Appendix 7.4.3 Details of Computational Model of Ground Noise Source

Ground Noise Source (Aircraft Taxiing)

The INM functions by first defining the topography and meteorology conditions of the HKIA three-runway system as well as the latitude and longitude of the NSR locations around the Airport Island. The aircraft taxi tracks (for arrival / departure) for every 30 mins. period derived from TAAM simulations are then imported into the INM model. By input of average taxi speeds and engine thrust levels for each aircraft taxiing operation in conjunction with the INM-derived shortest distance from the NSR location to each taxi track, the sound exposure ratio generated by each aircraft taxiing operation will be computed. Noise level adjustments will be adopted for atmospheric absorption (in accordance with the Society of Automotive Engineers (SAE) Aerospace Recommended Practice (ARP) 866A and SAE Aerospace Information Report (AIR) 1845), acoustic impedance (based on the temperature, pressure and humidity of the airport), time-varying aircraft speed and distance attenuation. The sound exposure levels for each aircraft taxiing operation are added at the NSR location to compute the cumulative sound exposure level. After obtaining the overall SEL at each NSR, A-weighted equivalent continuous noise level in dB for 30 mins. will be calculated accordingly. The prediction procedures used in the INM model are briefly described below (Details for the analytical equations can be referred to the Section 3.7.2 of INM 7.0 Technical Manual[1]):

- Define the topographical and meteorological information of the three-runway system as well as the locations of representative NSRs in the INM model;
- Input the aircraft taxi tracks (for arrival / departure) for every 30 mins. period derived from TAAM simulation data into the INM model;
- Input the average taxi speed for each single taxi-path segment into the INM model;
- Assign the aircraft type for each individual taxi track and input the average corrected net thrust per engine (in pounds) for the aircraft taxiing operation (i.e. the average net thrust per engine divided by the ratio of the ambient air pressure at aircraft altitude to the International Standard Atmosphere (ISA) air pressure at mean sea level) into the INM model;
- The shortest distance from each NSR location to each taxi track segment is derived to assess the NPD database. The NPD database comprises of ten INM distances with 200, 400, 630, 1000, 2000, 4000, 6300, 10000, 16000 and 25000 feet. Logarithmic interpolation / extrapolation is used to obtain noise level with the distance lying between INM distance values / outside the INM upper-bound distance value, respectively. However, for the case in which the distance between the ground noise source and the NSR is smaller than 200 feet (i.e. the INM lower-bound distance value), cylindrical divergence (i.e. line-source) is assumed for distance extrapolation. Thus, the A-weighted sound exposure level in 1/3 octave band frequency spectra (L_{AE}) will be automatically generated (or calculated);
- Appropriate noise level adjustments for atmospheric absorption (AA_{ADJ}) and acoustic impedance (AI_{ADJ}) are automatically applied to L_{AE} based on the inputted meteorological information. Thus, the A-weighted sound exposure level in 1/3 octave band frequency spectra with AA_{ADJ} and AI_{ADJ} adjustments ($L_{AE,P,d\text{-}ADJ}$) will be obtained;
- Further noise level adjustments for noise fraction adjustment (NF_{ADJ}), aircraft speed duration adjustment (DUR_{ADJ}), directivity loss (DIR_{ADJ}) and lateral attenuation (LA_{ADJ}) are automatically applied to $L_{AE,P,d\text{-}ADJ}$ based on the inputted topography information, aircraft taxi speed and locations of aircraft taxi track in the HKIA three-runway system as well as the representative NSRs. This step obtains the sound exposure ratio due to a single taxi-path segment for a taxiing operation with a fixed wing aircraft (E_{seg}) as shown in the equation below;

$$E_{seg} = 10^{\frac{LAE_{P,d-ADJ} + NF_{ADJ} + DUR_{ADJ} + LA_{ADJ} + DIR_{ADJ}}{10}}$$

[1] INM Version 7.0 Technical Manual, Federal Aviation Adminstration, U.S. Department of Transportation, January 2008

where:
$L_{AE,P,d\text{-}ADJ}$ is the interpolated / extrapolated Noise-Power-Distance A-weighted sound exposure ratio with atmospheric absorption (AA_{ADJ}) and acoustic impedance (AI_{ADJ}) adjustment, in dB;

NF_{ADJ} is the noise fraction adjustment due to an aircraft moving along a finite single taxi-path segment instead of infinite length of taxiway, in dB;

DUR_{ADJ} is the aircraft speed duration adjustment for aircraft speeds other than 160 knots, in dB. The duration adjustment is applied to account for the effect of time-varying aircraft speed;

LA_{ADJ} is the lateral attenuation adjustment on the sound due to over-ground propagation including ground reflection and refraction effect, airplane shielding effects, as well as other ground and engine/aircraft installation effects; and

DIR_{ADJ} is the ground-based directivity adjustment resulting from the normalized noise pattern defined by a 360-degree area in the horizontal plane around a noise source.

- Input the number of operations for every 30 mins. period (N) to compute the total sound exposure ratio for a single taxi-path segment operation for each specific aircraft ($E_{tot,seg}$). The total sound exposure ratio due to the entire taxiing operation of the specific aircraft throughout the 30 mins. period ($E_{tot,flt}$) can be obtained by summing the ratios associated with each single taxi-path segment and expressed as follows;

$$E_{tot,seg} = N \times E_{seg}$$
$$E_{tot,flt} = \sum_{i=1}^{n_{seg}} E_{tot,seg(i)}$$

where:
n_{seg} is the number of single taxi-path segment for the entire taxiing operation of each specific aircraft throughout the 30 mins. period.

- The total sound exposure ratio for all taxiing operations throughout the 30 mins. period ($E_{tot,30mins}$) can be obtained by summing the ratios associated with the entire taxiing operation for each specific aircraft and converted to a decibel value of SEL at the NSR, as shown in the equations below;

$$E_{tot,30mins} = \sum_{k=1}^{n_{flt}} E_{tot,flt(k)}$$
$$SEL = 10\log[E_{tot,30mins}]$$

where:
n_{flt} is the number of entire taxiing operations for each specific aircraft throughout the 30 mins. period.

- A-weighted equivalent continuous noise level in dB for 30 mins. will then be calculated accordingly based on the formula below:

$$L_{Aeq,30mins} = SEL - 32.6 + C_{facade}$$

where:
C_{facade} is the correction factor with +3dB(A) for façade reflection; and

<u>Ground Noise Source (Operation of Aircraft Engine Run-up Facilities)</u>

Noise level arising from the operation of the aircraft engine run-up facility will be assessed with the use of the INM built-in NPD curves. The INM built-in NPD data are corrected with atmospheric absorption (in accordance with the Society of Automotive Engineers (SAE) Aerospace Recommended Practice (ARP) 866A and SAE Aerospace Information Report (AIR) 1845), acoustic impedance (based on the temperature, pressure and humidity of the airport) and distance attenuation. The NPD data in conjunction with the topographical and meteorological information, engine run-up facility plan of the three-runway system, orientations of the aircraft engines, ground-based directivity adjustment and total run-up duration within 30mins. operation of aircraft engine run-up facility are used to compute the Sound Exposure Level (SEL) at the NSR. After obtaining the overall SEL at each NSR, A-weighted equivalent continuous noise level in dB for 30 mins. will be calculated accordingly. The prediction procedures used in the INM model are briefly described below (Details for the analytical equations can be referred to the Clause 3.7.3 of INM 7.0 Technical Manual):

- Define the topographical and meteorological information, locations and orientations of the aircraft engine run-up facility of the HKIA three-runway system as well as the representative NSRs in the INM model;
- Input the corrected net thrust per engine (in pounds) for the aircraft engine run-up test (i.e. the net thrust per engine divided by the ratio of the ambient air pressure at aircraft altitude to the International Standard Atmosphere (ISA) air pressure at mean sea level) into the INM model;
- The shortest distance from each NSR location to the engine run-up facility is derived to assess the NPD database. The NPD database comprises of ten INM distances with 200, 400, 630, 1000, 2000, 4000, 6300, 10000, 16000 and 25000 feet. Logarithmic interpolation / extrapolation is used to obtain noise level with the distance lying between INM distance values / outside the INM upper-bound distance value, respectively. However, for the case in which the distance between the ground noise source and the NSR is smaller than 200 feet (i.e. the INM lower-bound distance value), cylindrical divergence (i.e. line-source) is assumed for distance extrapolation. Thus, the A-weighted maximum noise level in 1/3 octave band frequency spectra (L_{Smx}) will be automatically generated (or calculated);
- Appropriate noise level adjustments for atmospheric absorption (AA_{ADJ}) and acoustic impedance (AI_{ADJ}) are automatically applied to L_{Smx} based on the inputted meteorological information. Thus, the A-weighted maximum noise level in 1/3 octave band frequency spectra with AA_{ADJ} and AI_{ADJ} adjustments ($L_{Smx,P,d\text{-}ADJ}$) will be obtained;
- Further noise level adjustments for directivity loss (DIR_{ADJ}) and lateral attenuation (LA_{ADJ}) are automatically applied to $L_{Smx,P,d\text{-}ADJ}$ based on the inputted topography information, locations and orientations for the aircraft engine run-up facilities of the HKIA three-runway system as well as the representative NSRs. This step obtains the mean square sound pressure ratio due to a single run-up operation (P_{runup}) as shown in the equation below;

$$P_{runup} = 10^{\frac{[L_{Smx,P,d-ADJ} - LA_{ADJ} + DIR_{ADJ}]}{10}}$$

where:
$L_{Smx,P,d\text{-}ADJ}$ is the interpolated / extrapolated Noise-Power-Distance A-weighted maximum noise level with atmospheric absorption (AA_{ADJ}) and acoustic impedance (AI_{ADJ}) adjustments, in dB;

LA_{ADJ} is the lateral attenuation adjustment on the sound due to over-ground propagation including ground reflection and refraction effect, airplane shielding effects, as well as other ground and engine/aircraft installation effects; and

DIR_{ADJ} is the ground-based directivity adjustment resulting from the normalized noise pattern defined by a 360-degree area in the horizontal plane around a noise source.

- Input the engine run-up duration ($t_{run\text{-}up}$) and the number of operations (N) in 30 mins. The mean-square sound-pressure ratio for each aircraft engine run-up test within 30 mins. ($E_{run\text{-}up}$) is arithmetically summed up and converted to a decibel value of SEL at each NSR, as shown in the equation below;

$E_{run\text{-}up} = N \times t_{run\text{-}up} \times P_{runup}$
$SEL = 10\log[E_{run\text{-}up}]$

- After obtaining the overall SEL at each NSR using INM model, A-weighted equivalent continuous noise level in dB for 30 mins. can be calculated accordingly based on the formula below;

  $L_{Aeq,30mins} = SEL - 32.6 + C_{facade}$

  where:

  C_{facade} is the correction factor with +3dB(A) for façade reflection; and

<u>Ground Noise Source (Operation of APUs)</u>

The methodology adopted for assessing ground noise impact associated with operation of APUs is based on the prediction method set out in *ISO-9613 "Acoustics – Attenuation of sound during propagation outdoors – Part 2: General method of calculation"* [2] which can be summarized as follows:

- Obtain the Sound Power Levels (SWLs) in frequency spectra for the APUs;
- Divide the taxiing paths under the operation of APUs into segments;
- Apply appropriate attenuations / correction factors for the effects of geometrical divergence, air absorption, ground absorption and intervening obstructions / ground & façade reflections and total duration per 30 mins. period between each segment and the NSRs, respectively;
- Adopt appropriate correction factors for tonality, intermittency and impulsiveness, where applicable; and
- Predict noise levels at the NSRs for unmitigated scenario and mitigated scenario (if required) under the three operation modes.

Mathematically, the computation of the corrected noise level (CNL) associated with each segment at the NSRs based on the above procedures can be expressed as follows:

$CNL = Lw - A + C_{gr} + C_{facade} + C_{time} + C$

where:

Lw is the sound power level in frequency spectra (in decibels) produced by the APUs relative to a reference sound power of one picowatt (1pW);

A is the attenuation (in decibels) that occurs during propagation from each segment to the NSR which is basically described as follows:

$A = A_{div} + A_{atm} + A_{ga} + A_{bar}$

where:

A_{div} is the attenuation due to geometrical divergence (i.e. distance attenuation) as below.

For a stationary noise source, distance attenuation can be expressed as follows:
$A_{div} = 20 \log D + 8$ [where D is the distance in m]

A_{atm} is the attenuation due to air absorption;

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

A_{ga} is the attenuation due to ground absorption (0dB, by assuming with hard ground for conservative approach); and

A_{bar} is the attenuation due to screening.

C_{gr} is the correction factor for ground reflection (+3dB, by assuming with hard ground for conservative approach);

C_{facade} is the correction factor with +3dB(A) for façade reflection;

C_{time} is the correction factor for taking into account of total duration per 30 mins. period for operation of APUs within each segment which is governed by the formula below:

C_{time} = 10log[T/1800] where T is the time in second for total duration per 30 mins. period of operation of APUs within each segment.

C is the correction factor taking into account of tonality, impulsiveness and intermittency effects, where applicable, according to the statutory requirements stipulated in “Technical Memorandum of Noise for the Assessment of Noise from Places Other than Domestic Premises, Public Places or Construction Site (TM)”.

The corrected noise levels (in $L_{Aeq,30mins}$) arising from each segment will be aggregated for obtaining the overall noise levels at NSRs associated with operation of APUs under the three operation modes.