The next generation of supplementary aviation noise metrics and their use in managing aviation noise.

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ABSTRACT

Successful aviation noise management and sustainable airport development relies on describing noise exposure effectively, understanding its impacts, and communicating these effectively. We need the right tools to describe noise and its impacts in a meaningful way. Furthermore, decision makers need a balanced scorecard to make informed decisions based on the outcomes from an appropriate suite of analysis tools.

This paper summarizes our previous work which examined the limitations of traditional noise contours for describing noise exposure based on long-term averages and considered a more targeted contour based on shorter-term noise measures. It looks at supplementary ways of describing the physical exposure to aircraft noise events including those developed in Australia in 2000. These are revisited and we will show in our presentation, by using recent case examples, how we have applied and/or refined them using GIS techniques. We also highlight key information from our companion paper on aircraft noise effects on health and its monetization. All these elements are required for effective management of aviation noise.

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1. INTRODUCTION

Successful aviation noise management and sustainable airport development relies on describing noise exposure effectively, understanding its impacts, and communicating these effectively. We need the right tools to describe noise and its impacts in a meaningful way. Furthermore, decision makers need a balanced scorecard to make informed decisions based on the outcomes from an appropriate suite of analysis tools. The general process of strategic noise management is summarized in Figure 1.

The first stage of the process is to clearly define the objective of any analysis. This could include deciding between options for increasing capacity at an existing airport, targeting the most effective noise mitigation options, identifying the preferred location of a new airport or runway etc.

The second stage is to consider a range of candidate options or scenarios that could be adopted to meet the overall objective.

The third stage is to collate and analyse relevant information on each of the candidate options and present this in a transparent and meaningful way. This includes descriptions of the noise exposure, likely impacts, associated costs, and other key non-acoustic factors. This requires a suite of analysis and presentation tools and being mindful of the specific questions that need considering. Within this stage, we also need to consider how the candidate options align with any strategic priorities such as minimizing total population or new people overflown, or maximizing opportunities for noise sharing

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or offering a level of respite.

In the final stage, the information needs to be presented for each of the candidate options into a balanced scorecard in such a way that it assists the decision maker to compare and contrast options and reach a preferred solution. In generating this information, some of the candidate options may be optimized, through for example applying mitigation, and whole process could therefore be iterative as represented by the feedback loop shown.

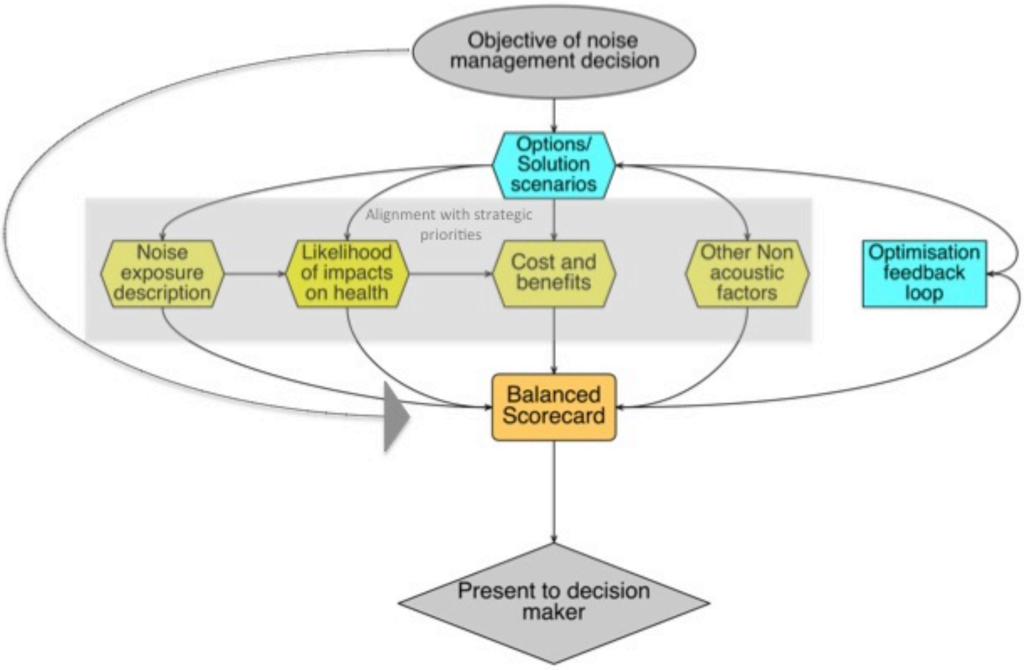


Figure 1 – The Process of Strategic Noise Management

This focus of this paper is on the description of the noise exposure - in relation to the third stage of this process. We build on our previous work on optimizing traditional noise contours to reflect community experience, and then consider how supplementary metrics introduced in Australia in 2000 can be refined using GIS tools. We have termed this the next generation of supplementary aviation noise metrics. We then highlight key information from our companion paper on aircraft noise effects on health and its monetization and conclude that all these elements are required for the effective management of aviation noise.

2. DESCRIBING NOISE EXPOSURE USING THE NEXT GENERATION OF SUPPLEMENTARY AVIATION NOISE METRICS

2.1 Types of Descriptors

Figure 2 shows the types of descriptors used for describing aviation noise. The first set shown on the left hand side can be described as the traditional or conventional. Traditionally noise contours are used to depict areas exposed to different measures of noise. These contours are adopted for both technical assessments as well as for conveying information to the general public. In the UK the contours are usually presented as long-term average values (annual or 92 day summer). The average summer daytime LAeq contour is used by the UK government, Lden (as well as Lnight, Leve, Lday) is used by the EU for strategic noise mapping, ANEF is used in Australia for land-use compatibility around airports, and DNL for land-use planning compatibility in the US. A variety of exposure metric values are adopted to reflect different impacts in the UK, with the summer Leq 57dBA often quoted as showing the onset of annoyance, the Leq 69dBA as representing significant impacts, and Lden 55dBA aligning with EU Noise Action Plans Policy. These metrics and therefore the contours are based are all essentially based on long-term averages. Although these descriptors have particular roles to play in strategic noise assessment, they do not adequately describe the actual community experience. They therefore have been, and still are, regularly criticized being described as unhelpful, lacking transparency and at times as sending completely the wrong messages.

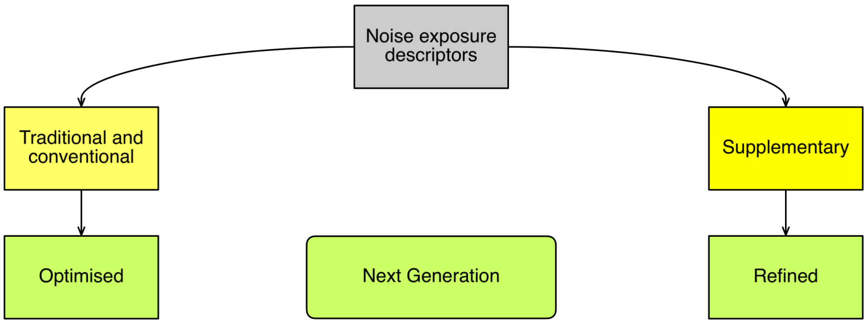


Figure 2 – Next Generation of Noise Exposure Metrics

The second set of descriptors shown on the right hand side of Figure 2 relate to the initial work by the Australia Government developing supplementary noise descriptor concepts as described in their paper in 2000 (1). This work was based on the belief that people want to be told about aircraft noise exposure in their own language—where the flight paths are, how many movements, what time of the day etc. Flight movement charts were developed and were considered as primary information, to which was added information on respite, numbers of noisy events (N70s), Person Event Index (PEI) and the Average Individual Exposure (AIE).

There have been a number of direct applications of the new descriptors deriving from the above studies. Primarily the descriptors have been used in environmental assessments and/or as communication tools. In North America the N70 is now in relatively common use as a supplementary metric. Even though it cannot be directly computed using the FAAs Integrated Noise Model, it is cited on an FAA funded website, NoiseQuest, as being “the most popular supplementary noise metric [in the United States]”.

There are examples where the metrics have been used for more formal applications. In Austria the mediation agreement for the expansion of Vienna Airport uses N65 metrics as one of the agreed controls (*Results of the mediation process*, 2005). In Sweden, the LFV is proposing to adopt the N70 and N80 as formal legislative tools for aircraft noise management (*New environmental permit for Arlanda*, 2010).

These concepts have been now been adopted globally. Often the long-term average noise contours are presented with these supplementary data to give a more transparent and complete picture of aircraft noise exposure. Some have suggested a range of supplementary indices to depict the noise effects of most interest to airport neighbours to engage in more informed policy making (2) and suggest that a summary could be given of noise effects on a typical day (2). Noise descriptors evolve over time; both the traditional noise contour concepts and the initial supplementary metrics have improved through experience in their application, and with the introduction of new, or more widely accessible technological tools for analysis. With these new faster technology and capabilities, we can now add further to ways to present meaningful exposure and information – a new generation of supplementary noise metrics.

2.1.1 Optimisation of Conventional Contours

In 2013, two of the authors published a paper on the role of noise contours in communicating aircraft noise exposure (3). In this work we recognised the limitations of long-term average contours in providing sufficient information on actual community experience. In particular insufficient information is provided to help answer questions such as:

- How does the noise exposure change throughout the day/week/month?
- If I live at x, why are some days worse than others?
- How does the mode of runway operation on a given day change the noise exposure pattern?
- How does the noise exposure change if the airport introduces a new aircraft type/removes an aircraft type?
- What is the noise exposure impact of a specific route or change to a route?
- How does the long-term average relate to day-to-day exposure?

Noise descriptors should be tailored towards the specific questions that are being addressed. We suggest that in addition to using descriptors based on long term averages, adopting a more targeted approach to noise contour modeling based on shorter-term metrics could address more specific issues and better describe the daily experience, which longer-term average metrics do not reflect. These could better inform on daily impacts, airport noise management decisions, effectiveness of noise mitigation and strategic planning.

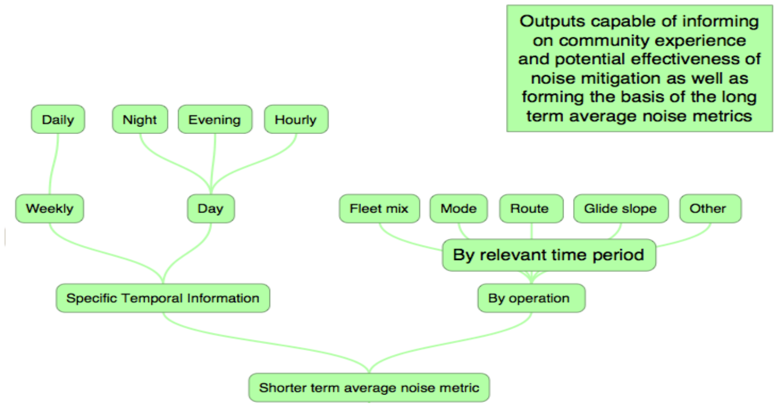


Figure 3: Basis of Targeted Noise Contour Modeling

One such example of this optimised approach to noise contouring is a video showing how hourly Leq contours (57 and 63 dBA) vary during the day starting at 0400. The video clearly shows the use of TEAM (Tactically Advanced Arrival Mode) and runway alternation, and how these airport operational techniques can change the community noise exposure experience throughout the day.

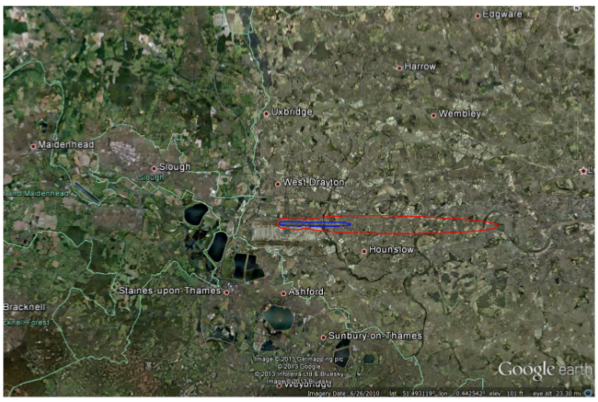


Figure 4: Opening Caption of video giving example hourly Leq (57 and 63dBA) contours at LHR Airport, UK.

2.1.2 Refinement of Supplementary Metrics

In 2011, one of the authors published a paper on the evolution of aircraft noise descriptors in Australia over the past decade (4). This showed that many of the supplementary metrics are being used for decision-making and are enabling interested members of the public to become engaged in the decision-making processes. We promote the principle that noise descriptors should be tailored towards the specific questions that are being addressed i.e. fit for purpose. In the UK, we have built on some of the concepts first introduced in 2000. In particular we have been looking at the increasing demand for information on noise sharing and potential opportunities for providing respite.

Here we present examples showing the how the N65 grid information using Geographical Interface System (GIS) can be used to present how the spread of noise over the surrounding population. We have also considered conceptual ways of presenting different respite patterns. It is worth also considering how these concepts can be developed further in the future to help in addressing questions on noise sharing, respite or other key questions considered important in an assessment.

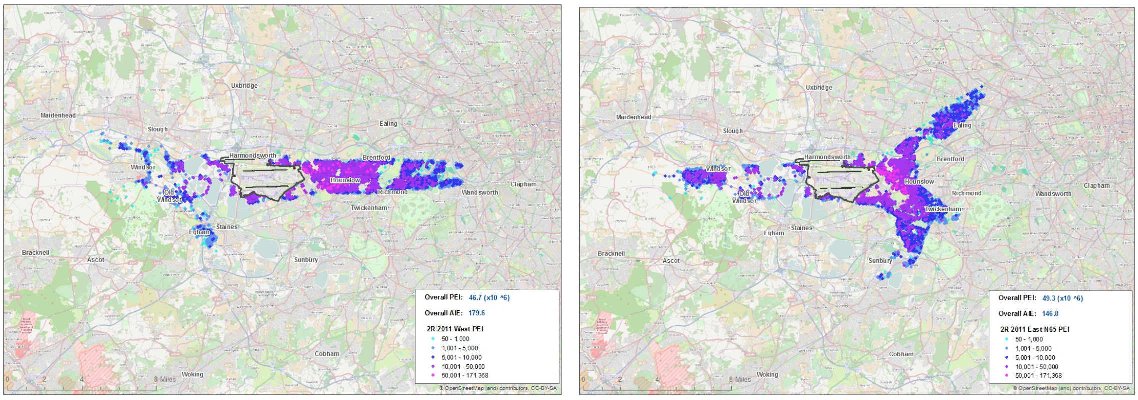
<u>Development of PEI and N65 contours using GIS presentation techniques to show noise load and noise sharing</u>

The Persons Events Index is an indicator of the total noise load generated by an airport and is calculated as the sum of the number of instances where an individual is exposed to an aircraft noise event greater than a given dB value. The PEI is summed over the range between N min (a defined cut-off level) and N max (the highest number of noise events louder than x dB(A) persons are exposed to during the period of interest). It is effectively calculated by summing at each cell, the number of events above Lmax of say 65 dB multiplied by the population within the cell. The minimum cut off value is say 50 events. The PEI is therefore expressed as PEI (65,50). The total PEI number is often large can be expressed in units $x10^6$. It is usually given as a single number and used with the AIE (Average Individual Exposure) to compare between different noise management options. The shortcomings of this descriptor is that it is limited to information within the N65 contour boundary and no information is provided on by how much the Lmax level of 65 dB(A) is exceeded. It also did not show how the noise load is shared by the surrounding population.

In applying these principles recently to better understand how the current noise load varies locally between Easterly and Westerly operations at a UK airport, we have used a GIS system to plot the PEI at each cell to show how the noise load is distributed across the surrounding areas. Figures 5 and 6 show how the PEI is geographically spread around a UK airport on Easterly and Westerly operations and therefore how the noise load differs between these different operations overall as well the location of where the PEI is the highest etc.

These pictures are one representation of how the noise is shared by the population. It focuses on people not just areas. As the number of aircraft operations at airports grows, there is increasing anecdotal evidence that communities are requesting and acknowledging the benefits and fairness of noise sharing. Recent social survey work in the UK (yet to be published) is likely to emphasize this. Therefore, we require fundamental noise descriptors that enable communities to show how the noise is being shared locally.

Another method trialed in the UK to show how noise is shared locally is to look at the geographical spread of the number of noisy events across operations or time periods. For this we have tested the use of N65 contours (for departures only) focused on N=25 events, 50 events, 100 events and 150 events (any number of events could have been used and the N65 was chosen as a maximum noise level greater than 65 dB(A) could considered to interrupt conversation between 2 people or could disturb TV watching – but any other justifiable level could be chosen). Figure 7 illustrates how the number of *"noisy events"* across 16 hours is distributed on an example westerly day at LHR, taking into account that the runway is alternated at 1500h. The illustration was built by taking N65 shaded contours for departures from the northern runway for 25, 50, 100 and 250 events in increasing depth of colour. This was then overlaid with similar for the southern runway. The resultant picture depicts the trend in distribution of number of aircraft noise events above 65 dB(A) Lmax varying from light blue for 25 events, to dark blue for 300 events for a 16 hour day.



Figures 5 and 6: Examples of geographical distribution of PEI on Westerly and Easterly Operations at LHR, UK showing how noise is shared by the local population

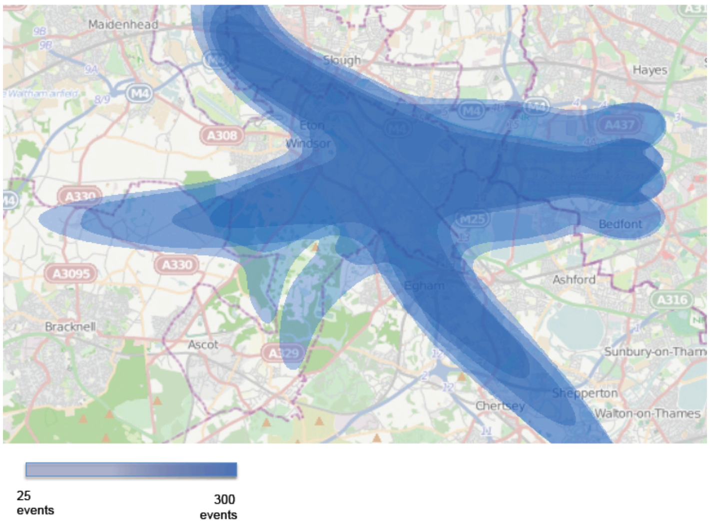


Figure 7: An illustration how the number of events greater than 65 dB Lmax across 16 hours is distributed on an example westerly day at LHR (departures only), taking into account runway alternation.

When these pictures are considered alongside track plots and density plots and the other long-term average metrics they provide a very clear and simple means for communicating the experience.

Development of illustrations to show respite from aircraft noise

Respite from aircraft noise is commonly understood to be related to predictable breaks from aircraft overflights. Due to expanding airport capacity, for communities the prime issue has become not how many movements or how much noise they received, but whether they were able to get a break from the noise.

For policy and business management, respite has become an efficient tool for noise mitigation. In Australia the respite issue has been on the public agenda for more than 20 years. It was integrated in the development of the Long Term Operating Plan for Sydney Airport, after the opening of the 3rd runway. In the UK, aviation authorities expects actions on the provision of predictable periods of respite, as this has been increasingly considered a principle for airport’s operations with perceived benefits in the community. In particular, the UK Aviation Policy Framework (APF) recommends exploring options to share noise between communities on an equitable basis and that airspace planning should ensure that predictability is afforded to communities, to the extend that this is within their control.

However, the definition, monitoring, reporting and valuation of respite are particular challenges. Respite is intuitively understood and considered to be important by the general public, but we require a better formal definition of respite that both corresponds closely to the public's intuitive idea of what respite is and can be quantified to a numerical value that can be related back to the actual experience of aircraft noise over an extended period of time. In Australia the measurement of respite is by clock hours: if an hour has no aircraft movements it is counted as respite but even a single aircraft movement disqualifies that hour. Respite is then presented as a percentage of the total hours of operation at the airport (typically curfew and night time periods with no activity are not counted as hours of operation to avoid inflating the figure). This measure neatly illustrates the difficulty of combining ease of understanding with the necessity of reflecting what the public actually experiences on the ground: The advantages are it is easily understood and can be calculated for different periods of the day such as "morning", "daytime" and "evening". The disadvantages are that where there are a small number of flights the exact timing of these flights can produce very different respite figures, and where an area lies between two flight paths and is affected by both, the respite figures for the two flight paths do not necessarily reflect the combined value in the same way that they would with a measure such as the N70. For example where the two flight paths show arrivals and departures from a particular runway end the area in between could be affected almost continuously as the wind shifts direction but have a 50% respite figure for both flight paths.

The development of indicators for the management of respite to ensure the development of opportunities to implement respite as part of noise management programmes is being continued in the UK. Recently the UK Aviation Commission identified relief or respite from noise as important but provided no guidance on how to assess or evaluate its effectiveness and/or value. Respite is a function of the noise level that could cause disturbance and the degree of overflight. Both of these aspects are the subject of significant debate. In submitting its proposal for a third runway, Heathrow's submission adopted a technique for showing respite, based on routes but not noise. It assumed that respite could occur within a distance of 15 nm from the airport. All arrival and departure routes (based on PBN) were buffered by 500m to reflect what could be considered to be direct overflight. A population postcode was selected with a count of the number of corridors that overfly the postcode point for both easterly and westerly operations. To establish the amount of respite, the number of modes is converted into percentages for easterly and westerly operations (for the example given in the submission - 0 modes= 100% respite, 1 mode = 75% respite, 2 modes = 50% respite, 3 modes = 25% respite, 4 modes = 0% respite). Respite over the total year (if required) can be calculated from the overall modal split (E/W). An example of one of the pictures is given in Figure 8 below.

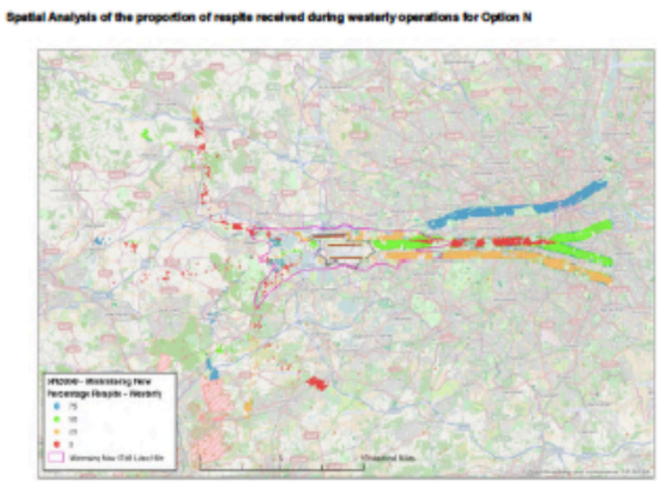


Figure 8: An illustration how potential respite was illustrated in Heathrow's submission to the UK Aviation Commission, giving the spatial analysis of the proportion of respite

(source: http://your.heathrow.com/wp-content/uploads/2014/07/01-Heathrow-3RNW-Air-and-Ground-Noise-Assessment.pdf)

We have recently developed some additional conceptual respite pictures from N65 grid information to better understand the potential opportunities for respite. These are based on routes **and noise** and follows the following principles:

1. Assignment of a condition to define respite e.g. as an example only - no more than 2 events at grid location in any hour above 65 dB(A) Lmax.
2. For each time period, for each grid point, assign a '1' if respite condition is met, or a '0' if not met.
3. Total all scores for each grid point across all time periods.
4. Calculate percentage of respite score across maximum score possible for all time periods.
5. Plot % respite across geographical areas.

The resultant pictures show the concepts only, and could be used for the basis for development of ways to show respite once the definitions and our understanding of perceptions and valuation of respite have been developed further. This could include different conditions being met, taking into account values in adjacent grid cells etc. These illustrations may be shown at the presentation after external publication in the UK.

3. UNDERSTANDING, PRESENTING AND COLLATING OTHER KEY INFORMATION

The previous sections have focussed on optimising the noise exposure descriptors within our stages for Strategic Noise Management as shown in Figure 1. In this section we briefly reflect on the other key information required in the process; likely health impacts, costs and benefits, and other non-acoustic factors. Our related and companion papers on this issues are given in papers (5,6 and 7).

This work has shown that the link between aircraft noise effects and potential impacts is neither simple, nor linear, as commonly presented. In fact, it depends on many aspects and non-acoustic factors such as how one effect can modify another, the number of effects, the cumulative exposure and individual sensitivity to noise, the risk factors associated with health conditions and the influence of modifiers and confounders factors.

In general, the strength of evidence for cardiovascular disease, self–reported sleep disturbance, reading aged for cognitive development in children and annoyance tends to be sufficient to support an association. There is no universal agreement on the robustness of dose–response and definition of thresholds. However, some common general thresholds or benchmarks are often adopted to indicate potential health effects for aircraft noise e.g. in the UK we often use with the summer Leq 57 dBA as showing the onset of annoyance. Any benchmarks used in aviation noise management must be shown to be chosen appropriately, and the limitations and uncertainties of their adoption should be highlighted in any assessment that estimates the number of people likely to have their health impacted.

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 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; and a monetisation methodology appropriate for each effect. The 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. In our companion paper (6) we have proposed a range of guiding principles for the use and application of monetary values in noise policy and management. What is important here is to understand how to balance the costs and benefits. This includes the costs of health impacts, social costs, value of enhanced benefits of proposal scenarios, mitigation costs, and operational costs. Such valuation comparisons should be used as a tool to compare different candidate options, not to derive absolute values to be taken out of the context for which they were prepared.

Finally it is necessary to understand the role of the non-acoustic factors in the decision making process. Consideration then needs to be given on to how this information can be communicated effectively. It may be possible to include relevant data within a GIS package to facilitate noise management decisions. We are currently looking into the feasibility of using GIS tools with cost information for the design of noise compensation packages.

In addition to the information on noise exposure descriptors, health risks, and costs and benefits, the decision makers must also consider the relevant 'strategic priorities'. In the case of Heathrow's Runway 3 submission, alignment with three key priorities were examined –minimization of total population affected, minimization of the number of new people impacted, maximization of the opportunities for respite.

In the final stage of a strategic noise assessment, the information needs to be presented for each of the candidate options into a balanced scorecard in such a way that it assists the decision maker to compare and contrast options and reach a preferred solution.

4. SUMMARY CONCLUSIONS

We have presented a process for strategic aviation noise management and placed the need for effectively describing the noise exposure in context. The next generation of supplementary noise metrics has been introduced - these and others are constantly evolving. Conventional contours and metrics based on long term averages can be supplemented with shorter-term targeted contours to better reflect community experience, "supplementary metrics" can be developed to show impacts across the surrounding community using GIS systems, and health effects and monetary information can be used to better understand and balance impacts.

Technological advances have enabled a large toolbox of aircraft noise descriptors and there is a general acceptance that we are going to have to work with multiple descriptors if aircraft noise is to be effectively managed in the future. However, these need to be targeted and tailored to providing information on the relevant key questions. These targeted noise descriptors and meaningful ways of presenting them, together with information on health, costs, and agreed policy objectives can be drawn together to present a balanced scorecard for use in effective aviation noise decision-making worldwide.

As acousticians, we should aim to provide all the relevant information in the best way possible to facilitate the decision making process, but it is ultimately the responsibility of the decision maker to chose the final solution.

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