THE NOISE GAP INDEX: A NEW WAY TO DESCRIBE AND ASSESS AIRCRAFT NOISE IMPACTS ON THE COMMUNITY

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Abstract

It is well known that aircraft noise potentially disturbs (or annoys) the daily activities (such as communication, study, sleep, rest and relaxation) of residents living in the vicinity of airports. This particular type of annoyance can be a cause of stress and evidence is emerging that appears to associate some forms of health risk with this stress. Current research being undertaken by the authors is aimed at developing a better understanding of the impacts of aircraft noise on community health and well-being. The present paper is concerned with a major component of the research which involves the development of a new index for describing and assessing aircraft noise. Subsequently it is planned to apply this index in exploring the correlations that might exist between community health and well being and aircraft noise. The index, which has been termed the Noise Gap Index (NGI) has been developed on the assumption that people living in areas of different background noise may have different reactions to the same aircraft noise level. Parameters involved in the NGI are the LAeq of the background noise level and the LAeq of the aircraft noise, along with a Number-Above-Index (NA) and a Time-Above-Index (TA). An extensive noise monitoring program has been implemented in a number of suburbs around Sydney (Kingsford Smith) Airport and the resulting data applied in developing the NGI. The paper summarises these noise data, describes their analyses and finally presents the NGI. This paper reports work in progress.

Introduction

Communities surrounding major commercial airports have been suffering from over flight noise, particularly when aviation industry is rapidly growing (OECD 2002) [1]. Long-term aircraft noise exposure can potentially create chronic stress. This, in turn, may cause persistent increase in stress hormone level and blood pressure which is a risk factor of health problems (HECS 2001) [2].

To promote the harmonisation of airport development and livable communities around the airports, the study currently being undertaken by the authors is investigating the nature of and the extent to which community health and well-being might be impacted by exposure to aircraft noise. Outcomes of this research will lead to improved aircraft noise management plans at airports.

The fundamental hypotheses (see Figure 1) that are being tested and addressed by this research are the following (Issarayangyun et al 2003) [3].

"Aircraft noise has indirect health impacts on the community. Aircraft noise annoys people by disturbing their daily activities and then creating stress which finally becomes a mediating factor of health problems in the future."

The present paper is concerned only with that component of the research which involves the development of a new index for describing and assessing aircraft noise. The paper, which reports on work in progress, proposes a new way to describe and assess aircraft noise in such a way that is easy to understand by the layperson and fully covers all relevant aspects of the potential impacts of aircraft noise.

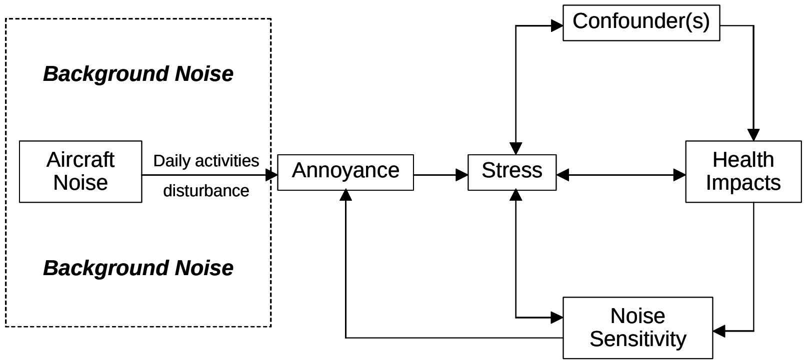

Figure. 1 Research hypotheses.

The noise investigation

The noise investigation component of the research centered around Sydney's Kingsford Smith Airport (KSA) at Mascot. It involved determining, in a variety of residential areas, both typical ambient noise levels along with the noise levels associated with aircraft over flights. For these noise data to suit the requirements of the research program, due allowance for the effects of non-aviation noise sources had to be made; consequently, noise stations were set up in randomly selected households which were mostly located in what could be termed "local traffic" areas. Households located close to railway lines, noisy industrial areas and major highways were excluded. Suburbs included in the study were Tempe, Sydenham, St Peters, Marrickville, Stanmore, Petersham, Newtown, Banksia, Mascot, Kurnell and Rosebery.

Measurement method

Noise data were collected by the first author at 20 stations in the above suburbs from 7am to 5pm on various days from April to November 2003. Twenty minute samples per hour were measured using a Bruel and Kjaer sound level meter Type 2236. It was mounted in front of each residence 1 m from the nearside lane of traffic and at least 1 m from the façade (AS 1055.1-1997)[4]. Several environmental noise indices were recorded throughout each measurement period. In addition, the noise sources and events heard by the first author were manually noted.

The primary index of interest, particularly in quantifying the background noise, was the L_{Aeq} because it would be used subsequently to develop a new parameter which the authors have termed the Noise Gap Index (NGI). This parameter differentiates between aircraft noise and background noise in a novel manner which is necessary to address the hypotheses of Figure 1.

The NGI has been based on the assumption that people living in areas of different background noise level may have different reactions to the same aircraft noise level.

To quantify the aircraft noise levels for input into the NGI, a suitable aircraft noise index was required. A Number-Above (NA) metric was selected for this purpose according to recommendations provided by the Australian Department of Transport and Regional Services (DoTRS). Their recommendations were based on DoTRS's experiences that the sound equivalent energy techniques with time-of-day weighting such as ANEI and DNL are insufficient to reflect community responses toward aircraft noise because these noise indicators are never fully understood by the layperson. (Southgate et al 2000) [5].

The NA is defined as the number of noise events during a given period that are louder than a selected threshold level. The study obtained average annual day of N70 contour maps around Sydney Airport which are periodically produced by Airservices Australia (see Figure 2).

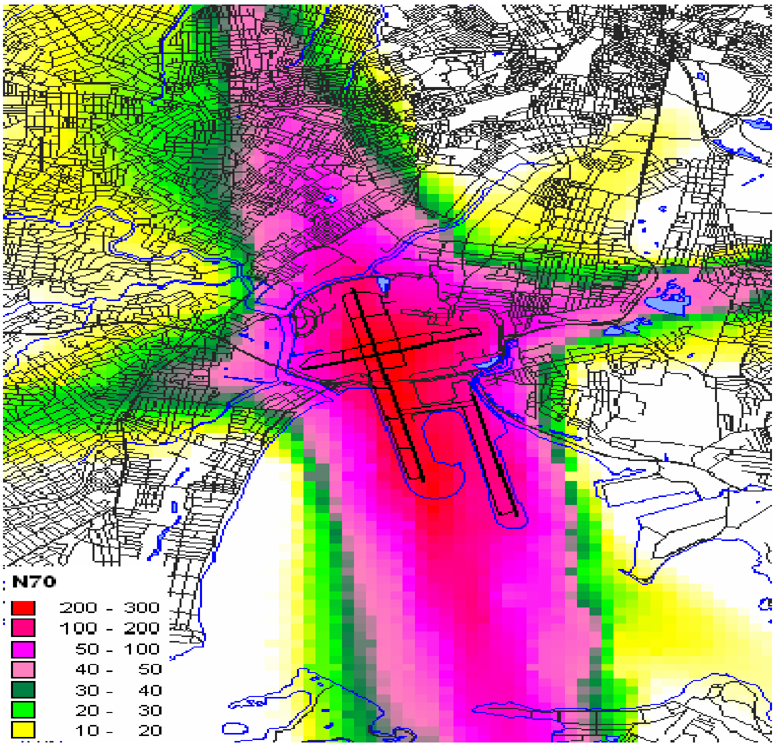

Figure 2. Daily Average Number of Aircraft Noise Events louder than 70 dB(A) around KSA for the period 01 April to 30 June 2002. (Provided by Airservices Australia).

The level of 70 dB(A) has been chosen because it is commonly the case that the outdoor sound level will be attenuated approximately 10 dB(A) by the structure of house. An internal noise level of 60 dB(A) is the sound pressure level of a noise event that is likely to interfere with conversation or with listening to the radio or the TV [5].

Comparisons between the NA of aircraft noise and the $L_{Aeq,T}$ of background noise could not be made directly because of the inherent differences between these two indices. The NA of aircraft noise would need to be transferred into an index measured in dB(A). Consequently, the concept of the day-night average sound level (DNL) was adapted to overcome this problem. The DNL also employed the concept of energy sound equivalent but using the sound exposure level (L_{AE}) as the single-event sound level descriptor with time-of-day weighting factors. Nevertheless the time-of-day weighting was ignored because the measurement periods involved in the present study did not cover the night time. Therefore, the adjustment factor of the time interval was varied depending on the background noise time interval, as explained subsequently.

Typical resulting data

Large amounts of data were collected and typical examples of these appear in Figure 3. It presents a noise time curve at a residence in Stanmore during a peak period of arriving aircraft into KSA in the morning. The rectangular points on the peaks identify aircraft over flight noise. Note that the frequency of landing during this particular morning peak period was approximately one landing per two minutes. The other environmental noise sources during this period were observed to be low and the predominant noise source during this period was from aircraft over-flights.

Figure 4 then illustrates a common situation at the same residence during a morning period when there were no aircraft over-flights. In this case the predominant noise source happened to be from a street cleaning truck. For the present study, this type of noise source was termed an unusual noise and is one that did not occur typically (or hourly). It may have happened once a day and perhaps two or three times a week, or less, depending on the type of noise source involved.

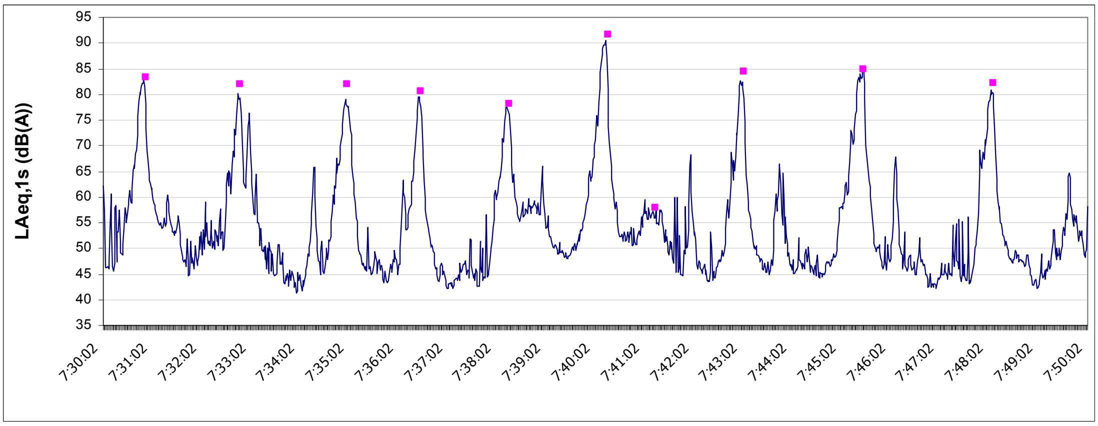

Figure 3. Typical noise time curve at a residence during a peak morning period of aircraft landings.

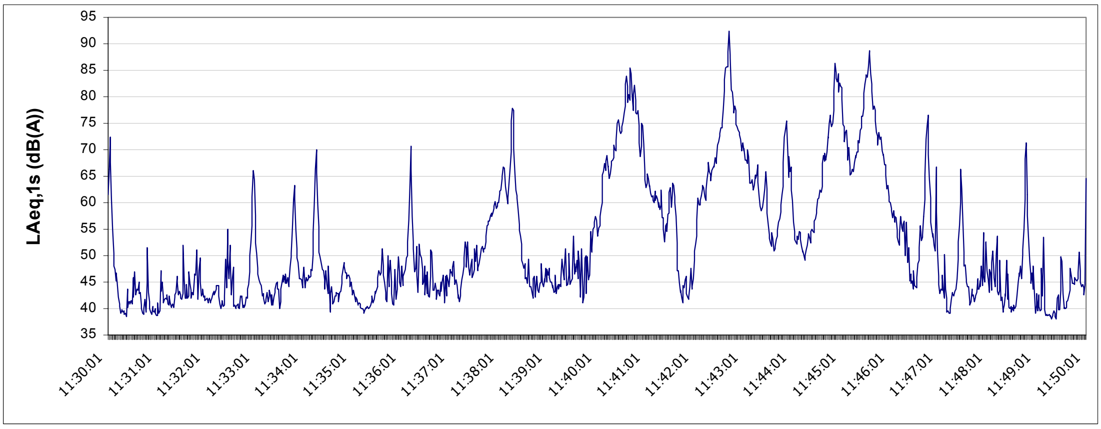

Figure 4. Noise time curve at the residence of Figure 3 during a morning period with no aircraft overflights.

Typically these sources included ambulance sirens, fire alarms, garbage trucks, along with noise from community activities such as lawn mowing, children playing and dogs barking. While it can be argued that these unusual noises commonly contribute to community noise, the sources of this noise usually operate rather infrequently and for very short time periods. Consequently such unusual noise sources were excluded from the present study.

Analysis of the background noise levels

After detailed reviews of the extensive data set such as those of Figures 3 and 4, it became apparent that the calculation of the background noise levels was not an easy task. The fluctuations of the background noise levels were unpredictable and varied from day to day or even hour to hour. Therefore, the approach taken was to exclude all the aircraft and unusual noise peaks from the noise time curves (such as that of Figure 3) so that what remained were the background noise time curves.

The data of these background noise curves were then applied to determine the background noise level $L^{b}_{Aeq,Tk}$ at each noise station. From there the noise stations were classified into two groups based on their background noise environment.

A so called “high noise group” included those noise stations located in areas where the background noise level was influenced by traffic noise from nearby highways or major roads.

Conversely, the “low noise group” represented those locations where the impacts of traffic noise from other roads were either very low or negligible.

Figure 5 illustrates the average $L^{b}_{Aeq,Tk}$ of the background noise levels for the high and low noise groups. The subsequent application of the data of Figure 5 would be to assist in the classification of the background noise levels at residences shown on aircraft noise contour maps. While such classifications can be rather straight forward when the residences are located close to a major road, it becomes quite complicated when the residences are located in the middle of a residential street or where the effects of traffic noise from nearby major roads can be much less apparent.

The long-term time average A-weighted sound pressure level of the background noise level ($L^{b}_{Aeq,(7am\text{-}6pm)}$) was determined from Figure 5 for the "high" and "low" noise station groups to be 59.4 dB(A) and 54.3 dB(A), respectively.

Analysis of the aircraft noise levels

As mentioned previously, the current research adopted the DoTRS concept that outdoor sound levels of 70 dB(A) or more are likely to interfere with indoor activities such as watching TV and conversing. Therefore it was assumed that the level of aircraft noise that disturbs indoor activities would also be 70 dB(A) or more, so that aircraft noise events less than 70 dB(A) were discarded from the analysis. The data such as those of Figure 3 were revisited to determine the N70 values. In addition, the sound exposure levels of aircraft noise (L_{AEk}) equal to or louder than 70 dB(A) were calculated. Once more, in concert with DNL concept, the L_{AEk} values were then adjusted with a time factor (T_k) according to Equation 1

$$L^{a}_{Aeq,Tk} = L_{AEk} - 10\log(T_k) \qquad (1)$$

Where:

$L^{a}_{Aeq,Tk}$ is the average A-weighted sound pressure level of aircraft noise at each noise station (dB(A)).

L_{AEk} is the sound exposure level of aircraft noise that equals or exceeds 70 dB(A) during the k^{th} background noise time interval (dB(A)).

T_k is the k^{th} background noise time interval (second).

The long-term time average A-weighted sound pressure levels of aircraft noise at each noise station were then calculated by Equation 2.

$$L^{a}_{Aeq,LT} = 10\log[\textstyle\sum^{K}_{k=1}(\text{antilog}0.1L^{a}_{Aeqj,Tk})] \qquad (2)$$

Where:

$L^{a}_{Aeqj,Tk}$ is the time average A-weighted sound pressure level of aircraft noise in the kth reference background noise time interval

K is the number of reference background noise time intervals.

Figure 6 illustrates the relationship between $L^{a}_{Aeq,LT}$ and N70. A regression analysis of these data resulted in formula of Equation (3), the R^2 of which turned out to be 0.82.

$$L^{a}_{Aeq,7am\text{-}6pm} = 20.217\log(N70) + 35.52 \qquad (3)$$

With N70 › 0.

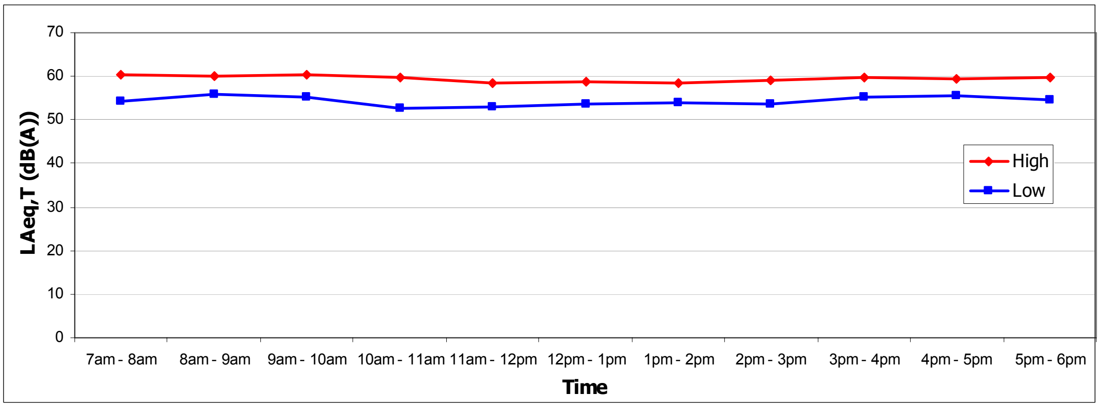

Figure 5. Background noise levels ($L^{b}_{Aeq,Tk}$) for the high and low noise groups.

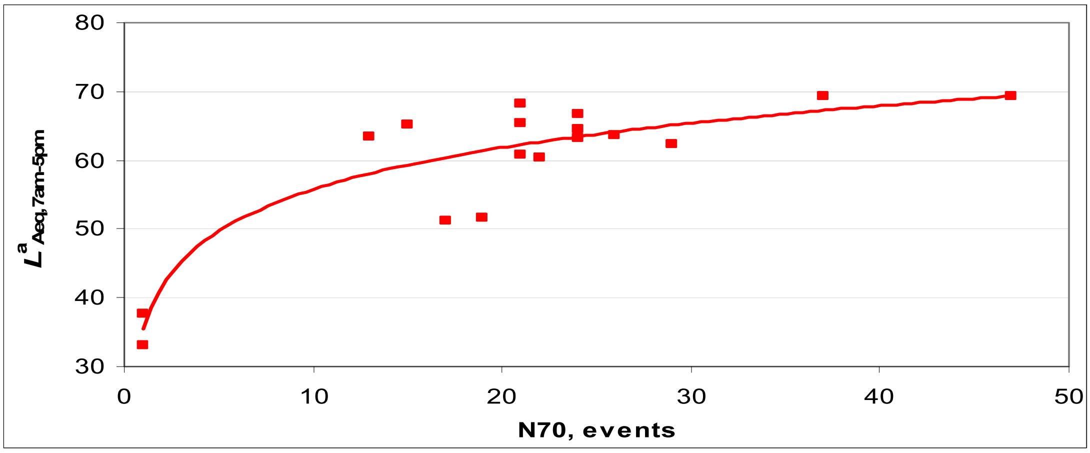

Figure 6. Relationship between $L^a_{Aeq,7am\text{-}5pm}$ and N70 for all data in the high and low background noise groups.

The Noise Gap Index (NGI)

The NGI is defined simply as the difference between aircraft noise and background noise. In the present case the NGI became the difference between the $L^a_{Aeq,LT}$ and the $L^b_{Aeq,LT}$ as given in Equation 4. It is noted that this formulae is practical during 7am – 5pm and when N70 is equal or higher than zero.

$$NGI = L^a_{Aeq,LT} - L^b_{Aeq,LT} \qquad (4)$$

Now by substituting Equation 3 into Equation 4 and also by applying the background levels of 59.4 and 54.3 dB(A) as determined from Figure 5, Equation 4 becomes Equation 5 below.

$$NGI = 20.217\log(\mathrm{N70}) - Z\ ;\ \ \mathrm{N70} \geq 0 \qquad (5)$$

Where Z is an adjustment factor

= 23.88 in high background noise areas

= 18.78 in low background noise areas.

Concluding remarks

An ongoing research program dealing with the health and related effects of exposure to aircraft noise is being conducted by the authors, in collaboration with the UNSW School of Public Health and Community Medicine (Faculty of Medicine). This work in progress required the development of a better way of quantifying aircraft noise impacts on residences. To achieve this objective a new analysis of aircraft noise in relation to background noise was devised and applied to an extensive set of empirical data collected for the research program around Sydney's Kingsford Smith Airport. This analysis culminated in the production of the NGI for both "high" and "low" background noise levels.

At the time of writing this paper a substantial survey of health and well being of residents both exposed to varying levels of aircraft noise and not at all so exposed was under way. It is planned to relate the outcomes of this survey to the degree of exposure to aircraft noise, as quantified by the NGI, in order to test the hypotheses also presented in the paper concerning a relationship between aircraft noise exposure and indirect health impacts.

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