots (e.g. expressways/major arterial roads/MRT tracks) would be subjected to the requirement to carry out land traffic Noise Impact Assessment if any parts of the new residential and noise sensitive developments[3] are within the line of sight from the land traffic noise sources/hotspots.

6 Waiver of the requirement to carry out land traffic Noise Impact Assessment could be requested from National Environment Agency and could be granted on a case-by-case basis. For example, a proposed development, which will be totally shielded off from the traffic by another existing development, could apply for waiver to carry out Noise Impact Assessment.

7 The Noise Impact Assessment should cover the following:

(i) Understanding the existing noise environment and establishing the baseline condition;
(ii) Prediction of the noise impact on the residential and noise sensitive developments;
(iii) Assessment of the noise impact on the residential and noise sensitive developments;
(iv) Establishing of the need for mitigation measures to meet NEA's noise requirement; and
(v) Verification of the effectiveness of the mitigation measures if mitigation measures are needed as in (iv).

8 The International Standard for Assessment of Environmental Noise ISO 1996 "Acoustics – Description and Measurement of Environmental Noise" is the principal standard referred to for environmental noise assessment. It is divided into 2 parts:

ISO 1996-1:2016:	Basic quantities and assessment procedures
ISO 1996-2 2007:	Determination of environmental noise levels

[1] The QPs/Acoustic Consultants should consult NEA or LTA to ascertain the equivalent road category for NCAT road.
[2] The distance is calculated from road reserve line or MRT 1st reserve line, whichever is nearer to the development plot, to the boundary line of the development plot.
[3] Noise sensitive developments are developments (other than residential) where the occupiers are likely to be affected by significant land traffic noise e.g. hospitals, nursing homes, boarding houses/hostels. QPs and Acoustic Consultants are encouraged to consult NEA when unsure whether the proposed development is considered noise sensitive.

Understanding the existing noise environment and establishing the baseline condition

9 This section covers the purposes for which baseline noise levels are required, the means of determining them and the factors that influence the method used. It also sets out a systematic approach to presenting the baseline information.

10 The objective is to enable Acoustic Consultants and Qualified Persons (QPs) to prepare the baseline information to an appropriate level of detail for the assessment. The section is structured as follows:

(i) Definition and purpose of baseline; and
(ii) Determining the baseline.

Baseline Definition and Purpose

11 Baseline noise refers to the noise environment in an area that is affected by the land traffic noise sources (e.g. expressways/major arterial roads/MRT tracks). The baseline noise levels measured will be representative and relevant within 12 months in which the assessment is carried out and these baseline noise levels may be referred to as existing (or current).

12 The existing baseline noise levels can serve several purposes in the assessment process:

(i) They provide a context for the existing noise levels which could impact the proposed residential and noise sensitive developments;
(ii) They may demonstrate that the existing noise environment is already unsatisfactory;
(iii) They serve as important data for projecting the future noise levels that would impact the proposed residential and noise sensitive developments;
(iv) They serve as information to better understand the impact that residential and noise sensitive developments would be subjected to; and
(v) They provide data to be used to calibrate the noise prediction models.

Determining the Baseline

13 The sound level meters used to measure the noise levels would need to comply with the standards specified in the International Electro-technical Commission Publication 61672 (Class 1), or any other comparable standards. It should have a valid (annual/biennial) traceable calibration and checked in the field before and after any measurements by the use of an acoustic calibrator with a valid (annual) traceable calibration[4]. If the calibration level at the end of the survey reefs by more than +/- 1 dB, the survey should be repeated.

14 The principal noise index to be recorded will generally be the LAeq, T, the A-weighted equivalent continuous level averaged over a specified time period, T (the sampling interval). This time period must be specified for the measurement result to

[4] The frequency of calibration as recommended by the sound level meter manufacturers.

be meaningful. Most modern instrumentation will provide different exponential time weightings and noise measurements are to be conducted with the fastest time weighting.

15 The typical environmental noise measurement parameters are as follows:

L_{AeqT}	The average noise level during the measurement period (T), which includes all noise events. The L_{Aeq} has been found to correlate with human tolerance of noise;
L_{A90}	The noise level exceeded for 90% of the time. Commonly used to describe steady background noise at a location;
L_{A10}	The noise level exceeded for 10% of the time. Commonly used to describe traffic noise;
L_{Amax}	The instantaneous maximum sound level measured during the sample period; and
L_{Amin}	The minimum sound pressure measured during the sample period.

16 Typically noise measurements are taken in "free field" and “representative”[5] traffic. It should be taken at 10m from the road edge to avoid near field measurement[6] and at least 3.5m from any facade. Where feasible, if the residential development is a high-rise development, the Acoustic Consultant should include additional baseline noise measurements at an elevated height in the line of sight of the noise source(s) and at a suitable floor of nearby development(s) to determine the baseline noise level. In addition, baseline noise measurements should be attended by the Acoustic Consultant who should record down any anomaly recorded in baseline noise measurements. The microphone should be at a height of 1.2 - 1.5m above the ground. If the minimum of 3.5m from any facade is not possible, the microphone should be 1m from any façade and a facade reflection correction of -3 dB(A) should be applied.

17 Measurements are best avoided when raining or wind > 5m/s. Windshield shall be used during measurements at all times. The monitoring result shall be excluded from the analysis when the wind > 5m/s or there are heavy rain.

18 Representative sampling intervals should be selected and justified. Normally, a sampling interval of 15 minutes shall be used and noise assessment should be carried out during both peak (8-9am & 6-7pm) and off-peak hours. These may need to be supplemented with shorter or longer sampling intervals in certain cases. Ideally, sampling over different days and at different times during the day will help to ensure that the survey is statistically representative. Where noise emissions are relatively unsteady, a series of measurements should be undertaken over a typical period of 4 hours during daytime and over a minimum of 2 hours during evening and night-time, particularly for larger facilities with numerous external noise sources.

19 It is essential to ensure that sufficient measurement points are identified to provide representative noise data on the land traffic noise sources/ hotspots. The measurement points should be selected such that there exists at least one

[5] The baseline noise measurements should be taken at a location where there is no influence of reflection from nearby surfaces, other than the ground, and during incident free traffic condition.

[6] If there are site constraints preventing the conducting of baseline noise measurements at 10m from the road edge, the Acoustic Consultant should select the next best representative measurement location of not less than 4m or not more than 15m from road edge as recommended by Calculation of Road Traffic Noise.

assessment point able to represent the noise level at each affected façade of the proposed residential and noise sensitive developments for mitigated and unmitigated scenarios. If the residential and noise sensitive development is abutting other road such as a CAT 3 road leading to the major noise source, baseline noise measurement for that CAT 3 road should be conducted[7].

20 The existing baseline noise measurement report shall contain:

(i) The manufacturer, model type and serial number of the sound level meter, calibrator and microphone used;
(ii) The windshield and other microphone attachments used;
(iii) The date the equipment was last calibrated to a traceable standard;
(iv) A statement of on-site calibration before and after the measurements;
(v) The frequency weighting networks and meter responses used;
(vi) A description of the measurement site and of the range of sound sources including the type of sound;
(vii) A map of the measurement site showing the locations of the measurement positions;
(viii) Details of the intervening ground between sources and measurement positions and the presence of barriers;
(ix) The time and date of the measurement;
(x) A description of the meteorological conditions;
(xi) The noise level e.g. L_{A90} (where practicable);
(xii) The names of the person/s that undertook the survey and drafted the survey report; and
(xiii) Tabular values and graphical presentations of the measured and rated noise levels for each measurement period.

Prediction of the noise impact on the residential and noise sensitive developments

21 Noise levels at a receiver point can be calculated or predicted. Noise prediction is typically carried out as part of the noise impact assessment process. Prediction shall be made using proprietary 3D noise modelling software (SoundPLAN, CadnaA or other equivalent) that is in accordance with, for example CRNT (Calculation of Road Traffic Noise) and any equivalent standards relevant to MRT train noise emission. Acoustic Consultants / QPs should clearly state the standards adopted and modules used in the noise prediction. Acoustic Consultants / QPs could make reference to the Traffic Impact Assessment (TIA) (if available) and translate the current and future predicted traffic counts from all connecting roads into the parameters of 3D noise modelling. For MRT train source, the descriptions and configuration of train carriage and service frequencies shall be presented in the report. The baseline noise levels from the measurement as stated in Para 20 shall be used to calibrate the noise modelling results.

22 For buildings within the 70m and facing land traffic noise sources (e.g. expressways/major arterial roads/MRT tracks), the vertical facade noise propagation

[7] The Acoustic Consultant should take into consideration the noise impact from other minor roads that the proposed residential and noise sensitive developments are fronting during noise modelling as the proposed residential and noise sensitive development will be subjected to the noise impact from these roads during the façade and/or indoor noise measurements.

contours from the lowest to the highest habitable floors which showed noise impact from major noise source to affected facades of residential and noise sensitive development shall be presented. In addition, horizontal contours of the worst affected floor / unit shall be presented to assess the noise dispersion. The noise contours shall take into account the effects of reverberant noise due to reflections from other blocks within the development and existing buildings in the close proximity, if any. Noise contour line should be in increments of not more than 1 dB(A) and should be clearly labelled to show the regions of the affected facades of residential and noise sensitive receivers meeting the noise requirements.

23 The predicted data of noise modelling tools should be validated using measured data to ensure that modelling tools are applicable in Singapore's context and the Acoustic Consultant should demonstrate that the modelling and measured data are accurate. The accuracy of the noise modelling tools should not exceed 1 dB(A) and the accuracy of the noise modelling tools shall be taken into consideration during the assessment of the noise impact and being used as the correction factor.

Assessment of the noise impact on the residential and noise sensitive developments

24 The noise levels of the new residential and noise sensitive development shall comply with the following NEA's noise requirement:

(i) The noise levels at any façade of the buildings[8] of the new residential and noise sensitive development shall be designed to meet the façade noise level of 67 dB(A) (Leq 1hr); and

(ii) The indoor noise level shall be designed to meet the noise level of 57 dB(A) (Leq 1hr)[9] under natural ventilation[10].

25 The assessment shall show the noise impact on the new residential and noise sensitive development and identify the locations or areas within the residential and noise sensitive developments, if any, which are unable to comply with the above noise requirements.

Establishing of the need for mitigation measures to meet NEA's noise requirement

26 For better noise management, developers shall first review the layout design of the development such as the building orientation, locating less noise sensitive buildings like multi-storey carparks fronting the road, and adopting designs that are less sensitive to traffic noise to shield the traffic noise. After reviewing the layout design of the development, if the assessment shows that the noise levels at certain locations or areas within new residential and noise sensitive development are unable to comply with the noise requirement stipulated in Para 24 (i) and (ii), mitigation measures shall be taken.

[8] The façade of the buildings refers to façade of noise sensitive rooms such as bedrooms, living rooms, study rooms, etc. It is not applicable to façade of kitchen, toilets, storeroom, yard which are not noise sensitive. Façade also refers to balconies, private roof and sky terraces which occupants can access.

[9] Acoustic Consultants to provide a detailed breakdown of each noise reducing component with the appropriate reasons to justify the predicted indoor noise levels.

[10] Natural ventilation shall be provided as stated under the latest prevailing version of the BCA Approved Document.

27 When aiming to reduce the effects of land traffic noise on people, it is important to consider the:

(i) Noise sources;
(ii) Transmission path; and
(iii) Noise Recipient.

28 Land traffic noise levels usually decrease with increasing distance from the source because of geometrical spreading of the noise energy over a bigger surface and absorption of the noise by the atmosphere and by the ground. Normally, noise mitigation measures at source are considered as the preferred option. However, there is a limit to the decibel reduction at source for land traffic noise and mitigation measures should also be taken along transmission path and noise recipients' end for decibel reduction. Mitigation measures along transmission path, mainly barriers, can achieve additional reduction of noise levels. The sound insulation at recipients' end is the final barrier to the potentially intruding effects of noise.

29 The assessment shall show the types of mitigation measure to be taken within the residential and noise sensitive developments for each identified locations or areas which are unable to comply with the above noise requirements. The assessment shall also address how the mitigation measures would meet the requirements, including the technical specification of these mitigation measures, the standards that these mitigation measures could meet, and the expected reduction in decibel levels of these mitigation measures. Horizontal and vertical noise contours shall be presented to show the noise levels at the critical building facades with and without the noise mitigation measures.

29a A table with the façade and indoor noise levels on each level, at the critical building façades with and without the noise mitigation measures, shall be presented. The noise reduction provided by the proposed mitigation measures should be included in the table format as well.

29b Proposed mitigating measures should be practicable and does not impede use of living spaces (e.g. sliding door restrictors when used should allow for occupants to enter/leave the balcony comfortably and at 1 panel wide).

Verification of Noise Level in Noise Sensitive Space

30 After the completion of the installation of these mitigation measures, post development measurements should be conducted to verify the effectiveness of the mitigation measures and to ensure that the noise levels of the new residential and noise sensitive development shall comply with the following NEA's noise requirement.

(i) The noise measurements shall be carried out for a duration of 24 hours each for one weekend and one weekday; and tabulated in an equivalent continuous noise level over 1 hour (Leq 1 hour). The noise measurements shall be carried out at different levels (minimally low, middle, and high levels) in the balconies, living rooms and master bedrooms/bedrooms of the proposed residential development after completion of the

development [11] and prior to Temporary Occupation Permit (TOP). Additional noise measurement locations would be required depending on the height and layout of the developments. Noise measurements on different floor levels shall be carried out concurrently to obtain the façade vertical noise profiles. Time setting of all sound level meters shall be synchronized to enable direct comparison of noise readings and possibly, checking of any anomaly;

(ii) At least 10% of the units[12] fronting traffic noise sources should carry out noise measurements;

(iii) Measurements should not be affected by extraneous noise sources (e.g. construction works in the development). All construction activities should be halted during noise measurements. Developer / QPs should advise main contractor to take this into consideration in their construction schedule;

(iv) It is advisable for sound recordings and/or octave band measurements to be done in conjunction with the measurements for post monitoring analysis;

(v) The indoor noise report should include chart and/or table showing noise measurement results, building plans showing locations of indoor noise measurements, calibration certificates, photographs of how the indoor noise measurement was conducted should be included in the report and RT measurements including relevant calculations;

(vi) Acoustic Consultants who would like to consult NEA on the proposed indoor noise measurement locations should do so as early as possible (i.e. proposed locations can form part of the noise impact assessment report). Prior to conducting measurements, the Acoustic Consultant should assess the site (e.g. changes to building design, traffic conditions), including conducting spot measurements. This is to verify the appropriateness of the earlier proposed noise measurement locations and to adjust them, if necessary; and

(vii) It is advisable to engage the Acoustic Consultant who prepared the noise impact assessment report to conduct the post development noise measurements and report.

31 Similar to the baseline monitoring, the sound level meters used to measure the noise levels would need to comply with the standards specified in the International Electro-technical Commission Publication 61672 (Class 1), or any other comparable standards. It should have a valid (annual/biennial) traceable calibration and checked in the field before and after any measurements by the use of an acoustic calibrator with a valid (annual) traceable calibration[13].

32 The principal noise index to be recorded will generally be the LAeq, T, the A-weighted equivalent continuous level averaged over a specified time period, T (the sampling interval). This time period must be specified for the measurement result to be meaningful. Most modern instrumentation will provide two different exponential time weightings – 'fast' (with a nominal exponential-time constant of 125 milliseconds) and 'slow' (nominal exponential time constant of 1 second). Fast, is

[11] The Acoustic Consultant could submit an indoor noise measurement methodology if the 24-hour indoor noise measurement is extensive (e.g. >30 noise measurement points) for the new residential and noise sensitive development.
[12] This is referenced from Para 1.30 in United Kingdom (UK)'s Approved Document Part E on Resistance to the Passage of Sound (2003 edition incorporating 2010, 2013 and 2015 amendments) and Building Control Guidance Note.
[13] The frequency of calibration as recommended by the sound level meter manufacturers.

generally the preferred time-weighting, especially for statistical data and for variable noise levels.

33 For the façade noise level, the noise level should be taken at 1m from the façade wall.

34 For indoor noise level, the noise level should be taken from the centre of the rooms such as living room, bedrooms, etc. with windows or balcony door opened. The microphone should be at a height of 1.2 - 1.5m above the floor. Vacant room is reverberant and results in build-up of reverberant noise and echo. For representative measurement, the room should be furnished or be filled with absorptive materials. The amount of absorptive material will be determined by the Reverberation Time (RT) in the room. The typical RT can be considered as 0.5 seconds for residential. Hence, the Acoustic Consultant could either add absorptive material to achieve RT of 0.5 seconds before indoor noise measurement is made or conduct a RT test in the room according to ISO 3382, using interrupted or impulse method and normalise the RT to obtain the noise reduction due to furnishing.

35 A comparison should be made between the predicted noise level with mitigation measures and the post development measurements to verify the effectiveness of the mitigation measures. Further mitigation measures would be needed if the post development measurements showed that the noise levels for the new residential and noise sensitive developments are unable to comply with the requirement.

36 For future traffic noise sources/ hotspots, assumptions applied (e.g. height of train track, alignment and operating conditions, road traffic volume etc.) through consultation with the relevant authorities and sources of information shall be clearly stated.

PART 2

37 This Part would focus on the land traffic Noise Impact Assessment on **existing** residential and noise sensitive developments located in close proximity to **new** transport-related developments (e.g. expressway (CAT 1)/major arterial roads (CAT 2, NCAT[14])/above-ground MRT tracks/bus interchanges/ bus depots), inclusive of the expansion of existing transport-related infrastructures.

38 New transport-related developments (e.g. expressway/major arterial roads/MRT tracks/bus interchanges/ bus depots), inclusive of the expansion of existing transport-related infrastructures located within 70m[15] from the residential and noise sensitive developments[16] would be subjected to the requirement to carry out land traffic Noise Impact Assessment.

[14] The QPs/Acoustic Consultants should consult NEA or LTA to ascertain the equivalent road category for NCAT road.
[15] The distance is calculated from road reserve line or MRT 1st reserve line, whichever is nearer to the development plot, to the boundary line of the development plot.
[16] Noise sensitive developments are developments (other than residential) where the occupiers are likely to be affected by significant land traffic noise e.g. hospitals, nursing homes, boarding houses/hostels. QPs and Acoustic Consultants are encouraged to consult NEA when unsure whether the proposed development is considered noise sensitive.

39 Waiver of the requirement to carry out land traffic Noise Impact Assessment could be requested from National Environment Agency and could be granted on a case-by-case basis. For example, a proposed development, which will be totally shielded off from the traffic by another existing development, could apply for waiver to carry out Noise Impact Assessment.

40 The Noise Impact Assessment should cover the following:

(i) Understanding the existing noise environment and establishing the baseline condition;
(ii) Prediction of future noise level which might be generated;
(iii) Prediction of the noise impact on the residential and noise sensitive developments;
(iv) Assessment of the noise impact on the residential and noise sensitive developments;
(v) Establishing of the need for mitigation measures to meet NEA's noise requirement; and
(vi) Verification of the effectiveness of the mitigation measures if mitigation measures are needed as in (v).

41 The International Standard for Assessment of Environmental Noise ISO 1996 "Acoustics – Description and Measurement of Environmental Noise" is the principal standard referred to for environmental noise assessment. It is divided into 2 parts:

ISO 1996-1 2016:	Basic quantities and assessment procedures
ISO 1996-2 2007:	Determination of environmental noise

Understanding the existing noise environment and establishing the baseline condition

42 This section covers the purposes for which baseline noise levels are required, the means of determining them and the factors that influence the method used. It also sets out a systematic approach to presenting the baseline information.

43 The objective is to enable Acoustic Consultants and Qualified Persons (QPs) to prepare the baseline information to an appropriate level of detail for the assessment. The section is structured as follows:

(i) Definition and purpose of baseline; and
(ii) Determining the baseline.

<u>Baseline Definition and Purpose</u>

44 Baseline noise refers to the noise environment in an area which may include the noise from the current land traffic noise sources. The baseline noise levels measured will be representative and relevant within 12 months in which the assessment is carried out and these baseline noise levels may be referred to as existing (or current).

45 The existing baseline noise levels can serve several purposes in the assessment process:

(i) They provide a context for the existing noise levels which could impact the proposed residential and noise sensitive developments;
(ii) They may demonstrate that the existing noise environment is already unsatisfactory;
(iii) They serve as important data for projecting the future noise levels that would impact the proposed residential and noise sensitive developments;
(iv) They serve as information to better understand the impact that residential and noise sensitive developments would be subjected to; and
(v) They provide data to be used to calibrate the noise prediction models.

Determining the Baseline

46 The sound level meters used to measure the noise levels would need to comply with the standards specified in the International Electro-technical Commission Publication 61672 (Class 1), or any other comparable standards. It should have a valid (annual/biennial) traceable calibration and checked in the field before and after any measurements by the use of an acoustic calibrator with a valid (annual) traceable calibration[17]. If the calibration level at the end of the survey reefs by more than +/- 1 dB, the survey should be repeated.

47 The principal noise index to be recorded will generally be the LAeq, T, the A-weighted equivalent continuous level averaged over a specified time period, T (the sampling interval). This time period must be specified for the measurement result to be meaningful. Most modern instrumentation will provide different exponential time weightings and noise measurements are to be conducted with the fastest time weighting.

48 The typical environmental noise measurement parameters are as follows:

L_{AeqT} The average noise level during the measurement period (T), which includes all noise events. The L_{Aeq} has been found to correlate with human tolerance of noise;
L_{A90} The noise level exceeded for 90% of the time. Commonly used to describe steady background noise at a location;
L_{A10} The noise level exceeded for 10% of the time. Commonly used to describe traffic noise;
L_{Amax} The instantaneous maximum sound level measured during the sample period; and
L_{Amin} The minimum sound pressure measured during the sample period.

49 As the residential and noise sensitive developments are likely to be impacted by the noise from the land transport infrastructures, it is critical to establish the existing noise level at these developments. The noise level should be taken at both the façade and the indoor of these residential and noise sensitive developments (if practically feasible).

[17] The frequency of calibration as recommended by the sound level meter manufacturers.

50 Typically noise measurements are to be taken in "free field" and representative traffic[18]. For the façade noise level, the noise level should be taken at 1m from the façade wall. For indoor noise level, the noise level should be taken from the centre of the rooms such as living room, bedrooms, etc with windows or balcony door opened. The microphone should be at a height of 1.2 - 1.5m above the floor.

51 If there is an existing road, noise level should also be taken at 10m from the road edge to avoid near field measurement[19], if any, and at least 3.5m from any facade. In addition, baseline noise measurements should be attended by the Acoustic Consultant who should record down any anomaly recorded in baseline noise measurements. The microphone should be at a height of 1.2 - 1.5m above the ground. If the minimum of 3.5m from any facade is not possible, the microphone should be 1m from any façade and a facade reflection correction of -3 dB(A) should be applied. If not, noise level should also be taken at 10m from the proposed road edge.

52 Measurements are best avoided when raining or wind > 5m/s. Windshield shall be used during measurements at all times. The monitoring result shall be excluded from the analysis when the wind > 5m/s or there are heavy rain.

53 Representative sampling intervals should be selected and justified. Normally, a sampling interval of 15 minutes shall be used and noise assessment should be carried out during both peak (8-9am & 6-7pm) and off-peak hours. These may need to be supplemented with shorter or longer sampling intervals in certain cases. Ideally, sampling over different days and at different times during the day will help to ensure that the survey is statistically representative. Where noise emissions are relatively unsteady, a series of measurements should be undertaken over a typical period of 4 hours during daytime and over a minimum of 2 hours during evening and night-time, particularly for larger facilities with numerous external noise sources.

54 If there is an existing road, the traffic condition is to be established during the sampling intervals for the prediction of the future noise level which might be generated. The traffic condition would include the following:

(i) Category of the road;
(ii) Traffic volume in number of vehicles per hour;
(iii) Travelling Speed of the vehicles;
(iv) Percentage of heavy vehicles such as buses, heavy good vehicles more than 3.5 tonnes, etc;
(v) Road gradient; and
(vi) Type of road surface.

55 It is essential to ensure that sufficient measurement points are identified to provide representative noise data for establishing the baseline noise level. The measurement points should be selected such that there exists at least one assessment point able to represent the noise level at each affected façade of the residential and noise sensitive developments. As the residential and noise sensitive

[18] The baseline noise measurements should be taken at a location where there is no influence of reflection from nearby surfaces, other than the ground, and during incident free traffic condition.
[19] If there are site constraints preventing the conducting of baseline noise measurements at 10m from the road edge, the Acoustic Consultant should select the next best representative measurement location of not less than 4m or not more than 15m from road edge as recommended by Calculation of Road Traffic Noise.

developments are mainly high rise buildings, it is also essential to establish the vertical noise pattern of the residential and noise sensitive developments. It would be recommended for noise measurements to be taken for every 5 floors.

56 The existing baseline noise measurement report shall contain:

(i) The manufacturer, model type and serial number of the sound level meter, calibrator and microphone used;
(ii) The windshield and other microphone attachments used;
(iii) The date the equipment was last calibrated to a traceable standard;
(iv) A statement of on-site calibration before and after the measurements;
(v) The frequency weighting networks and meter responses used;
(vi) A description of the measurement site and of the range of sound sources including the type of sound;
(vii) A map of the measurement site showing the locations of the measurement positions;
(viii) Details of the intervening ground between sources and measurement positions and the presence of barriers;
(ix) The time and date of the measurement;
(x) A description of the meteorological conditions;
(xi) The noise level e,g, L_{A90};
(xii) The names of the person/s that undertook the survey and drafted the survey report;
(xiii) Tabular values and graphical representations of the measured and rated noise levels for each measurement period; and
(xiv) Traffic conditions for each measurement period, if applicable.

Prediction of future noise level which might be generated

57 In order for the noise impact assessment to be robust, the predicted land traffic noise levels must be the values expected at the relevant time. It should take into consideration the vehicular population growth rate and the recommended assessment year. The current vehicle population growth rate is 0.5% in Singapore and the recommended assessment year is 15 years from assessment years adopted internationally. Consultants / QPs are to consult LTA on the future noise levels prediction under Singapore's context.

58 For future traffic noise sources/ hotspots, assumptions applied (e.g. height of train track, alignment and operating conditions, road traffic volume etc.) through consultation with the relevant authorities and sources of information shall be clearly stated. Comparisons should be made to existing transport infrastructure/ reports as far as possible to ensure that the prediction does not underestimate the impact on the development.

Prediction of the noise impact on the residential and noise sensitive developments

59 Noise levels at a receiver point can be calculated or predicted. Noise prediction is typically carried out as part of the noise impact assessment process. Prediction shall be made using proprietary 3D noise modelling software (SoundPLAN, CadnaA or

other equivalent) that is in accordance with, for example CRNT (Calculation of Road Traffic Noise) and any equivalent standards relevant to MRT train noise emission. Acoustic Consultants / QPs should clearly state the standards adopted and modules used in the noise prediction. Acoustic Consultants / QPs could make reference to the Traffic Impact Assessment (TIA) (if available) and translate the current and future predicted traffic counts from all connecting roads into the parameters of 3D noise modelling. For MRT train source, the descriptions and configuration of train carriage and service frequencies shall be presented in the report. The baseline noise levels from the measurement as stated in Para 56 shall be used to calibrate the noise modelling results.

60 For buildings within the 70m and facing land traffic noise sources (e.g. expressways/major arterial roads/MRT tracks), the vertical facade noise propagation contours from the lowest to the highest habitable floors which showed noise impact from major noise source to affected facades of residential and noise sensitive development shall be presented. In addition, horizontal contours of the worst affected floor / unit shall be presented to assess the noise dispersion. The noise contours shall take into account the effects of reverberant noise due to reflections from other blocks within the development and existing buildings in the close proximity, if any. Noise contour lines should be in increments of not more than 1 dB(A) and should be clearly labelled to show the regions of the affected facades of residential and noise sensitive receivers meeting the noise requirements.

61 The predicted data of noise modelling tools should be validated using measured data to ensure that modelling tools are applicable in Singapore's context and the Acoustic Consultant should demonstrate that the modelling and measured data are accurate. The accuracy of the noise modelling tools should not exceed 1 dB(A) and the accuracy of the noise modelling tools shall be taken into consideration during the assessment of the noise impact and being used as the correction factor.

62 The QP and Acoustic Consultant should also include future affected residential and noise sensitive developments in the noise prediction study. If there are no existing affected residential and noise sensitive developments, the QP and Acoustic Consultant should show that the future affected residential and noise sensitive developments meet the land traffic noise requirements in Para 64.

Assessment of the noise impact on the residential and noise sensitive developments

63 The occupants of the existing residential and noise sensitive developments would likely be used to their currdvent living environment and it would be difficult for them to accept the increase in environmental noise due to new transport-related developments (e.g. expressway/major arterial roads/MRT tracks/bus interchanges/ bus depots), inclusive of the expansion of existing transport-related infrastructures. Hence, it is recommended that the perceived environmental noise at the existing residential and noise sensitive development should not be worse off after the construction of the new transport-related developments. The difference between the predicted noise level and the baseline noise level should be kept within 3 dB(A).

64 In the circumstances that Para 63 could not be met, the transport-related development shall be designed to meet with the following requirements:

(i) The noise level of 67 dB(A) (Leq 1hr) at any façade of the building[20] of existing residential and noise sensitive development; and
(ii) The indoor noise level of 57 dB(A) (Leq 1hr)[21] under natural ventilation[22] of existing residential and noise sensitive development (if noise measurements could be carried out within existing premises)

65 The assessment shall show the noise impact on the existing residential and noise sensitive developments and identify the locations or areas within the residential and noise sensitive developments, if any, which are unable to comply with the above noise requirements.

Establishing of the need for mitigation measures to meet NEA's noise requirement

66 If the assessment shows that the noise levels at certain locations or areas within residential and noise sensitive development are unable to comply with the noise requirements stipulated in Para 63, Para 64 (i) and (ii), mitigation measures shall be taken.

67 When aiming to reduce the effects of land traffic noise on people, it is important to consider the:

(iv) Noise sources;
(v) Transmission path; and
(vi) Noise Recipient.

68 Normally, noise mitigation measures at source are considered as the preferred option. New transport-related developments (e.g. expressway/major arterial roads/MRT tracks/bus interchanges/ bus depots), inclusive of the expansion of existing transport-related infrastructures, shall ensure that mitigation measures are in place for decibel reduction.

69 There is a limit to the decibel reduction at source for land traffic noise and mitigation measures should also be taken along transmission path and noise recipients' end for decibel reduction. Mitigation measures along transmission path, mainly barriers, can achieve additional reduction of noise levels. The sound insulation at recipients' end is the final barrier to the potentially intruding effects of noise. However, this may not be possible for existing residential and noise sensitive developments.

[20] The façade of the buildings refers to façade of noise sensitive rooms such as bedrooms, living rooms, study rooms, etc. It is not applicable to façade of kitchen, toilets, storeroom, yard which are not noise sensitive. Façade also refers to balconies, private roof and sky terraces which occupants can access.
[21] Acoustic Consultants to provide a detailed breakdown of each noise reducing component with the appropriate reasons to justify the predicted indoor noise levels.
[22] Natural ventilation shall be provided as stated under the latest prevailing version of the BCA Approved Document.

70 The assessment shall show the types of mitigation measure to be taken at new transport-related developments, the transmission paths and recipients' end. The assessment shall also address how the mitigation measures would meet the requirements in Para 63 and 64, including the technical specification of these mitigation measures, the standards that these mitigation measures could meet, and the expected reduction in decibel levels of these mitigation measures.

Verification of Noise Level at Existing Residential and Noise Sensitive Development

71 After the completion of the installation of these mitigation measures, post development measurements should be conducted to verify the effectiveness of the mitigation measures and to ensure that the noise levels at the existing residential and noise sensitive development shall meet the requirements in Para 63 and 64.

(i) The noise measurements shall be carried out for a duration of 24 hours each for one weekend and one weekday; and tabulated in an equivalent continuous noise level over 1 hour (Leq 1 hour). The noise measurements shall be carried out at different levels (minimally low, mid and high levels) at façade of existing residential development after completion of the transport-related development and prior to TOP. Additional noise measurement locations would be required depending on the height and layout of the transport-related development and the affected residential development. Noise measurements on different floor levels shall be carried out concurrently to obtain the façade vertical noise profiles. Time setting of all sound level meters shall be synchronized to enable direct comparison of noise readings and possibly, checking of any anomaly;

(ii) Where possible, measurements should not be affected by extraneous noise sources (e.g. construction works in the development). All construction activities shall be halted during noise measurements. Developer / QPs should advise main contractor to take this into consideration in their construction schedule;

(iii) It is advisable for sound recordings and/or octave band measurements to be done in conjunction with the measurements for post monitoring analysis;

(iv) The indoor noise measurement report should include chart and/or table showing noise measurement results, building plans showing locations of indoor noise measurements, calibration certificates, photographs of how the noise measurement for each point was conducted;

(v) Acoustic Consultants who would like to consult NEA on the proposed facade and/or indoor noise measurement locations should do so as early as possible (i.e. proposed locations can form part of the noise impact assessment report). Prior to conducting measurements, the Acoustic Consultant should assess the site (e.g. changes to building design, traffic conditions), including conducting spot measurements. This is to verify the appropriateness of the earlier proposed noise measurement locations and to adjust them, if necessary; and

(vi) It is advisable to engage the Acoustic Consultant who prepared the noise impact assessment report to conduct the post development noise measurements and report.

72 Similar to the baseline monitoring, the sound level meters used to measure the noise levels would need to comply with the standards specified in the International Electro-technical Commission Publication 61672 (Class 1), or any other comparable standards. It should have a valid (annual/biennial) traceable calibration and checked in the field before and after any measurements by the use of an acoustic calibrator with valid (annual) traceable calibration[23].

73 The principal noise index to be recorded will generally be the LAeq, T, the A-weighted equivalent continuous level averaged over a specified time period, T (the sampling interval). This time period must be specified for the measurement result to be meaningful. Most modern instrumentation will provide two different exponential time weightings – 'fast' (with a nominal exponential-time constant of 125 milliseconds) and 'slow' (nominal exponential time constant of 1 second). Fast, is generally the preferred time-weighting, especially for statistical data and for variable noise levels.

74 For the façade noise level, the noise level should be taken at 1m from the façade wall.

75 For indoor noise level, the noise level should be taken from the centre of the rooms such as living room, bedrooms, etc. with windows or balcony door opened. The microphone should be at a height of 1.2 - 1.5m above the floor. Vacant room is reverberant and results in build-up of reverberant noise and echo. For representative measurement, the room should be furnished or be filled with absorptive materials. The amount of absorptive material will be determined by the Reverberation Time (RT) in the room. The typical RT can be considered as 0.5 seconds for residential. Hence, the Acoustic Consultant could either add absorptive material to achieve RT of 0.5 seconds before indoor noise measurement is made or conduct a RT test in the room according to ISO 3382, using interrupted or impulse method and normalise the RT to obtain the noise reduction due to furnishing.

76 A comparison should be made for between the predicted noise level with mitigation measures and the post development measurements to verify the effectiveness of the mitigation measures. Further mitigation measures would be needed if the post development measurements showed that the noise levels at the existing residential and noise sensitive developments are unable to meet the requirements in Para 61 and 62.

[23] The frequency of calibration as recommended by the sound level meter manufacturers.

References

(i) Guidelines for Environmental Noise Impact Assessment Institute of Environmental Management and Assessment, UK (November 2014)
(ii) Guidelines for Community Noise Impact Assessment and Mitigation, I-INCE Publication Number 11-1 (March 2011)
(iii) Technical Guidelines for Noise Impact Assessment, Ministry of Ecology and Environment, The People's Republic of China (1995)
(iv) Traffic Impact Assessment Guide, Alberta Infrastructure and Transportation, Canada (February 2021)
(v) Road Traffic Noise Impact Assessment Guidance Note, Environmental Protection Department, Hong Kong (December 2010)
(vi) Calculation of Road Traffic Noise (CRTN), Department of Transport, Welsh Office, UK (1998)
(vii) Environmental Noise, Consultnet.ie