Reliability of aircraft noise evaluation by measurement for comparison with prediction

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ABSTRACT

This paper discusses the reliability of measured airport noise evaluation compared with prediction. In Japan, airport noise mitigation measures are performed based on yearly-average airport noise predictions. It is necessary to realize a high reliability in predictions, which are determined by comparing them with noise measurements in order to confirm their validity. However, various factors including microphone height, SN ratio and SEL calculation procedure and incomplete observations affect the reliability of measured noise evaluation. When evaluating yearly-average aircraft noise using short-term measurements, the reliability changes dependent on the measurement period in addition to the afore mentioned factors. Thus, it is necessary to estimate the long-term average using short-term noise measurements and result of continuous noise monitoring or average aircraft operation number.

The sound of airport ground activities such as APU or taxiing can be heard in the surroundings of the airport, but the sound propagation significantly changes dependent on meteorological conditions. In other words, airport ground noise becomes louder and audible only in cases of favorable conditions for sound propagation. But, evaluation of yearly-average sound exposure due to aircraft noise requires average-day sound exposure of the year. So, it is necessary to consider what conditions we should suppose for noise measurement.

Keywords: Airport noise, Aircraft noise, measurement, Prediction, Reliability
I-INCE Classification of Subjects Number(s): 52.2, 76.1.3

1. INTRODUCTION

In Japan, the national noise guidelines "Environmental Quality Standards for Aircraft Noise" (EQSAN) for preserving an acoustical environment around the airport were revised to use L_{den} instead of WECPNL; and have been enforced since April, 2013. The EQSAN requires evaluation of yearly-average cumulative noise exposure level in L_{den}, being based on noise measurement over a period of seven consecutive days at a location where the aircraft noise situation is typical of the area.

Therefore, L_{den} evaluation using short-term measurement is often carried out around the airport. Unattended continuous noise monitors can easily evaluate the yearly-average aircraft noise exposure, but it is costly to install and maintain such monitors. Short-term noise measurement is also performed as a means of supplementing unattended continuous aircraft noise monitoring, because of limited numbers of noise monitors installed to cover the wide surrounding area of the airport, when examining the validity of noise zones established for environmental countermeasures. Besides, short-term measurement enables us to grasp the present situation of noise exposure, but it is not available for evaluating the future situation regarding an increasing demand in aircraft movements.

In japan, various environmental countermeasures for aircraft noise are carried out within noise zones specified based on the predictive evaluation of yearly-average noise exposure. Thus, high accuracy and reliability are required in the prediction. In case a predicted future noise exposure area is smaller than the current, in spite of increased aircraft movements, due to an increase of lower noise aircraft, it is hard for residents living around the airport to accept it unless predictions are proved as highly accurate with good reliability by comparison with reliable measurements.

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The revised EQSAN requires taking into account noise contributions due to aircraft ground activities such as aircraft taxiing, APU operation and engine run-up test, i.e., airport ground noise. These sounds can be heard in the surroundings of the airport, but the sound propagation significantly changes depending on meteorological conditions. In other words, airport ground noise becomes louder and audible only in cases of favorable conditions for sound propagation.

Evaluation of annual average sound exposure due to aircraft noise requires 'average-day' sound exposure of the year. So, it is necessary to consider what conditions we should suppose for noise measurement. This paper discusses the reliability of measured airport noise evaluation compared with prediction. Accuracy in prediction depends on the modeling superiority and availability of sufficient data such as aircraft operations and movements.

2. Consider the required accuracy in noise measurement and prediction

Firstly, it should be considered what we are looking for in relation to accuracy in noise measurement and prediction.

In an airport noise prediction, it is necessary to inevitably assume a simplified typical scheme of aircraft movements and sound characteristics; thereby it is feasible to evaluate cumulative noise exposure due to airport activities as well as it is possible to predict future trends of noise exposure and conduct various trade-off studies. As mentioned above, noise zones for environmental countermeasures performed under the laws are decided by the results of airport noise prediction in assumption of annual average noise exposure. Using it as a basis, the accuracy in prediction is required to be within 1dB as a rigid target. But, in comparison between the predictions of the current situation of annual noise exposure and measurements by unattended continuous noise monitoring, there are some stations that have differences beyond 1dB. So, as a realistic goal, it is better to accept differences within 1dB average for the whole location area and at most within 2dB for individual locations.

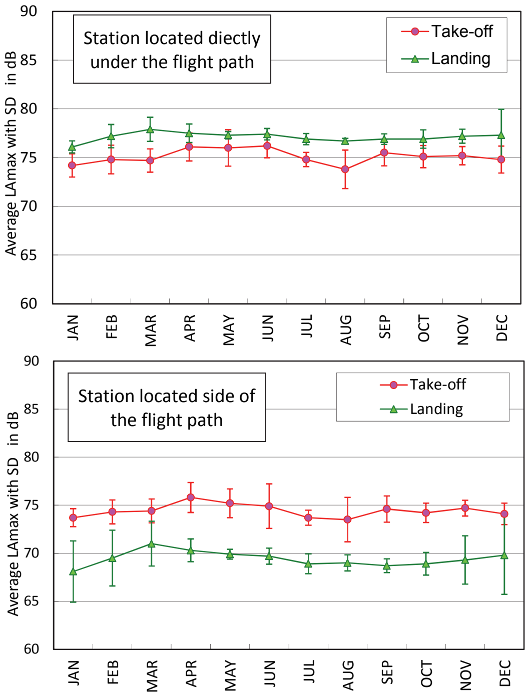


Figure 1 – variation in monthly average and SD of aircraft take-off and landing noise ($L_{\mathrm{AS,max}}$).

It is possible to gain confidence in measurement results from residents living around the airport. In actuality, however, accuracy of measurement results depends on measurement conditions and flight status (season, weather, wind etc.). It is also susceptible to background noise.

Figure 1 shows the variation in monthly average of aircraft take-off and landing noise ($L_{\mathrm{AS,max}}$) observed in unattended continuous aircraft noise monitoring at Narita Airport. The upper figure shows the results obtained at a station located directly under the flight path, and the lower figure shows the results obtained at a station location looking up from the side of the flight path. Each figure plots average noise levels and standard deviation (SD), shown as marks and vertical ranges. Generally, when an aircraft is in the air, fluctuations in observed noise level are hardly affected by wind conditions. It can also be seen from the figure; there is a 2-3dB fluctuation in the average value throughout the year.

One of the important roles of actual noise measurement is that it is possible to verify the validity of predictions. We have a rigid target of noise prediction accuracy within 1dB, so it is needless to say that it is necessary to set the same target for noise measurement accuracy. An integer unit is used to compare and evaluate against EQSAN standard values. In accordance, it will not affect the integer value of the measurement result, i.e. accuracy of measurement is required within 0.5dB or 1dB as a rigid target. From other viewpoint, environmental countermeasures for aircraft noise in Japan are usually performed by the contour lines at intervals of 5dB, and when the uncertainty reaches at least more than half that figure, the validity of the line cannot be secured. Thus, a realistic target of measurement accuracy of within 2dB is the maximum acceptable.

Therefore, it is important to carry out measurement and evaluation with care in order to minimize various factors affecting the uncertainty of measurement results, so that high reliability and good accuracy can be maintained.

3. Factors affecting the reliability of aircraft noise measurement results

3.1 SEL calculation

The Ministry of the Environment has issued the 'Guidance Manual for Measurement and Evaluation of Aircraft Noise (GMMEAN)'[1] , as triggered by the revision of EQSAN, in order to maintain the reliability of the results in a unified manner.

According to it, an aircraft sound event is characterized by the sound exposure level; SEL (L_{AE}) and the maximum sound pressure level (L_{ASmax}) which is 10dB or more above the background noise level. The SEL calculation method is defined by an energy sum of sound level above "L_{ASmax} - 10dB". If the noise floor stays below "L_{ASmax} - 15dB", it is able to determine L_{AE} within a difference of 0.5dB around the true value (i.e., L_{AE} without background noise). On the other hand, if the noise floor rises higher than "L_{ASmax}-15dB" (SN ratio 10-15dB), effects of background noise on L_{AE} calculation inevitably becomes significant. That would contaminate the L_{AE} calculation by around 1dB or more. If a large number of noise events with scant SN ratios were included in measurements, the reliability of the measured result would be so reduced. It is therefore required to consider other suitable measurement points with better with better SN ratios.

Recently, rapid prominent changes in noise level with extraordinarily peculiar tonal sound have been reported during the approach of some new low-noise aircraft as in the example in Figure 2. SEL calculation by the defined procedure may result in an error of 2 dB or more. In such case, expanding the L_{AE} calculating target range to "L_{ASmax} -15dB or -20dB" if needed, leads to maintaining accuracy of measured evaluation.

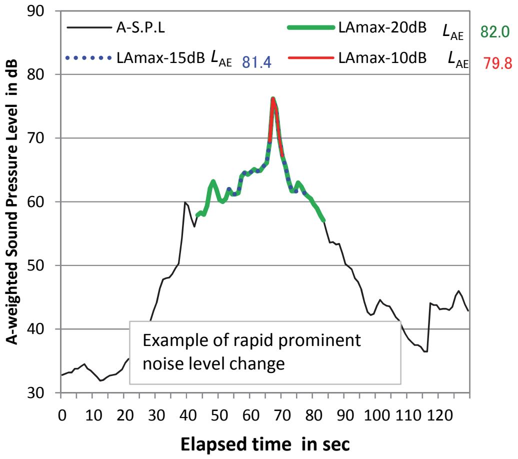


Figure 2 – Example of rapid prominent noise level changes; L_{AE} calculation result changes as the target range is expanded.

3.2 Overlapping of sound disturbances and aircraft noise

There are so many event-like background sounds, which may be observed at measurement sites, such as sounds from independent cars passing by, broadcasts over outdoor PA systems, ringing from insects or cicadas, to name just a few. Such sounds sometimes happen to overlap with an aircraft sound event and disturb L_{AE} measurement.

In case of manned measurement, the observer can aurally detect the overlapping of such sound disturbances and later exclude the disturbance or compensate with an average noise level from the rest of the secure measurement results in the L_{AE} calculation. These estimated L_{AE} calculation can be recovered to within a difference of 2dB around the true value. But, in the case of unmanned noise monitoring, it is always difficult to detect the overlap of such disturbances even if equipped with a function for sound source discrimination.

Regarding a different examination, it is reported that the measurement result obtained from a continuous monitoring station which was affected by a certain amount of road traffic noise, estimated an error of 0.5dB or more in mistaken aircraft noise which was found to be due to road traffic noise. Furthermore, if the ratio of sound disturbances overlapping aircraft noise exceeds of 20%, it will cause an error of 1dB or more in the result of L_{den} evaluation.

3.3 Differences in microphone heights

International standard ISO 20906[2] determines that microphone height is at least 6 m above ground to minimize interference effects from ground reflections. The EQSAN requires that microphone height is 1.2m to 1.5m above ground in order to unify with similar environmental standards for other noise sources such as road traffic or high-speed railways SHINKANSEN. A height of 4m is allowed in the case of placing a microphone on the roof of a building. However, the influence of sound propagation over ground is only considered as excess ground attenuation in aircraft noise prediction. Therefore, it is desirable to choose a measurement environment with as little as possible influence of extra ground reflection.

The following examination results describe the effects of differences in microphone heights.

- The Influence of ground reflection is different depending on surface. Acoustically hard surfaces, such as pavement, tend to affect reflection, so that results recorded at a height of 1.5m become larger than results at 4.0m. The difference is at most 0.5 dB on average in case of jet aircraft, dispersion of the L_{ASmax} is larger than of L_{AE}.
- The trend varies depending on flight mode, take-off or landing, due to differences in dominant frequency components or relationship of ground reflection and flight path.
- There is no clear difference in recorded results in case microphone is located above acoustically soft surfaces, such as grass.
- In case aircraft is operating on the ground, such as during take-off rolling or when using thrust reversers after touchdown, where sound propagates over ground, the result recorded at a microphone height of 4.0m is larger than at 1.5m.
- If the microphone is installed on the roof of a building, it might be strongly affected by surface reflections especially if the roof has waterproof treatment. So, it is recommended to place a microphone at a height of 4.0m or more above the roof surface.
- On the other hand, care must be taken to ensure that microphones are installed in a high enough place to be able to pick up sounds from a wider area than just at the ground, because the residual background noise increases and it is difficult to keep good SN ratio to identify aircraft noise in measurement.

3.4 Sensitivity of the sound level meter

We also have to pay attention to the individual characteristics of the sound level meter that is used for the measurement; differences in microphone sensitivity, etc. In Japan, metrological traceability of sound level meters has been secured by periodical laboratory inspection of verification tests on the basis of the internal electrical calibration signal prescribed by the national law of "Measurement Act". Therefore, it is not possible to perform any level adjustment of the overall sensitivity of a sound level meter by the external acoustical calibrator. So, we check the validity of the overall sensitivity by comparing level difference between an internal electrical calibration value and external acoustical calibration. The guidance manual GMMEAN indicates the difference should be maintained within 0.7dB and that there is a possibility of failure of the apparatus in the case of a difference beyond that. It recommends excluding it from use in the measurement and then rechecking.

Figure 3 shows the distribution of level difference between external acoustical calibration and internal electrical calibration checks for all sound level meters which are owned and administrated by our organization. We periodically check our metrological instruments by ourselves including all IEC61672-1 class 1 sound level meters using acoustical calibrator (Piston phone 114.0dB, 250Hz, class LS in IEC 60942). The results shown in Figure 3 are derived from these checks. The result shows the level differences vary widely from -0.5dB to +0.2dB, although the center is 0.0dB. Moreover, sensitivity has tended to decrease with the passage of years since the periodical verification test based on the law.

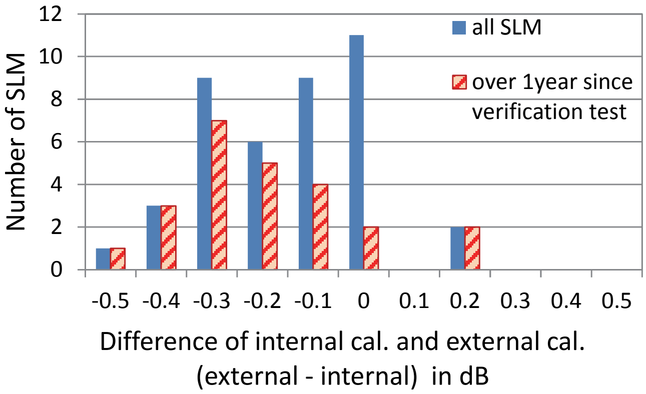


Figure 3 – Distribution of level difference between external calibration level using acoustical calibrator and the internal electrical calibration of the sound level meter (SLM).

4. Reliability of yearly-average using the results of short-term measurements

4.1 Validity of yearly-average using short-term noise measurement

The EQSAN requires evaluation of yearly-average cumulative noise exposure level in L_{den}, which is basically estimated by short-term noise measurement over a period of seven consecutive days, at a location where the aircraft noise situation is typical of the area. If the situation changes dramatically from one season to another, short-term noise measurement must be repeatedly performed, e.g., twice a year in summer and winter, or four times a year in each season. However, noise exposure situations change every moment and from place to place, dependent on various causes such as changes in runway use due to wind conditions, scatters of flight tracks and altitudes due to air traffic control, changes of sound propagation due to meteorological conditions and so on. Therefore, a matter of concern exists whether we can really make a valid determination of long-term average cumulative noise exposure level by using the results of short-term noise measurement.

We examined the relationship of short-term average L_{den} and yearly-average L_{den}[3]. We compared fluctuations in short-term average of consecutive observations of daily L_{den}, against one-year long records of noise observations by unattended noise monitoring at various points around several airports (Tokyo-Narita, Tokyo-Haneda, Osaka-Itami).

Figure 4 shows line graphs of standard deviation (SD) values of level fluctuation in short-term average L_{den} estimations around the yearly average, dependent on the following averaging periods;

(1) “One day,”
(2) “One week,”
(3) “Two consecutive weeks,”
(4) “Four consecutive weeks.”
(5) “One week, two times (i.e., one week every six months, or twice a year in summer and winter),”
(6) “One week, four times (i.e., one week every three months, or four times a year in each season).”

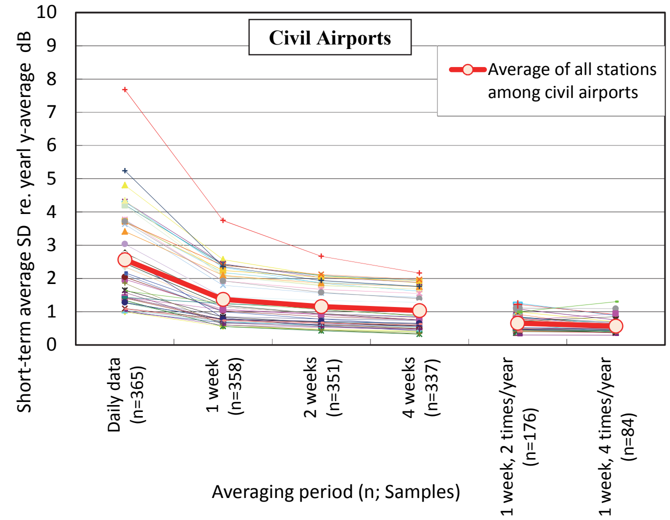


Figure 4 – Standard deviation (SD) of fluctuation in short-term average L_{den} estimations around the yearly average.

Each thin line shows the results of each of the monitoring stations respectively, where the bold line represents the average of all stations. What you can see from these graphs are as follows;

- The longer the averaging period becomes the smaller the SD of a consecutive short-term measurement is.
- SD of seasonally repeated short-term measurements is smaller compared with that of a consecutive short-term measurement; for example, in case of a two-week measurement, SD of a twice-a-year measurement (every six months) is 0.66 dB, While SD of a consecutive two-week measurement is 1.15dB.
- SD becomes lower than 1 dB if we perform seasonally repeated short-term measurements (twice a year or four times a year). It suggests that the evaluation of yearly-average L_{den} using short-term measurement almost ensures the realistic target of measurement accuracy in chapter 2.

4.2 Further improvement in the reliability of the yearly-average L_{den} estimation

Short-term noise measurement repeated twice or four times a year makes it possible to obtain good reliability of yearly-average L_{den}. Nevertheless, STD of the yearly-average remains 0.6~1.0 dB at the lowest, which is not always sufficient for a precise examination of the validity of the prediction results. In such cases, it is necessary to improve the reliability of the method of yearly-average L_{den} estimation.

Two methods are recommended by the guidance manual GMMEAN. One way is to use the result of unattended continuous noise monitoring over a long period including the period of short-term measurement at a near-by location (called ‘Reference Station Method’). Another is to calculate yearly-average L_{den} using both single event sound exposure levels and yearly-average statistics of aircraft movements for each flight mode (take-off and landing) and for each runway (called ‘Statistical Calculation Method’).

The following details the 'Reference Station Method'; if an unattended noise monitoring station is installed close to a point of short-term noise measurement and if aircraft flyover situations are similar to each other, it is expected that the noise exposure situations would be similar to each other, too. It is possible to estimate yearly-average L_{den} by adding the difference of yearly-average and short-term average of the reference monitoring station which highly correlates with the short-term measurement point in noise exposure and flight situations.

$$L_{\text{den,year,P}_\text{s}} = L_{\text{den,short,P}_\text{s}} + \left(L_{\text{den,year,P}_\text{r}} - L_{\text{den,short,P}_\text{r}}\right) \tag{1}$$

Where;

P_s: Short-term noise measurement point

P_r: Reference unattended continuous monitoring station (which has high correlation with P_s)

Short: Measurement term of Ps

Year: Annual period or fiscal year including ‘Short’

Next, we made an examination of the validity of the ‘Reference Station Method' of improving the reliability using one-year long noise observations at many unattended aircraft noise monitors, as with the examination shown in Figure 4. The verification steps are as follows;

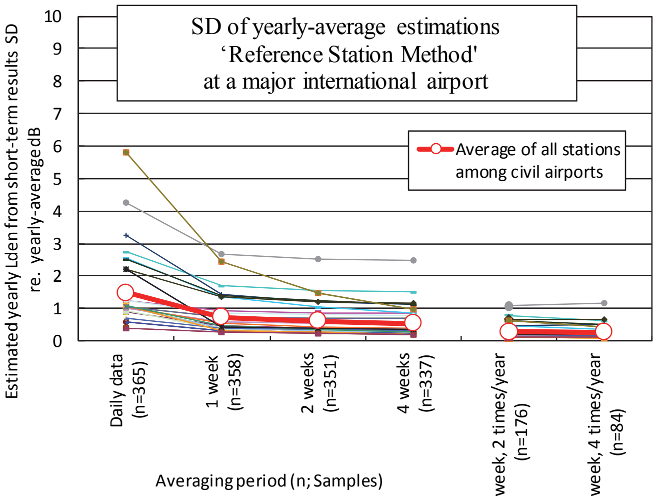
i) Select two noise monitors where noise exposure situations are similar to each other,

ii) Select one as a point of short-term measurement, and consider another as a reference, and

iii) Calculate estimated yearly-average L_{den} using Eq.(1).

Examination was repeated for the six periods the same as before; (1) one day, (2) one week, (3) two consecutive weeks and (4) four consecutive weeks, (5) one week, two times (one week every six months) and (6) one week, four times (one week every three months).

Figure 5 shows the result of the examination. The table below the graph shows a comparison of standard deviation (SD) values for each period for actual measurement, estimation and the difference between the two being expressed as improvement. These results suggest that Eq. (1) makes it possible to improve the reliability of yearly-average estimation sufficiently as long as we can select an appropriate reference point. If we perform seasonally repeated short-term measurements, SD becomes equal to, or lower than about 0.3dB. This can satisfy even the rigid target of measurement accuracy mentioned in chapter 2.



Comparison of average SD among monitors in dB

	Averaging period of ‘Reference Station Method'					
	Daily	1 week	2 weeks	4 weeks	1 week, 2times	1 week, 4times
Measurements	2.56	1.37	1.15	1.03	0.66	0.57
Estimations	1.49	0.74	0.61	0.54	0.30	0.27
Improvement	1.07	0.63	0.54	0.49	0.36	0.30

Figure 5 – Standard deviation (SD) of fluctuation in the estimated yearly average L_{den} using ‘Reference Station Method' around the yearly average.

The second ‘Statistical Calculation Method’ is to estimate yearly-average L_{den} using both measured single event sound exposure levels (L_{AE}) and yearly-average statistics of aircraft movements for each flight mode (take-off and landing) and for each runway, as in the following equation (2) .

$$L_{\text{den, year,estimation}} = 10\log_{10}\left(\frac{1}{86400}\sum_i\sum_j\sum_k\sum_l N_{ijkl}\cdot 10^{\frac{L_{AE,PU}+\Delta_k}{10}}\cdot r\right) \tag{2}$$

Where;

N: Yearly-average statistics of aircraft movements

i: Runway and direction (or flight track)

j: Flight mode (take-off or landing)
k: Time-period
l: Aircraft type
$L_{\mathrm{AE},\,PU}$: Average of measured SEL of each PU
PU: Process Unit, at least classified into i (runway direction) and j (flight mode)
(If able) further classified into l (aircraft type) or k (time-period)
Δ_k: weighting value depends on time-period, 0-6,22-23 +10dB, 19-21 +5dB
r: The ratio of the number of noise observations and the number of flight operations

Also, we made an examination of the validity of ‘Statistical Calculation Method' of improving the reliability. But, this study needs detailed records of flight movement number or aircraft types of each airport, so we were limited to using the results of the continuous monitoring stations around Narita Airport capable of obtaining such detail. The verification was performed by one-year long noise observations at 33 unattended aircraft noise monitors. We carried out the L_{den} estimate calculation based on assuming the same short-term measurement periods as before, and compared it with an actual average L_{den} of the year.

Table 1 shows a comparison of standard deviation (SD) values for each period for actual measurement, ‘Statistical Calculation Method’ estimation and the difference expressed as improvement. From the results, it also suggests that the ‘Statistical Calculation Method’ Eq. (2) makes it possible to improve the reliability of yearly-average estimation. If we perform short-term measurements repeated each season, SD becomes about ±0.25dB. It is possible to suppress an error in the noise evaluation value to within 0.5dB. This can also satisfy even the rigid target of measurement accuracy mentioned in chapter 2, just as in the case of the ‘Reference Station Method’ estimation. In addition, regarding the 'Process Unit' classification, there are no clear differences in the STD value of the estimation even when subdividing into the following categories, “Aircraft type” or “Time-period” from “Runway and Flight mode”. In other words, by at least dividing with distinction of runway direction and flight mode (take-off or landing), it is possible to maintain the reliability of the evaluation value by yearly-average estimation.

Table 1 – Comparison of average SD of the estimated yearly average L_{den} using ‘Statistical Calculation Method’ of the yearly average obtained from 33 monitoring stations around Narita Airport.

		Averaging period of estimation					dB
Items	PU Classification	daily	1 week	2 weeks	4 weeks	1 week, 2times	1 week, 4times
Measurements		2.99	1.61	1.39	1.28	0.79	0.45
Estimation 'Operation Number Method'	1) Runway and flight mode	1.69	0.80	0.66	0.54	0.55	0.23
	2) Aircraft type added to 1)	1.68	0.82	0.69	0.58	0.55	0.23
	3) Time zone added to 2)	1.70	0.86	0.69	0.57	0.58	0.25
Improvement	1) Runway and flight mode	1.30	0.81	0.73	0.74	0.24	0.22
	2) Aircraft type added to 1)	1.31	0.79	0.70	0.70	0.24	0.22
	3) Time zone added to 2)	1.29	0.75	0.70	0.71	0.21	0.20

5. Airport ground noise

The revised EQSAN decided an expansion of target sounds for noise evaluation; it requires taking account of contributions of sounds resulting from aircraft operations on the airport ground surface, if necessary, such as taxiing, engine run-up and use of auxiliary power units on the apron.

Generally, whenever an aircraft taxis, noise is observed close to the airport in the area along the taxiway. The guidance manual GMMEAN introduces an example of distribution of airport ground noise observed during short-term measurement at some domestic airports; according to it, measurement points located close to taxiways identify that ground noise contributes 1dB to 3dB to L_{den}.

However, in areas distant to a taxiway or an apron, i.e. in the surroundings of the airport, these sounds can be heard but the sound propagation is significantly affected by changes in meteorological conditions. In other words, airport ground noise becomes louder and audible only in cases of favorable conditions for sound propagation. In such areas, contribution by ground noise to L_{den} is not so much, at most below 1dB.

Here, we briefly introduce the results of ground noise from the unattended consecutive noise monitoring system installed by NAA (Narita Airport Corporation) at Narita Airport. In 2010, two old monitoring systems intended for independently detecting for flyover noise and ground noise were replaced with a new single system which monitors both flyover noise and ground noise around the airport simultaneously, so as to conform to the revised standard[4]. Figure 6 is an enlarged view of the vicinity of the airport showing locations of related ground noise monitoring stations.

Figure 7 shows results of ground noise measurement results for the 2013 fiscal year from point M-2 which is located midway between the two runways and about 600m distance from the nearest taxiway, as shown in Figure 6. From the upper part of figure 7, looking at monthly changes of ground noise observations numbers, we can see that they increase in autumn and winter, but decrease in summer. Regarding time-period from the lower part of figure 7, the number of observations is larger at night and early in the morning. These results suggest that ground noise can be heard even in an area surrounding an airport when good conditions exist for noise propagation where temperature inversion due to radiation cooling and background noise stay at a low level. Further, the most prominent type of ground noise observed is due to taxiing.

Figure-8 shows frequency distribution of daily L_{den} from point M-2 that was calculated dividing into ground noise and fly-over noise respectively, throughout of fiscal 2013. The L_{den} calculated only limited to fly-over noise are concentrated around 60dB with narrow distribution. On the other hand,

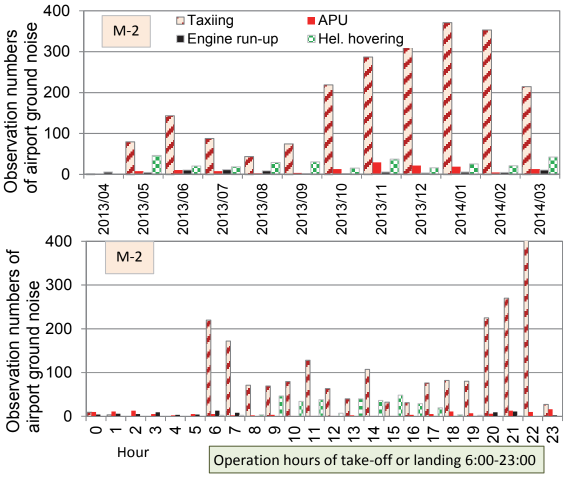


Figure 7 – Ground noise measurement results for fiscal 2013 from point M-2.

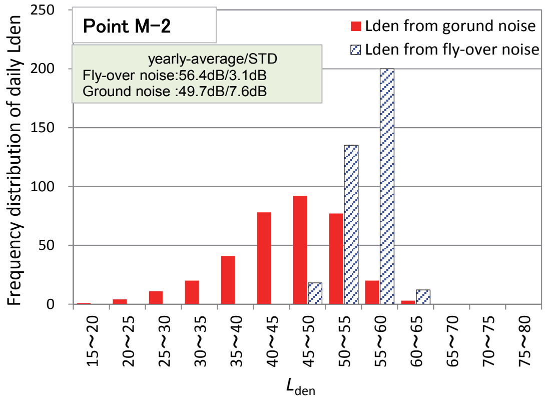


Figure 8 – Frequency distribution of daily L_{den} from point M-2 dividing ground noise and fly-over noise.

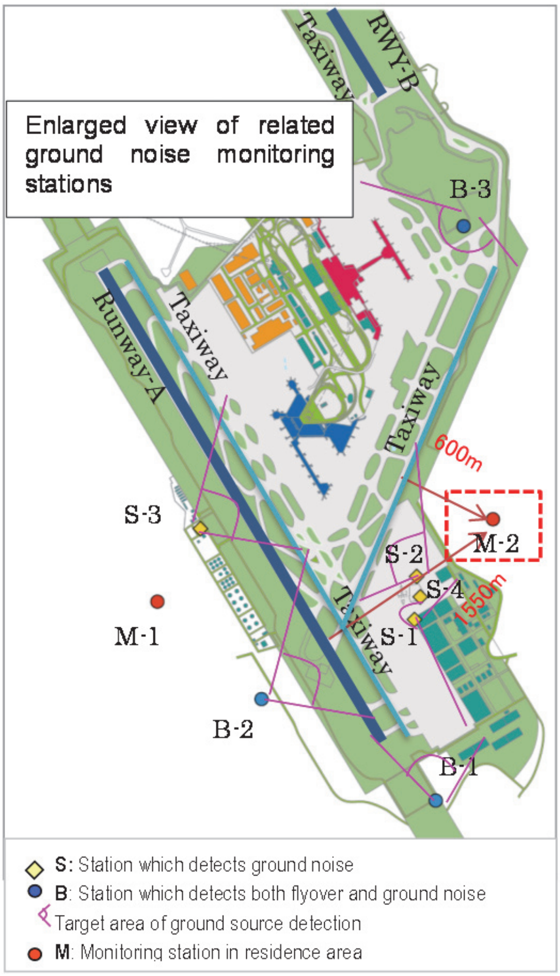


Figure 6 – Site location map related stations of ground noise monitoring by NAA.

the L_{den} of airport ground noise has a very large range of distribution from 15dB to 50dB. The center is 50dB which is 10 dB lower than the center of L_{den} distribution from fly-over. Note that, it is not shown in the figure, about 20% days of the year has no measurement results from airport ground noise at point M-2. (The measurement device worked normally, but there was no target noise from ground activities at the airport)

From these results, it can be seen that we must be aware of the possibility that there could be large differences between $L_{\mathrm{den,ground\ noise}}$ evaluated from short-term measurement and the actual yearly-average of $L_{\mathrm{den,ground\ noise}}$.

In addition, the airport ground noises observed at the surroundings of the airport usually stay at a low level, but continue to last a long time. Also, fly-over sound events often overlap ground noise, so it is not easy to detect they begin and how long they continue. In this way, it is not so easy to accurately isolate and measure the only ground noise except for in the proximity of the taxiway. Also, uncertainty that is included in the evaluation value of ground noise is large.

The Civil Aviation Bureau of Japan (JCAB) and Airport Environment Improvement Foundation (AEIF) developed an L_{den} prediction model based on the concept of segment modeling. In 2010, that was revised in order to calculate the influence of airport ground noise such as using APU or engine run-up operation. Concerning the ground noise database, we decided to prepare it as a NPD (Noise level; $L_{\mathrm{A}E}$ Power Distance) table, as used for fly-over noise. It worked together with segment model cooperatively. After that, in 2012, we modified the model even more to be able to consider insertion loss of a finite-length thin barrier due to noise embankments and barriers. Also, we started to build up a noise database in order to calculate noise contribution due to aircraft ground activities such as APU, engine-test and taxiing. Since then, we have carried out noise measurements iteratively to get the database of ground noise source characteristics and directivity [5].

Regarding noise prediction for airport ground noise, there are many issues to be considered more as well as measurement of ground noise. One of the issues is what meteorological conditions we should suppose in noise prediction of ground noise that agree with 'yearly-average ground noise level', because observed ground noise varies greatly depending on meteorological conditions, as mentioned above. It is necessary to have practical ways of calculating adjustments due to insertion loss caused by thick rectangular structures such as embankments and terminal buildings. It is also necessary to further consider how to calculate excess ground attenuation in ground noise sources such as APU, engine run-up, taxiing, to be able to keep more reliability in predictions. In an airport ground noise prediction, if it is classified into actual movement of ground traffic and APU operation on an apron, it is just too complex. Consequently, the calculation time becomes enormous. Therefore, a simplified typical scheme of aircraft movements and sound characteristics should be assumed.

Note: There is a related paper concerning the prediction of airport ground noise in this congress [6]. Anyway, in many cases, although the contribution of airport ground noise to L_{den} in areas surrounding the airport is usually only 0.5 dB or less, the prediction of airport ground noise model has several issues that need further examination as well as the measurement of airport ground noise for which to be compared to.

6. CONCLUSIONS

This paper described the reliability of measured airport noise evaluation compared with prediction. In Japan, airport noise mitigation measures are performed based on yearly-average airport noise predictions. First, we considered what we are looking for in relation to accuracy in noise measurement and prediction. In accordance with evaluation against a standard value, the accuracy of measurement is required within to be 0.5dB or 1dB as a rigid target, because it will not affect the integer value of the measurement result. Also, the accuracy in prediction is required to be within 1dB as a rigid target, because environmental countermeasures zones are decided by prediction results.

The noise measurements are not only obtained from unattended continuous long-term aircraft noise monitoring, but are also often carried out using a short-term measurement. We described various factors including microphone height, SN ratio and SEL calculation procedure and incomplete observations affect the reliability of measured noise evaluation. When evaluating yearly-average aircraft noise using short-term measurements, the reliability changes dependent on the measurement period in addition to the afore mentioned factors. If we perform short-term noise measurement twice or four times a year, it is possible to get a good reliability of yearly-average L_{den}. If we require more precise evaluation, it is necessary to improve the reliability of yearly-average L_{den}. There are two yearly-average L_{den} estimation methods, and we verified that both methods make it possible to improve the reliability of yearly-average estimation sufficiently.

We briefly introduced the consecutive noise monitoring results of airport ground noise, which is a noise contribution due to aircraft ground activities such as aircraft taxiing, APU operation and engine run-up tests. The observation numbers of ground noises increases in autumn and winter or night and early in the morning. These results indicate ground noise can be heard when background noise stays at a low level in addition to significantly good sound propagation exists depending on meteorological conditions when temperature inversion due to radiation cooling, so on. The L_{den} of airport ground noise has a very large range of distribution.

Finally, we briefly reviewed the L_{den} prediction model based on the concept of segment modeling. It can calculate the influence of airport ground noise with consideration of insertion loss of a finite-length thin barrier. Anyway, the prediction of airport ground noise model has several issues that need further examination as well as the measurement of airport ground noise for which to be compared with.

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