Comparing noise contours calculated using existing and measurement-based NPD data for two major airports in Vietnam

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ABSTRACT

The rapid development of air traffic in Asia along with the urbanization process made the increasing population living around airports exposed to higher noise levels. A noise map is helpful to track the level of change and evaluate the environmental impact due to the airport noise for appropriate countermeasures. This study is one of the first attempts to access an appropriate method to create noise maps for Vietnam in the absence of required data and limited technical means. Field measurements were conducted at Noi Bai International Airport (HNBIA) and Da Nang International

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Airport (DNIA), which were jointly used by the military and the civil aviation, in November 2017 and August 2018, respectively. Data related to the flight paths and operation of the aircraft were processed and input in the Integrated Noise Model (INM). Particular characteristics of the two airports such as climate conditions, geographical location, and operation of specific military aircraft types caused the difference between Noise-Power-Distance (NPD) data created by field measurement data and available NPD data in INM. The estimated noise levels using INM's existing and measurement-based NPD were compared with field measurement data to clarify the accuracy of the estimation process proposed in this study.

Keywords: Aircraft noise, Noise-Power-Distance, Noise map
I-INCE Classification of Subject Number: 76

1. INTRODUCTION

An estimation based on actual flight operation conditions is essential to precisely predict aircraft noise exposure around a specific airport. Since noise levels at each noise affected area could be visualized on a contours map, this tool is expected to effectively contribute to raising public awareness about airport noise problem. The noise map also provides a basis for appropriate land-use and flight path planning to limit the noise impact on residents living in the vicinities of the airports.

Many noise prediction models have so far been developed to calculate noise contours around airports such as the Integrated Noise Model (INM), Japan's airport noise prediction model (JCAB Model), etc. However, these existing models either consist of databases which correspond to the specific operation conditions of their target airports. The validity of the noise map produced by these models for the airport with different aircraft types, technical and climate conditions is still questionable.

For better managing the environment around the airports while enhancing aviation traffic, Vietnam government plans to produce noise maps for all 21 airports until 2020 based on the guideline of the International Civil Aviation Organization (ICAO) (1). Although the mandatory data is given access to, some information is not available due to technical and security issues. Particularly, many airports in Vietnam are used for both military and civil aircraft including major airports located near residential areas. Therefore, it is necessary to have a prediction tool to produce an accurate noise map for the management of current and future noise environment around airports, especially for civil-military mixed-used airports.

This study presents the first efforts of creating noise maps for the two major airports: Noi Bai International Airport (HNBIA), and Da Nang International Airport (DNIA), the second and third largest airports in Vietnam, using INM with consideration of its appropriateness. Both of these airports share the runways with Vietnamese People's Air Force so the noise maps must take into account the contributions of civil and military aircraft events

The main purposes of this study are to: (1) verify the accuracy of the noise level predicted by INM; (2) improve the noise estimation accuracy by using measurement-based NPD data; (3) Develop a reliable method of noise map estimation for aviation environment management in Vietnam and sustainable air traffic development in Vietnam and other Asian countries.

2. METHODS

2.1. Field measurement and data collection

2.1.1. Noise measurements at residential areas around the airports

Field noise measurements were conducted at 13 sites around HNBIA (Figure 1) and 6 sites around DNIA (Figure 2) by using sound level meters (Rion NL-42). The measurements lasted for seven days in HNBIA and three days in DNIA. The noise levels measured at these sites were used for assessing the validity of the estimated noise levels by INM. By selecting the same sites with those selected at the previous surveys, measurement data made it possible to observe the changes in noise exposure situations around the two airports over time. Sound level meters were set up on the rooftop of the representation house at each site. However, since it was impossible to access the rooftop of the representative house at Site A6 at the vicinity of HNBIA, the same house selected at the previous surveys, due to the housing reform, the sound level meter was installed on the balcony of the house at Site 6.

Figure 1. Map of measurement sites in HNBIA

Figure 2. Map of measurement sites in DNIA

2.1.2. Measurements for establishing NPD databases

Noise-Power-Distance (NPD) data represents the relationship between the noise levels and distances from receiving point under the flight path to the aircraft. While the NPD relationships are adjusted by the meteorological and geographical conditions of the specific airport, INM is specialized for the United States' airports. In addition, most of the Russian-made military aircraft operated in Vietnam are not included in INM. Therefore, the validity of the noise maps produced for the airports in Vietnam by using INM was examined by comparing the noise levels estimated with INM's existing NPD databases and those created from field measurements. Figure 3 shows a diagram of the measurement process for establishing NPD data which was carried out for two days at each airport. The elevation angles and one-third octave band levels of noise were measured simultaneously at selected locations near two ends of the runways as shown in Figure 4 and 5.

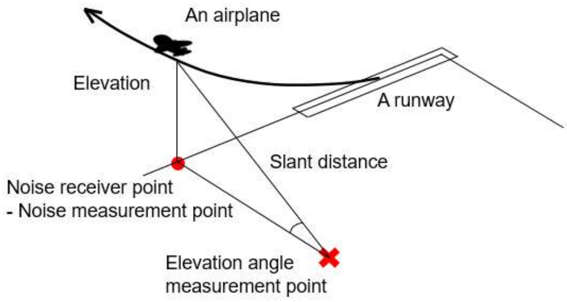


Figure 3. Diagram of elevation angle and noise measurement

Figure 4. The position of elevation angle and frequency characteristic measurement for creating NPD in HNBIA

Figure 5. The position of elevation angle and frequency characteristic measurement for creating NPD in DNIA

2.1.3. Flight path measurement

Automatic Dependent Surveillance-Broadcast (ADS-B) is a precise satellite-based surveillance system. Aircraft onboard ADS-B system can broadcast its own position utilized by GPS. ADS-B receiver is attached to a laptop and gathers all the information broadcasted by aircraft operating around the airport. In this study, the ADS-B receiver was used to collect the actual flight paths of operated civil aircraft. However, military aircraft have not equipped this device, the manual observation was carried out to obtain the data of touch-down, lift-off points and operation time of both civil and military aircraft events.

Table 1. Operating civil and military aircraft types in HNBIA and DNIA

Noi Bai International Airport – Civil aircraft (November 14th, 2017)					
Type	Departures	Arrivals	Type	Departures	Arrivals
A321	75	71	A330	2	2
A320	53	55	B772	2	2
B789	11	11	B777	2	2
A359	10	10	A319	1	2
AT72	7	7	B747-800F	0	1
A333	4	5	E90	1	1
A332	4	4	A330F	1	1
B738	4	4	B777F	1	0
B747F	3	4	B787	1	1
B747-400F	3	2	B739	1	0
B773	2	2	PC12	0	1
C208	2	2			
A332F	1	2			
Noi Bai International Airport – Military aircrafts					
November 14th, 2017			November 15th, 2017		
Type	Departures	Arrivals	Type	Departures	Arrivals
Su-22	8	11	Su-22	10	11
C17	1	1			
C17A	0	1			
Da Nang International Airport (August 15th, 2018)					
Type	Departures	Arrivals	Type	Departures	Arrivals
A321	65	64	B772	2	2
A320	31	32	B744	1	1
B738	17	17	A319	1	1
AT72	2	2	A333	1	1

2.1.4. Airport operation data

Airport operation data including flight logs and weather conditions were provided by the airport managers. Although HNBIA is in northern Vietnam which has four seasons, the flight operation at HNBIA is categorized into winter (late October to late March) and summer (in the remaining period) schedules. Da Nang has a tropical monsoon climate with two seasons: wet season (September to December) and dry season (January to August). Depends on the weather condition, runway used for landing and taking off might varies.

According to the flight logs, the average arrivals and departures a day in HNBIA is approximately 400 flights and 250 flights for DNIA. As shown in Table 1, A320 and A321 aircrafts occupied the majority of all the flights with a total of 64% for HNBIA and 80% for DNIA. It is worth noting that 40 military flight events were measured and recorded during the field measurement conducted in two days at HNBIA. No military aircraft was operated during the measurement period at DNIA because of operation termination for special safety investigation.

2.2. Data analysis

2.2.1. Calculation of L_{den} in residential areas

The noise data of each day for each site was compared with flight logs to identify the aircraft events and then calculate the day-evening-night average sound level (L_{den}) to compare with the result from noise maps. The day, evening and night periods are different between countries, depend on the activity pattern of daily life. In Vietnam, they are defined as the periods from 06:00 to 18:00, from 18:00 to 22:00, and from 22:00 to 06:00, respectively (2).

2.2.2. Calculation of measurement-based NPD data

A-weighted sound exposure level at recording point ($L_{AE,0}$) was calculated following Equation 1, in which L_i is the instantaneous noise level sampled at 0.1 seconds in the time interval when the difference between $L_{A,Smax}$ and L_i was less than 10 dB, where $L_{A,Smax}$ is the maximum noise level in this time interval.

$$L_{AE,0} = 10\log_{10}\left(\sum_{i=1}^{n} 10^{Li/10}\right) - 10 \qquad \text{[Eq.1]}$$

The sound exposure level of a single aircraft noise event according to a distance to the noise source or an airplane, $L_{AE,r}$, was calculated based on a procedure described in a document of ECAC DOC.29 version 2 (3):

$$L_{AE,r} = L_{AE,0} + \left(L_{ASmax,r} - L_{ASmax,0}\right) + 7.5\log_{10}\left(\frac{D}{D_0}\right) \qquad \text{[Eq. 2]}$$

Considering the fact that the flight speed of military aircraft is much higher than civil aircraft, and consequently, the decay of sound by the slant distance to the sound source becomes much faster. Thus, the equation in the ECAC DOC.29 was modified to take into account this difference. The following equation was used for calculating military aircraft noise event as follows:

$$L_{AE,r} = L_{AE,0} + \left(L_{ASmax,r} - L_{ASmax,0}\right) + 10\log_{10}\left(\frac{D}{D_0}\right) \qquad \text{[Eq. 3]}$$

$L_{A,Smax,r}$: Maximum A-weighted sound pressure level according to the distance to the noise source

D: the distance to the noise source (m)

D_0: the distance from the noise source to the measurement point (m)

In which, $L_{A,Smax,r}$ is calculated with the decay by the distance between D and D_0 due to geometrical spreading and sound attenuation due to air absorption according to ISO 9613-1(4).

2.2.3. Flight path analysis

In this study, flight paths were analyzed using ADS-B data. Firstly, all the monitored flight routes were visualized using a Python program. Then, all the data of the flights which didn't take off or land at the airport were removed. From the visualized flight route map, the flight path data of the representative routes were defined by categorizing all the data according to aircraft types and operational modes.

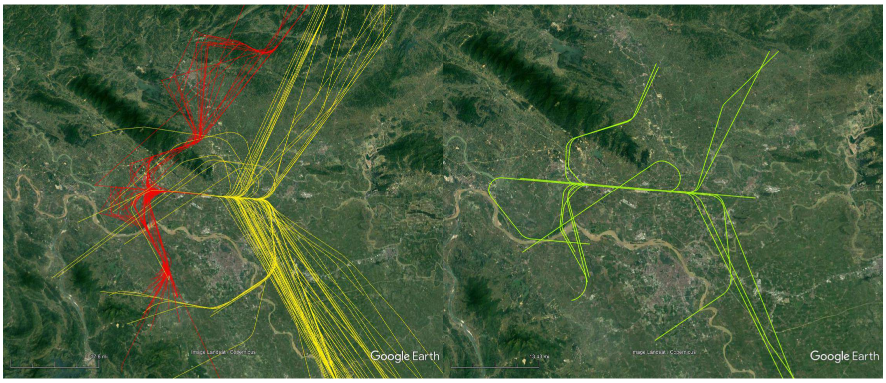


Figure 6. Flight routes in one day and the representative flight paths

2.3 Conditions of the noise predictions

By comparing the predicted noise levels with the field measured values while changing the NPD used for the prediction, it was examined which predicted result is consistent with the measured value. The conditions of the prediction are shown in Table 2.

Table 2 Conditions of the noise predictions

Case No.	Targeted aircrafts for the prediction	NPD using for the prediction	Airfields
Case 1	Civil aircrafts only	INM's	HNBIA
Case 2	Civil & military aircrafts (F-16)	INM's	HNBIA
Case 3	Civil & military aircrafts (Su-22)	Civil: INM's Su-22: Measurement-based	HNBIA
Case 4	Civil & military aircrafts (Su-22)	Measurement -based	HNBIA
Case 5	Civil aircrafts only	INM's	DNIA
Case 6	Civil aircrafts only	Measurement -based	DNIA

Case 1 is a prediction of civil aircraft noise in HNBIA, using INM's NPD. Case 2 is a prediction adding the contributions of military aircraft noise to the result of case 1, using INM's NPD. Since NPD of military aircrafts operated in Vietnam are not included in INM, NPD of F-16 was used for the military prediction instead of Su-22. It was assumed that F-16 have similar performance characteristics with Su-22, both of which have single engine. In case 3, NPD of military aircraft noise in case 2 was changed to that of Su-22 which was derived from field measurement. Case 4 is a prediction using NPD derived from the field measurement for both civil and military aircraft noise predictions. Cases 5 and 6 are predictions in the vicinities of DNIA. Military aircraft were not operated during the survey period, so these 2 cases are predictions for civil aircraft only. One is the prediction using NPD included in INM, and the other is the result of using NPD based on the field measurement.

Note that, field measurement data of Site A6 at HNBIA was excluded from the comparison because the obtained noise level was considerably decreased, possible up to 10 dB, due to the inappropriateness of the setting location of the microphone. Data of Sites A12 and A13 at HNBIA were not taken into account since they are out of estimation boundary. Field measurement data at Site 4 in DNIA is missed due to recording setting mistake.

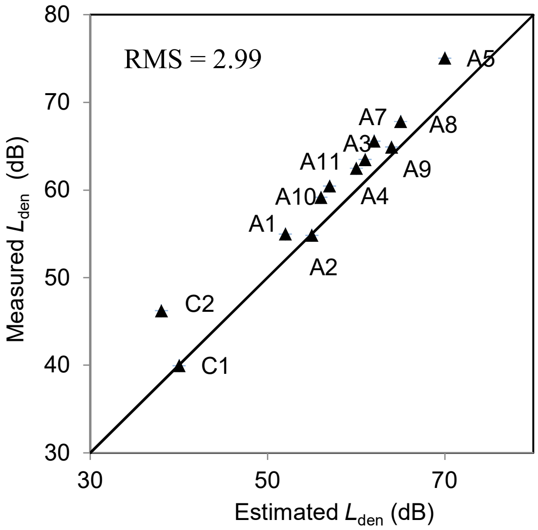
3. RESULTS AND DISCUSSION

Figures 7 shows the results in the cases 1-4, the correlation between the estimated L_{den} by the predictions and L_{den} measured at HNBIA in November 14th, 2017 at each site. The consistency between the predictions and the measured values was examined by comparing the RMS (root mean square error). Comparing the result in the case 1 with those of in the cases 2 and 3, it can be seen that the correspondence with measured values is improved by considering military aircraft. Furthermore, the results of the case 3 are more consistent with the field measured values than the case 2. This suggests that Vietnamese military aircrafts are needed to create NPD based on field measurements. On the other hands, comparing the result in the case 3 with the case 4, estimation of civil aircraft noise using NPD of INM is better correspondence with actual measurement values than that using measured-based NPD.

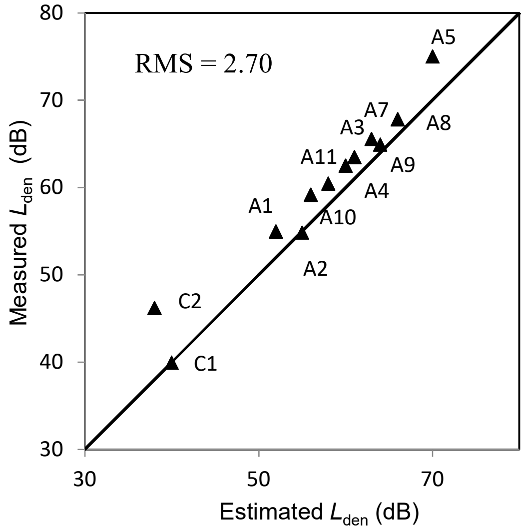
Figure 8 shows the results in the cases 5-6, at DNIA, using INM's existing NPD data and measurement-based NPD data of civil aircrafts and the noise levels obtained by field measurement at the sites around the airport. Estimated noise levels using measurement-based NPD data was found to be less correlated with measured L_{den} than that estimated with INM's NPD data.

From these results, the following can be said.

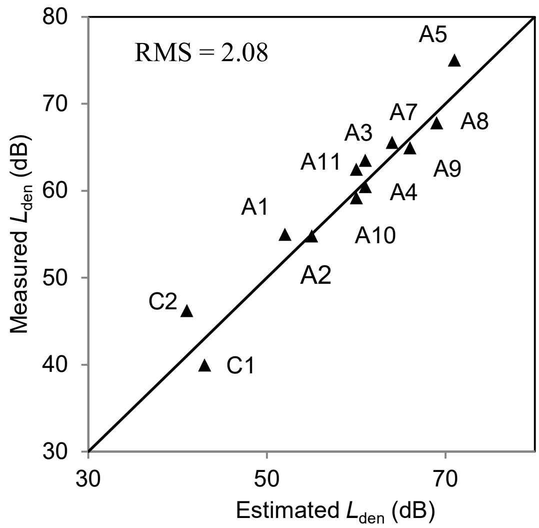
- It is important to include military aircraft in the prediction (Comparing the case 1 with the cases 2 and 3).
- Because NPD of military aircrafts operated in Vietnam are not included in INM, it is necessary to create NPD based on field measurement (Comparing the case 2 with the case 3).
- For civil aircraft, the prediction is not necessarily improved simply by creating the NPD from the results obtained by measurement. This suggests that it is necessary to consider the take-off weight, thrust setting, etc. that are peculiar to civil aircrafts (Comparing the case 3 with the case 4, the case 5 with the case 6).



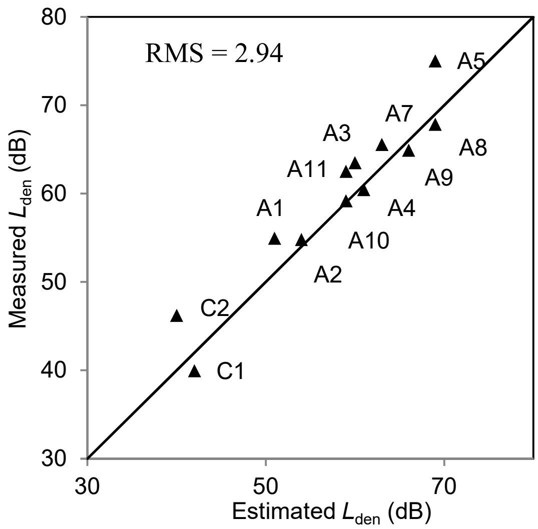
Case 1 (Civil aircraft only, by INM's NPD)



Case 2 (Civil & military, by INM's NPD)

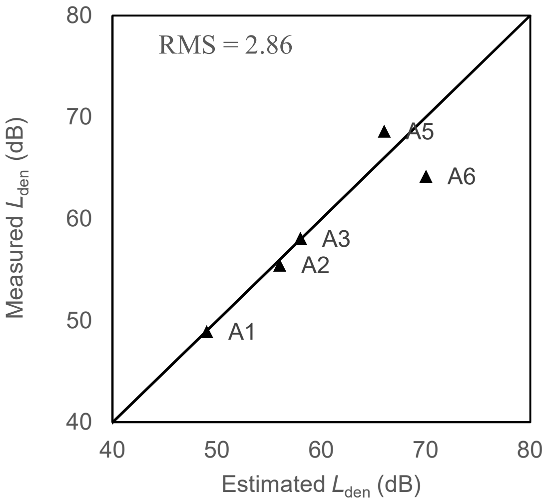


Case 3 (Civil, by INM's NPD & military, by measurement-based NPD)

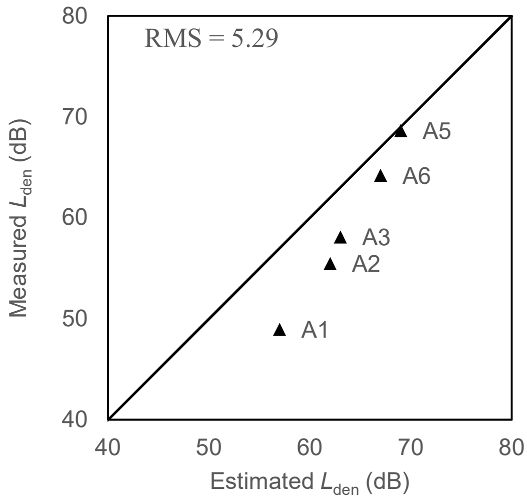


Case 4 (Civil & military, by measurement - based NPD)

Figure 7. Comparison of estimated and measured L_{den} at HNBIA



Case 5 (Civil aircraft only, by INM's NPD)



Case 6 (Civil aircraft only, by measurement - based NPD)

Figure 8. Comparison of estimated and measured levels at DNIA

4. CONCLUSIONS

In this study, L_{den} was estimated for the two major airports in Vietnam. INM's existing NPD data was replaced by measurement-based NPD data for specific conditions of HNBIA and DNIA in the estimation. Applying the Russian military airplane Su-22's NPD data obtained from measurement improved the estimation of L_{den} at HNBIA. Further study is needed to improve the validity of the estimation and develop a noise prediction model characterized by specific conditions of Vietnam. In particular, it is unclear whether it is necessary to use NPD based on field measurements for predicting civil aircraft noise level. It is necessary to examine using detailed information of the operation profile. Furthermore, improvements such as adopting different standard procedural profiles in INM or input the runway usage will be considered. A new approach in defining the NPD data and flight tracks that saves human labor might also be considered for higher efficiency and quality of field measurement-based estimation.

5. REFERENCES

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