PEOPLE, POLICY, AND HEALTH: ASSESSING HISTORIC INTERVENTIONS IN PRACTICE

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Policy-makers not only require means of assessing the effects of noise but an understanding of what measures will reduce or limit community noise exposure in practice. To that end, in 2012 the Department of Environment, Food and Rural Affairs in England commissioned a study to examine retrospectively the effects of noise policies that had been implemented in England over the previous 50 years. Those interventions, which were initiated at international, national and local level, were intended to manage noise impact or reduce noise exposure by using emission limits, regulations, and planning controls. In the case of aircraft noise, the measure used to assess the effectiveness of policy was the area within the 57dBA $L_{eq,16hr}$ noise contour. Over the period examined there had been a large increase in the number of Air Transport Movements (ATMs) at the six airports studied and so a method was devised to determine the area had there been no increase in ATMs. That Defra study was focussed on the effect of the policies in reducing noise exposure; for this paper the data collected in the original study have been reviewed to determine whether benefits in terms of health effects such as annoyance, sleep disturbance and cardiovascular disease can also be demonstrated.

Keywords: aircraft noise, historic interventions, health

1. Introduction

In January 2012 Defra commissioned a research project from Rupert Taylor Ltd to carry out '*An investigation into the effect of historic noise policy interventions*' to cover the period from about the early 1960s [1, 2]. Interventions in the form of primary and secondary legislation, policy advice and guidance, codes of practice and regulations, and British Standards have continued since that time and European and international guidance and regulations have also addressed various noise issues over a similar period and have influenced national policy either indirectly (e.g. by informing national guidance) or by being directly transposed into national regulations.

That research project formed the first part of Defra's consideration of the implications for noise policy of possible changes in the acoustic environment over the next 50 years and the study investigated five policy areas which:

- required compliance with increasingly stringent ICAO aircraft noise emission limits
- required compliance with increasingly stringent EC road vehicle noise emission limits
- changed the Building Regulations regarding sound insulation that aimed to reduce neighbour and neighbourhood noise
- legislated on general noise nuisance & specific noise sources (to control neighbour and neighbourhood noise), and
- legislated specifically to control construction noise (to reduce neighbourhood noise).

This paper considers the intervention to reduce aircraft noise to determine whether any health benefits of the policy can be determined.

2. Approach to the analysis

2.1 Scope of Defra study

The Defra study addressed a range of policies and noise sources and in the case of aircraft noise the effectiveness of the intervention was assessed by considering the change in the area within the 57 dBA $L_{eq,16hr}$ noise contour (or an equivalent contour, see Section 3.2.3). That criterion was selected primarily because historically it had been used when considering the environmental impact of airports. Consequently data on changes in the contour area were available for six airports (the first year in which data were available is shown in brackets for each airport): London Heathrow (1972), London Gatwick (1972), Manchester (1990), London Stansted (1988), London Luton (1976), and Birmingham (1993). The acquired data showed the actual areas that occurred as a result of the combined effects of several factors in addition to the policy intervention itself – i.e. enforcing the reductions in the ICAO noise limits which led to the fleet mix changing towards quieter aircraft. There were also changes (mainly increases) in the number of Air Traffic Movements (ATMs) each year and other factors such as local operational measures. The change in the contour area is particularly influenced by the large increase in ATMs that occurred at most airports over the study period.

In order to obtain alternative estimates of the effects of the policy, a method was therefore devised to adjust the 57 dBA $L_{eq,16hr}$ contour areas to take account of the change in the number of ATMs that had occurred compared to the starting year. Using this method enabled assessments of the areas within the 57 dBA $L_{eq,16hr}$ contour to be made for two additional scenarios: first, assuming that the policy had been in place (i.e., aircraft noise emission levels reduced over the study period) but there had been no increase in ATMs, and secondly, assuming that the actual increase in ATMs had occurred but that there had been no policy in place (and hence no reduction from the aircraft noise emission levels at the start of the study period).

For some of the years data were also available of the population within the 57 dBA $L_{eq,16hr}$ contour but the area enclosed was used in preference to the population enclosed principally because the population within a given contour is affected by the population density and distribution (the shape of the contour can affect the population within it). Consequently, the contour area was considered a more direct measure of the policy effects over time than the population exposed. Furthermore, had the population been used instead of the area, the alternative assessments described above that adjusted the area to account for changes in the ATMs could not have been implemented.

2.2 Scope of the new study

For the airports and periods studied there was some information on the population within some or all of the 57, 63, and 69 dBA $L_{eq,16hr}$ contours. It was therefore possible, in principle, to determine the change in the population exposed within these bands over some of the study period and hence attempt to estimate any health benefits that might have occurred. Those population figures relate to the combined effects of the reduction in aircraft noise emission limits brought about by the policy and the change (mainly increases) in ATMs over the study period. Unfortunately, the method described above that enabled the contour areas to be adjusted to take account of the changes in ATMs cannot be applied directly to population data if only the numbers within the contour bands are available. Consequently, the assessment undertaken in this new study relates to the combined effects of the policy and the actual ATM changes.

2.3 Relationship between aircraft noise exposure and effects on people

The relationship between noise from aircraft and effects on people has been studied in the UK since at least the early 1960s by conducting surveys of both aircraft noise to estimate noise exposure and related social surveys to determine the response of members of the exposed community [3].

The range of effects studied has increased from annoyance and sleep disturbance to include impacts on children's progress in reading and direct physical health effects such as cardiovascular diseases and the European Environment Agency (EEA) [4] and the World Health Organization (WHO) [5] have published guidance on estimating the effects of noise exposure in terms of annoyance and other responses, though not for all effects for all noise sources.

2.4 Health effects considered in the new study

The EEA report [4] presents relationships between exposure to aircraft noise and annoyance, sleep disturbance, hypertension, and cognitive impairment (primarily related to effects on schoolchildren). The noise indices specified in those relationships are L_{den}, L_{night}, $L_{den,}$ and L_{dn} respectively whereas the noise exposure data from the Defra study uses the $L_{eq,16hr}$ index. Although a conversion factor between $L_{eq,16hr}$ and L_{den} or L_{dn} could be estimated (see Section 3.2.4) that is not the case for conversion to L_{night} and so sleep disturbance was not included in the review. An assessment of the effects on cognitive impairment over the study period requires information on the locations of schools and the numbers of pupils attending them in order to estimate their noise level exposure. However, only basic population data were available and so cognitive impairment was also excluded from the study. Thus the effects considered were annoyance and hypertension.

3. Population data and dose-response relationships

3.1 Dose-response relationship for annoyance

Both the EEA and WHO reports referred to above [4, 5] use the expressions from a European Commission (EC) position paper [6] for the dose-response relationship between the percentage of people highly annoyed (%HA) by aircraft noise and noise level in which the noise level is expressed using the index L_{den}, which is defined in an EC directive [7]. The EEA report [4] notes that that relationship has been criticised because recent survey data appeared to show an increase in peoples' sensitivity over time and that although it had not been possible to identify a single cause, there did appear to be a change in the trend around 1990. This issue is of potential significance for the analysis attempted in this paper because the population data for some airports extends from the 1970s to 2009.

A recent paper by Gelderblom et al [8] investigated the stability over time of the Community Tolerance Level (CTL), a concept introduced by Fidell et al [9], and appears to have found a satisfactorily explanation for this matter. Gelderblom et al [8] reviewed 62 studies of aircraft noise annoyance from the period 1961 to 2015 and classified them as either "low-rate change" (LRC) or "high-rate change" (HRC) airports using definitions they quote from Janssen & Guski [10, submitted] who proposed this classification. In summary, Gelderblom et al [8] showed that analysing the studies as a single dataset replicated the effect of increased sensitivity over time (albeit to a lesser degree than other studies have done) but that including the LRC/HRC classification in the analysis resulted in two distributions. One of these – for the LRC category airports – was relatively stable over time and in fairly good agreement with the EEA response curve for CTL (which is equivalent to a %A of 50%). The second distribution – for the HRC airports – was also fairly stable over time but was 9 dB ± 3 dB lower than the first one, which indicated increased sensitivity/lower tolerance for the HRC category airports.

Gelderblom et al [8] point out that "*The distribution of the two types of studies (LRC vs. HRC) explains these findings. The great majority of the HRC studies were conducted relatively recently (later than 1996). This group is therefore (overly) well represented in the past two decades*". Thus the use of the EEA annoyance dose-response relationship seems justified in the case of LRC airports.

3.2 Use of data from Defra study

3.2.1 Initial considerations

There are several initial considerations to address in applying the EEA dose-response expressions to the data available for the airports in this study. First, as noted in the previous section, a decision has to be made on the category – LRC or HRC – to apply to each airport. Secondly, until 1990 the official scale for aircraft noise in the UK was the Noise and Number Index (NNI), consequently noise contours and their associated populations were reported as values of NNI. Since 1990 UK aircraft noise contours are designated as dBA values using the $L_{eq,16hr}$ index. Finally, it should be noted that the EU guidance for the relationship between aircraft noise and annoyance response and for hypertension effects uses the L_{den} index, not $L_{eq,16hr}$.

3.2.2 Classification of airport as HRC or LRC

According to the definitions quoted by Gelderblom et al [8] an airport is classified as LRC if there is "*no indication of a sustained abrupt change of* [actual] *aircraft movements, or the published intention of the airport to change the number of movements* [ATMs] *within 3 years before and after the study*". The 'abrupt change' in ATMs is further defined as " *... a significant deviation in the trend of aircraft movements from the trend typical for the airport. Each trend is calculated by means of total movement data during a five year period. If the typical trend is disrupted significantly and permanent, we call this a "high-rate change airport"*.

The first of these criteria can be tested by examining the available data on annual ATMs for the airports in the Defra study [1, 2]. The second criterion is less straightforward to determine, though if the ATM trend shows an 'abrupt change' that might be an indication that public discussion of that change could have occurred in advance. Two of the airports in the original Defra study [1, 2] appear in the list of studies reviewed by Gelderblom et al [8]. They classify two studies at London Heathrow (LHR) in 1961 and 1967 as LCR and one study at Birmingham Airport (BHX) in 1997 as HCR on the basis of announced changes that from 1997 would double that airport's capacity. Janssen & Gusksi [11] also classified a 2003 study at LHR as being for a LRC airport.

Table 1 shows the five-year ATM totals for each airport normalised to the number of ATMs at the end of the first 5-year period for each airport in order to highlight the ATM trends.

Table 1: 5-year ATM values normalised by airport to ATMs in years 1 to 5 of data

Airport	Start	Elapsed years from start of airport data						
Code	**Year**	**5**	**10**	**15**	**20**	**25**	**30**	**35**
LHR	1972	1.0	1.0	1.1	1.4	1.6	1.7	1.8
LGW	1972	1.0	1.8	2.4	3.0	3.1	4.0	4.1
STN	1988	1.0	2.1	4.4	4.6			
MAN	1990	1.0	1.2	1.4	1.5			
BHX	1993	1.0	1.4	1.2				
LTN	1976	1.0	1.3	1.6	1.0	2.0	2.8	3.5

Key to Airport Codes		
LHR = London Heathrow	LGW = London Gatwick	STN = London Stanstead
MAN = Manchester	BHX = Birmingham	LTN = London Luton

Table 1 shows that at London Heathrow (LHR) the change in the 5-year ATMs is gradual over most of the 35-year period apart from an unsustained step at the 20 year point, and so it seems reasonable to regard LHR as an LRC airport. For Birmingham (BHX) the period covered by the data is rather short and the initial step (after 10 years, in 2003) is not sustained. However, Birmingham was classified as an HRC airport in the late 1990s [8]. The profiles for some other airports are less straightforward to categorise over the period for which data are available and the total period might need to be considered in separate parts, see, in particular, London Luton (LTN) comparing years 0 to 15 with years 15 to 35.

3.2.3 Change in the UK from NNI to $L_{eq,16hr}$ contours

Regarding the change in 1990 from the use of noise contours using NNI values index to values of $L_{eq,16hr}$, the values used were selected so that "*the Leq contours would match the existing NNI ones* [*ie*, 35, 45, 55] *as closely as possible and thus represent the same degree of annoyance, on average, as the 1988 NNI contours"* [12]. That was the justification in the original Defra study [1, 2] for regarding the area within historic 35 NNI contours and the subsequent 57 dBA $L_{eq,16hr}$ contours as representing equivalent impacts. It is therefore considered reasonable for the purposes of estimating annoyance effects in the present study to treat the 35, 45, 55 NNI contours as equivalent to the 57, 63, and 69 dBA $L_{eq,16hr}$ contours respectively.[1]

3.2.4 Conversion from $L_{eq,16hr}$ to L_{den}

Conversion factors between noise levels using different indices are available for road traffic [4, 5] but those references highlight the difficulty of providing factors in the case of aircraft noise and for $L_{eq,16hr}$ values. Miedema and Oudshoorn [13] provide general rules for converting between L_{den} (also referred to as DENL) and L_{dn} (also referred to as DNL) for aircraft which they derived from a review of large number of airport studies, but they did not consider conversion to L_{den} from $L_{eq,16hr}$.

The relationship between $L_{eq,16hr}$ and L_{den} is determined by the noise profile over the 24-hour period which varies between airports. It can be particularly influenced by the night-time noise level since that does not affect the value $L_{eq,16hr}$ but can increase L_{den} owing to the 10 dB night-time weighting applied. However, night time activity might be restricted by local regulations. The range of values for the difference between $L_{eq,16hr}$ and L_{den} has therefore been investigated for LHR using potential time patterns for the noise level based on data published by the airport owners [14, 15].

The approach was to derive a series of noise level profiles in which the hourly level was varied with reference to a standard noise level; thus for the period 0700-1900 (day) the noise level for every hour was assumed to be 1 (= 0 dB). At LHR there are restrictions within the period 2330-0600 (part of night-time) [15] and the relative level for that period was estimated to be 0.1 (= –10 dB). The highest value for L_{den} therefore occurs when the noise level for the remaining periods (2300-2330 and 0600-0700) are set at the reference level use for the daytime period (ie, 1, = 0 dB). For that case L_{den} was 2.3dB greater than $L_{eq,16hr}$. The profile that produced the smallest difference between L_{den} and $L_{eq,16hr}$ was with the noise levels for the periods 2200-2300, 2300-2330, and 0600-0700 set to 0.5 (= –3 dB); for this profile L_{den} was 1.3 dB greater than $L_{eq,16hr}$. However, changing the profile by setting the noise level for the period 0600-0700 back to 1 (= 0 dB) resulted in the difference increasing to 2.0 dB. The actual profile might well be different over the years 1972 – 2009 and so as a conservative estimate it has been assumed that L_{den} is 2 dB greater than $L_{eq,16hr}$ at LHR.

3.3 Population data from the Defra study

The most complete set of population data in terms of years covered with data for all the 57, 63, and 69 dBA $L_{eq,16hr}$ contours is available for LHR and so that data (1974 – 2009) has been examined. The trend is for the population within each of the above three noise contours to reduce over time and the rate of reduction is such that the 1974 population in the 57-63 dBA $L_{eq,16hr}$ band falls to half its original value after about 9 years and after a total of about 19 years has fallen to a value lower than the initial population in the 63-69 dBA $L_{eq,16hr}$ band. Thus the population in a given band is not only reducing in number but the actual people within the band are changing and are eventually a different population from the people initially exposed. This raises two questions: first

[1] The $L_{eq,16hr}$ values in [12] were 57, 63.5, and 70 dB, but the contours produced have values of 57, 63, and 69 dB.

what the relevance of the duration of exposure to a specific noise level or band is and secondly, what rate of change occurs in exposed populations.

3.3.1 Role of duration of aircraft noise exposure in annoyance and hypertension effects

The noise annoyance response considered in a recent WHO review [11] is related to "*long-term exposure, i.e. related to residents who live in a more or less noisy area for at least one year, and answer noise annoyance questions related to a long time.*"

In a review of studies of the cardiovascular effects of aircraft noise, Berry [16] noted that Huss et al [17] only found a statistically significant effect between L_{dn} and myocardial infarction in subjects who had lived in the same place for at least 15 years and that Floud et al report [18] that "*A statistically significant association was found between exposure to night-time aircraft noise and [self-reported] 'heart disease and stroke' in people who had lived in the same home for 20 years or more*, …". Berry [16] further observes that in relation in relation to hypertension effects Jarup et al [19] (who used data from the same study as Floud et al [18]) reported a significant exposure response relationship for night-time aircraft noise (though not for daytime aircraft noise exposure); the subjects in that study had all lived for a minimum of 5 years near one the airports in the study. However, Jarup et al [19] do not report any investigation of the effects of residence duration apart from the initial requirement for inclusion of the subjects in the study.

Although duration of exposure is considered to be a relevant factor in determining response, and some studies have found a statistically significant relationship linked to exposure duration for some health effects, there do not yet appear to be definitive conclusions in relation to annoyance or hypertension effects and aircraft noise assessed with the L_{den} index specified in the EEA report [4].

3.3.2 Factors affecting the stability of populations exposed to aircraft noise

Gelderblom et al [8] considered this issue and reported that within all OECD countries between 2% and 15% of the population changes residence annually. They showed that for a percentage moving rate of 10% and a fixed population, after seven years more than half of the initial population will have moved. Thus even when the noise generation is stable the duration of exposure to a given noise band can change over a relatively short period.

A recent study on population trends in the vicinity of ten UK airports [20] reports that between 1991 and 2011 the UK population grew by 10% but comments "*Since airports are large centres of activity and employment, they can stimulate population growth.*" and calculates that in the area surrounding London Heathrow the population grew by 21% over the same period.

4. Results and Conclusions

There are no firm data for aircraft noise on which to base the effects of exposure duration. However, given the rate at which it was found that the in-band population at LHR has changed, for illustrative purposes the average population in the bands 57-63 and 63-69 dBA $L_{eq,16hr}$ at LHR has been calculated at 5-year intervals from 1974 to 2008. The relationships in [4] have then been used to estimate the numbers of people in each period 'annoyed' and 'highly annoyed' (for L_{den} values of 62 & 68 dB respectively) and the Attributive Fraction (AF) for hypertension in populations exposed to L_{den} values of 62 and 68 dB. The results are summarised in Table 2 which shows that the numbers of people annoyed/highly annoyed fell to 14% of the initial value (0.27 to 0.04) over that 35-year period, despite an increase in ATMs of 84%.

For the hypertension analysis the approach is based on the relative risk method in [4]. To show the effect of the reducing population in each period exposed in each band they have been expressed as a proportion of a reference population taken as the combined population in the 57-63 & 63-69 dBA $L_{eq,16hr}$ bands for the first 5-year period (1974 to1979). The ORs for each level (1.57 for 62 dB L_{den} and 2.36 for 68 dB L_{den}) were then calculated from which the Attributive Fraction (AF) was determined for each 5-year period. These reduced AF values therefore assume that a reducing proportion of a fixed population is exposed, whereas in fact the composition of the exposed population changes as well as reducing in number. Bearing this in mind it should be noted that the AF value falls to zero after the first two 5-year periods.

Table 2: 5-year Normalised values of Population, Annoyance, and AF for Hypertension

		Elapsed years from start of airport data						
Population		5	10	15	20	25	30	35
Leq,16hr	Lden	*5-year mean population*		*Normalised to 57-63 band in period 1974-1978*				
57-63	62	1.00	0.57	0.32	0.21	0.15	0.13	0.13
63-69	68	0.17	0.12	0.09	0.06	0.05	0.04	0.03
Annoyance		*5-year mean population*		*Normalised to 57-63 band in period 1974-1978*				
	%HA	0.27	0.16	0.10	0.06	0.05	0.04	0.04
	%A	0.51	0.31	0.19	0.12	0.09	0.08	0.07
Hypertension	*Proportion of exposed population has been normalised to starting population*							
Attributive Fraction		0.41	0.02	0	0	0	0	0

In conclusion, the results presented in his paper can only be indicative since no account has been taken of the uncertainties arising from the assumptions, the published confidence limits of the exposure-response relationships, or potential unreliability in population data [20]. Nevertheless, it illustrates some important points for the assessment of noise-related health effects in practice. It transpires that the duration of exposure of a specific 'population' to a given level can be relatively short because of changes to population composition. This can arise not only from the normal influence of occupiers moving into or out of an area, or population growth (which might be enhanced near airports), but by the shrinking of noise contour areas over time. Reduction in noise contour areas not only reduces the number of people exposed but changes the composition of that population since it includes people previously exposed to higher bands. The implications are that further research is required on the role of duration in dose-response relationships for health effects and how the effects from periods of exposure at different levels should be combined.

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