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NOISE CONTROL FOR A BETTER ENVIRONMENT

A study on the relation between $WECPNL_K$ and L_{den} in the vicinity of Korean military airports

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ABSTRACT

Weighted Equivalent Continuous Perceived Noise Level $WECPNL_K$, which is a modified version of $WECPNL_{ICAO}$, has been used to evaluate aircraft noise in Korea. But other countries used L_{den} instead of WECPNL, such as US and European countries. Accordingly, many studies have been conducted to apply L_{den}. Recently, the 'Enforcement Decree of the Noise and Vibration control Act' was revised on September 19th, 2017 in Korea, L_{den} will be used from January 1st, 2023 after a 5-year deferment period.

In order to confirm the proper criteria for noise at the military airport, it is necessary to set a conversion formula by means of the relation between $WECPNL_K$ and L_{den}. In Korea, such relation has been examined positively for the civil airports, while few studies have been carried out to have relation for the military airports. In this paper, the relationship between $WECPNL_K$ and L_{den} is examined by analyzing noise level data of three military airports.

Keywords: Aircraft noise, $WECPNL_K$, L_{den}
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1. INTRODUCTION

Currently, the criteria of noise exist only for the civil airports in Korea; there exist no such criteria for the military ones. Hence, it is deemed necessary to set the appropriate criteria of the noise for the military airports. In order to set the noise criteria for the military airports, however, it is essential to review those for the civil airports. In case of the civil airports, the criteria of the noise are set according to Article 9 of the 'Enforcement Decree of the Noise and Vibration Control Act'(1); the upper limit of the noise in the neighborhood of the airport is $WECPNL_K$ 90, while that for the other areas is $WECPNL_K$ 75. Further, the 'Enforcement decree of the Airport noise Prevention and Areas Assistance Act'(2) specifies the lower limits of the criteria more specifically: $WECPNL_K$ 95 or higher for the zone #1, $WECPNL_K$ 90 ~ 95 for the zone #2, and $WECPNL_K$ 75 ~ 90 for the zone #3.

However, beginning from 2023, the unit of the noise evaluated will change from $WECPNL_K$ to L_{den}, and the criteria for the noise will change from $WECPNL_K$ 90 to L_{den} 75 dB(A) and from $WECPNL_K$ 75 to L_{den} 61 dB(A). Also, The Ministry of Environment published a conversion formula between $WECPNL_K$ and L_{den} as below.

$$L_{den} = 0.89 \times WECPNL_K - 5.91$$

However, the military aircraft are irregular in terms of their operation schedules with diverse take-off and landing patterns, it is necessary to examine the above formula to the military airport. Therefore, this paper is intended to derive a conversion formula between $WECPNL_K$ and L_{den} in military airports on the basis of aircraft noise measurement.

2. MEASUREMENT INDEX

2.1 $WECPNL_{ICAO}$ (3)

$WECPNL_{ICAO}$ originated from the "Special Meeting on Aircraft Noise in the vicinity of Aerodromes" of International Civil Aviation Organization(ICAO), which was held in 1969. $WECPNL_{ICAO}$ was proposed as an evaluation index for long-term continuous exposure to noise caused by multiple aircraft. The operation number of aircraft, noise level of flying aircraft, noise duration, time when noise occurs, and seasonal factor were considered, and perceived noise levels of each time zone were weighted for ECPNL.

$$\mathrm{WECPNL} = 10\log\left[\frac{d}{24}10^{\left(\frac{ECPNL_d}{10}\right)} + \frac{e}{24}10^{\left(\frac{ECPNL_e}{10}\right)}\frac{n}{24}10^{\left(\frac{ECPNL_n}{10}\right)}\right] + \mathrm{S}$$

Where, $ECPNL_d$ is the ECPNL of daytime, $ECPNL_e$ is that of evening time, and $ECPNL_n$ is that of night time. The distinction of daytime, evening time and night time varies according to different countries. Korea adopts the daytime (07:00 ~ 19:00), the evening time (19:00 ~ 22:00) and the night time (22:00 ~ 07:00). Here, d, e and n are 12, 3 and 9 respectively. S is a correction value due to season.

2.2 WECPNL$_K$

In Korea, WECPNL$_J$ of Japan, which is a simple version of WECPNL$_{ICAO}$, has been adopted. The history of airport noise modeling in Japan goes back to the early 1970s, where jet aircraft began to dominate the aviation industry. As people living in the vicinities of large airports were affected by noise, this problem became a social issue. The Japanese government conducted a large-scale investigation of aircraft noise and attempted to construct a noise exposure map for nearby areas. However, as the measurement was limited, it was difficult to identify the accurate states of exposure. Accordingly, in 1978, JCAB (Japan Civil Aviation Bureau) developed a new model based on that of WECPNL$_{ICAO}$[(4)(5)]. Since then, both Japan and Korea have used the simplified WECPNL$_K$ for over 30 years. WECPNL$_K$ is as follows. And $\overline{WECPNL_K}$ is average WECPNL$_K$ during m days.

$$WECPNL_K = \overline{L_{max}} + 10\log(N_d + 3N_e + 10N_n) - 27$$

$$\overline{WECPNL_K} = 10\log\left[\frac{1}{m}\left(\sum_{i=1}^{m} 10^{0.1\,WECPNL_i}\right)\right]$$

2.3 L$_{den\ total}$

This aircraft noise index was proposed by EPA (Environmental Protection Agency) in 1973 and has been most widely used around the world including the US and Europe. Depending on division of time zones, either bipartite (day-night) or tripartite (day-evening-night) index is used. As the same noise level is perceived to be higher in the evening or at night than in daytime, weighted values of +0 dB(A), +5 dB(A) and +10 dB(A) were set for day, evening and night, respectively. The formula below is applied.

$$L_{den} = 10\log\left[\frac{1}{86400}\left(d \times \sum_i 10^{\frac{L_{di}}{10}} + e \times \sum_j 10^{\frac{L_{ej}+5}{10}} + n \times \sum_k 10^{\frac{L_{nk}+10}{10}}\right)\right]$$

Where, L_d is the daytime of equivalent noise level, L_e is the evening time of equivalent noise level, L_n is the night time of equivalent noise level. If daytime is 07:00 ~ 19:00, evening time is 19:00 ~ 22:00, night time is 22:00 ~ 07:00, d=43200, e=10800, n=32400.

2.4 L$_{den\ event}$

This aircraft noise index was referenced from L$_{den}$. For calculation of aircraft noise, extract exposed noise level of each times when affect over 10 dB(A) of background noise during over 10sec.

$$L_{den} = 10\log\left[\frac{1}{86400}\left(\Delta t_d \times \sum_i 10^{\frac{L_{di}}{10}} + \Delta t_e \times \sum_j 10^{\frac{L_{ej}+5}{10}} + \Delta t_n \times \sum_k 10^{\frac{L_{nk}+10}{10}}\right)\right]$$

3. NOISE MEASUREMENT AROUND MILITARY AIRPORTS

This study measured $WECPNL_K$ in A airport where only a few civil aircraft are operated, B airport where both civil aircraft and fighter are operated together, and C airfield in which only fighters are operated. The equipment used for noise measurements were NL-42, NL-20, and TES-53H

The directions of aircraft take-off and landing and the operation patterns were considered for nearby areas where residents have filed complaints about aircraft noise. Among areas with high populations, 6 points of A airport, 8 points of B airport and 6 points of C airfield were selected. The measurement was had once in A airport, twice in B airport and also twice in C airfield. The locations of those points are presented below.

3.1 A airport

This airport are used both for civil and military purposes. However, the take-off and landing of civil aircraft occurred only twice a day. Apart from usual fighter, the airport was a base of a aerobatic team. Figure 1 shows the detailed locations of 6 measurement points. Since most of the residents live to the north of the airport, the measurement points are concentrated in the northern part. A-4 located in a straight line from the runway was selected to identify noise levels occurring during the take-off and landing of aircraft.

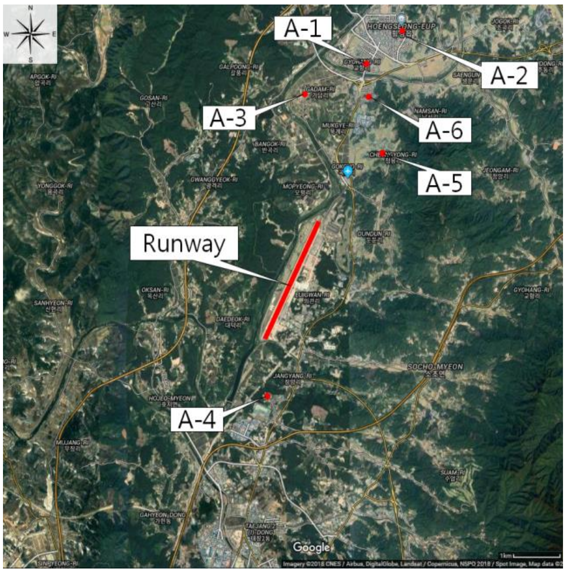

Figure 1: Information of measurement point in A airport

3.2 B airport

Both civil aircraft and fighter are operated in this airport. About 17 civil aircraft were operated on average in one day from September to November, during which the measurement was conducted. Since the air force team used this airport as its base, the aircraft noise had complex patterns. The noise was measured at 8 points, as illustrated in Figure 2. B-4, 6 and 7 were close to the runway, and the remaining points were evenly distributed either in or out of the extension of the runway

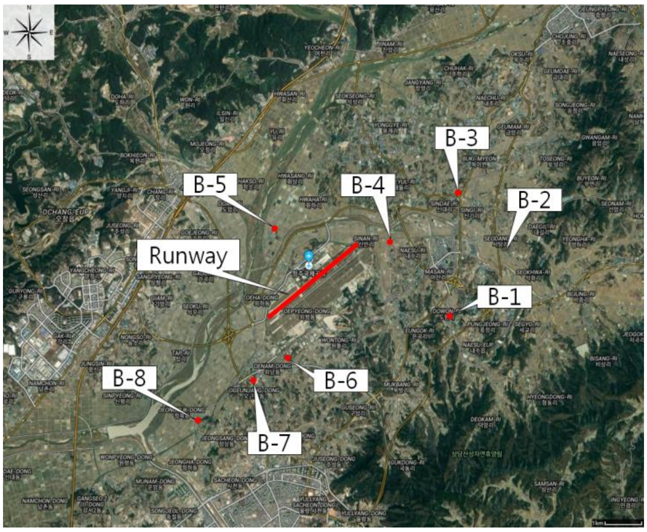

Figure 2 : Information of measurement point in B airport

3.3 C airfield

C airfield used to be operated and managed by Korea Airport Authority. However, as the number of visitors decreased, the ownership of the buildings and facilities has been transferred to the Ministry of National Defense. Thus, this airfield is being used only for military purposes. Noise measurement was performed at 6 points, as shown in Figure 3. C-2 and 6 were close to the runway, and the remaining points were evenly distributed either in or out of the extension of the runway.

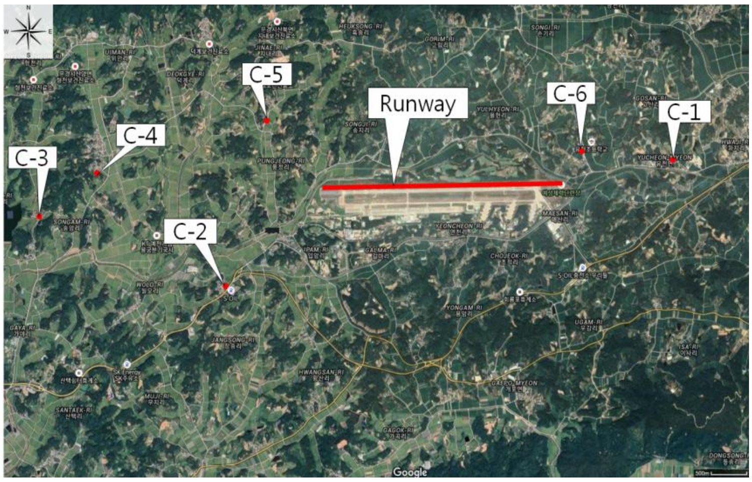

Figure 3 : Information of measurement point in C airfield

4. CONCLUSIONS

4.1 Relation between $\overline{WECPNL_K}$ and $\overline{L_{den}}$

The Figure 4 shows the comparison on average for a week among $\overline{WECPNL_K}$, $\overline{L_{den}}$ event and $\overline{L_{den}}$ total. If we adopt a week average, we need to compensate for the total duration of $\overline{WECPNL_K}$, and then, the coefficient of determination R^2 of $\overline{WECPNL_K}$ and $\overline{L_{den}}$ event was 0.92608, while that of $\overline{WECPNL_K}$ and $\overline{L_{den}}$ total was 0.84162. The regression formula is as follows. The p-value of intercept and slope in $\overline{WECPNL_K}$ and

$\overline{L_{den}}$ event were 0.02282 and 1.15392e-19, respectively, while those in $\overline{WECPNL_K}$ $\overline{L_{den}}$ total were 0.11574 and 2.37806e-14, respectively. Since the intercept exceeds 0.l05 in $\overline{WECPNL_K}$ and $\overline{L_{den}}$ total, it was not deemed significant. In this case, it was judged appropriate to use $\overline{L_{den}}$ event. For correlations between $\overline{WECPNL_K}$ and L_{den} event or between $\overline{WECPNL_K}$ and $\overline{L_{den}}$ total, the following regression formulas can be determined.

$$L_{den}\text{ event} = 0.92009\ WECPNL_K - 9.12206 \qquad R^2 = 0.92608$$
$$L_{den}\text{ total} = 0.73128\ WECPNL_K + 7.52534 \qquad R^2 = 0.84162$$

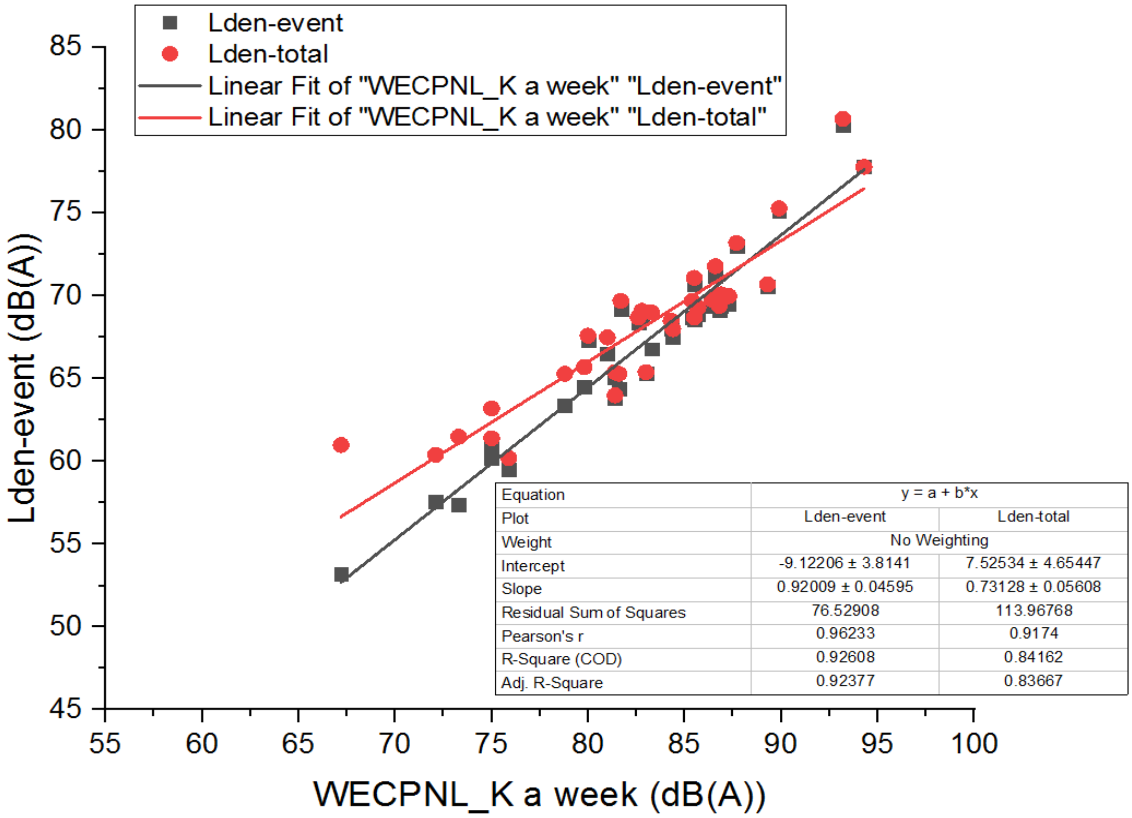

Figure 4 : Comparison among $WECPNL_K$ a week and L_{den} event and L_{den} total on all airports

4.2 Relation between $WECPNL_K$ and L_{den}

The researcher used the data calculated for A airport, B airport, and C airfield to analyse the correlation between $WECPNL_K$ measured for a day and L_{den} event and between $WECPNL_K$ measured for a day and L_{den} total, respectively. Here, $WECPNL_K$ was not compensated for the continued time.

The correlation between $WECPNL_K$ measured for a day and L_{den} event is shown in Figure 5, while that between $WECPNL_K$ measured for a day and L_{den} total is shown in Figure 6. In order to examine the significance of the formulas, it is essential to check their p-values. The p-value of the correlation between $WECPNL_K$ and L_{den} event and that between $WECPNL_K$ and L_{den} total were 1.3551e-123 and 2.619e-79 in the slope, respectively, and 4.25142e-8 and 1.12972e-13 in the intercept, respectively. The p-values were less than 0.05. Hence, the induced regression formula was deemed significant in both terms of slope and intercept. The coefficient of determination R^2 in $WECPNL_K$ and Lden event was 0.91425, and that in $WECPNL_K$ and L_{den} total was 0.79037. In both cases, the coefficient of determination R^2 is very high, and therefore, the regression formula could be set as a linear one. On the other hand, the value of L_{den} event shows a high degree of fitness compared with that of L_{den} total, it is deemed more appropriate to use the L_{den} event when we analyze the correlation with $WECPNL_K$. The regression formulae between $WECPNL_K$ and L_{den} event and between $WECPNL_K$ and L_{den} total are shown as follows.

$$L_{den}\text{ event} = 0.93422\ WECPNL_K - 8.55470 \qquad R^2 = 0.91425$$
$$L_{den}\text{ total} = 0.66565\ WECPNL_K + 14.28766 \qquad R^2 = 0.79037$$

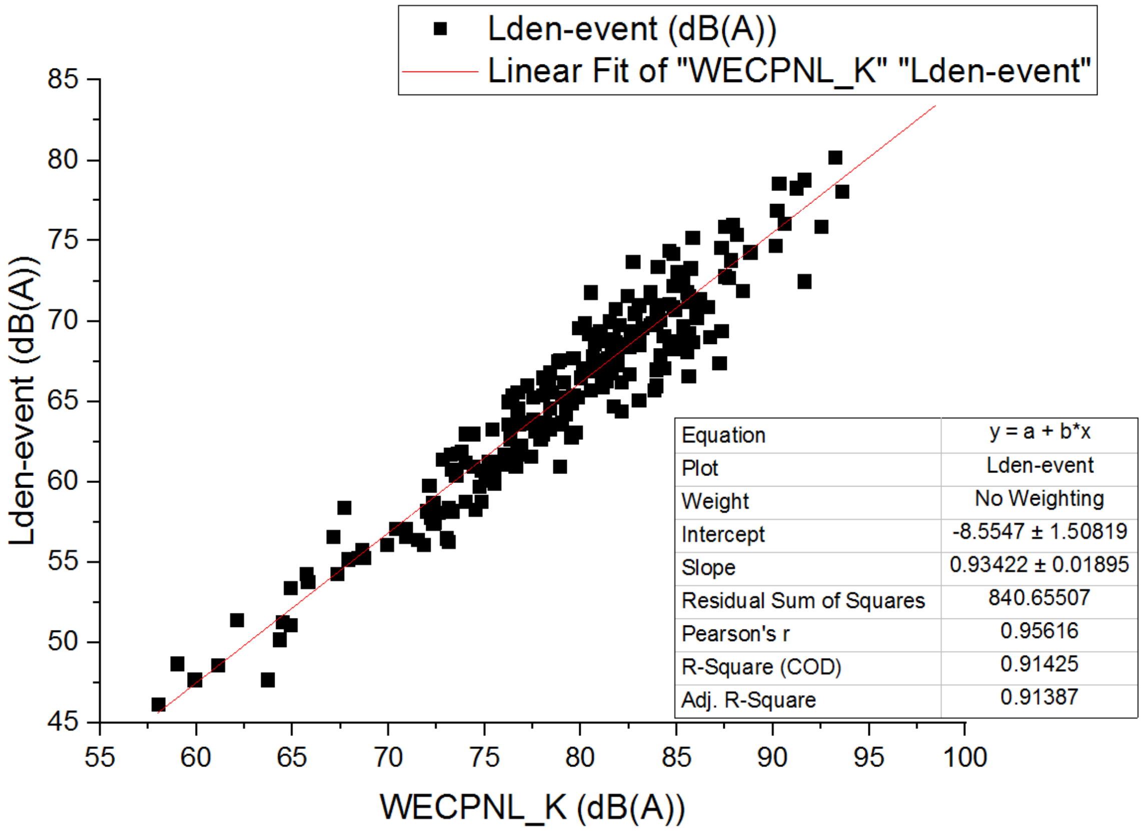

Figure 5 : Comparison between $WECPNL_K$ and L_{den} event on all airports

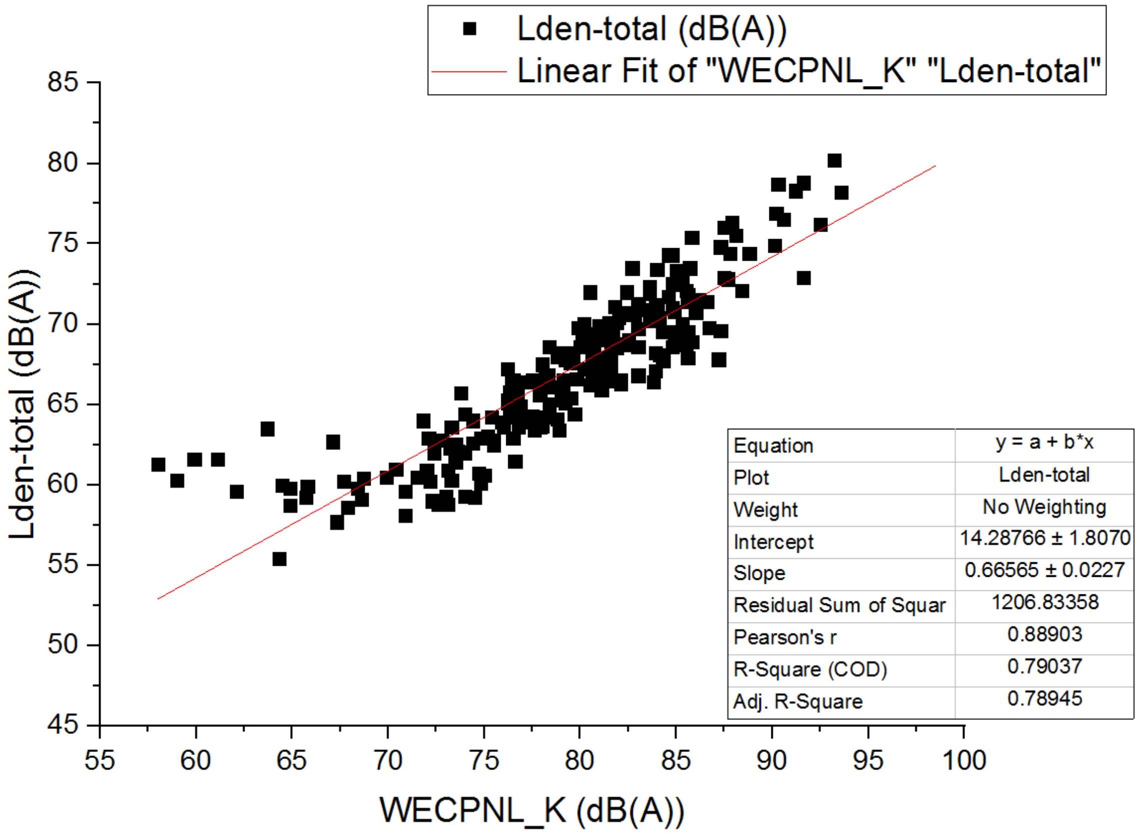

Figure 6 : Comparison between $WECPNL_K$ and L_{den} total on all airports

5. CONCLUSION

Recently, as the aircraft noise evaluation criteria are expected to change from $WECPNL_K$ to L_{den}, the researcher sampled A airport, B airport and C airfield where the fighter use primarily, and thereby, analyzed the correlations between two formulas. This study may well be concluded as follows;

Firstly, In all proportional conversion formulas, L_{den} events show higher correlation coefficients than L_{den} total, and therefore, it is desirable to measure the airport noise with the L_{den} events.

Secondly, If the daily $WECPNL_K$ has been compensated for time, the results will be more correlation coefficients than the daily $WECPNL_K$. The results are similar to the conversion formula suggested by Ministry of Environment.

$$L_{den}\text{ event} = 0.87974\ WECPNL_K - 5.98608, \qquad R^2 = 0.944222$$

6. ACKNOWLEDGMENTS

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