The Potential of Event-based Aircraft Noise Modelling and Web Mapping in Communicating and Researching Effects

James TROW\textsuperscript{1}; Andrew KNOWLES\textsuperscript{2}

\textsuperscript{1} Amec Foster Wheeler Environment and Infrastructure UK Limited, United Kingdom
\textsuperscript{2} Anderson Acoustics, United Kingdom

ABSTRACT

Aircraft noise modelling and communication has historically relied on presenting average conditions and exposures representative of years, months and days. Average exposure contours and metrics are now recognized as being unsuitable for communicating aircraft noise issues and can lead to mistrust as they do not reflect the experience of communities. By harnessing noise modelling tools with custom data-processing software and by utilizing web mapping techniques, the authors show how an event-based approach could provide a major breakthrough in communicating and assessing aircraft noise effects by providing more transparent and accessible access to metrics that better reflect experience. The authors also highlight how the approach could yield new metrics that could further understanding and contribute to the research of aircraft noise effects.

Keywords: Aircraft Noise, Noise Modelling, GIS, Communication, Web-mapping

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1. INTRODUCTION

Since the growth of affordable air travel, the number of aircraft arriving and departure airports has increased. For communities living near to airports or under flight paths, aircraft noise is a major concern with the ever increasing weight of evidence linking between health effects to long-term exposure to aircraft noise.

Since the 1960’s there have been many studies that have sought to identify the effects of exposure to noise. This led to methods and metrics that enabled noise exposure to be measured and computed and the effects determined through research. This resulted in levels of noise exposure that were adopted by Governments to set policies to aid decision making and the representation of noise around airports using noise contours. These contours have allowed decisions to be made, enable the aviation industry to track its performance and define areas where people need protecting from noise by developing noise insulation policies.

Whilst noise contours have been an incredibly value tool to Governments, decision makers and the aviation industry, communities often view them as untrustworthy as they do not reflect how they experience noise. Furthermore, communities often cite the way airport noise is communicated to them as a source of distrust as they do not describe the totality of the noise issues associated with airports.

In recent years, Governments and the aviation industry have recognized that more work is needed to adequately communicate and establish a meaningful and proactive dialogue on noise with communities. For example, in the UK the Government’s 2013 Aviation Policy Framework (2) sets expectations on information and communication including “... metrics which describe noise in ways which communities can easily understand.”

\textsuperscript{1} james.trow@amecfw.com
\textsuperscript{2} andy@andersonacoustics.co.uk
Further to the matter of communicating and explaining aircraft noise, there are emerging gaps in our understanding of how aircraft noise effects. These gaps include furthering our understanding of the value of respite from aircraft noise, and how airspace can be designed to best achieve respite.

In this paper we identify how an alternative approach to the modelling aircraft noise, using an ‘event-based’ method coupled to statistical analysis techniques and innovations such as interactive web mapping could provide opportunities to improve how the aviation industry communicates noise to communities and how it may also unlock a new generation of metrics that could aid research.

2. AN EVENT-BASED APPROACH

2.1 What do we mean by ‘event-based’?

Aircraft noise modelling requires noise to be calculated based on airport activity. When noise models, such as INM and AEDT calculate noise, that activity is usually aggregated and scaled to reflect an average of a period to produce average metrics. All aircraft noise modelling tools are quite capable of calculating noise information associated with specific events. In fact, the information that they store and can output is quite comprehensive and event information is usually deposited as part of the calculations. Aside from noise event level information such as maximum noise level ($L_{A_{max}}$), single event level (SEL) and time-above values, noise modelling tools can also output information such as altitude, speed and the angle of view of aircraft. As such it is possible for aircraft noise models to output a wide range of information regarding specific aircraft events.

An ‘event-based’ approach relies on computing information for all potential events that may occur within an airport’s schedule. At major civil airports, activity is well understood, movements are scheduled and planned with the aircraft types known. On this basis, at any given time, it is relatively straightforward to understand what aircraft will be taking off or landing, where it will be coming from and to, and thus what route it will take. This means that each line of the schedule effectively becomes an aircraft event where noise information for that event can be made available.

An ‘event-based’ approach therefore seeks to attribute noise information for each aircraft event by using airport schedules. The schedules themselves also provide further information that can help build up an understanding of how aircraft noise occurs such as the time of events, their number, the aircraft and even the airline.

By collating and compiling all of this information, the approach enables an illustration of airport noise to be presented that reflects how the noise occurs. The schedule can be interpreted to reflect operating directions as well as operating practices and modes. Average metrics can still be produced however using the ‘event-based’ approach, aircraft noise can be presented and understood for any given circumstance from a single model run.

2.2 Making the approach possible

In facilitating the approach, we have utilized the INM noise model. There are two areas of development which have been necessary to implement the ‘event-based’ approach.

The first development has been to auto-configure INM to set up noise models for each potential aircraft event in a consistent manner. This has been achieved through the development of a bespoke software tool. This pre-configuration tool can scan an airport schedule, identify aircraft types and weights, and identify using operating principles embedded within the tool which routes are available to aircraft on arrival and departure. From this it develops a series of single event models according to a particular operating mode or direction of interest.

The second development has been the preparation of a post-processing tool that is capable of scanning schedules for a given modes of operation and identifying the operating aircraft, route and weight. From this, the tool identifies the noise information output from the INM model along with other information output from the calculation process. Utilising this, the tool builds up an event by event compilation of metrics and information for a selected location and/or points on a grid. Once
metrics have been received by the tool from the INM model for each event, analysis can be undertaken.

Figure 1 presents an overview of an ‘event-based’ analysis.

![Diagram of process flow for 'event-based' analysis]

**Figure 1 – Process flow for ‘event-based’ analysis**

### 2.3 Analysis methods

The output of the post-processing to is such that for each mode of operation and for each schedule, a time-metric history is prepared for locations around the airport. Information such as $L_{A_{\text{max}}}$ aircraft event levels, SELs and altitudes are all available. This enables a range of analysis techniques to be employed including a number of statistical approaches such as the preparation of histograms, ranges, averages and the identification of trends and commonality.

Critically, as the time-metric history retains a diurnal relationship with the schedule, the noise information is also time-referenced. This means that analysis can be undertaken to understand how the noise occurs throughout the day or night. This facilitates a much greater understand of where and when the aircraft noise events occur which can provide important insight.

### 2.4 Limitations

The approach is highly computation which given modern computing power is not a barrier. However the amount of data that can be produced and managing this efficiently within databases can be challenging. For major airports with well over 500 movements per day, with multiple runways, operating modes and routes, storing noise level information for each event over an area enabling analysis of noise levels from 50 dB $L_{A_{\text{Smax}}}$ and above along with additional information such as populations and addresses can require several terabytes of storage.
Adopting an event-based approach does rely on some certainty in aircraft routing. The potential number of unique aircraft events at an airport can be substantial. Where aircraft do not follow the same routing all the time, and aircraft movements are widely dispersed around an instrument approach or departure, this adds further complexity as the selection of a route is not certain and not predicable. However in the future precision navigation will mean that aircraft will be assigned a route for which the aircraft will be able to follow very accurately. In this respect, the event-based approach will become more relevant and intuitive with future of airspace design and management.

Finally, since the approach relies on noise modelling, it is fundamental that the noise model underpinning the approach is representative of either existing or proposed airport operations.

2.5 Developing an Example

To demonstrate the potential of the event-based approach in communicating aircraft noise effects, we have prepared a noise model for an imitation three-runway airport operating around 1,050 movements per day. In this example prepared for this paper, it is assumed that the airport is operating in an easterly direction with its northern runway allocated to departures, its central runway operating arrivals, and its southern runway operating both arrivals and departures. A total of 11 different aircraft are considered in the schedule with different weights. This allows differences due to fleet mix to be considered and demonstrated.

3. A GENERATION NEW METRICS?

In recent years, acousticians and the aviation industry have sought to explore, develop and adopt new aircraft noise metrics when seeking to explain aircraft noise issues. This has largely been led by aviation-literate acousticians (2, 3, 4). However, many of these ‘supplementary metrics’ have been in existence for decades.

Retaining information from the airports schedule and operating practices alongside noise information obtained from the noise model provides an incredibly powerful method of studying how noise and aircraft movements change throughout the day. From this, it allows statistical processing to be undertaken whilst retaining key information regarding the frequency and time of occurrence of aircraft events. As most airport schedules are set to five minute slots, the approach can allow for noise exposure to be considered at this resolution. The following sections showcase a number of metrics and illustrations that are possible using the ‘event-based’ approach and relevant statistical analysis.

3.1 Metric Time-Lines

For any given location, the approach can enable a metric time-line to be prepared. Figure 2 below presents a metric time-line for a location which is affected by arrival noise under a final approach to a runway. The time-line presented is between 0700 to 2300 hours. The figure shows the average maximum noise level in each hourly period, the $L_{Amax}$ range, a variety of N-metrics and an hourly $L_{Aeq}$. The average altitude of overflight is also shown which varies very little during the day. The figure shows that for this location, experience of aircraft noise is not entirely constant during the day. The number of events at different levels changes throughout.

Of the metrics presented, the hourly $L_{Aeq}$ remains relatively consistent whilst it is shown that the range and average maximum noise levels in each hour can vary by over 10 dB. The statistical analysis of the maximum noise events using N metrics highlights that in each hour, the number of noise events of differing levels is not consistent despite average overflight remaining identical. This analysis shows that different metrics can present a different picture of the noise exposure during the day.

Employing a diurnal approach could open up opportunities in understanding and communicating airspace management and routing to communities, especially where airspace management seeks to provide respite during the day. It enables an understanding of how certain routes are being used at certain times, how the makeup of traffic using a certain routes affects noise levels on the ground, and could aid the investigation of complaints should these occur at specific times of the day.
3.2 Time Between and Number of Events

Extending the time-based approach further, any metric can be interpreted into a format that can potentially be better understood by communities in terms of the rate at which they are overflown. N-metrics seek to describe the number of events above a certain value however, when the approximate time between events of a certain level is known, this can describe aircraft overflight in a slightly different manner.

Figure 3 presents the average time between N60 events throughout the day in a range of bandings from less than 90 seconds to over an hour.
Going beyond, simply presenting the average time between aircraft events, it is possible to illustrate the number of events along each route regardless of noise level enabling very simple information to be provided i.e. how many and how often. An example of how this could be illustrated is provided in Figure 4.

3.3 Time-Above Distributions and Statistical Metrics

Time-above metrics have been used in a number of countries to help further understanding of how aircraft affect noise levels around airports. In the USA, the metric is reported quite widely and at some airports is used as a performance measure alongside other metrics.

For the example airport used in this paper, a number of locations have been selected and time-above metrics calculated in minutes. Unlike for standard noise calculation software which can calculate...
time-above at set decibel values as prescribed by the user, the ‘event-based’ approach enables a
distribution of time-above measures to be prepared over a series of noise level values (Lx).

Figure 5 presents a distribution chart for the time-above metric at two locations: one under an
arrival track; and the other under a departure route. In these examples, both locations result in the same
\( L_{A_{eq}, 16\text{hr}} \) noise level. However, it can be seen in Figure 5 that for the arrival location this location
spends at least 1 hour per day exposed to noise levels above 70 dB whereas for the departure location,
this occur at around 65 dB.

![Figure 5 – Example of a time-above distribution where \( L_{A_{eq}, 16\text{hr}} \) is equal](image)

Using time-above metrics generated over a range of Lx values, it is possible to generate further
metrics that pertain to statistical noise exposure, such as background (\( L_{A_{90}} \)), median (\( L_{A_{50}} \)) and the top
10\(^{th}\) percentile (\( L_{A_{10}} \)) noise levels. In the example presented in Figure 6 below, these metrics have been
calculated for day of operations along with the \( L_{A_{eq}} \).

![Figure 6 – Example of a time-above distribution producing statistical noise metric contours](image)

It would remain to be seen how useful or not such statistical analysis could be but the ability to
produce such metrics could be of value to researchers as discussed in Section 4.
3.4 Summary
The examples above show the possibilities of the ‘event-based’ approach in describing aircraft noise. These are just examples of what the approach can yield and indeed there may be opportunities to generate other potentially useful metrics that meet the requirements of researchers and communities. Ideally, the development of new metrics should be explored with focus groups including communities and researchers to see where and how they can add value and under what circumstances they are of use, for example to explain a proposed change, track performance or to redistribute aircraft more fairly.

4. POTENTIAL TO AID RESEARCH AND PLANNING
The ability to develop metrics from the basic components of an airports operations has significant potential in researching noise effects. Computing a range of metrics with information that enables operational characteristics to be included in the analysis of the corresponding noise information at receptors could be used to help further understanding of community responses.

4.1 An Example – Distance from Track and Reductions in Noise
The consideration of noise and operating characteristics is particularly relevant in research relating to the provision of predictable respite from aircraft noise, its perception, and how this can feature in airspace design.

As a simple illustration of how the ‘event-based’ approach can be used to help further understanding in areas such as these, Figure 7 demonstrates how a correlation of aircraft altitude, ground track distance, and maximum noise levels for arriving aircraft could be used to determine track separations and human perception. In this example, the analysis has sought to identify how maximum noise levels reduce as receptors move further away from the track for different aircraft altitudes. Such analysis can help understand at what attitudes and distances perceptible changes in noise levels may occur which may be helpful in designing airspace to better provide respite.

Figure 7 presents reductions in $L_{A_{\text{max}}}$ compared to directly under the arrival track at a selection of aircraft altitudes from 500ft to 5000ft. The Figure shows that as altitude increases, the track separation required to achieve a specific reduction in $L_{A_{\text{max}}}$ noise from directly under the track increases. It also shows that the higher the aircraft, the decreasing correlation between distance from track and reduction in $L_{A_{\text{max}}}$ due mainly to directivity. In general, if a 10 dB reduction in $L_{A_{\text{max}}}$ event noise is sought, the distance between two tracks would need to be in excess of 3km when aircraft at 5,000ft on approach, and 1km when aircraft at 1,000ft on approach.

Using information such as this could help airspace designers use track separation as a means of ensuring perceptible differences in the noise from different tracks thus improving the perception of respite.
4.2 Further Opportunities

The example above is just one potential application. In the field of research, the ability to understand relationships between multiple parameters and metrics is important.

When considering dose-responses to aircraft noise, exploring potential relationships between a multiple metrics has value. As illustrated in Section 3, the ability to calculate statistical measures of aircraft noise may provide further insight into relationships between aircraft noise, annoyance and health. Likewise, identifying the frequency and time-between events as illustrated in Section 3 could provide airports with useful tools in equitably sharing aircraft noise between communities.

5. ASSISTING COMMUNICATION THROUGH GEOSPATIAL WEB-MAPPING

The software tools developed to facilitate the ‘event-based’ approach presented in this paper rely on geospatial analysis techniques which are underpinned by geospatial databases and GIS systems. Over recent years, a number of GIS software developers have engineered web-based viewers for their GIS systems which can allow users to view, interrogate and navigate geospatial information. These viewers can be customized to present a narrative or can be left in a relatively raw but accessible form to enable
a user to query and comprehend the information themselves.

Providing transparent and accessible aircraft noise metrics may provide airports with opportunities to better communicate with communities when they seek to explain potential changes. It may also help communities understand how they are affected by certain modes of operation, and for how long. Whilst illustrating when and how they receive aircraft noise, such online web-mapping systems may also provide information as to when a certain mode of operation is scheduled to occur and how it will affect a community allowing an understanding of when outdoor space will or will not be overflown.

All of the event metrics presented in this paper can made accessible via web-mapping. Indeed, in certain systems it is possible for users to create their own metrics using database queries. As an example, Figure 8 below presents a very simple interactive web-mapping application where a member of the public can select a mode of operation, search their post code and receive information regarding their planned overflight for that day. In the example, the time-between N60 event contours are presented along with the N60 events at specific location under arrivals.

The ability for the web-mapping and underlying geospatial databases to work at receptor level could allow for opportunities for members of the public to identify their noise exposure and how they are or will be overflown through their post or zip codes. From this customized reports are possible which could be valuable tools when as part of engagement and consultation.

![Interactive web-map example prepared using geospatial database of event-based information](image)

Figure 8 –Interactive web-map example prepared using geospatial database of event-based information

Web-mapping and geospatial databases therefore provide a significant opportunities for the aviation industry to engage and communicate with communities. Such techniques may also serve as a portal from which other aspects of the airports community engagement could be accessed enabling noise to be balanced against other community activity and benefits provided by the airport.

6. CONCLUSIONS

We have identified how adopting an ‘event-based’ approach to airport noise modelling could provide significant opportunities in the field of aviation noise research and communication. The approach unlocks the potential for a new generation of aviation noise metrics which have a number of potential end-uses. The data that can be obtained from the approach makes it possible for operational aspects to be considered directly alongside noise information. Retaining diurnal aspects of the airport operations also allows short-term assessments to be easily undertaken for any mode of airport operation.

Underpinning the approach is specific software which relies on geospatial databases. Through careful interaction of these databases, it is possible to correlate a number of metrics which may aid the
consideration of noise in airspace design.

Harnessing web-mapping applications on top of geospatial databases has the capability and enables accessibility allow communities to activity engage, participate and understand how aircraft noise affects them.

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REFERENCES