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PERCEPTION AND SIGNIFICANCE OF TRANSPORTATION NOISE CHANGES

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1. INTRODUCTION

The purpose of a noise impact assessment is to assess the impacts of noise on humans [1]. It is therefore important that individual effects on humans are identified and assessed. For example, "Community Noise" [2] identifies sleep disturbance, annoyance and speech interference as the critical effects for dwellings. The different effects should be assessed individually having regard to absolute noise levels and noise exposure changes. The nature and extent of impacts should be assessed using the best available scientific knowledge of individual effects. For complex situations, reliance on a single noise index is not sufficient [2]. Although this paper discusses noise parameters, it should always be borne in mind that noise parameters are generally used as a predictor of effects. For sources of noise emission which affect large numbers of people, direct measurements of effects should be considered. Also, although the paper examines the significance of noise differences, this does not imply that consideration of differences is the exclusive or, indeed, the most important consideration. The paper does not consider the significance of changes relative to the context or absolute levels of noise from which the changes occur.

The question of the perception and significance of transportation noise change has been central to the noise debate at the current Heathrow Terminal 5 Public Inquiry. While "perception" relates to the detectability of a noise change by human hearing, "significance" relates to the effects (e.g. sleep disturbance, annoyance and speech interference) on humans of noise changes. Also, significance is generally concerned with complex noise indices rather than simple noise levels. This paper reviews and interprets evidence given to the Inquiry on noise changes, particularly changes in aircraft air noise expressed in terms of the LAeq,16h noise index and changes in road traffic noise expressed in terms of the LA10,18h noise index. The subject is discussed with respect to four questions:

(i) What is the minimum perceptible change for "simple" sounds? (Section 2)
(ii) Does perceptible change for "simple" sounds apply to noise indices? (Section 3)
(iii) Is the nature of the change to the noise index important? (Section 4)
(iv) How can noise changes be assessed? (Section 5)

It is not the purpose of this paper to comment upon evidence of other parties. Rather the range and depth of views are considered as a means of forwarding the debate.

2. PERCEPTIBLE CHANGE FOR "SIMPLE" SOUNDS

As a preliminary to the discussion of perceptible change for noise indices, the perceptible change for "simple" sounds (such as pure tones, steady noises and noise events) is considered.

Dr. Ollerhead [3] provides information that in controlled laboratory tests, level differences of less than 1 dB can be detected by people with average hearing, with "just noticeable differences" being around 0.5 dB. A 3 dB difference is stated to generally be clearly noticeable even in field conditions. Dr. Ollerhead commented on the perceptibility of two aircraft events [Day 333 p33]. He agreed that when aircraft pass over with the sort of regularity that they do at Heathrow, most people would readily be able to distinguish 3 dB difference, and many would be able to distinguish lesser difference.

Guidance on the perception of road traffic noise change was given by Mr. Kinsey [4]. He states that there is substantial evidence that people are unable to discriminate between road traffic noise levels which differ by less than 1 dB. Mr. Kinsey refers to recent studies of the perception of traffic noise, in which recordings were made of the noise emitted by the same group of vehicles travelling on adjacent sections of road having different surfaces. Individuals consistently identified the noisier of the two when the measured difference in noise level was 3 dB(A), but were unable to correctly identify the noisier one when the difference was 1 dB(A) or less (unfortunately he was unable to say which noise metric he was reporting).

The glossary of PPG24 [5] states that a change of 1 dB is only perceptible under controlled conditions, and that a change of 3 dB(A) is the minimum perceptible under normal conditions. Unfortunately, the glossary is open to interpretation because it is not clear whether the advice relates solely to sound levels, or additionally to noise indices. It may be relevant that the 3 dB(A) is stated to relate to decibels *"measured on a sound level meter"* [Day 391 p76]. The inference could be that the glossary should be understood as giving 3 dB(A) as the minimum perceptible change for a "sound level", rather than the minimum perceptible change for a "noise index" (which is separately referred to in the glossary). Certainly, if the 3 dB(A) minimum perceptible change is interpreted in this way as relating to a "sound level" rather than to a "noise index", there is no great inconsistency between the glossary and the evidence reviewed.

3. PERCEPTIBLE CHANGE FOR NOISE INDICES

Armed with some knowledge about the perceptible change for sound levels, this discussion now turns to the question of whether observations on the perceptible change of "simple" sounds can be translated into rules of perceptibility or, indeed, significance for a noise index such as LAeq,16h or LA10,18h. We need to consider the perceptible change where there is a numerical change in the noise index, and we need to consider whether people will be able to detect changes in period indices even if numerically the value does not change at all, but the pattern or distribution of noise events changes. LAeq,16h and LA10,18h both reflect a combination of individual noise events and number of events.

As an aid to answering these questions for aircraft noise, HIL/607 [6] was devised in order to provide illustrations of the sensitivity of the LAeq,16h noise index to changes. The document contained spreadsheet calculations of LAeq,16h (departures) for years 1994, 2016 with T5 and 2016 without T5, and used input data comprising aircraft fleet mix, departure SELs for different aircraft types and numbers of air traffic movements for the different years. Departure ATMs were assumed half of total ATMs. The departure SELs were derived from recorded values of LAmax [7]. Although the SEL values were derived from recorded data at monitoring points, the LAeq,16h values produced were intended only as illustrations and not predictions. A simplified example of the spreadsheet calculations is presented as Table 1.

Table 1
Example of spreadsheet from HIL/607

Base Case for 1994								
Aircraft Type	other	Light Ch3	Heavy Ch3	B747 Ch3	Concorde	Light Ch2	Heavy Ch2	B747 Ch2
LAmax	74.5	76.3	80.0	89.2	110.5	85.5	89.9	92.3
SEL	84.1	85.7	88.9	97.0	115.7	93.7	97.8	99.7
Fleet %	4.51	52.85	16.70	6.94	0.45	14.77	0.54	3.19
ATM	51.81	607.09	191.83	79.72	5.17	169.66	6.20	36.64
	N =	1148.7			average	SEL =	94.8	
Base Case for 1994: calculations of LAeq,16h dB (departures)								
Aircraft Type	other	Light Ch3	Heavy Ch3	B747 Ch3	Concorde	Light Ch2	Heavy Ch2	B747 Ch2
Leq	50.6	62.9	61.1	65.4	72.2	65.4	54.9	64.7
Total	Leq =	74.8						

The aim of the exercise was to explore changes in the LAeq,16h noise index resulting from various sensitivity tests of changes against the base table above. Some of these tests are described below.

(i) a fleet mix sensitivity test replaced all Chapter 2 aircraft (18.5% of the 1994 fleet mix) by quieter Chapter 3 equivalents for 1994. This gave a reduction in LAeq,16h of 0.7 dB. The difference in the average SEL between Chapter 2 and Chapter 3 aircraft is about 8 or 9 dB for the heavy and light aircraft, and about 3 dB for the B747 aircraft. Dr. Ollerhead agreed that phasing out Chapter 2 aircraft (18.5% of total) and replacing with Chapter 3 aircraft would be a significant difference for those who are affected [Day 345 p72], and be a significant benefit which would also shrink the contours if repeated everywhere [Day 345 p73].

(ii) the sensitivity of changes in movements was examined by trebling the number of movements in the hour beginning 2200 hrs. for 1994. This gave an increase in LAeq,1h for that hour of 4.8 dB, but increased LAeq,16h by 0.2 dB. Dr. Ollerhead was asked if the change would be readily appreciated by those experiencing it. He replied that in that one hour it would [Day 345 p82].

(iii) a second movement sensitivity test held the fleet mix constant for 1994, but used the hourly movements assumed by BAA for 2016 with T5. This gave an increase in LAeq,16h for 1994 of 0.4 dB. Although the increase in total 16 hour movements was 8.8%, the increases in hourly movements were 63% in the hour beginning 0600 hrs., 50% in the hour beginning 2100 hrs., 243% in the hour beginning 2200 hrs. and 396% in the hour beginning 2300 hrs. Dr. Ollerhead suggested that people would possibly feel more annoyed but that it would not be a marked increase [Day 345 p86].

(iv) a technology sensitivity test for 1994 assumed a reduction in each aircraft SEL by 0.5 dB, brought about by new aircraft technology, was accompanied by a doubling of movements in the hour beginning 2200 hrs. This gave an increase in LAeq,1h for that hour of 2.5 dB, and a reduction in LAeq,16h of 0.4 dB. The reduction in SEL of 0.5 dB was chosen since it appears to be about the limit of perceptible change per noise event under laboratory conditions, and seems unlikely to be noticeable under field conditions. It appears more than likely that the doubling of movements in one hour late in the evening would be noticeable. This could lead to increased annoyance, even though the LAeq,16h is reduced by 0.4 dB. Dr. Ollerhead suggested that an increase in contour area would occur which would not be insignificant [Day 345 p91].

These sensitivity tests show that the averaging process inherent in LAeq,16h can conceal changes which are perceptible even though, in terms of numerical change, the effect on LAeq,16h is small, or even moves in the opposite direction from what had been expected. The averaging process in LA10,18h is different in form to that in LAeq,16h but can produce similar results. It is self evident that road traffic flows and associated noise energy could be distributed differently throughout the 18 hour day with the potential for giving very different effects and impacts even though the numerical change in LA10,18h may be small.

These illustrations show that because of the averaging processes in LAeq,16h and LA10,18h, perceptible changes for these noise indices differ from that for a sound level. It is shown in Sections 4 and 5 below that perceptible changes for LAeq,16h and LA10,18h brought about respectively by changes in air traffic movements and road traffic flow, also differ from perceptible change for simple sounds. It is plain that whatever may be right and wrong in terms of perceptible change for "simple" sounds such as individual aircraft and road traffic noise events, rules of thumb applied to period noise indices such as LAeq,16h and LA10,18h can catch out the unwary.

4. CHANGES IN NOISE INDICES AND THEIR EFFECTS

The discussion now seeks to establish whether the nature of the change in a noise index is important in terms of its effects (e.g. sleep disturbance, annoyance and speech interference). For example, would a change in a noise index brought about by one means produce the same effect as an identical change in the noise index brought about by some other means? Also, would a given change in a noise index produce the same change in a particular effect irrespective of the circumstances?

Opinion on this subject seems to be divided. Mr. Neil applied a 2 dB test of significance irrespective of the circumstances [8], and equally for the LAeq,16h and LAeq,24h parameters [9]. It was put to Mr. Neil that an increase of 2 dB in LAeq,16h could represent an increase in aircraft movements alone of 60% [Day 347 p52]. Dr. Ollerhead's view was that in terms of annoyance, changes in LAeq,16h of 1 dB are probably insignificant, while an increase of 3 dB and above would be clearly significant and *"is going to be a significant measurable increase in community annoyance. Between these two limits, it is marginal."* [Day 346 pp77,78]. Dr. Ollerhead did not explain how he had arrived at this conclusion, but it would seem that it was expressed as though it had general application, i.e. independent of the circumstances. We know, however, that Leq was adopted as a an aircraft noise index following the ANIS report [10] which is a cross sectional study. It is known that government, at least, is content to rely upon the LAeq,16h contour as a measure of annoyance and as the foundation for the claims that *"there has been a substantial improvement in the noise climate around the airport over the past two decades"* [11]. It is implicit in this statement that the trade-off between individual noise event levels and numbers of events is adequately reflected in the LAeq,16h parameter. The trade-off inherent in LAeq,16h is determined by the equal energy principle which assumes that event sound energy and number of events have the same effects on humans. Around Heathrow, there has been a reduction in noise emissions of individual aircraft brought about by the phasing out of non-noise certificated aircraft and Chapter 2 aircraft. At the same time, there has been substantial growth in the number of air traffic movements, e.g. 3 month Leq period 16 hour ATMs increased from 774.1 in 1982 to 1148.7 in 1994.

There is growing concern that the LAeq,16h parameter should not be used as the sole determinant of assessing effects and that all the parameters, including the number of events should be used at least in complex cases [2]. At the T5 inquiry, there have been forcible representations and evidence that the noise climate around Heathrow has, in fact, deteriorated despite reductions in the LAeq,16h contour area [12]. It has been repeatedly and consistently argued that the deterioration has primarily resulted from the growth in the numbers of aircraft movements and, in particular, the growth in movements at more sensitive times, e.g. evening and early morning. There have been repeated calls for the earlier social survey work, carried out in the 1960s, to be updated. Regular monitoring of annoyance and health effects has been requested [13] and [Day 352 p61].

The validity of Leq as a predictor of the impact of aircraft noise on people was questioned by Dr. Jones [14]. He pointed out that according to the equal energy principle inherent in Leq, the value of Leq does not change if the number of planes is doubled but they are each 3 dB quieter. His evidence states *"..how much credence should we place in this shrinking [of Leq contour area] when it goes against all the evidence of increasing public protest and is based on the premise that a barely perceptible change in perceived loudness [of individual aircraft] can completely offset a doubling of numbers?"*

Dr. Leventhall pointed out that LAeq became popular on the assumption that humans responded directly to the total energy falling on them [15]. He questioned whether annoyance follows energy immission irrespective of "acoustic features" such as peak individual aircraft noise levels and number of aircraft events. Dr. Leventhall was asked whether event sound level and number of events are interchangeable under the equal energy principle inherent in Leq. His reply was *"That is perfectly correct, but the energy principle is a very mechanistic way of considering noise exposure.."* [Day 363 p98].

A paper by Fastl [16] reports results of a pilot study aimed at the question of trading loudness with number of aircraft operations. Noise immissions produced within a 15 mins. duration by four old loud aircraft versus sixteen modern quieter aircraft were evaluated in terms of perceived average loudness using laboratory experiments. Basic conclusions include the following: *"..If, however, the exchange of old versus modern aircraft goes with an increase in the number of operations, care has to be taken with respect to forecasts: Simple calculations based on Leq will be completely misleading!....the trading of loudness and number of operations of aircraft can not be based on simple equal energy concepts,.."*. A further paper by Looten [17] reviews the Fastl experiments and a number of noise surveys of aircraft annoyance. His conclusions include the following: *"Equivalent energy level measurement have neither psycho-acoustic nor biological basis. Both noise surveys and laboratory experiments* *prove the inadequacy of the equal energy concept to assess annoyance from aircraft noise during the day."*

Professor Berglund's view on the use of Leq contours is indicated by her statement that: "*A reduction in aircraft noise exposure as expressed in the iso-contours does not necessarily result in a reduction in annoyance or any other kind of health effects*" [13].

According to Mr. Turner [18], those who have lived close to Heathrow for many years acknowledge that many of the aircraft are less noisy than in the past but maintain that they have noticed the increase in aircraft numbers. Mr. Turner states that an examination of the data provides the reason: although the aircraft are less noisy, virtually every aircraft event still causes some form of intrusion, and with the increasing number of movements, the frequency of intrusion increases.

The trade-off between noise levels of individual aircraft and numbers of movements which is represented in LAeq,16h was questioned by Mr. Coates [19]. It was his belief that people do not respond according to the LAeq,16h contour: they respond more to an increase in number of movements than any change in the LAeq,16h contour would imply.

Mr. Cobbing [20] also questioned whether the equal energy principle was appropriate for assessing effects. The reason he gave was that disturbance from noise, such as speech interference, would not be expected to follow such a principle. Consider the following illustration. Table 1 above shows that, at the monitoring points, Chapter 2 and Chapter 3 B747s produced average LAmax values of 92.3 dB and 89.2 dB respectively, i.e. about 3 dB apart. The equal energy principle would suggest that, say, 100 Chapter 2 B747s would have the same effect as 200 Chapter 3 B747s. However, reducing the LAmax value of a B747 by 3 dB would mean that it would still be well above thresholds for causing disturbance. Consequently, substitution of 100 Chapter 2 B747s by 200 Chapter 3 B747s would mean that disturbance would occur twice as often.

Although opinion seems divided as to whether a change in a noise index would evoke an equal response irrespective of what caused the change, it is plain that the perception of changes in a noise index brought about by changes in aircraft movements or by changes in road traffic flow would be different from the perception of changes in the index brought about by other means. Mr. Kinsey [4] has suggested that a change in road traffic noise level of less than 1 dB would not be perceptible. This contrasts with the traffic noise nuisance relationship presented in Figure 3 of Chapter 3 of DMRB [21] which suggests that a 1 dB increase in LA10,18h would result in 21% increase in the percentage of people bothered very much or quite a lot by traffic noise. This may provide the reason why Section 5.10 of Chapter 5 of the DMRB points out that the traffic noise nuisance relationship, for estimating changes in percentage bothered resulting from changes in LA10,18h, is based on surveys of noise changes "*caused by changes in traffic flow*" and "*will not necessarily give a good prediction if traffic noise changes were brought about by some other means, such as barriers or low noise road surfaces.*" Such advice finds support in a 1982 paper by Langdon and Griffiths [22] which reports the results of surveys showing that reductions in traffic noise brought about by acoustic barriers may have a different effect on traffic noise nuisance compared with reductions in traffic noise brought about by reductions in traffic flow. A similar effect was noted in a 1986 paper by Griffiths and Raw [23]. This phenomenon is not surprising because barriers and traffic flow reduction do not have the same effects on the fluctuating instantaneous sound level and the time pattern of road traffic noise. This also suggests that the magnitude of a change in response to a change in exposure to road traffic noise would be dependent upon the circumstances causing the change in noise exposure.

When assessing changes, it is important to consider changes in the character of the noise as well as the time pattern of the noise. For example, the introduction of a different road surface may not alter the time pattern and distribution of the noise exposure from road traffic, but could alter the frequency spectrum of the noise. It has been suggested that *"the same level of noise from different road surfaces can elicit quite different responses"* [24]. Barriers too would change the frequency spectrum of the received noise which could potentially affect the perceived benefit of any reductions in LA10,18h index levels.

5. ASSESSING NOISE CHANGES

Human response to noise is complex. This point is demonstrated by the large variations found in individual responses to noise and the large variations in the response of individual communities to noise. Community response is poorly correlated with measurements of noise exposure. So what, then, should be used as a means of assessing the magnitude of any change in effect resulting from a change in noise exposure? It is recommended that longitudinal studies provide a reliable means of understanding the effect of any change in circumstances. There is nothing new about this recommendation. In 1980 the World Health Organisation identified the need for *"longitudinal studies of communities exposed to major changes in environmental noise to refine existing dose-response (noise-annoyance) relationships and to include the effects of adaptation and societal changes on public reaction to noise"* [25]. A similar recommendation is made in the recent document from the Institute for Environment and Health that *"longitudinal studies are far more informative than cross sectional studies and should therefore be encouraged"* [24].

Where longitudinal studies have been carried out they have challenged the conventional wisdom which has been based on cross sectional studies. This point is demonstrated by a consideration of the evolution of guidance for the assessment of road traffic noise. Guidance specifically relating to changes in the LA10,18h noise index can be found in Part B, Section 1.4 of the Manual of Environmental Appraisal [26]. Section 1.4.2 of the MEA reported that noise surveys did not identify different levels of general dissatisfaction with traffic noise until the LA10,18h noise levels were at least 3 dB apart. As is made clear in Section 1.4.3 and Appendix 1 of the MEA, these studies were essentially of the steady-state or cross sectional type. Whilst Section 1.4.3 of the MEA referred to the potential for changes in LA10,18h of less than 3 dB(A) to have *"appreciable benefits or disbenefits"* immediately following a change in traffic flow, the methodology relied upon these steady-state studies. The DMRB [21] replaces the MEA, and takes into account the results of longitudinal studies (including noise and social surveys carried out before and after a change in traffic flows). These studies are reported in the Griffiths and Raw paper [23], and a 1992 paper by Baughan and Huddart [27].

The Griffiths and Raw research [23] took the form of social surveys at a number of sites carried out before and after traffic noise changes associated with traffic flow changes. It was found that nuisance ratings changed more than would be predicted from a relation between exposure and nuisance derived under "steady state" conditions. In a follow-up paper in 1989 [28], the same authors found that the excess change in nuisance was more than a short term effect, with much of it persisting for seven to nine years.

The Baughan and Huddart paper [27] reports the results from "before" and "after" surveys carried out with the aim of deriving reliable equations for predicting the effects of traffic noise changes on traffic noise nuisance. The changes in traffic noise at the survey sites were all the result of changes in traffic flow. Changes in dissatisfaction were measured at sites where the LA10,18h changes were only +0.2 dB, +0.3 dB and -0.4 dB (although 24 hour traffic flows changed by +7.9%, +26.8% and -26.8% respectively). Linear regression analysis indicated that percentage change in 24 hour traffic flow gave a better fit to changes in dissatisfaction than did changes in LA10,18h. Nevertheless, the equation adopted was a cubic equation relating measured changes in dissatisfaction to measured changes in LA10,18h. This equation gives measurable changes in dissatisfaction for a change in LA10,18h of 1 dB and less. One conclusion states that where traffic levels have changed abruptly the surveys show that ratings of perceived nuisance change more than would be expected from a relation based on steady-state surveys.

The DMRB method for the assessment of changes in traffic noise nuisance has been the subject of some criticism. Baughan and Huddart, themselves, recognise the limitations of the studies and the paucity of data at the noise increase sites. These longitudinal studies have been illuminating and helpful. Further similar work based upon a broader range of circumstances will enhance the levels of confidence in the quantitative assessment of changes in nuisance attributable to changes in road traffic flows. Our present knowledge of changes in other effects, and for other transportation sources, is more limited. Without further longitudinal studies our ability to quantify effects and changes in effects is likely to remain limited and uncertain.

6. CONCLUSIONS

1. It is unlikely that a change in LAeq,16h noise exposure resulting from a change in air traffic movements would have the same effect as the same change in LAeq,16h noise exposure brought about by some other means, for example quieter aircraft. Similarly, a change in LA10,18h noise exposure resulting from a change in road traffic flow is not likely to have the same effect as the same change in LA10,18h noise exposure brought about by some other means, such as changes from different road surfaces or noise barriers.

2. Transportation noise impact assessments based solely upon changes in the LAeq,16h and LA10,18h noise indices may well be inadequate. Changes in the pattern, frequency and distribution of the noise events should be appraised. Changes in the character of the noise should be considered. Each critical effect should be assessed.

3. It appears clear that assessment of the effects of changes in noise exposure judged according to steady state surveys are not adequately representing public perception. Changes in individual effects resulting from changes in noise exposure should be assessed using longitudinal studies. In the absence of such studies, any assessment of changes in effects will suffer from uncertainty.

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DoT, HIL, BAA, HAC, LAH and FANG references are Heathrow Terminal 5 Public Inquiry documents. Inquiry Transcripts are referred to by Inquiry day number.

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