Road Traffic Noise Assessment Method
Hong Kong

(RONOSS-HK)

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Environmental Protection Department
The Government of the Hong Kong
Special Administrative Region

Contents

1 Introduction

1.1 Background

1.1.1.1 This memorandum describes the methodologies and procedures for calculating noise from road traffic under Road Traffic Noise Assessment Method Hong Kong (RONOSS-HK). These methodologies and procedures provide guidance to the calculation of road traffic noise in Hong Kong, especially for planning applications, e.g. environmental impact assessment of proposed roads, land use planning, etc.

1.1.1.2 The memorandum is divided into four sections: (1) Noise Emission; (2) Noise Propagation; (3) Noise Prediction at Receptor; and (4) Innovative Noise Mitigation Designs (INMDs). A general method of calculation is set out, step by step, for predicting noise level at receptor, taking into account different traffic parameters, road configuration, site settings, etc.

1.2 Structure of Memorandum

1.2.1.1 The structure of this Memorandum is as follows:

Section 1	Background and structure of this Memorandum
Section 2	General procedures of RONOSS-HK
Section 3	Procedures for calculating noise emission
Section 4	Procedures for calculating noise propagation effect
Section 5	Procedures for combining noise levels
Section 6	Procedures for applying INMDs

2 General Procedures of Noise Prediction

2.1 General

2.1.1.1 The calculation methodology in this memorandum applies to the prediction of road traffic noise only. In this memorandum, the final calculated noise level is expressed in terms of $L_{10\ (1\text{-hour})}$ dB(A). The value of $L_{10\ (1\text{-hour})}$ dB(A) is the noise level exceeded for 10% of the time over a period of one hour, which is generally used for calculating road traffic noise levels.

2.1.1.2 Calculations are performed in frequency range of 63Hz to 8kHz octave bands. Noise predictions for each frequency band are first calculated. The predicted noise level is then obtained by summation of noise level calculated for each frequency band after A-weighting correction.

2.1.1.3 For the purpose of calculation of road traffic noise in Hong Kong, consideration of road segments within 300m from the receptor is generally acceptable given the unique and compact setting of Hong Kong city landscape, and the significant attenuation offered by geometric divergence and other attenuation factors at large distance.

2.1.1.4 For road traffic noise assessment for noise sensitive façades (e.g. façade with opened window for ventilation), the receptor, i.e. noise assessment point, is generally placed at 1m away from the façade.

2.1.1.5 Formulae and tables in this memorandum are definitive over the quoted range of validity and requirements. Extrapolation outside of these ranges may lead to progressive and significant error. The methodologies under this memorandum do not take account of extraneous noise sources, e.g. noise from construction site, railway and aircraft.

2.1.1.6 This memorandum may be updated and supplemented by the Environmental Protection Department from time to time to take into account changing circumstances.

2.1.2 General Procedures

2.1.2.1 The methodologies and procedures of predicting road traffic noise at a receptor from a road with steady traffic flow consists of five main parts as listed below. The following steps in the procedures are described with details in following sections and are shown diagrammatically in **Chart 2.1**.

a) Divide the source line of the road into point sources per metre (**Section 3** refers);

b) Calculate the sound power per frequency band for each vehicle category forming the traffic flow for each point source (**Section 3** refers);

c) Calculate the noise level per frequency band at the receptor taking into account distance attenuation, ground effect, screening and reflection for each point source (**Section 4** refers);

d) Combine the contributions from all point sources at each frequency band to give the predicted noise level at the receptor (**Section 5** refers); and

e) Apply noise attenuation for INMDs, if needed (**Section 6** refers).

Chart 2.1 Flow Chart for Predicting Noise from Road

Step 1 - Divide road into Point Sources

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Divide the source line into point sources with 1m interval

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Step 2 - Noise Emission

↓

- Sound power per metre per frequency band
- Road surface correction
- Road gradient correction

↓

Step 3 - Noise Propagation

↓

- Distance attentuation
- Ground effect correction
- Screening correction
- Reflection

↓

Step 4 - Predict Noise Level at Receptor

↓

- Summation of noise levels of each frequency band in A-weighting
- Summation of contributions from each point source

↓

Step 5 - Apply INMDs if needed

3 Noise Emission

3.1 General

3.1.1.1 The noise emission strength of a traffic flow mainly corresponds to traffic flow volume, vehicle speed and vehicle composition, and also depends on the type of road surface and gradient.

3.1.1.2 This section provides methodologies and procedures for the calculation of noise emission for road traffic flow with regard to each frequency band, as summarised in **Table 3.1** with details presented in the following sections. Procedures for calculations are illustrated in **Section 3.3**

Table 3.1 Summary of Methodologies for Calculation of Noise Emission

	Methodologies for Prediction
Vehicle Classification	• Three vehicle categories defined. • Provide 4th vehicle category for further development to cater for new types of vehicles that are substantially different from those in categories 1 to 3. (see **Section 3.2.1**)
Source Configuration	• Determine location of source line. • Divide the source line into point sources per metre. (see **Section 3.2.2**)
Traffic Flow	• Summation of noise emission of each vehicle category. (see **Section 3.2.3**)
Rolling & Propulsion Noise	• Calculate both rolling and propulsion noise of vehicles. (see **Section 3.2.4**)
Road Surface	• Correction factors for Low Noise Road Surface (LNRS). (see **Section 3.2.5**)
Gradient	• Consider both uphill and downhill situations. (see **Section 3.2.6**)

3.2 Methodology

3.2.1 Vehicle Classification

3.2.1.1 The road traffic noise source shall be determined by combining the noise emission of vehicles forming the traffic flow. These vehicles are grouped into three separate vehicle categories with regard to their noise emission characteristics, namely Light Vehicles, Heavy Vehicles, and Powered Two-wheelers, as shown in **Table 3.2**.

3.2.1.2 An optional fourth category is provided for further development to cater for new vehicles emerging in the future which are substantially different from those in categories 1 to 3 in terms of noise emission, e.g. electric vehicles and hydrogen fuel-cell vehicles which have limited propulsion noise. Details of the vehicle classification in this memorandum is given in **Table 3.2**. Vehicle classes as defined in Annual Traffic Census (ATC) published by Transport Department (TD) are also provided in **Table 3.2** for reference.

Table 3.2 Vehicle Categories in RONOSS-HK

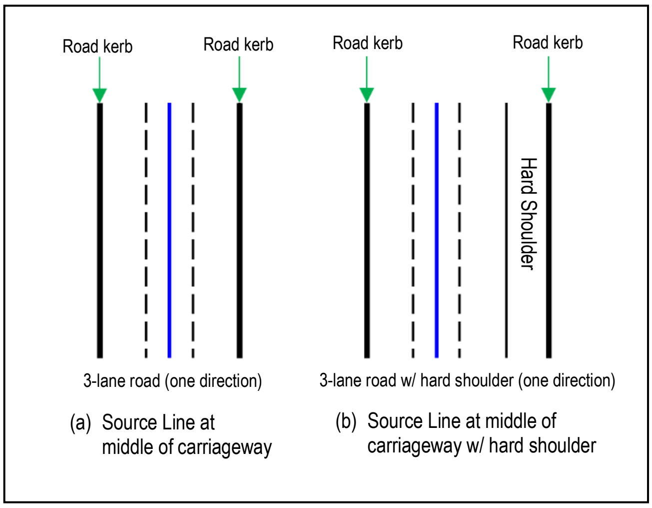
Category	Name	Description	Vehicle class in TD's ATC
1	Light Vehicles	Vehicles with Gross Vehicle Weight ≤ 5.5 tonnes	• Private Cars • Taxi • Light Goods Vehicle
2	Heavy Vehicles	Vehicles with Gross Vehicle Weight > 5.5 tonnes	• Private Light Buses • Public Light Buses • Medium/Heavy Goods Vehicles • Non-franchised Buses • Single Deck Franchised buses • Double Deck Franchised buses
3	Powered Two-wheelers	Motorcycles, tricycles, mopeds	• Motor cycles
4	Open Category	To be defined according to future needs	N/A

3.2.2 Source Configuration

3.2.2.1 The noise emission of traffic flow on a carriageway is represented by a source line characterised by its sound power per metre per frequency band. The source line should generally be placed at the middle of each carriageway. Examples are demonstrated in **Figure 3.1**.

3.2.2.2 Care should be taken in determining the middle of a carriageway for placing the source line, taking into consideration the road condition. For example, when the concerned carriageway consists of hard shoulders or lay-bys, the area of the hard shoulder and lay-bys should generally not be considered in determining the middle of a carriageway for placing the source line.

Figure 3.1. Example of Placing Source Line in Different Scenarios



3.2.2.3 The source line is then divided into continuous distribution of single point sources per metre with evenly distributed directional sound power. The point sources are placed at 0.05m above the road surface. In this methodology, the point sources are considered as omni-directional sources, i.e. radiating uniformly in all directions.

3.2.3 Traffic Flow

3.2.3.1 The sound power level of the source line corresponds to the sum of noise emission of individual vehicles in the traffic flow, taking into account the time spent by the vehicles travelling at the concerned road section. Therefore, the sound power level of each point source for each vehicle category per frequency band is defined by:

$$L_{W',pt,i,m} = L_{W,i,m,v_m} + 10 \times log\left(\frac{Q_m}{1000 \times v_m}\right) + R_{rs} \qquad \text{(Eq. 3.1)}$$

where,

$i =$ Frequency band
$m =$ Vehicle category
$L_{W',pt,i,m} =$ Sound power under frequency band *i* of each point source for respective vehicle category (re. 10^{-12} W)
$L_{W,i,m,v_m} =$ Instantaneous directional sound power of a single vehicle under respective vehicle category and frequency band *i* at speed v_m (re. 10^{-12} W)
$Q_m =$ Hourly traffic flow of respective vehicle category
$v_m =$ Vehicle speed of respective vehicle category, in km/h
$R_{rs} =$ Correction factor for type of road surface in **Section 3.2.5**.

3.2.3.2 **Eq. 3.1** above is applicable to smooth and steady traffic flow under constant vehicle speed. All vehicles under the same category are considered to be travelling at the same speed.

3.2.3.3 For the purpose of road traffic noise assessment, the specified speed limit of the concerned road should generally be used as the vehicle speed for all vehicle categories in **Eq. 3.1**. In case other vehicle speeds are proposed for road traffic noise assessment, justifications with relevant supporting information should be provided to the authority for consideration.

3.2.4 Rolling & Propulsion Noise

3.2.4.1 The instantaneous directional sound power of a single vehicle comprises of two main noise sources:

- Rolling noise due to road/tyre interaction (with aerodynamic noise incorporated);
- Propulsion noise produced by the engine, exhaust, etc, of the vehicle.

3.2.4.2 For light vehicles and heavy vehicles (categories 1 and 2), the instantaneous directional sound power at frequency band *i* corresponds to the summation of the rolling and propulsion noise as follows.

$$L_{W,i,m,v_m} = \left[10 \times log\left(10^{L_{WR,i,m,v_m}/10} + 10^{L_{WP,i,m,v_m}/10}\right)\right] + K_{m,v_m} \qquad \text{(Eq. 3.2)}$$

where,

L_{W,i,m,v_m} = Instantaneous directional sound power of a single vehicle under category 1 or 2 and frequency band *i* at speed v_m

L_{WR,i,m,v_m} = Sound power level for rolling noise of a single vehicle under category 1 or 2 and frequency band *i* at speed v_m

L_{WP,i,m,v_m} = Sound power level for propulsion noise of a single vehicle under category 1 or 2 and frequency band *i* at speed v_m

K_{m,v_m} = Correction factor for respective vehicle category at speed v_m in **Table 3.3**

3.2.4.3 For powered two-wheelers (category 3), only propulsion noise is considered:

$$L_{W,i,m=3,v_{m=3}} = L_{WP,i,m=3,v_{m=3}} + K_{m=3,v_{m=3}} \qquad \text{(Eq. 3.3)}$$

where,

$L_{W,i,m=3,v_{m=3}}$ = Instantaneous directional sound power of single vehicle under category 3 and frequency band *i* at speed $v_{m=3}$

$L_{WP,i,m=3,v_{m=3}}$ = Sound power level for propulsion noise of single vehicle under category 3 and frequency band *i* at speed $v_{m=3}$

$K_{m=3,v_{m=3}}$ = Correction factor for vehicle category 3 at speed $v_{m=3}$ in **Table 3.3**

Table 3.3 Correction Factors for Respective Vehicle Categories

	Speed, km/h				
Vehicle Category m	**50**	**70**	**80**	**100**	**110**
1 - Light Motor Vehicle	+ 3.7	+ 1.6	+ 0.9	+ 0.1	+ 0.0
2 - Heavy Vehicles	+ 3.2	+ 3.3	+ 3.4	+ 3.8	+ 4.0
3 - Powered Two-wheelers	+ 5.6	+ 3.5	+ 2.5	+ 0.8	+ 0.0

Note:
[1] In case other vehicle speeds will be used instead of specified speed limit of the road, the correction factor K_{m,v_m} should be calculated based on the following formulas:

- 1 – Light Vehicle: $K_{m=1,v_{m=1}} = 0.0011v_{m=1}^2 - 0.237v_{m=1} + 12.8$
- 2 – Heavy Vehicle: $K_{m=2,v_{m=2}} = 0.0003v_{m=2}^2 - 0.0345v_{m=2} + 4.2$
- 3 – Powered Two-wheelers: $K_{m=3,v_{m=3}} = 0.0003v_{m=3}^2 - 0.14v_{m=3} + 11.8$

3.2.4.4 For speeds less than 30km/h, the sound power levels L_{WR,i,m,v_m} and L_{WP,i,m,v_m} shall have the same sound power levels as vehicle speed = 30km/h.

Rolling Noise

3.2.4.5 For rolling noise, the sound power level under frequency band *i* for a vehicle under category 1 or 2 is calculated based on **Eq. 3.4** with the consideration of the sound power coefficients for rolling noise in **Table 3.4**.

$$L_{WR,i,m,v_m} = A_{R,i,m} + B_{R,i,m} \times log\left(\frac{v_m}{v_{ref}}\right) \quad \text{(Eq. 3.4)}$$

where,

$L_{WR,i,m,v_m} =$ Sound power level for rolling noise of a single vehicle under respective vehicle category and frequency band *i* at speed v_m

$A_{R,i,m}, B_{R,i,m} =$ Sound power coefficient for rolling noise under frequency band *i* for each vehicle category

$v_m =$ Vehicle Speed of respective vehicle category, in km/h

$v_{ref} =$ Reference vehicle speed = 70 km/h

Propulsion Noise

3.2.4.6 For propulsion noise, the sound power level under frequency band *i* for a vehicle under category 1, 2 or 3 is calculated based on **Eq. 3.5** which considers the sound power coefficients for propulsion noise in **Table 3.4** and the effect of road gradient in **Section 3.2.6**:

$$L_{WP,i,m,v_m} = A_{P,i,m} + B_{P,i,m} \times \frac{(v_m - v_{ref})}{v_{ref}} + \Delta L_{WP,grad,i,m,v_m} \qquad \text{(Eq. 3.5)}$$

where,

L_{WP,i,m,v_m}	=	Sound power level for propulsion noise of a single vehicle under respective vehicle category and frequency band *i* at speed v_m
$A_{P,i,m}, B_{P,i,m}$	=	Sound power coefficient for propulsion noise under frequency band *i* for each vehicle category
v_m	=	Vehicle Speed of respective vehicle category, in km/h
v_{ref}	=	Reference vehicle speed = 70 km/h
$\Delta L_{WP,grad,i,m,v_m}$	=	Correction for the effect of road gradient on propulsion noise under frequency band *i* for each vehicle category

Table 3.4 Sound Power Coefficients for Rolling Noise and Propulsion Noise

Vehicle Category *m*	Frequency, Hz	Sound Power Coefficients[1]			
		A_R	B_R	A_P	B_P
1	63	83.3	30.0	98.1	– 1.3
	125	89.3	41.5	92.8	7.2
	250	88.1	38.9	91.6	7.7
	500	93.8	25.7	89.5	8.0
	1000	100.9	32.5	87.8	8.0
	2000	97.5	37.2	90.5	8.0
	4000	87.7	39.0	86.9	8.0
	8000	77.9	40.0	79.7	8.0
2	63	89.0	30.0	106.0	– 1.9
	125	93.7	35.8	101.5	4.7
	250	96.5	32.6	103.8	6.4
	500	101.7	23.8	101.8	6.5
	1000	102.4	30.1	103.6	6.5
	2000	95.9	36.2	100.2	6.5
	4000	88.8	38.3	93.8	6.5
	8000	85.5	40.1	87.7	6.5
3	63	0	0	88.9	4.2
	125	0	0	88.4	7.4
	250	0	0	90.4	9.8
	500	0	0	94.6	11.6
	1000	0	0	97.5	15.7
	2000	0	0	99.7	18.9
	4000	0	0	94.8	20.3
	8000	0	0	89.6	20.6

Note:
[1] The sound power coefficients are based on local road side noise measurements in Hong Kong, with reference to the coefficients in Common Directive (EU) 2021/996 – Establishing Common Noise Assessment Methods according to Directive 2002/49/EC of the European Parliament and of the Council.

3.2.5 Road Surface

The correction factors for road surface depends upon a number of factors, e.g. texture of road surface, material and amount of negative macrotextures. The correction factors for LNRS in Hong Kong, including polymer modified friction course (PMFC) and 6mm Polymer Modified Stone Mastic Asphalt (PMSMA6), as required under **Eq. 3.1** are listed in **Table 3.5**. No correction factor is needed for other types of road surfaces, i.e. corrector factor = 0 dB for other types of road surfaces. The correction is attributed to all frequency bands equally.

Table 3.5 Correction Factors for LNRS

Road Surface	Road type	Correction factor R_{rs}, dB
PMFC	High speed roads	- 2.5
	Local roads with smooth traffic flow	- 2.5
PMSMA6	Local roads	- 2.5

3.2.5.1 For other claimed noise reduction corrections values or other types of road surfaces with noise reduction properties compared to typical road surfaces, the claimed noise reduction corrections along with justifications with relevant supporting information (e.g. road-side measurement data) should be provided to the Authority for consideration.

3.2.6 Road Gradient

3.2.6.1 The effect of road gradient on the propulsion noise depends on slope and vehicle speed. For each vehicle category, the corrections of road gradient for both upward and downward directions of the vehicle as required in **Eq. 3.5** are calculated based on the equations in **Table 3.6**. No gradient correction for powered two-wheelers (category 3) is required. The correction is attributed to all frequency bands equally.

Table 3.6 Gradient Correction

Vehicle Category, m	Correction $\Delta L_{WP,grad,i,m,v_m}$, dB	Slope, s	
1	$\frac{Min(12\%;-s)-6\%}{1\%}$	$s<-6\%$	(Eq. 3.6)
	0	$-6\% \leq s \leq 2\%$	(Eq. 3.7)
	$\frac{Min(12\%;s)-2\%}{1.5\%} \times \frac{v_m}{100}$	$s>2\%$	(Eq. 3.8)
2	$\frac{Min(12\%;-s)-4\%}{0.7\%} \times \frac{v_m-20}{100}$	$s<-4\%$	(Eq. 3.9)
	0	$-4\% \leq s \leq 0\%$	(Eq. 3.10)
	$\frac{Min(12\%;s)}{1\%} \times \frac{v_m}{100}$	$s>0\%$	(Eq. 3.11)
3	0	-	

3.2.7 Summation

3.2.7.1 The sound power level of each point sources on the source line under frequency band *i* can be calculated by summation of sound power level of each vehicle category.

$$L_{W',pt,i} = 10\,log\left(10^{L_{W',pt,i,m=1}/10} + 10^{L_{W',pt,i,m=2}/10} + 10^{L_{W',pt,i,m=3}/10} + 10^{L_{W',pt,i,m=4}/10}\right) \quad \text{(Eq. 3.12)}$$

where,

$i =$ Frequency band

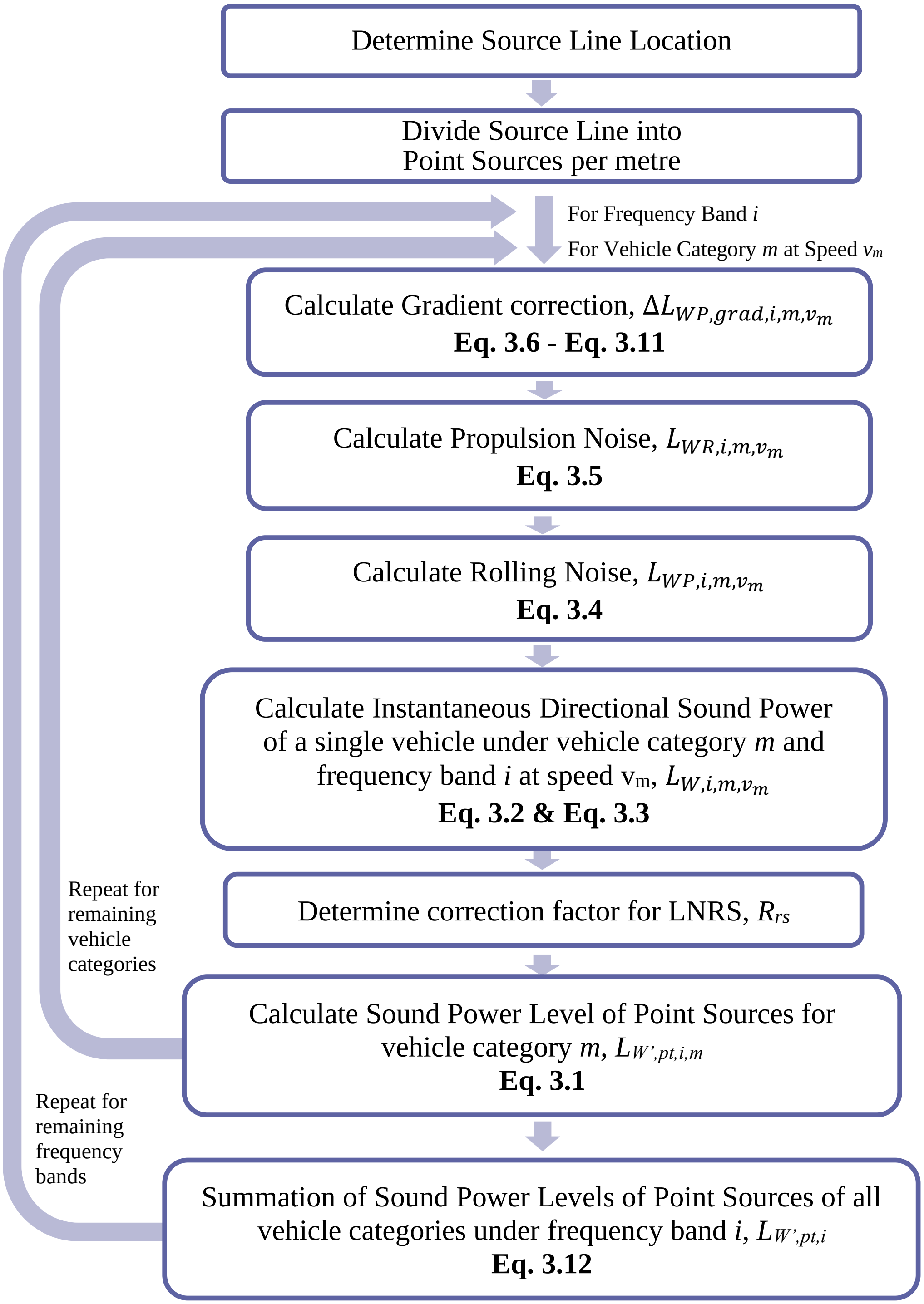
$L_{W',pt,i} =$ Sound power under frequency band *i* of each point source for all vehicle categories

$L_{W',pt,i,m} =$ Sound power under frequency band *i* of each point source for respective vehicle category

3.3 Calculation Procedure

3.3.1.1 The procedures for calculating the sound power level of the point sources per metre on the source line are illustrated below.

Chart 3.1 Procedure for Calculating Sound Power Level



4 Noise Propagation

4.1 General

4.1.1.1 After obtaining the sound power level per frequency band for point sources in **Section 3**, further corrections are needed to predict the noise level at receptor, taking into account the attenuation of noise during its outdoor propagation to the receptor as appropriate, e.g. effects of distance from the source line, screening from any intervening obstacles, reflection from nearby structures.

4.1.1.2 This section provides methodologies and procedures for calculating the attenuation of traffic noise during its outdoor propagation, as summarised in **Table 4.1** with details presented in the following sections. Procedures for calculations are illustrated in **Section 4.3**.

Table 4.1 Summary of Methodologies and Procedures for Noise Propagation

	Methodologies and Procedures for Prediction
Distance Attenuation A_{div}	• To calculate the attenuation due to geometrical divergence. (See **Section 4.2.2**)
Ground Effect A_{gr}	• To include a correction of 3 dB(A) for simulating the noise propagation above a reflective ground surface (See **Section 4.2.3**)
Screening A_{bar}	• To consider both horizontal and lateral diffractions (See **Section 4.2.4**)
Reflection	• To consider reflection in terms of image-sources. (See **Section 4.2.5**)

4.2 Methodology

4.2.1.1 For a point source with sound power level at a given frequency band, the equivalent sound pressure level at a receptor under the given frequency band is obtained using the equation below.

$$SPL_{pt,i} = L_{W',pt,i} - A_i \qquad \text{(Eq. 4.1)}$$

where,

$SPL_{pt,i} =$ Sound pressure level at receptor under frequency band *i* of each point source

$L_{W',pt,i} =$ Sound power under frequency band *i* of each point source / image-source for all vehicle categories

$A_i =$ Total attenuation along the propagation path under frequency band *i*

4.2.1.2 The total attenuation along the propagation path consists of the following corrections.

$$A_i = A_{div} + A_{gr} + A_{bar} \qquad \text{(Eq. 4.2)}$$

where,

$A_i =$ Total attenuation along the propagation path under frequency band *i*
$A_{div} =$ Attenuation due to geometrical divergence
$A_{gr} =$ Correction due to ground effect
$A_{bar} =$ Attenuation due to screening

4.2.2 Distance Attenuation A_{div}

4.2.2.1 The correction for geometrical divergence regarding omni-directional point sources in free-field (i.e. without the consideration of a ground surface) is calculated as below:

$$A_{div} = 20\,log(d) + 11 \qquad \text{(Eq. 4.3)}$$

where,

$A_{div} =$ Attenuation due to geometrical divergence
$d =$ Slant distance between the source/image-source and the receptor, in metres

4.2.3 Ground Effect A_{gr}

4.2.3.1 The ground characteristics in Hong Kong, especially that in developed areas and urban areas, are mainly hard-surfaced pavements such as concrete and bricks. To account for ground reflection of unique ground characteristics of Hong Kong, a correction of -3dB for simulating the noise propagation above a reflective ground surface (i.e. semi-free field) is required, i.e. A_{gr} = -3 dB.

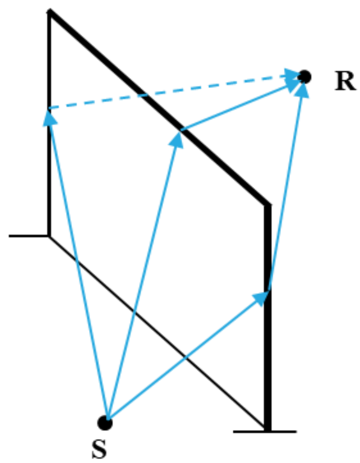
4.2.4 Screening A_{bar}

4.2.4.1 The attenuation given by a screening obstacle, i.e. screening correction, mainly corresponds to the wavelength of the sound λ, and the difference between pathlengths of diffracted sound and direct sound (path difference). Therefore, unlike other propagation corrections, screening correction is considered frequency-dependent as the degree of attenuation depends on the wavelength of the sound λ.

4.2.4.2 The diffraction effect in this methodology considers both the horizontal and lateral edges of an object, such as buildings and barriers, on the propagation path as presented in **Figure 4.1**. The object is considered as a screening obstacle if it satisfies the following requirements:

- Has sufficient surface density (e.g. ≥ 10kg/m^2), such that sound transmitted through the obstacle is negligible compared to sound diffracted from edges of the obstacle;
- Has a closed surface, without gap, slit or hole; and
- The horizontal dimension of the object normal to the source-receptor line is larger than the wavelength at the concerned frequency band.

Figure 4.1. Different Propagation Paths at an Obstacle located on ground



4.2.4.3 For calculating the screening correction for each frequency band, the concerned frequency band should be used for calculation[1]. In simple calculation for screening correction, it can be assumed that only one significant diffraction path exists from the source to the receptor.

4.2.4.4 The screening correction over the top edge of screening obstacle on ground and the lateral edge of screening obstacle are defined as follow. For diffraction over edges of overhanging obstacles, **Eq. 4.5** may also be used.

Diffraction over the top edge of screening obstacle on ground

$$A_{bar} = D_z - A_{gr} \qquad \text{(Eq. 4.4)}$$

where,

$A_{bar} =$ Attenuation due to screening

[1] In the context of Hong Kong, speed of sound may generally be assumed as 344m/s for calculating the wavelength λ for concerned frequency band.

$D_z =$ Attenuation for diffraction at particular frequency band
$A_{gr} =$ Correction due to ground effect

Diffraction around lateral edge and edges of overhanging obstacles

$$A_{bar} = D_z \qquad \text{(Eq. 4.5)}$$

where,
$A_{bar} =$ Attenuation due to screening
$D_z =$ Diffraction attenuation

4.2.4.5 The diffraction attenuation D_z is calculated based on the following equations.

4.2.4.6

$$D_z = 10\log\left(3 + (\frac{20}{\lambda})C_3\delta\right) \qquad \text{(Eq. 4.6)}$$

where,
$D_z =$ Attenuation for diffraction at particular frequency band
$\lambda =$ Wavelength of the sound at the concerned frequency band, in metres
$C_3 =$ Equal to 1 for single diffraction (see **Figure 4.2**); For double diffraction, please refer to **Eq. 4.7** (**Figure 4.3**)
$\delta =$ Difference between the pathlengths of diffracted and direct sound, in metres, as calculated by **Eq. 4.8** for single diffraction and **Eq. 4.9** for double diffraction

$$C_3 = \frac{1 + \left(\frac{5\lambda}{e}\right)^2}{\frac{1}{3} + \left(\frac{5\lambda}{e}\right)^2} \qquad \text{(Eq. 4.7)}$$

where,
$\lambda =$ Wavelength of the sound at the concerned frequency band, in metres
$e =$ Distance between the two diffraction edges in the case of double diffraction (see **Figure 4.3**), in metres

4.2.4.7 The pathlength difference δ for single diffraction and double diffraction is calculated as shown in **Eq. 4.8** and **Eq. 4.9** below, and as illustrated in **Figure 4.2** and **Figure 4.3**.

$$\delta = SO + OR - d \qquad \text{(Eq. 4.8)}$$

$$\delta = SO_1 + e + O_2R - d \qquad \text{(Eq. 4.9)}$$

where,

$SO =$ Distance from the source to the diffraction edge, in metres

$OR =$ Distance from the diffraction edge to the receptor, in metres

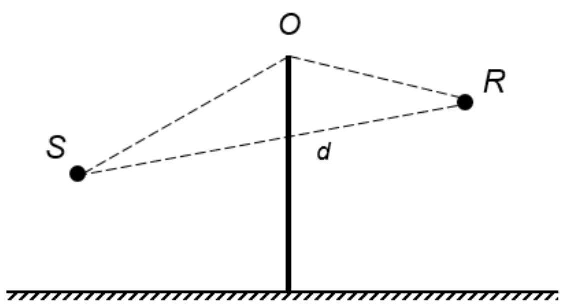
$SO_1 =$ Distance from the source to the first diffraction edge, in metres

$O_2R =$ Distance from the second diffraction edge to the receptor, in metres

$e =$ Distance between the two diffraction edges in the case of double diffraction (see **Figure 4.3**), in metres

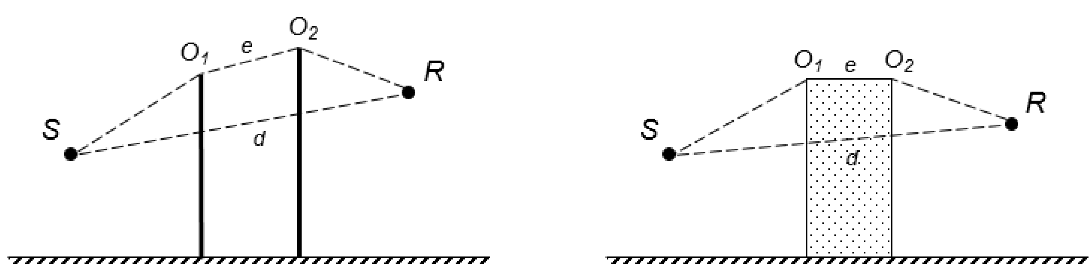
$d =$ Slant distance between the source/image-source and the receptor, in metres

Figure 4.2. Determination of the Pathlength Difference for Single Diffraction



$$\delta = SO + OR - d$$

Figure 4.3. Determination of the Pathlength Difference for Double Diffraction



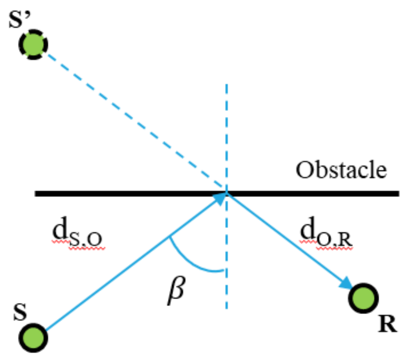
$$\delta = SO_1 + e + O_2R - d \qquad \delta = SO_1 + e + O_2R - d$$

4.2.4.8 For situations in which there are multiple screening obstacles between the source and receptor, the attenuation for diffraction D_z may be calculated approximately by use of **Eq. 4.6**, by choosing the two most effective screening obstacles and neglecting the screening effects from the others. The attenuation for diffraction D_z in any frequency band should not be greater than 20 dB in the case of single diffraction and 25 dB in case of double diffraction.

4.2.5 Reflection

4.2.5.1 Reflections on hard and rigid obstacles and structures with reflecting surface, such as buildings, reflective barriers and viaduct structures, are dealt with by means of image-sources (see **Figure 4.4**). The reflections on ground are not dealt with under this section as they have been considered in the correction for ground effect in **Section 4.2.3** above. Near-side façade reflection to the receptor positioned at 1m from facade, if any, would be catered by means of image-sources.

Figure 4.4. Reflection on an Obstacle dealt with by the Image-Source Method (S: Source, S': Image Source, R: Receptor)



4.2.5.2 The reflections from an object shall be considered if all the following requirements are met:

- A specular reflection can be constructed as shown in **Figure 4.4**;
- The magnitude of sound absorption coefficient of the surface of the object is less than 0.8; and
- The reflecting surface can satisfy the minimum dimension in length or height for the frequency band under consideration:

$$l_{min} > \frac{1}{cos\beta}\sqrt{\frac{2\lambda\, d_{S,O} d_{O,R}}{d_{S,O} + d_{O,R}}} \qquad \text{(Eq. 4.10)}$$

where,

$l_{min} =$	minimum dimension in length or height of the reflecting surface, in metres
$\lambda =$	Wavelength of the sound at the concerned frequency band, in metres
$d_{S,O} =$	Distance between the source and the point of reflection on the object, in metres
$d_{O,R} =$	Distance between the point of reflection on the object and the receptor, in metres

4.2.5.3 For obstacles and structures which are not fully reflective, the sound absorption coefficient of the surface should be considered in calculating the sound power level of the image-source, as in **Eq. 4.10**. For reference, the sound absorption coefficient of flat hard surface of buildings is approximately 0.1, or may even be lower in some cases (e.g. glass walls).

$$L_{W'',pt,i} = L_{W',pt,i} + 10\log(1-\alpha) \quad \text{(Eq. 4.11)}$$

where,

$L_{W'',pt.i}$ = Sound power under frequency band *i* of formed image-source

$L_{W',pt,i}$ = Sound power under frequency band *i* of each point source or (n-1)th image-source for all vehicle categories

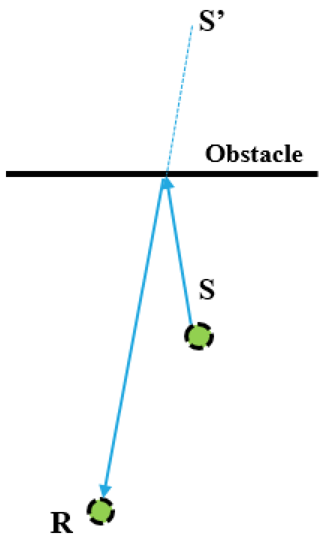
α = Sound absorption coefficient of the reflecting surface of the obstacle ($0 \leq \alpha \leq 1.0$)

4.2.5.4 The noise propagation effects considered in **Section 4.2.2** to **Section 4.2.4** are then applied to account for propagation effect from the image-source to the receptor.

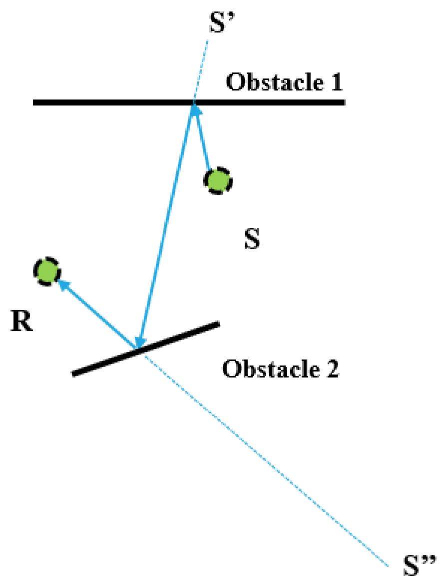
4.2.5.5 Hong Kong is a compact city with extensive high-rise buildings and roads situated between buildings. Therefore, reflection up to 3rd order should generally be considered in calculating road traffic noise in Hong Kong. However, in case reverberant effects are anticipated, such as urban areas with narrows roads surrounded by high-rise buildings on both sides of the roads, or receptors located at confined environment, a higher order of reflection may be needed for more accurate prediction.

4.2.5.6 As stated in **Section 2**, consideration of the road segments within 300m from the receptor is generally acceptable for calculation of road traffic noise in Hong Kong. Therefore, in prediction of the noise contribution due to reflections, consideration of the overall reflected path distance within 300m is generally sufficient, i.e. image-sources with overall reflected path distance of more than 300m to the receptor can be disregarded in calculation. Illustrations are shown in **Figure 4.5**.

Figure 4.5. Illustration on Consideration of Reflected Path Distance



Take into account contribution from S' if $d_{R,S'} \leq 300m$



Take into account contribution from S'' if $d_{R,S''} \leq 300m$

4.2.6 Other Propagation Effects

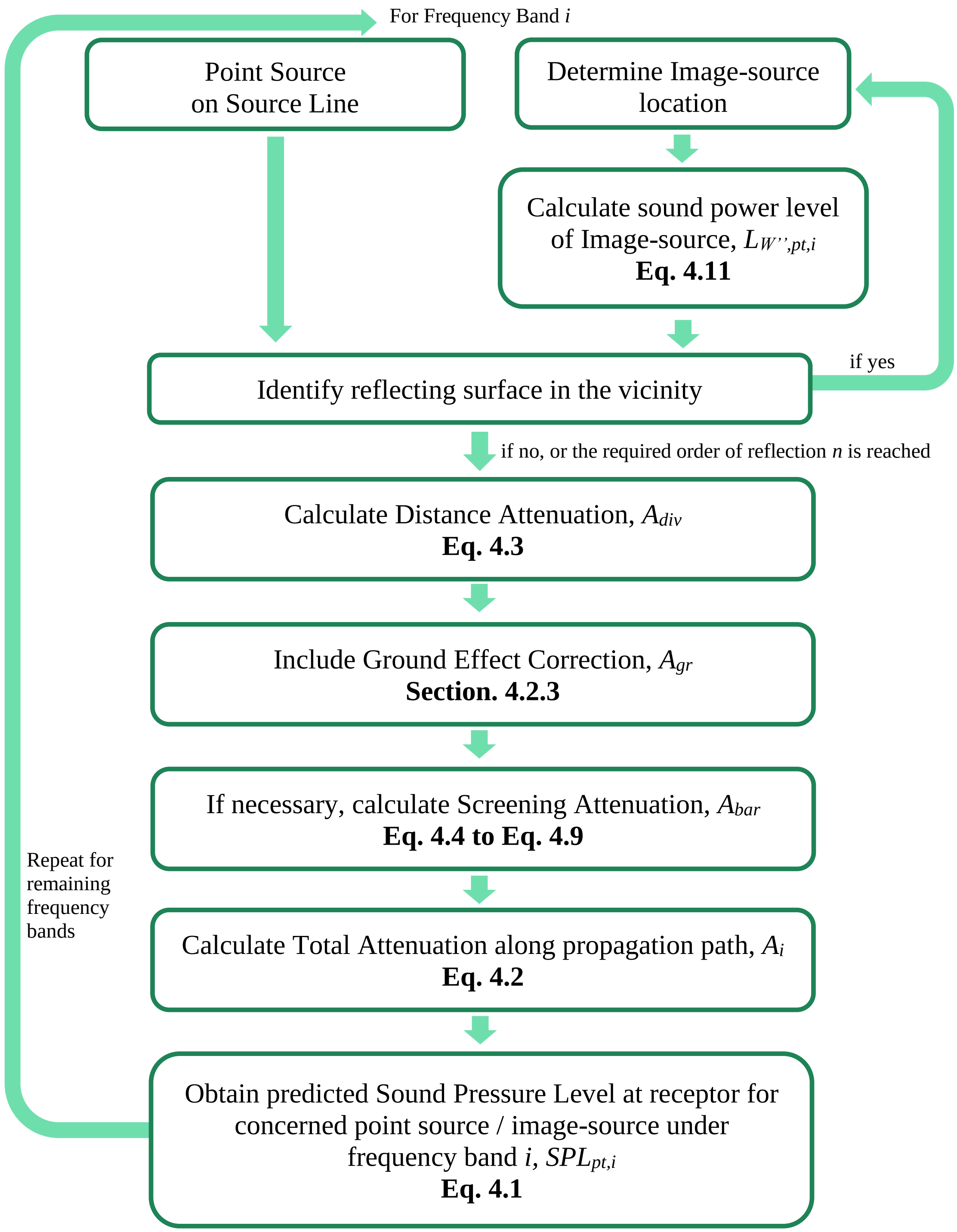
4.2.6.1 The attenuation due to other propagation effects is not considered in this methodology. Attenuation due to atmospheric absorption, for example, is considered unnecessary in this memorandum since in Hong Kong road traffic noise is mostly dominated by road in the vicinity of the receptor, and that Hong Kong possesses a humid subtropical climate, which leads to insignificant attenuation due to atmospheric absorption in close range.

4.2.6.2 In case attenuation due to other propagation effects is to be considered in the calculation of traffic noise, relevant justifications should be provided to the Authority for consideration.

4.3 Calculation Procedure

4.3.1.1 The procedures for calculating the attenuation of traffic noise during its propagation for each point source on the source line are illustrated below.

Chart 4.1 Procedure for Calculating Attenuation during Propagation



5 Noise Prediction at Receptor

5.1 General

5.1.1.1 After obtaining the sound pressure level at receptor under each frequency band from each point source, it is necessary to sum up these sound pressure levels to obtain the overall predicted noise level.

5.1.1.2 This section provides methodologies and procedures for the summation of noise levels at different frequency bands in A-weighting and summation of contributions from point sources, with details presented in the following sections.

5.2 Summation in A-weighting

5.2.1.1 As mentioned in **Section 2**, the final calculated noise level is expressed in terms of $L_{10\ (1\text{-hour})}$ dB(A). Thus, summation of noise levels adopting A-weighting correction according to IEC 61672-1 in **Table 5.1** is required based on **Eq. 5.1**.

$$SPL_{pt} = 10log \sum_{i=1} 10^{(SPL_{pt,i}+A_{wi})/10} \qquad \text{(Eq. 5.1)}$$

where,

$SPL_{pt} =$ A-weighted noise level at receptor for particular point source / image-source

$SPL_{pt,i} =$ Sound pressure level at receptor under frequency band *i* for each point source / image-source

$A_{wi} =$ A-weighting correction according to IEC 61672-1 (see **Table 5.1**)

Table 5.1 A-weighting Correction from IEC 61672-1

Frequency, Hz	63	125	250	500	1000	2000	4000	8000
A-weighting Correction	-26.2	-16.1	-8.6	-3.2	0.0	+1.2	+1.0	-1.1

5.3 Summation of Contributions from Point Sources

5.3.1.1 To arrive at the overall predicted noise level in $L_{10\ (1\text{-hour})}$ dB(A) at receptor, the combination of noise level contributions from all the point sources which comprise the source lines in consideration (i.e. combine noise level contributions logarithmically for the overall noise level) is required.

$$L_{10(1-hour)} = 10log\sum_{i=1} 10^{\frac{SPL_{pt}}{10}} \qquad \text{(Eq. 5.2)}$$

where,

$L_{10(1-hour)} =$ A-weighted overall noise level at receptor for all point sources in $L_{10(1\text{-hour})}$

6 Innovative Noise Mitigation Designs

6.1 General

6.1.1.1 As the developable land for housing development is very limited in Hong Kong, it is unavoidable that many potential housing sites are situated close to major roads and/or railways. Special designs of building envelope, which are capable of effectively reducing noise entering into the residential units and allowing sufficient natural ventilation at the same time, have been delved and put in use in newly developed housing developments.

6.1.1.2 The Innovative Noise Mitigation Designs (INMDs) like acoustic windows (AW) and enhanced acoustic balconies (EAB) are the “think out-of-box” solutions providing high degree of noise reduction and at the same time allowing natural ventilation. The open window living environment offered by such innovative designs is a preferred form of sustainable living over the last-resort of provision of window insulation and air-conditioning.

6.1.1.3 The adoption of INMDs as noise mitigation measures for road traffic depends on numbers of factors, such as types of INMDs, horizontal incident angle to each road from corresponding facade.

6.1.1.4 This section provides methodologies and procedures for the adoption of INMDs for road traffic. The noise attenuation for INMDs is extracted from the Environmental Protection Department (EPD)’s website and *Practice Note on Application of Innovative Noise Mitigation Designs in Planning Private Residential Developments against Road Traffic Noise Impact* (PN) (**Appendix 6.1**), as summarised in **Table 6.1** with details presented in the following sections.

Table 6.1 Summary of Noise Attenuation for INMDs under EPD’s PN

INMDs[2]	Horizontal Incident Angle to Road from Corresponding facade	Noise Attenuation, dB(A)[1]
Acoustic Windows (Baffle Type)	0° (i.e. Parallel to the road)	-6
	30-60°	-7
Acoustic Windows (Baffle Type) w/ addition of Sound Absorptive Material (SAM)	0° (i.e. Parallel to the road)	-7.5
	30-60°	-8.5
	30°	-8

INMDs[2]	Horizontal Incident Angle to Road from Corresponding facade	Noise Attenuation, dB(A)[1]
Acoustic Windows (Baffle Type) + 1.5m architectural fin	60°	-9
Acoustic Windows (Baffle Type) w/ SAM + 1.5m architectural fin	30°	-9.5
	60°	-10.5
Enhanced Acoustic Balcony (Side-hung Type)	0° (i.e. Parallel to the road)	-2
	30-60°	-3
Enhanced Acoustic Balcony (Side-hung Type) w/ SAM	0° (i.e. Parallel to the road)	-3.5
	30-60°	-4.5
Enhanced Acoustic Balcony (Baffle Type)	0° (i.e. Parallel to the road)	-8
	30-60°	-11
Enhanced Acoustic Balcony (Absorptive Baffle Type)	0° (i.e. Parallel to the road)	-9.5
	30-60°	-12.5

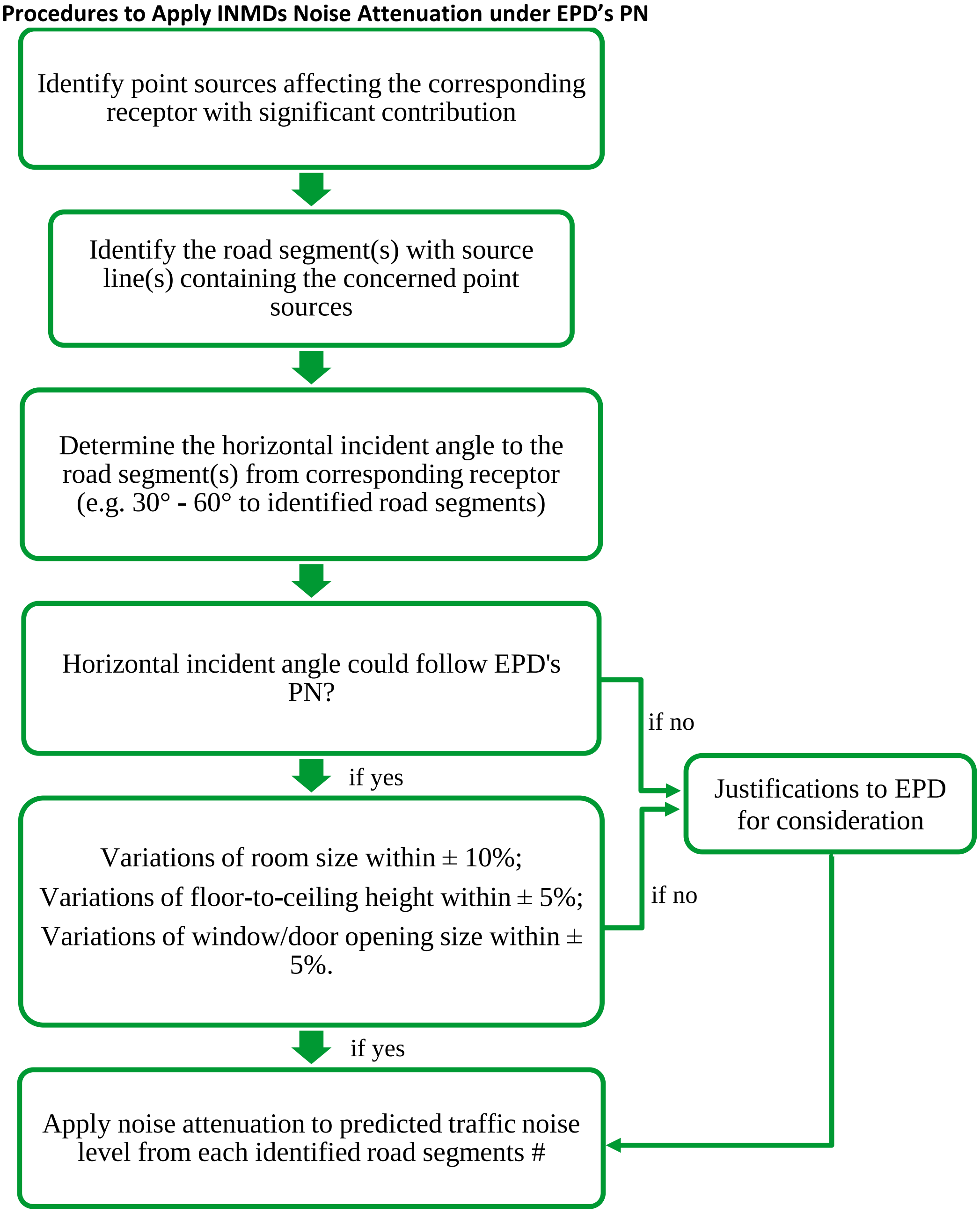
Note:
[1] The noise attenuation values are extracted from the *Practice Note on Application of Innovative Noise Mitigation Designs in Planning Private Residential Developments against Road Traffic Noise Impact* (PN) published in December 2021.
[2] Requirements as stated in the PN should be observed prior to adoption of attenuation values stated in the table.

6.1.1.5 For other types of INMDs with different design from that in EPD's PN, or other claimed noise attenuation values for cases not listed in **Table 6.1**, the claimed noise attenuation along with justifications, with relevant supporting information (e.g. mock-up test results), should be provided to the authority for consideration.

6.2 Implementation of INMDs

6.2.1.1 **Chart 6.1** below provides guidance to the implementation of the noise attenuation of INMDs under EPD's PN dated Dec 2021, for reference only. In case there are deviations to the requirements shown in **Chart 6.1** and EPD's PN, the requirements in EPD's PN should prevail.

Chart 6.1 Procedures to Apply INMDs Noise Attenuation under EPD's PN



Note:

The predicted noise level is not the actual noise level at the receptor at 1m from the external façade with INMD after the application of INMD. The predicted noise level is the equivalent noise levels at the receptor at 1m from the external façade after accounting the reduction in noise levels inside the flat/room offered by the proposed INMDs.