Evaluation and prediction of airport noise in Japan

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1. Introduction

It is a quarter century since the Environment Agency notified 'Environmental Quality Standard against Aircraft Noise' [1]in Japan. During the years the Ministry of Transport has made, under the Standard, a lot of environmental measures to alleviate the impact of aircraft noise around airports, which results in a great improvement in acoustical environment around airports. First, this paper briefly reviews the Standard and a noise evaluation index $WECPNL_J$ in the Standard. Then, it describes the basic idea of an airport-noise prediction model JCAB Model, which has been developed by Civil Aviation Bureau of the Ministry of Transport, together with some recent result of examination about the accuracy of noise prediction. Finally, it refers to the relationship between $WECPNL_J$ and L_{dn}.

2. Environmental Quality Standard for Aircraft Noise and $WECPNL_J$

In 1971 ICAO published an ANNEX 16[2], in which it recommends *WECPNL* as the basic noise index for evaluation of environmental noise effects due to aircraft noise around airports. It may have been expected to unify noise indices among countries. Japan was probably one of the first to use *WECPNL* as the basic index for specifying noise standards, although it uses the following simplified form of WECPNL, i.e. $WECPNL_J$. Calculation of *EPNL* requires a complex procedures using frequency analysis and it was not of practical use at that time. The simplification is based on the assumptions that the duration time of aircraft noise events is approximately 20 s and that $EPNL \sim L_{Amax}+13$. Noise limits for preservation of desirable acoustical environment around airports are specified using $WECPNL_J$ in the 'Standard as follows;

70 $WECPNL_J$ or less in areas for exclusively residential use (Type-1), and
75 $WECPNL_J$ or less in areas, where to maintain quiet life environment,
other than Type-1 (Type2).

These values, which can be approximately converted to 57 and 62 dB in L_{dn}, are rather strict limits, because subsidization to soundproofing have been fulfilled for existing houses located in areas, where $WECPNL_J$ is greater than 75. In addition, areas where $WECPNL_J$ is greater than 90 have been subject of house relocation and of development of green buffer zones, etc.

3. Aircraft Noise Prediction Program in Japan

Civil Aviation Bureau (CAB), Ministry of Transport, first developed their own aircraft noise prediction program in 1978. We call it JCAB Model in the following. Previous FAA Prediction Model[3] was referred to as the basis during the development of the first edition of JCAB Model. It uses several basic data such as (1) Noise-Distance Data, which determine relationship of L_{Amax} to source-receiver distance according to engine thrust values for various aircraft types, (2) Altitude Profiles showing the transition of flight altitude and engine thrust, and (3) Flight Trucks defining projections of flight paths onto the ground. It usually calculates noise prediction in $WECPNL_J$ on the basis of information on airport and flight operation and depicts noise contours. In the calculation, it first determines a flight altitude and an engine thrust value at minimum distance on the flight route from an observation point. Next, it calculates noise exposure due to the flight using Noise-Distance Data. The model takes account of correction due to excess ground attenuation according to elevation angle looking up at the aircraft. It also takes flight route dispersion into account. $WECPNL_J$ is calculated by adding up all energy contribution of noise exposure calculated for all types of aircraft and flight operations with the corrections.

4. Recent topics about factors affecting the accuracy of noise prediction

4.1 JCAB Model and its basic data have been revised several times to improve the accuracy in prediction since the initial development in 1978. Here, we illustrate the way in which we examined the validity of basic data regarding flight and noise performance to improve prediction accuracy when some new types of aircraft have been introduced to use. Altitude profile data and noise-distance data are usually prepared relating to engine power, being based on information provided from airlines together with general flight procedures in combination with using power, aircraft weight, flap angle, etc. The provided information, however, is not always match actual flight operation in service. Figure 1 is an example showing a comparison of a measured altitude profile with basic data of the prediction model. The measured flight profile of aircraft (○) was surveyed using double theodolite system with video cameras and the engine power data was obtained from flight recorder readings after the flight. On the other hand, the dotted line shows a predicted altitude profile using 'full rating' power (maximum take-off thrust and maximum climb thrust). The X marked line indicates a predicted altitude profile using thrust derated by 15% of full rating (i.e. 85% of maximum take-off thrust), which is the airline's recommendation to the pilot at that take-off weight. In the figure, values of engine power (in thrust) are also indicated at distances 10000, 20000 and 30000 ft. A substantial difference can be seen between the ○ - marked measured altitude profile and the airline's recommendation, while the measurement agrees the dotted line (the full rating power). Normal prediction of altitude profile is made with this derated power at this weight. As a result of flight recorder check, it was found that the pilot of this flight had used full rating power instead of airline's recommendation (Recommendation was not mandatory in this case.). Our understanding is that the predicted altitude should meet the actual altitude if the prediction is based on the correct aircraft weight and engine power. So, the confirmation of aircraft weight and engine power used at every airport is essential before the prediction of aircraft performance and its noise.

4.2 Figure 2 illustrate an example we examined the validity of noise-distance database for a new aircraft type. In the figure, which shows a comparison of noise levels between measurement and prediction database, we can see discrepancy of 3.5 dB on the average between measurement and prediction. The measurement was done at 3 points directly under the flight path (elevation angle: 90~70°) to avoid the problems which are induced by EGA. At the same time, we calculated noise levels using the prediction model with actual flight altitude and engine thrust data when aircraft flew above the measurement points. Although we applied to the aircraft manufacturer for information about this discrepancy, we obtained no clear answer yet. Figure 3 shows another comparison for a new aircraft type, in which case measurement and prediction was in a good correspondence. Our supposition regarding the discrepancy is as follows: (1) The noise-distance data may have been obtained from measurement for noise certification test, using extrapolation at long distances. Noise certification flights require special techniques to maneuver the aircraft, which does not match daily flight. The collected data is optimistic accordingly. (2) Data for noise certification is all measured at altitudes or distances around 1000 ft. Extrapolation to a wider range , e.g. to 5000 ft or more causes deterioration in accuracy.

Finally, the prediction of aircraft noise at points on the ground laterally displaced from the projection of an aircraft flight path, e.g., as required for prediction of contours of equal noise levels, requires a knowledge of sound-propagation phenomena. At the present JCAB model also uses procedure of SAE AIR 1751[4], but as it is often overestimated, so we applied the procedure described in SAE AIR 1751 with slight modification, which is to use a modified equation of air to ground attenuation up to a 2 dB lower maximum value than the original experientially. We are advancing the examination of a new procedure to evaluate lateral attenuation by field test.

5. Relationship between *WECPNL*$_J$ and L_{dn}

As Prof. Dr. Tachibana introduces, in Japan, L_{Aeq} was commonly applied for the index of the Environmental Quality Standard for general noise problems except aircraft noise. Regarding aircraft noise, as stated above, *WECPNL*$_J$ has been used as index and tool to promote the sound-proofing or house relocation since 1971 and is familiar among the people now. Though it seems that there is no urgency for change the index *WECPNL*$_J$ to L_{dn}, some studies were about the relationship *WECPNL*$_J$ to L_{den}. Figure 4 shows the comparison of *WECPNL*$_J$ to L_{dn} ,those were calculated by measured L_{Amax} and L_{AE} at four major airports in Japan. From the result that the correlation efficient is 0.97, simple translation from *WECPNL*$_J$ to L_{dn} is possible in this case.

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Figure 1 Comparison of altitude profile

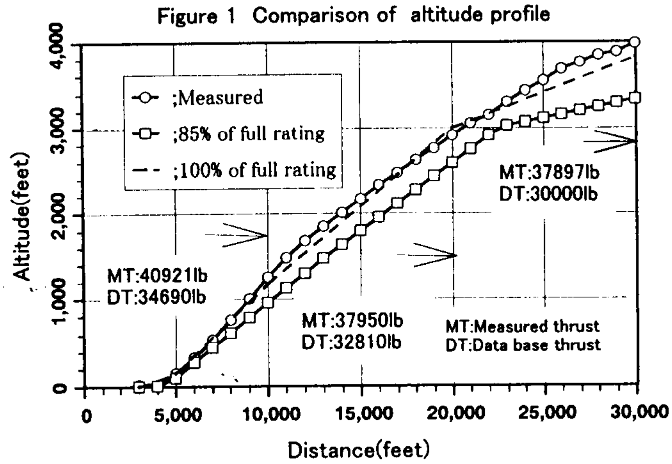


Figure 2 Comparison of noise level case1

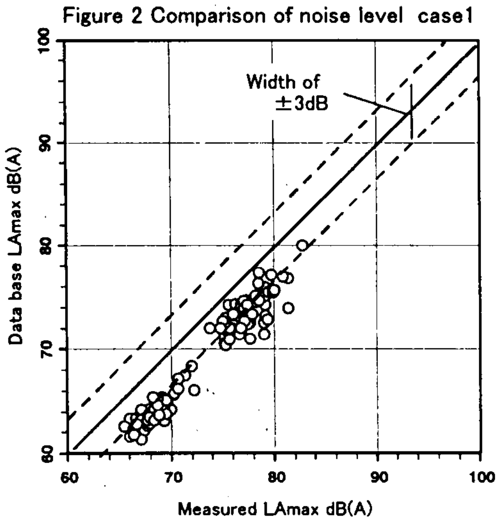


Figure 3 Comparison of noise level case2

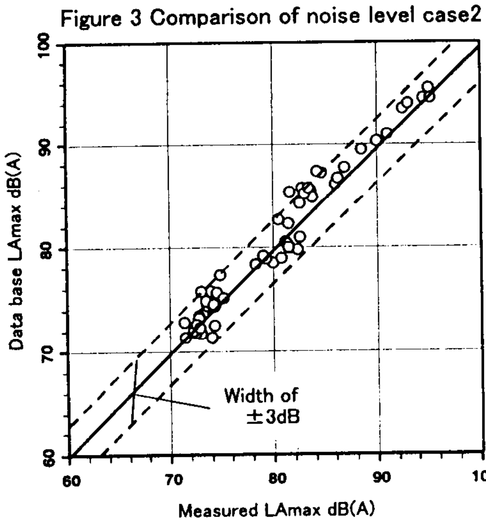
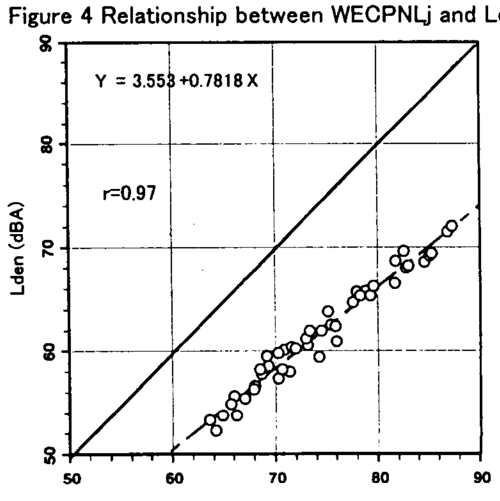


Figure 4 Relationship between WECPNLj and Lden



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(3) Integrated Noise Model (INM) Version 1 User's Guide, FAA, 1978.

(4)Prediction Method for Lateral Attenuation of Airplane Noise During Takeoff and Landing, SAE-AIR-1751, March 1981, reaffirmed March 1991.