THE ECONOMIC VALUATION OF AIRCRAFT NOISE EFFECTS: A CRITICAL REVIEW OF THE STATE OF THE ART

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1 INTRODUCTION

The quantification of the effects of aircraft noise on health and quality of life and the associated monetisation of those effects has taken on significance as a major field of study with important implications in policy making and business management.

This is recently new area of study that has been developed independently for each type of effect analysed. It has emerged as a key issue in the sustainable aviation policy agenda as the industry continues to growth. Nevertheless, limitations on the scientific evidence base to establish causal relationship and thresholds have prevented the calculation of accurate monetary values [1]. Our latest research explores this same issue [2, 3].

This paper aims to provide a comprehensive review of the valuation of the effects of aircraft noise on human health and quality of life and its implication within UK noise policy and sustainable airport operations. We present monetary estimates for selected London Airports as a reference for future calculations, which should be considered as indicative only. We emphasize that these values should be used to enhance understanding of trends rather than absolutely quantify values.

We argue that monetisation of aircraft noise effect is a very complex process require of complex system of policies. There is no single universal policy tool that can give solutions to all concerns. Aircraft noise management is a context dependant process: there is noise silver bullet and it requires the interaction of academics, practitioners and policy makers.

2 RELEVANCE OF MONETISATION AND UK AVIATION POLICY

The worldwide air transport industry is expected to grow from 5% to 6% over the next 20 years. In the UK, forecasts predict a significant growth in demand for aviation between now and 2050, bringing the London airport system under very substantial pressure in 2030 and exceeding capacity by 2050 [4]. This forthcoming growth leads to important economic benefits that will continue to boost UK economic prosperity and the local economy of surrounding airport communities. However, it will also leads to negative side-effects on the environment and local people.

Noise has been identified as the most important issue by far for local communities above safety, air pollution or local employment [5]. This has put noise on the top of management and political agenda, urging a better understanding of the extent of aircraft noise effects and the role it plays within a sustainable aviation policy.

In 2012 the UK Government set up an Independent Commission tasked with identifying and recommending options for expanding UK airport’s capacity. Three shortlisted options were announced at the end of 2013, two at Heathrow and one at Gatwick Airports as possible locations for a new runway. The objective of the Government is to strike a fair balance between the negative impacts of noise and positive economic impacts of flights [4].

The Commission is undertaking a Sustainability Appraisal [6] for those three options, which incorporate monetising effects from aircraft noise on annoyance, sleep disturbance and cardiovascular diseases. After consultation, the Commission recognised the limitations of their initially proposed methodologies, in particular relating to hedonic pricing for monetising aircraft noise annoyance. In turn, it determined to follow the Disability-adjusted life years (DALY) approach presented in the latest WHO report [7].

Monetary values of aircraft noise effects can provide a common language to assist sustainability appraisal and policy-making and analysis. They also enable comparison and contextualization of noise in sustainability policy and management, by helping to understand the balance between benefits and negatives effects of aviation. Monetary values seem to appear as a useful tool in balancing the cost and benefits of airport operations and their externalities.

3 AIRCRAFT NOISE EFFECTS – OVERVIEW

Human response to noise is very complex and varies between people and places. The extent of the response is influenced by many elements, besides the pure acoustical ones, such as personal, attitudinal and social factors.

The link between noise effects and potential impacts is neither simple, nor linear, as commonly presented. It depends on how one effect can modify another, the cumulative exposure and individual sensitivity to noise, the risk factors associated with health conditions and the influence of modifiers and cofounders factors [8]. This result in a complex web of pathways between noise and health, meaning there is no simple cause-effect model between aircraft noise exposure and health.

The evidence base that supports a link between each particular health outcome and noise exposure has developed independently. Table 1 presents the strength of evidence of effects of aircraft noise on health, in terms of specific cause-effect pathways. This table is based on author's reviews of key international guidelines from WHO and European Commission [1, 7, 9, & 10]. The standardised evidence categories are those used by the WHO.

Table 1: Summary of strength of evidence that supports an association

Health Effect		Strength of evidence	Issues
Annoyance (indirect; psychological, psychosocial)		Sufficient	Complex interaction with other health effects and non-acoustic factors. Debate on metrics and scope of analysis
Sleep disturbance (indirect; psycho-physiological)	Awakenings	Sufficient	A number of awakenings are normal. No agreement on threshold levels
	Self-reported	Sufficient	Subject to bias
	Long term effects and performance	Inadequate / Lacking	Complex mechanisms underlying long-term effects. No conclusive evidence of decrements in chronic objective long term effects
Cardiovascular (indirect; physiological)	Acute Myocardial Infarction – AMI Hypertension Coronary Heart Disease	Sufficient	Aircraft noise may be a risk factor for CVD, but not causal link has been conclusively proven. No evidence of effects on children Importance of confounding factors
Cognitive development	Adults	Inadequate / Lacking	Lack of data; no firm conclusions can be drawn

(indirect; physiological)	Children	Sufficient	Evidence from primary school reading age and recognition memory in the short term. Uncertainties on the existence of long-term effects. The scale of effect is relatively small compare with other "life events"
Mental health (indirect; psychological)		Lacking	Some evidence of symptoms, but not of severe clinical disorders
Hearing impairment (direct; physiological)		None	No effects at environmental noise levels <75dB (A)

4 ECONOMIC VALUATION OF AIRCRAFT NOISE EFFECTS

Economic valuation of environmental effects on health and quality of life is a recent field of research which a burgeoning importance over the last years.

In the UK, the Interdepartmental Group on Cost and Benefits Noise subgroup- IGCB(N), a DEFRA led group, was established to provide advice on the economic evaluation of noise and ensure that noise impacts are appraised consistently. The IGCB(N) has provided guidelines on effects can be part of a valuation methodology [11], as follows:

- Acute Myocardial Infarction (AMI) effects can be monetised using the 2006 Babisch dose-response function. Policy makers must be mindful of the uncertainties associated with this curve.

- New research has updated previous recommendations on Hypertension effects [12]. This study proposes a methodology to monetise the effects of environmental noise hypertension outcomes.

- Quantification of sleep disturbance impacts is possible for policy appraisal but evidence is not sufficiently developed to monetise these quantified effects. This is a priority area for monitoring policy-oriented research.

4.1 What do we need for monetisation?

In order to define whether or not is possible to include specific noise related effects as part of an economic valuation framework it is fundamental to have:

✓ A sufficient strength of evidence that supports the link between each particular health outcome and noise exposure

✓ Robust dose-response relationships to quantify the link and ideally accounts for causality

✓ A monetisation methodology appropriate for each effect

✓ Analysis and interpretation of results

This can be understood as the basic process to follow when planning and undertaking monetisation of noise effects. In order to responsibly orient noise management or policy decisions, it is important that policy makers are aware of the many limitations and uncertainties that results may have. It is important to note that this is complex field of work that requires the interaction of academics, practitioners and policy makers.

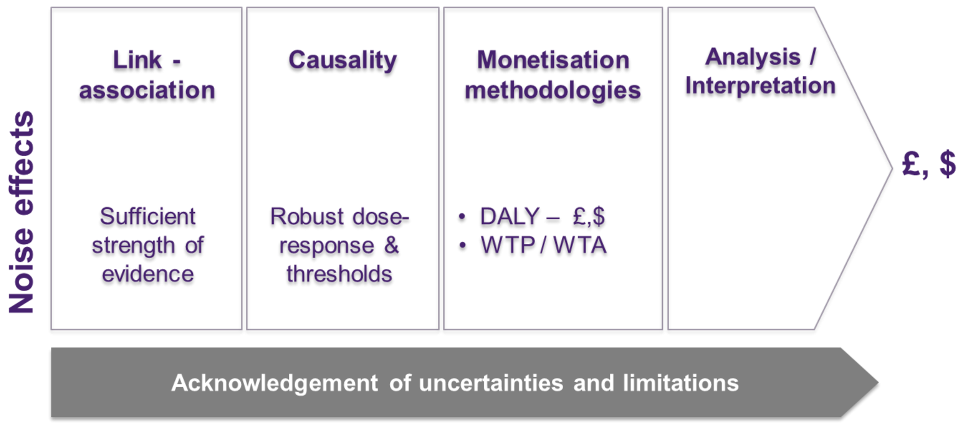

Figure 1: Monetisation process

4.2 Approaches for economic valuation

The monetisation of aircraft noise effects can be split in two types of approach.

One approach relates to the cost of lost productivity caused by exposure to aircraft noise, which commonly requires the estimation of the Disability Adjusted Life Years (DALY) as suggested by the WHO. This is an approach used for quantification and associated monetisation of aircraft noise effects on health. The IGCB(N) recommends the UK monetary cost per DALY to be £60,000 [11]

The other approach relies on the estimation of the willingness to pay to avoid (WTP) or to accept (WTA) a certain level of noise, which can be undertaken using either revealed preference (e.g. hedonic pricing, HP) or stated preference - SP (e.g. contingent valuation) techniques. This approach is commonly used to monetise the “cost of aircraft noise”, without a specific reference to any particular effect.

The following sections of this paper outline a general framework for monetising aircraft noise effects and provide specific in depth analysis for each particular effect.

4.3 Annoyance

In the UK annoyance is currently one of the most debated issues regarding aircraft noise effects. Concerns around the metric used, the validity of noise contours in LAeq to estimate people annoyed and potential increases in noise sensitivity, are key elements that add complexity to the debate.

Recent studies concluded that no annoyance curve can represent the annoyance situation of all airports, highlighting the validity of official curves used in the EU and US for such a process. It shows that Less 20% of the variance in annoyance judgments can be explained by acoustical variables [13, 14].

There have also been important developments in recent years with the emerging concept of Community Tolerance Level [15]. This concept is currently being applied in a major revision of the International Standard ISO 1996, expected to be published at the end of 2014 [ref to be supplied]

Generally there are two approaches for monetising the effects of aircraft noise on annoyance; one is the estimation of the Burden of Annoyance and other is the calculation of the WTP / WTA. Nevertheless, the UK Airports Commission established the Burden of Annoyance as the approach to follow for policy appraisal of annoyance effects from aircraft noise [6]. This paper updates previous publications [2] and follows the same approach to that suggested by the Commission.

The Burden of Annoyance combines exposure data, with the EU Position Paper on dose-response relationship between aircraft noise and annoyance and a disability weight (DW) that ranges from 0.01 -0.12, with a central value of 0.02 [7].

The main limitations of this approach are the use of a unique relationship to explain annoyance situations across all airports and the high degree of uncertainty due to the large range for the DW. There are doubts about the extent to which monetising annoyance make sense to noise policy making. How to weight universally a subjective and self-reported impact comes as one of the most concerning issues around these methodologies

4.4 Sleep Disturbance

Sleep disturbance-related effects are a well-developed area of research but there is currently no agreement on a single dose – response relationship to inform an economic valuation methodology [16]

A recent paper presented by Basner [17] in ICBEN 2014 Conference showed half of the variance in response is due to inter-individual differences, meaning that the relationship between night- time aircraft noise and sleep disturbance depends on individual noise sensitivity. The same study developed different relationships for specific noise sensitivity level. This may have important implications in night noise policy and regulation and International standards.

The Civil Aviation Authority in the UK proposed in 2013 a methodology to evaluate the loss of productivity resulting from sleep disturbance [18]. This uses the percentage highly sleep disturbed function (%HSD) for Lnight from the EU Position Paper on night time noise [19], derived from Miedema work [20]. The basic principle is to determine the additional cost or net benefit of a proposed policy measure compared with a baseline using DALYs approach.

A major limitation relies on the use of a unique relationship to all airports and cases. There are also uncertainties associated with the high degree of unexplained variance and bias that results poses. This is due do the large uncertainty interval for the disability weight (which ranges from 0.04 to 0.1 with a central value of 0.07) and because the %HSD is based on self-reported studies. The uncertainty in the dose-response relationship was not considered in the analysis of DW.

4.5 Cardiovascular disease: Acute Myocardial Infarction and Hypertension

According to Babisch [21], the hypothesis that chronic long-term exposure to environmental noise increases the risk of cardiovascular diseases has been confirmed in large epidemiological studies. However, the relationship specifically to aircraft noise is much less well understood.

Recent studies have contributed to both strength of evidence and definition of better and robust dose-responses. However, there are many confounding factors that have not been isolated at this time [22, 23].

Acute Myocardial Infarction

Cardiovascular effects related with Acute Myocardial Infarction- AMI can be monetised by using the 2006 Babisch relationship, which establishes a NOAEL of 60 dB Lday, to assess the additional risk with raising road traffic noise levels [24]. According to Babisch, apropos aircraft noise, no other alternative exists at present than to take the AMI risk curves derived from road traffic noise studies as an approximation for aircraft noise.

Monetisation of AMI effects can be done by using the DALYs approach [7].

The authors warn about the multiple uncertainties around this function, and the risk that noise management decisions based on this links might not have the expected results. Most of the uncertainties are related with the variability on responses across population due to differences in individual noise sensitivities, the role of habituation, effects from air pollution and other non-identified confounders, and applicability of the curve against other noise sources.

Moreover, recent research shows large number of technical and scientific uncertainties that prevents using this curve to establish threshold levels; meaning that this curve cannot be used to establish a NOAEL/LOAEL. More studies are needed examining the full range of exposures to better define the dose-response relationship. [25]

Hypertension

The latest study from Harding [12] has contributed to IGCB(N) work, by identifying three noise-related hypertension (HT) outcomes (AMI, stroke and dementia) and proposing a method for monetisation of those effects using the quality adjusted life years (QALY) approach.

In their methodology, Harding used van Kempen & Babisch 2012 pooled estimate as a first step in quantifying the link between environmental noise and HT. To quantify each outcome, the risk of HT associated with an increase of noise levels above 55dB LAeq 16 hours was combined with the risk associated with HT for AMI, stroke and dementia.

Monetisation was undertaken using the “QALY loss” approach. This is a similar measure to DALYs, which instead of disability weights (DW) uses health weights. This study estimated that the cost of additional HT-related cases due to environmental noise exposure in the UK was around £1.09bn, providing and insight into the scale of health impacts due to environmental noise exposure. If using Babisch & van Kamp risk estimates, results increased to £2.53bn. This is because the proportion of population exposed above recommended levels is greater for L_{den} than for $L_{Aeq.}$

The main limitations of this methodology are the use of non-aircraft risk rates if using van Kempen & Babisch and uncertainties on availability of data.

5 ESTIMATION OF MONETARY COSTS FOR SELECTED UK AIRPORTS

We have estimated the change in the monetary cost of aircraft noise on cardiovascular disease (AMI), sleep disturbance and annoyance using DALYs estimation for selected London Airports: Heathrow (LHR), Gatwick (GTW) and Stansted (STN) between 2011 and 2006.

Due to limitations on the availability of information, it wasn’t possible to undertake estimates for other London or UK Airports.

Noise exposure data

For all three airports, we have used L_{den} and $L_{night,\ 8h}$ 2006 noise maps contours produced and published by DEFRA according to the Environmental Noise Directive, END, and English Regulations [26]. We have used the 2006 and 2011 Strategic Noise Mapping Contours for each airport, produced by the Environmental Research and Consultancy Department (ERCD) of the CAA in the UK [27-32]. These contours are based on air traffic movements over the entire year. Data published at these reports are the same than DEFRA data.

Since data was only available at 5dB steps from 55dBA to 75dBA for L_{den} and $L_{Aeq,\ 16hrs}$, and from 50dBA to 70dBA for $L_{night,\ 8h}$ midpoints values were chosen for each band in order to undertake estimations.

These reports use different data set for population between 2006 and 2011. For 2006 noise maps, the population data is based on 2001 UK Census, updated in 2005. For 2011, the population data is based on the 2011 UK Census. Although this limitation, this was the only consistent information available across airports that allowed reasonable comparison and aggregation.

Methodology

We used the methodology proposed in this paper, including the corresponding dose-responses for each effect in the estimation of the DALYs. We have adopted the recommended UK monetary cost per DALY of £60,000 [11, 18].

Results

Acute Myocardial Infarction

To estimate the number of additional AMI cases resulting from noise exposure, we have used a low threshold of 55dB $L_{Aeq,\ 16hrs}$ which according to Babisch no effects were found below this level [24].

An AMI risk of 0.0596%, based on the UK AMI risk of death (72%) was used. We have assumed that the underlying prevalence of AMI in UK population is the same for each of the populations analysed. To estimate the number of DALYs a disability weight (DW) of 0.405 was considered. An average of 11 years loss of life and a mean disability weighting of 7.94 was used for AMI mortality [7, 11, 18].

The monetary cost due to AMI effects from aircraft noise in the three London Airports was valued at around £133m for 2011 compared with £142m in 2006. There is net change in cost of -£9m (-7%).

Sleep disturbance

Despite the multiple limitations mentioned in the previous section regarding the use of a unique dose-response, we have estimated the monetary cost of sleep disturbance due to aircraft noise from London Airports, using the EU official curve. These estimates can just indicate a trend on cost evolution across years, instead of absolute cost.

Due to limitations on the availability of the data, the lower threshold used for these calculations was 50dBA $L_{night,\ 8h}$.

The monetary cost due to sleep disturbance effects from aircraft noise in three London Airports varies in range of £53m to £133m in 2011 and £53m to £132m in 2006 depending on the DW. Using the central value of DW at 0.07 as recommended by WHO [7], monetary estimates were valued at £93.4 m for 2011 and £92.1m in 2006. This shows a marginal change of 1.4% in the cost over 5 years, mainly due to a decrease in the population exposed to aircraft noise during night.

Annoyance

As in the case of sleep disturbance, in order to have a broad understanding of trends in cost of aircraft noise in London, we have provided calculations using the EU annoyance dose-response curve and Burden of Annoyance methodology. As mentioned above these estimations are full of uncertainties and limitations that must the considered when interpreting and using these results.

Due to limitations on the availability of the data, the lower threshold used for these calculations was 55dBA L_{den}.

Due to large uncertainty interval for the DW, monetary cost due to annoyance from aircraft noise in the three London Airports varies in a range of 12 times between the lowest and highest value. There was almost no significant change between 2006 and 2011 estimations. For both years, the monetary cost of aircraft noise annoyance at selected London Airports varies between £77m to £925m. Using the central value of DW (0.02), the cost was estimated at £154m for both years.

This evidences the high degree of uncertainty and variability that should be considered when interpreting and using these results. It also raises questions about the reliability and accuracy in the results and to what extent makes sense to monetising annoyance effects.

All the results presented in this paper must be used as indicative only and to provide some insight into the scale of the health impacts from aircraft noise exposure at three London Airports. No definitive conclusion can be given on an absolute cost of aircraft noise effects around these Airports. Also, we recall on multiple caveats associated with this process when interpreting these results.

6 POLICY IMPLICATIONS AND CONCLUSIONS

Monetisation of aircraft noise effect appears as a critical issue for noise policy makers and private airport operators to facilitate decision-making. It can provide a common language to assist noise policy making; it helps to understand how noise can affect human's health and quality of life and can help to establish research priorities. Also, monetary values can vindicate the need for policy interventions on this matter and could provide economic indicators and signals for the design of sustainable and efficient noise policies and instruments.

However, it is a very complex process, due to the complex nature of noise and how it affects people, the difficulty in establishing causal relationships and the multiple uncertainties associated with valuation methodologies.

There are currently no unique and universally accepted methodologies for quantifying and monetising aircraft noise effects. This is a context dependant process: there is noise silver bullet and it requires the interaction of academics, practitioners and policy makers.

We argue that monetary values should always be used to enhance understanding of trends rather than absolutely quantify values. The precautionary and sustainability principles should guide their application within noise policy and business management.

Some challenges remain in the process of understanding and applying monetary values of aircraft noise effect within noise policy, such as how to aggregate the different cost in relation to understanding the balance between positive and negative impacts that aviation can bring.

We have estimated the cost of aircraft noise on AMI sleep disturbance and annoyance at three London Airports. All the results presented in this paper must be used as indicative only and to provide some insight into the scale of the health impacts from aircraft noise exposure at three London Airports. No definitive conclusion can be given on an absolute cost of aircraft noise effects around these Airports. Also, we recall on multiple caveats associated with this process when interpreting these results.

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